

1  
00:00:00,520 --> 00:00:03,600  
[Music]

2  
00:00:08,839 --> 00:00:13,500  
all right how are we doing up in the

3  
00:00:11,519 --> 00:00:15,330  
booth we got the big thumbs up ladies

4  
00:00:13,500 --> 00:00:18,719  
and gentlemen please give a thank you to

5  
00:00:15,330 --> 00:00:21,740  
mr. Thomas Murphy mr. grant justice

6  
00:00:18,719 --> 00:00:21,739  
getting it out to the hood

7  
00:00:23,000 --> 00:00:27,809  
good evening ladies and gentlemen and

8  
00:00:25,649 --> 00:00:30,209  
welcome to the Space Telescope public

9  
00:00:27,809 --> 00:00:32,098  
lecture series it is my pleasure to be

10  
00:00:30,210 --> 00:00:35,399  
your host I am dr. Frank summers of the

11  
00:00:32,098 --> 00:00:37,709  
office of public outreach and when you

12  
00:00:35,399 --> 00:00:39,899  
came in hopefully you can't and picked

13  
00:00:37,710 --> 00:00:42,270  
up one of our pretty pictures this is a

14  
00:00:39,899 --> 00:00:44,520  
brand-new pretty picture on that we

15  
00:00:42,270 --> 00:00:49,170  
haven't given out before it is the

16  
00:00:44,520 --> 00:00:52,050  
southern Crab Nebula which I don't guess

17  
00:00:49,170 --> 00:01:01,260  
you could see a crab there I see more of

18  
00:00:52,049 --> 00:01:02,909  
a tick to be honest with you now this is

19  
00:01:01,259 --> 00:01:04,969  
a special image this was one that we

20  
00:01:02,909 --> 00:01:08,728  
released for Hubble's 29th anniversary

21  
00:01:04,969 --> 00:01:11,459  
and you'll see on the back that it's not

22  
00:01:08,728 --> 00:01:14,969  
a full-color image it's actually

23  
00:01:11,459 --> 00:01:17,819  
composed of several spectral lines put

24  
00:01:14,969 --> 00:01:19,950  
together ok so these are the spectral

25  
00:01:17,819 --> 00:01:21,750  
lines that were used to put it together

26  
00:01:19,950 --> 00:01:23,939  
so it's not how it would look to to the

27  
00:01:21,750 --> 00:01:25,709  
human eye it's how it looks in these

28  
00:01:23,938 --> 00:01:28,199  
specific spectral lines that Hubble

29

00:01:25,709 --> 00:01:29,759  
observed and of course astronomers use

30  
00:01:28,200 --> 00:01:32,070  
these spectral lines to pull out

31  
00:01:29,759 --> 00:01:34,769  
different physical characteristics of

32  
00:01:32,069 --> 00:01:36,269  
the object under study and I'm assuming

33  
00:01:34,769 --> 00:01:38,640  
that the text on the back tells you all

34  
00:01:36,269 --> 00:01:40,920  
about that you didn't get one there are

35  
00:01:38,640 --> 00:01:45,569  
some extra on you can get on your way

36  
00:01:40,920 --> 00:01:47,849  
out please silence your electronics

37  
00:01:45,569 --> 00:01:50,489  
actually I know what I did not silence

38  
00:01:47,849 --> 00:01:53,129  
my electronics you know and that would

39  
00:01:50,489 --> 00:01:53,969  
be embarrassing so airplane mode there

40  
00:01:53,129 --> 00:02:00,298  
we go

41  
00:01:53,969 --> 00:02:02,340  
okay let's see what else tonight yes we

42  
00:02:00,299 --> 00:02:04,200  
have the astronomers toolkit this is

43  
00:02:02,340 --> 00:02:06,118

gonna be an interesting talk it's a

44

00:02:04,200 --> 00:02:07,500

different kind of talk than we then we

45

00:02:06,118 --> 00:02:09,118

usually give we use to talk about all

46

00:02:07,500 --> 00:02:12,120

this science stuff and everything right

47

00:02:09,118 --> 00:02:13,949

here but we also have these wonderful

48

00:02:12,120 --> 00:02:16,140

talks about how we create some

49

00:02:13,949 --> 00:02:19,738

ants and Brandon's gonna do some stuff

50

00:02:16,139 --> 00:02:22,669

with hopefully a live demo yep live demo

51

00:02:19,739 --> 00:02:26,730

here okay he's gonna walk the tightrope

52

00:02:22,669 --> 00:02:29,958

let's see next month we have black holes

53

00:02:26,729 --> 00:02:32,579

and gravitational waves always a very

54

00:02:29,959 --> 00:02:34,699

popular topic from emmanuel Bertie

55

00:02:32,580 --> 00:02:38,280

across the street at Johns Hopkins

56

00:02:34,699 --> 00:02:40,139

November we have our infamous TBA who

57

00:02:38,280 --> 00:02:42,930

appears every now and then but always

58  
00:02:40,139 --> 00:02:45,179  
cancels before it's time for TBA to give

59  
00:02:42,930 --> 00:02:48,180  
the talk which means I will have

60  
00:02:45,180 --> 00:02:50,489  
somebody filled in that slot you never

61  
00:02:48,180 --> 00:02:52,860  
try and ask people to commit to talks in

62  
00:02:50,489 --> 00:02:54,539  
August over over summer break right so

63  
00:02:52,860 --> 00:02:56,130  
now it's September I can get their

64  
00:02:54,539 --> 00:02:59,310  
attention and I'll be able to fill that

65  
00:02:56,129 --> 00:03:02,159  
one in in December we have a very long

66  
00:02:59,310 --> 00:03:04,439  
title red and brown doors understanding

67  
00:03:02,159 --> 00:03:07,259  
our smallest and closest sub stellar

68  
00:03:04,439 --> 00:03:08,818  
neighbors okay this is understanding the

69  
00:03:07,259 --> 00:03:12,179  
stars around us that happen to be

70  
00:03:08,818 --> 00:03:14,039  
relatively small stars okay all right

71  
00:03:12,180 --> 00:03:16,319  
if you would like to know all about that

72  
00:03:14,039 --> 00:03:18,689  
you can go to our website and if you

73  
00:03:16,318 --> 00:03:21,719  
remember we changed our website over the

74  
00:03:18,689 --> 00:03:23,879  
summer we are now holding it and we're

75  
00:03:21,719 --> 00:03:26,129  
not hosting it mainly on we sit still on

76  
00:03:23,879 --> 00:03:30,299  
hubble site but our prime hosting site

77  
00:03:26,129 --> 00:03:32,699  
port is now stsci edu and we have a nice

78  
00:03:30,299 --> 00:03:34,909  
shortened public - lectures all right

79  
00:03:32,699 --> 00:03:37,679  
something even I could remember okay so

80  
00:03:34,909 --> 00:03:41,459  
this and so here is our website for the

81  
00:03:37,680 --> 00:03:44,609  
public lecture series and we have the

82  
00:03:41,459 --> 00:03:47,159  
links to the web casts here we have the

83  
00:03:44,609 --> 00:03:50,400  
sign up for the email stuff here we have

84  
00:03:47,159 --> 00:03:51,659  
information across here we also have you

85  
00:03:50,400 --> 00:03:53,969  
scroll down because these are now

86

00:03:51,659 --> 00:03:55,680  
optimized for phones all the websites

87  
00:03:53,969 --> 00:03:57,150  
are now optimized for looking at it on

88  
00:03:55,680 --> 00:03:59,189  
your phone these days so you got to do

89  
00:03:57,150 --> 00:04:00,510  
lots of scrolling but you get down and

90  
00:03:59,189 --> 00:04:03,299  
you can see of course our upcoming

91  
00:04:00,509 --> 00:04:05,449  
lectures as well as below that we have a

92  
00:04:03,299 --> 00:04:08,370  
complete listing of the past lectures

93  
00:04:05,449 --> 00:04:11,250  
plus we improve the individual lecture

94  
00:04:08,370 --> 00:04:14,810  
pages so that we have full information

95  
00:04:11,250 --> 00:04:18,029  
on them we have links to the whoops

96  
00:04:14,810 --> 00:04:22,168  
wrong one there we go

97  
00:04:18,029 --> 00:04:26,619  
links to the stsci webcast here links to

98  
00:04:22,168 --> 00:04:28,689  
the youtube web cast down here okay

99  
00:04:26,620 --> 00:04:31,990  
and I know that semi gratuitous use of

100  
00:04:28,689 --> 00:04:34,089

this little spotlight feature but the

101

00:04:31,990 --> 00:04:36,430

folks on that well online webcast cannot

102

00:04:34,089 --> 00:04:38,259

see my laser pointer if I use that so

103

00:04:36,430 --> 00:04:40,949

that's why I'm using the special

104

00:04:38,259 --> 00:04:43,990

spotlight feature here all right

105

00:04:40,949 --> 00:04:46,810

okay email the announcements you can

106

00:04:43,990 --> 00:04:48,189

sign up on our website or just if you

107

00:04:46,810 --> 00:04:49,990

want to write it down and hand it to me

108

00:04:48,189 --> 00:04:52,240

at the end of lecture I can put you in

109

00:04:49,990 --> 00:04:54,819

there you only get two or three left

110

00:04:52,240 --> 00:04:57,759

messages per month if you have comments

111

00:04:54,819 --> 00:05:00,719

or questions public lecture at STScI dot

112

00:04:57,759 --> 00:05:03,069

edu if you'd like to follow us on social

113

00:05:00,720 --> 00:05:06,460

media especially those of you on the

114

00:05:03,069 --> 00:05:10,120

webcast we have Facebook Twitter YouTube



115  
00:05:06,459 --> 00:05:12,430  
and Instagram myself I sometimes am on

116  
00:05:10,120 --> 00:05:14,139  
Facebook or Twitter although I will

117  
00:05:12,430 --> 00:05:16,689  
admit I took the entire month of August

118  
00:05:14,139 --> 00:05:17,560  
off from social media it's actually kind

119  
00:05:16,689 --> 00:05:19,629  
of refreshing

120  
00:05:17,560 --> 00:05:22,540  
I'll be back now that about now that the

121  
00:05:19,629 --> 00:05:24,759  
fall is hit tonight we also have the

122  
00:05:22,540 --> 00:05:26,110  
observatory the weather is very much

123  
00:05:24,759 --> 00:05:29,199  
permitting it looks very clear outside

124  
00:05:26,110 --> 00:05:31,300  
so after the lecture the Maryland Space

125  
00:05:29,199 --> 00:05:33,459  
Grant Observatory staff I'll have

126  
00:05:31,300 --> 00:05:35,050  
everybody meet down here and they can

127  
00:05:33,459 --> 00:05:37,839  
take some people across the street to do

128  
00:05:35,050 --> 00:05:39,250  
the observing also if you can't make it

129  
00:05:37,839 --> 00:05:39,699  
tonight or you want to come some other

130  
00:05:39,250 --> 00:05:42,728  
time

131  
00:05:39,699 --> 00:05:44,709  
MB dot space grant that Ord they have

132  
00:05:42,728 --> 00:05:47,589  
the observatory status on there every

133  
00:05:44,709 --> 00:05:48,909  
Friday evening by 5:00 or 6:00 p.m. they

134  
00:05:47,589 --> 00:05:50,859  
will post whether or not they're going

135  
00:05:48,910 --> 00:05:55,360  
to be open that evening and you can go

136  
00:05:50,860 --> 00:05:59,139  
do it then all right now our news from

137  
00:05:55,360 --> 00:06:02,350  
the universe for September 2019 and I

138  
00:05:59,139 --> 00:06:05,650  
only have one story for you tonight and

139  
00:06:02,350 --> 00:06:10,000  
they are i dropping images of Jupiter

140  
00:06:05,649 --> 00:06:12,788  
okay so we take pictures of Jupiter when

141  
00:06:10,000 --> 00:06:15,329  
it's at conjunction okay and we got

142  
00:06:12,788 --> 00:06:19,599  
another really good one

143

00:06:15,329 --> 00:06:21,639  
just a few days ago okay this is our

144  
00:06:19,600 --> 00:06:24,250  
image of Jupiter at conjunction this

145  
00:06:21,639 --> 00:06:27,038  
year and it's really you know like

146  
00:06:24,250 --> 00:06:29,079  
Jupiter always is it's gorgeous although

147  
00:06:27,038 --> 00:06:31,689  
you know you look at it you go alright

148  
00:06:29,079 --> 00:06:36,639  
well Hubble's taking pictures of Jupiter

149  
00:06:31,689 --> 00:06:40,209  
since the 1990s okay I mean what's here

150  
00:06:36,639 --> 00:06:44,620  
that we haven't seen already but we've

151  
00:06:40,209 --> 00:06:48,129  
so many times but that's actually the

152  
00:06:44,620 --> 00:06:52,389  
point is that Hubble can observe it year

153  
00:06:48,129 --> 00:06:56,769  
after year after year okay so look at

154  
00:06:52,389 --> 00:06:58,870  
the two no 2019 okay here is our 2014

155  
00:06:56,769 --> 00:07:01,779  
image all right and if I blink back and

156  
00:06:58,870 --> 00:07:04,899  
forth I go here and I go here they don't

157  
00:07:01,779 --> 00:07:07,989

look all that different right but by

158

00:07:04,899 --> 00:07:11,758

tracking it over the years we can see

159

00:07:07,990 --> 00:07:15,579

that the Great Red Spot on Jupiter is

160

00:07:11,759 --> 00:07:16,479

shrinking so here is a picture whoops

161

00:07:15,579 --> 00:07:19,389

sorry

162

00:07:16,478 --> 00:07:25,719

here's a picture from 1995 up here and

163

00:07:19,389 --> 00:07:27,699

then 2009 and 2014 and when you compare

164

00:07:25,720 --> 00:07:31,240

them you can see that the Great Red Spot

165

00:07:27,699 --> 00:07:34,660

is actually shrinking it's getting

166

00:07:31,240 --> 00:07:36,848

smaller at one time it was estimated to

167

00:07:34,660 --> 00:07:40,300

be three times the size of our planet

168

00:07:36,848 --> 00:07:42,430

and now it's down to about one time the

169

00:07:40,300 --> 00:07:45,668

size of our planet okay so by looking

170

00:07:42,430 --> 00:07:48,610

over the course of long numbers of years

171

00:07:45,668 --> 00:07:52,149

we can see that we can also see other

172  
00:07:48,610 --> 00:07:55,300  
changes so we follow these white ovals

173  
00:07:52,149 --> 00:07:58,388  
these were these smaller storms and from

174  
00:07:55,300 --> 00:08:04,360  
97 there were these three FA de and BC

175  
00:07:58,389 --> 00:08:08,400  
in 98 de and BC combined to make de and

176  
00:08:04,360 --> 00:08:11,470  
in 2000 F a and B II combined to make ba

177  
00:08:08,399 --> 00:08:15,008  
all will be a three white storms that

178  
00:08:11,470 --> 00:08:19,509  
combine to form oval be a in 2000 and

179  
00:08:15,009 --> 00:08:24,490  
then a few years later that oval turned

180  
00:08:19,509 --> 00:08:26,979  
red and became red spot jr. we saw for

181  
00:08:24,490 --> 00:08:30,038  
the first time ever the formation of a

182  
00:08:26,978 --> 00:08:33,370  
red spot so we're getting to see changes

183  
00:08:30,038 --> 00:08:35,769  
like this okay and that is why this

184  
00:08:33,370 --> 00:08:38,049  
latest image is not just some random

185  
00:08:35,769 --> 00:08:41,168  
image that we do but it's part of a very

186  
00:08:38,049 --> 00:08:43,418  
dedicated program and that program is

187  
00:08:41,168 --> 00:08:46,600  
called opal the outer planets

188  
00:08:43,418 --> 00:08:48,490  
atmospheres Legacy Program because this

189  
00:08:46,600 --> 00:08:52,149  
is one of the things Hubble really can

190  
00:08:48,490 --> 00:08:54,480  
do is look at these planets for years

191  
00:08:52,149 --> 00:08:57,639  
upon years and follow the transit

192  
00:08:54,480 --> 00:08:59,649  
so this is what Jupiter looked like this

193  
00:08:57,639 --> 00:09:03,039  
is a full global map of Jupiter taken by

194  
00:08:59,649 --> 00:09:06,329  
Hubble in 2015 by the Opal program okay

195  
00:09:03,039 --> 00:09:09,069  
and then this is what it looks like in

196  
00:09:06,330 --> 00:09:14,879  
2019 all right and we could we go back

197  
00:09:09,070 --> 00:09:18,610  
and forth 2015-2019 you'll notice that

198  
00:09:14,879 --> 00:09:20,200  
this central band along here look at

199  
00:09:18,610 --> 00:09:23,470  
that color along the central band that

200

00:09:20,200 --> 00:09:25,629  
orange is color there I go back it's

201  
00:09:23,470 --> 00:09:27,580  
more of a whitish color one of the

202  
00:09:25,629 --> 00:09:29,710  
things they noted in this year's image

203  
00:09:27,580 --> 00:09:33,430  
was that the aerosol is at higher

204  
00:09:29,710 --> 00:09:35,620  
altitude along the equatorial belt

205  
00:09:33,429 --> 00:09:37,809  
seemed to be activated and they're

206  
00:09:35,620 --> 00:09:38,200  
getting a submit' bit of a more orange

207  
00:09:37,809 --> 00:09:41,649  
color

208  
00:09:38,200 --> 00:09:44,920  
we're also noting that yes the Great Red

209  
00:09:41,649 --> 00:09:48,850  
Spot has continued to shrink okay so

210  
00:09:44,919 --> 00:09:51,389  
that is a small Great Red Spot it's only

211  
00:09:48,850 --> 00:09:55,240  
the size of our entire planet okay

212  
00:09:51,389 --> 00:09:57,639  
that's that small but what do you notice

213  
00:09:55,240 --> 00:10:02,889  
even more even more

214  
00:09:57,639 --> 00:10:07,480

you notice that Red Spot jr. is no

215

00:10:02,889 --> 00:10:11,289  
longer red red we saw the first time the

216

00:10:07,480 --> 00:10:14,620  
formation of a red spot and now our red

217

00:10:11,289 --> 00:10:18,459  
spot has dropped out and has become a

218

00:10:14,620 --> 00:10:21,519  
white oval again so when I said these

219

00:10:18,460 --> 00:10:23,379  
were I dropping images I actually was

220

00:10:21,519 --> 00:10:26,919  
talking about somebody's been using eye

221

00:10:23,379 --> 00:10:32,259  
drops on Jupiter because we all know

222

00:10:26,919 --> 00:10:34,269  
that it gets the red out okay I wish it

223

00:10:32,259 --> 00:10:37,179  
were that easy of an explanation okay

224

00:10:34,269 --> 00:10:40,929  
we're losing the Great Red Spot the

225

00:10:37,179 --> 00:10:45,009  
grand spot jr. has gone away and we do

226

00:10:40,929 --> 00:10:47,769  
not know for sure why okay we do not

227

00:10:45,009 --> 00:10:49,629  
know why we're losing the red in Jupiter

228

00:10:47,769 --> 00:10:52,419  
all right but that's why we're doing



229  
00:10:49,629 --> 00:10:54,549  
this ople program so that we'll have the

230  
00:10:52,419 --> 00:10:57,009  
data to study these effects and then

231  
00:10:54,549 --> 00:10:59,169  
make better and better hypotheses all

232  
00:10:57,009 --> 00:11:04,000  
right I'm gonna leave you with one final

233  
00:10:59,169 --> 00:11:07,839  
image that's not Hubble but oh is it

234  
00:11:04,000 --> 00:11:10,960  
just gorgeous this is from the Juno

235  
00:11:07,840 --> 00:11:13,600  
in 2017 it's a close-up of one of those

236  
00:11:10,960 --> 00:11:16,210  
white ovals and look at all the

237  
00:11:13,600 --> 00:11:18,730  
hydrodynamics going on in here okay this

238  
00:11:16,210 --> 00:11:21,730  
is the kind of stuff I just love okay

239  
00:11:18,730 --> 00:11:24,190  
those beautiful natural swirls that come

240  
00:11:21,730 --> 00:11:27,039  
about in Jupiter's atmosphere are just

241  
00:11:24,190 --> 00:11:28,240  
amazing so I don't use this term well

242  
00:11:27,039 --> 00:11:30,039  
first of all to show you that it's

243  
00:11:28,240 --> 00:11:31,990  
really gorgeous because I love it but

244  
00:11:30,039 --> 00:11:34,419  
also to remind you that you need those

245  
00:11:31,990 --> 00:11:36,940  
missions that go to the planets to see

246  
00:11:34,419 --> 00:11:39,069  
these great details but they can only be

247  
00:11:36,940 --> 00:11:39,910  
there for a few years we've got Galileo

248  
00:11:39,070 --> 00:11:42,879  
juju

249  
00:11:39,909 --> 00:11:44,319  
we had Galileo Juno is there now we have

250  
00:11:42,879 --> 00:11:46,689  
these missions that can go to the

251  
00:11:44,320 --> 00:11:49,360  
planets for a few years but the value of

252  
00:11:46,690 --> 00:11:52,570  
Hubble is that it's been up there for 29

253  
00:11:49,360 --> 00:11:54,850  
years now and it can see the longer-term

254  
00:11:52,570 --> 00:11:55,690  
effects you can get the details with the

255  
00:11:54,850 --> 00:11:58,120  
space missions

256  
00:11:55,690 --> 00:11:59,770  
you get the long-term effects over over

257

00:11:58,120 --> 00:12:04,600  
decades with the Hubble Space Telescope

258  
00:11:59,769 --> 00:12:07,750  
okay all right and now we move to our

259  
00:12:04,600 --> 00:12:10,779  
featured speaker we are very happy to

260  
00:12:07,750 --> 00:12:13,509  
have here tonight dr. Brandon Lawton he

261  
00:12:10,779 --> 00:12:15,819  
is an astrophysicist in the office of

262  
00:12:13,509 --> 00:12:17,470  
public outreach whose research if you

263  
00:12:15,820 --> 00:12:21,480  
guys remember he has come here and

264  
00:12:17,470 --> 00:12:24,820  
talked about studies dust in galaxies

265  
00:12:21,480 --> 00:12:26,950  
the dust clouds are incredibly important

266  
00:12:24,820 --> 00:12:29,860  
because they're from which the stuff

267  
00:12:26,950 --> 00:12:31,270  
from which stars actually form it's dark

268  
00:12:29,860 --> 00:12:32,950  
and visible light so people don't pay as

269  
00:12:31,269 --> 00:12:34,689  
much attention to it but when we have

270  
00:12:32,950 --> 00:12:36,610  
Brandon around he always makes sure we

271  
00:12:34,690 --> 00:12:38,710

remember that the dust is really the

272

00:12:36,610 --> 00:12:42,930  
most important stuff all right

273

00:12:38,710 --> 00:12:47,139  
[Laughter]

274

00:12:42,929 --> 00:12:49,449  
however he is an astronomer in the

275

00:12:47,139 --> 00:12:51,939  
office of public outreach and in that

276

00:12:49,450 --> 00:12:54,820  
process we do a tremendous number of

277

00:12:51,940 --> 00:12:56,890  
activities with students with teachers

278

00:12:54,820 --> 00:12:59,620  
with the general public in which we

279

00:12:56,889 --> 00:13:02,350  
explain how astronomers learn what we

280

00:12:59,620 --> 00:13:04,929  
learn and he decided the other day last

281

00:13:02,350 --> 00:13:06,430  
time the last time I chatted with him to

282

00:13:04,929 --> 00:13:08,829  
do this he decided all right I'm gonna

283

00:13:06,429 --> 00:13:10,809  
take that and show off the astronomers

284

00:13:08,830 --> 00:13:11,790  
toolkit so ladies and gentlemen dr.

285

00:13:10,809 --> 00:13:16,469  
Brandon Leung

286  
00:13:11,789 --> 00:13:19,039  
[Applause]

287  
00:13:16,470 --> 00:13:25,670  
[Music]

288  
00:13:19,039 --> 00:13:29,669  
it's very wet Thank You Brad thank you

289  
00:13:25,669 --> 00:13:31,099  
got a fan club in here that should be

290  
00:13:29,669 --> 00:13:36,120  
one thank you

291  
00:13:31,100 --> 00:13:38,730  
okay now we have to know that was some

292  
00:13:36,120 --> 00:13:42,299  
of my dust you saw there that was yes

293  
00:13:38,730 --> 00:13:45,480  
all right thank you so much Frank all

294  
00:13:42,299 --> 00:13:47,689  
right so I started here like Frank said

295  
00:13:45,480 --> 00:13:51,899  
about ten years ago I was a postdoctoral

296  
00:13:47,690 --> 00:13:53,160  
researcher here working in dust now now

297  
00:13:51,899 --> 00:13:56,850  
I work in the office public outreach

298  
00:13:53,159 --> 00:13:58,139  
since about 2011 and we're gonna talk a

299  
00:13:56,850 --> 00:13:59,820  
little bit about the astronomers tool

300  
00:13:58,139 --> 00:14:01,110  
kit this is going to be a little bit of

301  
00:13:59,820 --> 00:14:04,170  
a whirlwind I'm it because astronomers

302  
00:14:01,110 --> 00:14:07,320  
have lots of tools as is all scientists

303  
00:14:04,169 --> 00:14:09,208  
all engineers do right but I want to

304  
00:14:07,320 --> 00:14:11,910  
also show you some things that you can

305  
00:14:09,208 --> 00:14:14,609  
take back with you that you can do on

306  
00:14:11,909 --> 00:14:19,620  
your own all right let's go to the next

307  
00:14:14,610 --> 00:14:21,899  
first a little bit more about me so I

308  
00:14:19,620 --> 00:14:27,360  
grew up in Washington State

309  
00:14:21,899 --> 00:14:29,309  
and I you know I grew up and I I have a

310  
00:14:27,360 --> 00:14:31,528  
similar sort of story that a lot of Sun

311  
00:14:29,309 --> 00:14:32,639  
astronomers do in scientists do they you

312  
00:14:31,528 --> 00:14:33,870  
know you look through the telescope for

313  
00:14:32,639 --> 00:14:35,759  
the first time and you see something

314

00:14:33,870 --> 00:14:37,470  
like Saturn and it sticks with you right

315  
00:14:35,759 --> 00:14:39,419  
you just you just fall in love with the

316  
00:14:37,470 --> 00:14:41,339  
night sky and my neighbor had this

317  
00:14:39,419 --> 00:14:43,409  
telescope and I saw Saturn through it

318  
00:14:41,339 --> 00:14:44,760  
and I was I was stuck and then my

319  
00:14:43,409 --> 00:14:46,559  
parents you know growing in Washington

320  
00:14:44,759 --> 00:14:48,360  
we didn't do a lot of trips around the

321  
00:14:46,559 --> 00:14:49,559  
country but we did save up because I

322  
00:14:48,360 --> 00:14:51,389  
really wanted to go to the Kennedy Space

323  
00:14:49,559 --> 00:14:53,789  
Center as a kid so we went there and

324  
00:14:51,389 --> 00:14:57,120  
that was an amazing trip and it meant a

325  
00:14:53,789 --> 00:15:00,179  
lot to me and really my love first for

326  
00:14:57,120 --> 00:15:02,789  
astronomy was born quite early but it

327  
00:15:00,179 --> 00:15:04,049  
wasn't really until I was an

328  
00:15:02,789 --> 00:15:06,000

undergraduate at the University of

329

00:15:04,049 --> 00:15:09,328

Washington which is that middle picture

330

00:15:06,000 --> 00:15:11,190

there where I really got to do sort of a

331

00:15:09,328 --> 00:15:13,979

participatory sport that is science that

332

00:15:11,190 --> 00:15:15,390

is astronomy okay you can really the

333

00:15:13,980 --> 00:15:17,100

best way to learn and the best way to

334

00:15:15,389 --> 00:15:18,689

appreciate anything is really to get in

335

00:15:17,100 --> 00:15:20,519

there and try to do some of it you're

336

00:15:18,690 --> 00:15:23,310

gonna make a lot of mistakes I certainly

337

00:15:20,519 --> 00:15:25,230

did but it's a lot of fun and so what I

338

00:15:23,309 --> 00:15:25,888

what I was able to do is that this man

339

00:15:25,230 --> 00:15:27,539

asteroid

340

00:15:25,889 --> 00:15:29,399

Observatory in the mountains of the

341

00:15:27,539 --> 00:15:31,048

Cascade Mountains in Washington State I

342

00:15:29,399 --> 00:15:32,249

got to spend entire summers up there



343  
00:15:31,048 --> 00:15:35,068  
basically by myself

344  
00:15:32,249 --> 00:15:37,379  
just taking images of the night sky I I

345  
00:15:35,068 --> 00:15:40,409  
was lucky to work on a research project

346  
00:15:37,379 --> 00:15:42,449  
with Professor Paulus Cody there and

347  
00:15:40,409 --> 00:15:43,350  
Professor Chris Stubbs on variable stars

348  
00:15:42,448 --> 00:15:47,039  
and I'll talk a little bit about

349  
00:15:43,350 --> 00:15:48,689  
variable stars later in this talk but I

350  
00:15:47,039 --> 00:15:50,639  
got it I got to do what's called

351  
00:15:48,688 --> 00:15:52,708  
differential photometry and I'll explain

352  
00:15:50,639 --> 00:15:54,329  
what that means later on these stars

353  
00:15:52,708 --> 00:15:55,979  
that vary over the course of night and

354  
00:15:54,328 --> 00:15:58,378  
it's a lot of fun to just be out there

355  
00:15:55,980 --> 00:16:01,619  
and doing science and then I took that

356  
00:15:58,379 --> 00:16:03,839  
to my graduate work in New Mexico that's

357  
00:16:01,619 --> 00:16:05,879  
the far right you can see the big

358  
00:16:03,839 --> 00:16:08,220  
telescope on the lower right is a 3.5

359  
00:16:05,879 --> 00:16:10,949  
meter telescope at Apache point

360  
00:16:08,220 --> 00:16:12,839  
observatory and that's where I fell in

361  
00:16:10,948 --> 00:16:16,858  
love with dust it's very dusty in the

362  
00:16:12,839 --> 00:16:19,139  
southwest so it makes a lot of sense but

363  
00:16:16,859 --> 00:16:21,540  
I did a lot of research on dust and I

364  
00:16:19,139 --> 00:16:24,629  
did research on some very intim attic

365  
00:16:21,539 --> 00:16:28,588  
mysterious things which I'll talk about

366  
00:16:24,629 --> 00:16:30,418  
as well in this talk okay so let's go

367  
00:16:28,589 --> 00:16:32,579  
ahead and move on I think a little

368  
00:16:30,418 --> 00:16:35,730  
history though to set the stage right

369  
00:16:32,578 --> 00:16:37,258  
because we have this toolkit but science

370  
00:16:35,730 --> 00:16:39,720  
is always built on the people that have

371

00:16:37,259 --> 00:16:41,699  
come before us and humans have had

372  
00:16:39,720 --> 00:16:43,829  
observatories for thousands of years

373  
00:16:41,698 --> 00:16:48,539  
okay so on the left there is an

374  
00:16:43,828 --> 00:16:51,238  
observatory and from in Portugal it's

375  
00:16:48,539 --> 00:16:53,969  
about 6,000 years old and it was

376  
00:16:51,239 --> 00:16:55,980  
actually partly a crypt as well but it's

377  
00:16:53,970 --> 00:16:57,860  
an observatory and the hypothesis for

378  
00:16:55,980 --> 00:17:01,079  
this Observatory is is that it allowed

379  
00:16:57,860 --> 00:17:04,318  
the people the nomads of the time and

380  
00:17:01,078 --> 00:17:09,658  
Portugal to go inside there and look out

381  
00:17:04,318 --> 00:17:11,490  
that viewing window to see stars before

382  
00:17:09,659 --> 00:17:13,620  
the Sun had set and they would look for

383  
00:17:11,490 --> 00:17:14,970  
stars that would signal the change of

384  
00:17:13,619 --> 00:17:16,318  
the seasons so they knew when to go to

385  
00:17:14,970 --> 00:17:18,808

the mountains with their herds or

386

00:17:16,318 --> 00:17:22,408

whatever they were doing so they they

387

00:17:18,808 --> 00:17:25,230

really needed that interior cavern of

388

00:17:22,409 --> 00:17:26,639

rocks there to block out the Sun so they

389

00:17:25,230 --> 00:17:28,649

could see the earliest point at which

390

00:17:26,638 --> 00:17:31,019

those stars in this case they think it's

391

00:17:28,648 --> 00:17:33,268

Aldebaran but the Stars as they were

392

00:17:31,019 --> 00:17:34,888

coming as they were coming up that

393

00:17:33,269 --> 00:17:35,569

signified spring or fall or

394

00:17:34,888 --> 00:17:38,369

what-have-you

395

00:17:35,569 --> 00:17:39,808

so and of course we all know that there

396

00:17:38,369 --> 00:17:42,079

is sundials and the

397

00:17:39,808 --> 00:17:44,729

and cultures across the world have had

398

00:17:42,079 --> 00:17:46,288

observatories where people have observed

399

00:17:44,729 --> 00:17:47,548

the night sky looked at the positions of

400  
00:17:46,288 --> 00:17:49,858  
the stars and so on

401  
00:17:47,548 --> 00:17:51,710  
so this is really a human endeavor

402  
00:17:49,858 --> 00:17:54,329  
that's gone on for thousands of years

403  
00:17:51,710 --> 00:17:55,979  
fast forward many thousands of years to

404  
00:17:54,329 --> 00:17:59,069  
just about four hundred years ago and

405  
00:17:55,979 --> 00:18:02,909  
you have a picture there painting of

406  
00:17:59,069 --> 00:18:05,158  
Tycho Brahe he in the late 1500s who we

407  
00:18:02,909 --> 00:18:07,169  
didn't have telescopes yet right that

408  
00:18:05,159 --> 00:18:11,820  
wasn't in our toolkit but what he had

409  
00:18:07,169 --> 00:18:13,259  
was he had an observatory and he had he

410  
00:18:11,819 --> 00:18:14,908  
had helped perfect some of the

411  
00:18:13,259 --> 00:18:17,759  
instruments of measuring very precise

412  
00:18:14,909 --> 00:18:19,830  
angles of the sky so for example sextant

413  
00:18:17,759 --> 00:18:21,479  
sand quadrants and things like that so

414  
00:18:19,829 --> 00:18:23,788  
that he could measure the positions of

415  
00:18:21,479 --> 00:18:25,950  
celestial objects incredibly accurately

416  
00:18:23,788 --> 00:18:27,598  
as well as have clocks that had the

417  
00:18:25,950 --> 00:18:29,848  
hours and seconds and so on so he knew

418  
00:18:27,598 --> 00:18:31,798  
exactly when those celestial objects

419  
00:18:29,848 --> 00:18:35,428  
were in that exact part of the sky and

420  
00:18:31,798 --> 00:18:38,579  
that was incredibly helpful because his

421  
00:18:35,429 --> 00:18:40,649  
assistant Johann Kepler used that very

422  
00:18:38,579 --> 00:18:43,319  
detailed information to come up with the

423  
00:18:40,648 --> 00:18:45,718  
Keplerian basically the Kepler in laws

424  
00:18:43,319 --> 00:18:48,269  
if you will the mote but that basically

425  
00:18:45,719 --> 00:18:51,149  
told us how the celestial or how the

426  
00:18:48,269 --> 00:18:53,519  
planets went around the Sun so his

427  
00:18:51,148 --> 00:18:55,949  
positions were incredibly detailed

428

00:18:53,519 --> 00:18:57,118  
incredibly valuable for the time and it

429  
00:18:55,950 --> 00:19:01,009  
really pushed the field of astronomy

430  
00:18:57,118 --> 00:19:05,668  
forward but of course the telescope

431  
00:19:01,009 --> 00:19:06,838  
helped us a great deal so it's it's

432  
00:19:05,669 --> 00:19:08,309  
probably the most well known in our

433  
00:19:06,838 --> 00:19:09,838  
toolkit I'm sure everyone's aware that

434  
00:19:08,308 --> 00:19:11,808  
we use telescopes right so here's a

435  
00:19:09,838 --> 00:19:14,098  
here's a painting of Galileo Galilei

436  
00:19:11,808 --> 00:19:17,700  
with a tellus I think this is when he's

437  
00:19:14,098 --> 00:19:20,608  
showing the the Catholic Church his his

438  
00:19:17,700 --> 00:19:23,308  
observations that's what it's portraying

439  
00:19:20,608 --> 00:19:24,989  
there but this was basically built from

440  
00:19:23,308 --> 00:19:28,950  
the spyglass which was thought to be

441  
00:19:24,989 --> 00:19:31,710  
invented in 1608 and Galileo took that

442  
00:19:28,950 --> 00:19:34,319

invention and tried to better it in some

443

00:19:31,710 --> 00:19:36,629

ways and he basically used it then to

444

00:19:34,319 --> 00:19:39,108

build a telescope to look up at the

445

00:19:36,628 --> 00:19:41,488

night sky in 1609 is when he did that

446

00:19:39,108 --> 00:19:42,838

okay so you can see we're progressing

447

00:19:41,489 --> 00:19:45,569

and the toolkit here we have telescopes

448

00:19:42,838 --> 00:19:47,788

now and now we just jump all the way to

449

00:19:45,569 --> 00:19:50,700

Hubble right so now we have telescopes

450

00:19:47,788 --> 00:19:53,250

where where we're not just using lenses

451

00:19:50,700 --> 00:19:56,190

like Galileo used for the optics

452

00:19:53,250 --> 00:19:58,470

where the where the glass lens collects

453

00:19:56,190 --> 00:20:00,509

and redirects the light to a focus where

454

00:19:58,470 --> 00:20:03,240

your eyeball is so you can see it but

455

00:20:00,509 --> 00:20:06,450

now we have these telescopes on the

456

00:20:03,240 --> 00:20:08,630

ground and in space that use mirrors to



457  
00:20:06,450 --> 00:20:11,490  
reflect the light to a focus and

458  
00:20:08,630 --> 00:20:13,080  
sensitive detectors to capture it thank

459  
00:20:11,490 --> 00:20:15,000  
goodness we don't need somebody peering

460  
00:20:13,079 --> 00:20:18,419  
through an eyepiece up there in space

461  
00:20:15,000 --> 00:20:20,940  
that would be very very painful so so

462  
00:20:18,420 --> 00:20:22,710  
we've really moved along with our

463  
00:20:20,940 --> 00:20:26,220  
technology so let's talk a little bit

464  
00:20:22,710 --> 00:20:28,829  
about telescopes before we move on I

465  
00:20:26,220 --> 00:20:30,360  
want to remind you all and I'm sure many

466  
00:20:28,829 --> 00:20:32,549  
of you are aware of this already that

467  
00:20:30,359 --> 00:20:34,740  
the light that we see with our eyes

468  
00:20:32,549 --> 00:20:36,509  
makes up a very small part of what's

469  
00:20:34,740 --> 00:20:38,670  
called the electromagnetic spectrum the

470  
00:20:36,509 --> 00:20:40,440  
light that we can see right and that's

471  
00:20:38,670 --> 00:20:42,000  
noted in the middle there the visible

472  
00:20:40,440 --> 00:20:43,410  
light there's a whole host of

473  
00:20:42,000 --> 00:20:46,890  
wavelengths or types of light that our

474  
00:20:43,410 --> 00:20:48,750  
eyes cannot see so those include higher

475  
00:20:46,890 --> 00:20:51,030  
energy light like gamma rays and x-rays

476  
00:20:48,750 --> 00:20:53,359  
and ultraviolet rays and lower energy

477  
00:20:51,029 --> 00:20:56,849  
light like infrared microwave and radio

478  
00:20:53,359 --> 00:20:58,949  
okay and our toolkit if we really wanted

479  
00:20:56,849 --> 00:21:01,289  
to understand the universe our toolkit

480  
00:20:58,950 --> 00:21:03,600  
needs to expand to be able to observe

481  
00:21:01,289 --> 00:21:05,460  
those wavelengths of light so we needed

482  
00:21:03,599 --> 00:21:08,639  
to build special telescopes that can

483  
00:21:05,460 --> 00:21:12,360  
capture and then detect and record those

484  
00:21:08,640 --> 00:21:14,460  
wavelengths so all these telescopes nASA

485

00:21:12,359 --> 00:21:17,579  
has a hopefully two telescopes up there

486  
00:21:14,460 --> 00:21:19,019  
a large region what reason why we have

487  
00:21:17,579 --> 00:21:20,849  
so many telescopes is because we need

488  
00:21:19,019 --> 00:21:23,490  
special technology to observe those

489  
00:21:20,849 --> 00:21:25,049  
different wavelengths this also shows

490  
00:21:23,490 --> 00:21:27,720  
you why we need to put telescopes in

491  
00:21:25,049 --> 00:21:30,210  
space for many wavelengths right so the

492  
00:21:27,720 --> 00:21:33,089  
colored lines show you how far down that

493  
00:21:30,210 --> 00:21:36,000  
wavelength reaches to the surface okay

494  
00:21:33,089 --> 00:21:38,189  
so thankfully gamma rays and x-rays

495  
00:21:36,000 --> 00:21:40,109  
don't make it to the surface it's a good

496  
00:21:38,190 --> 00:21:41,490  
thing all right but if we do in

497  
00:21:40,109 --> 00:21:42,990  
astronomy if we do want to understand

498  
00:21:41,490 --> 00:21:44,759  
the highest energy sources in the

499  
00:21:42,990 --> 00:21:46,589

universe it means we have to put our

500

00:21:44,759 --> 00:21:49,369

telescopes out there above the

501

00:21:46,589 --> 00:21:51,240

atmosphere where we can detect it

502

00:21:49,369 --> 00:21:52,559

visible light does reach it to the

503

00:21:51,240 --> 00:21:53,849

surface we have lots of optical

504

00:21:52,559 --> 00:21:55,169

ground-based telescopes but there's a

505

00:21:53,849 --> 00:21:57,809

reason why we would still want to put

506

00:21:55,170 --> 00:21:59,400

something like Hubble in space and it's

507

00:21:57,809 --> 00:22:01,019

because our atmosphere acts like a fit

508

00:21:59,400 --> 00:22:03,030

like a like a fishbowl like we're

509

00:22:01,019 --> 00:22:05,609

underwater right the atmosphere blurs

510

00:22:03,029 --> 00:22:06,960

the light as it comes from space so if

511

00:22:05,609 --> 00:22:09,148

you can get above the blurring

512

00:22:06,960 --> 00:22:11,100

miss fear right then you have a more

513

00:22:09,148 --> 00:22:13,949

clear vision of the universe and

514  
00:22:11,099 --> 00:22:16,199  
likewise you can see that you know for

515  
00:22:13,950 --> 00:22:17,669  
radio it's quite lucky you can have a

516  
00:22:16,200 --> 00:22:19,110  
lot of wavelengths reach the ground I

517  
00:22:17,669 --> 00:22:20,880  
want to point out this this is a very

518  
00:22:19,109 --> 00:22:22,740  
interesting NASA mission called Sofia

519  
00:22:20,880 --> 00:22:25,649  
where they actually just put a giant

520  
00:22:22,740 --> 00:22:29,159  
telescope in the site of a of a plane a

521  
00:22:25,648 --> 00:22:31,829  
jetliner and they fly that around to get

522  
00:22:29,159 --> 00:22:33,600  
some of the infrared wavelengths so they

523  
00:22:31,829 --> 00:22:37,019  
open up the entire side of the Joe the

524  
00:22:33,599 --> 00:22:39,719  
jetliner and they they observe okay so

525  
00:22:37,019 --> 00:22:41,908  
our toolkit is greatly expanded from the

526  
00:22:39,720 --> 00:22:45,569  
early days of Galileo where he just had

527  
00:22:41,909 --> 00:22:48,570  
his nice refracting telescope too now a

528  
00:22:45,569 --> 00:22:50,519  
whole suite of telescopes but of course

529  
00:22:48,569 --> 00:22:53,189  
telescopes aren't just the lenses in the

530  
00:22:50,519 --> 00:22:55,200  
mirrors they're also the other things on

531  
00:22:53,190 --> 00:22:57,808  
there that let us record the data right

532  
00:22:55,200 --> 00:22:59,460  
so telescopes capture the light but we

533  
00:22:57,808 --> 00:23:02,609  
need oh some way to record it we don't

534  
00:22:59,460 --> 00:23:04,528  
we you know we used to use our eyes for

535  
00:23:02,609 --> 00:23:08,000  
a while we use photographic plates but

536  
00:23:04,528 --> 00:23:11,880  
now we use something called C CDs

537  
00:23:08,000 --> 00:23:16,349  
charged couple devices which were first

538  
00:23:11,880 --> 00:23:18,720  
invented in 1969 by Bell Labs now C CDs

539  
00:23:16,349 --> 00:23:21,058  
are a wonderful invention because

540  
00:23:18,720 --> 00:23:23,130  
they're very set they're quite sensitive

541  
00:23:21,058 --> 00:23:24,569  
to light they and you can actually count

542

00:23:23,130 --> 00:23:26,730  
the photons of light that come in the

543  
00:23:24,569 --> 00:23:29,759  
way they work is there I kind of like to

544  
00:23:26,730 --> 00:23:31,620  
use an analogy where I pre you know you

545  
00:23:29,759 --> 00:23:35,339  
can pretend like if if someone asks you

546  
00:23:31,619 --> 00:23:37,079  
okay it's stormy outside and you want to

547  
00:23:35,339 --> 00:23:39,298  
play a game capture is you have these

548  
00:23:37,079 --> 00:23:41,460  
all these buckets capture as much rain

549  
00:23:39,298 --> 00:23:43,589  
as you can what would you do okay you

550  
00:23:41,460 --> 00:23:44,730  
could try to get one big bucket or you

551  
00:23:43,589 --> 00:23:48,058  
could try to get a bunch of smaller

552  
00:23:44,730 --> 00:23:49,710  
buckets right telescopes are like big

553  
00:23:48,058 --> 00:23:51,389  
light collecting buckets okay they

554  
00:23:49,710 --> 00:23:53,669  
collect all those raindrops but we still

555  
00:23:51,390 --> 00:23:55,288  
need to count those raindrops the CCD

556  
00:23:53,669 --> 00:23:57,840

detectors does that for us

557

00:23:55,288 --> 00:24:00,089

see CDs are basically have these little

558

00:23:57,839 --> 00:24:02,548

little little buckets in themselves

559

00:24:00,089 --> 00:24:04,259

these little pixels and a photon of

560

00:24:02,548 --> 00:24:06,269

light will hit that particular pixel and

561

00:24:04,259 --> 00:24:08,849

release electrons and we can count those

562

00:24:06,269 --> 00:24:11,099

electrons so it's like it's like a grid

563

00:24:08,849 --> 00:24:13,379

of little traps that basically collect

564

00:24:11,099 --> 00:24:16,379

the pixels and you get images like you

565

00:24:13,380 --> 00:24:19,440

see on the right so this detector here

566

00:24:16,380 --> 00:24:20,730

is the ACS detector that's on Hubble

567

00:24:19,440 --> 00:24:23,100

it's over

568

00:24:20,730 --> 00:24:24,950

10 years now and it captured that image

569

00:24:23,099 --> 00:24:29,819

on the right of the Whirlpool Galaxy

570

00:24:24,950 --> 00:24:32,279

now the ACS detector is 16 megapixels 16



571  
00:24:29,819 --> 00:24:34,500  
million pixels in that detector which is

572  
00:24:32,279 --> 00:24:36,869  
quite amazing given it was over 10 years

573  
00:24:34,500 --> 00:24:38,339  
ago that it was launched on Hubble of

574  
00:24:36,869 --> 00:24:41,099  
course now you can buy a camera a

575  
00:24:38,339 --> 00:24:44,009  
digital camera that has twice that if

576  
00:24:41,099 --> 00:24:45,869  
you want to spend the money our phones

577  
00:24:44,009 --> 00:24:49,230  
are getting to the point where they're

578  
00:24:45,869 --> 00:24:52,769  
getting not too far from this 8 10 12

579  
00:24:49,230 --> 00:24:56,039  
megapixels okay so this is an amazing

580  
00:24:52,769 --> 00:24:57,418  
instrument but the toolkit if we want to

581  
00:24:56,039 --> 00:25:00,269  
do more we have to do better we have to

582  
00:24:57,419 --> 00:25:04,470  
expand our tools so we have these C CDs

583  
00:25:00,269 --> 00:25:07,019  
these digital tools what can we do well

584  
00:25:04,470 --> 00:25:08,579  
here is I like to think one of the best

585  
00:25:07,019 --> 00:25:13,168  
examples of what we can do currently

586  
00:25:08,579 --> 00:25:16,079  
with our detectors this is another ACS

587  
00:25:13,169 --> 00:25:17,910  
the the ACS is that camera I showed you

588  
00:25:16,079 --> 00:25:19,168  
that it stands for advanced camera for

589  
00:25:17,910 --> 00:25:24,179  
surveys it's on the Hubble Space

590  
00:25:19,169 --> 00:25:26,700  
Telescope this is over 400 pointings

591  
00:25:24,179 --> 00:25:30,570  
of the Hubble Space Telescope to make

592  
00:25:26,700 --> 00:25:33,179  
this image this mosaic of our nearby

593  
00:25:30,569 --> 00:25:36,269  
Andromeda galaxy and this doesn't do it

594  
00:25:33,179 --> 00:25:38,880  
justice you if you actually download the

595  
00:25:36,269 --> 00:25:40,019  
full image and you can do this on you

596  
00:25:38,880 --> 00:25:42,240  
can do this online if you download the

597  
00:25:40,019 --> 00:25:44,069  
full image there's over a hundred

598  
00:25:42,240 --> 00:25:46,798  
million stars that you can make out in

599

00:25:44,069 --> 00:25:48,689  
this image okay this is only about a

600  
00:25:46,798 --> 00:25:50,849  
third of the Andromeda galaxy our nearby

601  
00:25:48,690 --> 00:25:53,690  
galaxies right so this is taking our

602  
00:25:50,849 --> 00:25:56,159  
detector technology and stepping across

603  
00:25:53,690 --> 00:25:58,890  
this galaxy and putting it together and

604  
00:25:56,160 --> 00:26:00,870  
and I should I should also mention that

605  
00:25:58,890 --> 00:26:03,660  
along with detectors our space

606  
00:26:00,869 --> 00:26:07,289  
telescopes have filters on them okay now

607  
00:26:03,660 --> 00:26:09,600  
if you want to study an object across

608  
00:26:07,289 --> 00:26:11,399  
all the colors you might you you might

609  
00:26:09,599 --> 00:26:12,869  
want to use filters to just study one

610  
00:26:11,400 --> 00:26:14,429  
color at a time and that's what Hubble

611  
00:26:12,869 --> 00:26:16,649  
has and all these telescopes have these

612  
00:26:14,429 --> 00:26:19,620  
filters so to make this image it used

613  
00:26:16,650 --> 00:26:21,419

multiple filters it and then it had you

614

00:26:19,619 --> 00:26:24,869

know essentially red green blue filters

615

00:26:21,419 --> 00:26:27,150

essentially and and then you can study

616

00:26:24,869 --> 00:26:28,889

them individually to see where the blue

617

00:26:27,150 --> 00:26:31,769

objects are which tend to be in this

618

00:26:28,890 --> 00:26:34,200

case new forming stars the red tends to

619

00:26:31,769 --> 00:26:34,500

be indications of older stars you might

620

00:26:34,200 --> 00:26:37,799

find

621

00:26:34,500 --> 00:26:39,170

dust the best thing in the universe but

622

00:26:37,799 --> 00:26:41,819

when you have the different filters

623

00:26:39,170 --> 00:26:44,100

right then you can study the pieces of

624

00:26:41,819 --> 00:26:47,159

the galaxy so filters in combination

625

00:26:44,099 --> 00:26:48,990

with these digital detectors allow us to

626

00:26:47,160 --> 00:26:51,150

study galaxies in greater detail than

627

00:26:48,990 --> 00:26:52,710

we've ever been able to do before so

628  
00:26:51,150 --> 00:26:55,500  
we're able to piece together essentially

629  
00:26:52,710 --> 00:26:57,779  
the history of our closest neighbor a

630  
00:26:55,500 --> 00:27:01,019  
big galaxy our closest big galaxy

631  
00:26:57,779 --> 00:27:02,609  
neighbor the Andromeda galaxy and so

632  
00:27:01,019 --> 00:27:04,589  
it's an amazing but let's do better and

633  
00:27:02,609 --> 00:27:08,699  
we're going to do better in the

634  
00:27:04,589 --> 00:27:12,509  
mid-2020s when w first launches ok w

635  
00:27:08,700 --> 00:27:16,259  
first is the wide field imaging Survey

636  
00:27:12,509 --> 00:27:19,259  
telescope and I'm sorry wide field

637  
00:27:16,259 --> 00:27:22,200  
Infrared Survey telescope and it's

638  
00:27:19,259 --> 00:27:26,269  
imaging is going to be amazing so here

639  
00:27:22,200 --> 00:27:29,100  
again is this 411 pointings of Hubble

640  
00:27:26,269 --> 00:27:32,039  
this this is by the way a ground-based

641  
00:27:29,099 --> 00:27:34,829  
image of the Andromeda galaxy and then

642  
00:27:32,039 --> 00:27:38,789  
overlaid is the Hubble 411 much higher

643  
00:27:34,829 --> 00:27:41,480  
resolution okay and then here is the

644  
00:27:38,789 --> 00:27:44,099  
footprint of the detector on the W first

645  
00:27:41,480 --> 00:27:46,500  
telescope the wide field imager over a

646  
00:27:44,099 --> 00:27:49,379  
hundred times the field of view same

647  
00:27:46,500 --> 00:27:54,210  
quality level of data as the Hubble okay

648  
00:27:49,380 --> 00:27:56,720  
so instead of instead of 16 megapixels

649  
00:27:54,210 --> 00:28:00,480  
we're talking like 288 megapixels camera

650  
00:27:56,720 --> 00:28:03,269  
ok so we're really going to get big

651  
00:28:00,480 --> 00:28:07,319  
images of the sky with this - with this

652  
00:28:03,269 --> 00:28:09,269  
telescope okay so our toolkit is always

653  
00:28:07,319 --> 00:28:10,649  
increasing but I need to put a caveat

654  
00:28:09,269 --> 00:28:12,329  
that the reason that the toolkit is

655  
00:28:10,650 --> 00:28:14,580  
increasing or the reason why we're

656

00:28:12,329 --> 00:28:16,939  
making our tools better is not because

657  
00:28:14,579 --> 00:28:20,460  
we can but it's because each generation

658  
00:28:16,940 --> 00:28:23,910  
of telescope or instrument before has

659  
00:28:20,460 --> 00:28:25,440  
given us mysteries that then dictate the

660  
00:28:23,910 --> 00:28:27,390  
kind of technology we need to solve

661  
00:28:25,440 --> 00:28:30,390  
those mysteries it's a never-ending

662  
00:28:27,390 --> 00:28:33,480  
science is a never-ending exploration so

663  
00:28:30,390 --> 00:28:35,280  
Hubble and other telescopes have have

664  
00:28:33,480 --> 00:28:36,870  
discovered amazing things but I've also

665  
00:28:35,279 --> 00:28:39,720  
to have also led us with a lot of

666  
00:28:36,869 --> 00:28:41,039  
mysteries and W first is going to be one

667  
00:28:39,720 --> 00:28:43,589  
of those missions that's really designed

668  
00:28:41,039 --> 00:28:45,629  
to understand some of those mysteries in

669  
00:28:43,589 --> 00:28:49,490  
particular I should mention the mystery

670  
00:28:45,630 --> 00:28:49,490

of dark energy and exoplanets

671

00:28:49,869 --> 00:28:54,589  
alright this is one of those little

672

00:28:53,119 --> 00:28:57,558  
places where I just wanted to take a

673

00:28:54,589 --> 00:29:00,649  
quick break and let me see if you can

674

00:28:57,558 --> 00:29:03,019  
see this and do an interactive I wanted

675

00:29:00,650 --> 00:29:05,179  
to point you to a resource

676

00:29:03,019 --> 00:29:12,410  
it's called Hubbell site I mean it's

677

00:29:05,179 --> 00:29:14,900  
called view space let me see ok all

678

00:29:12,410 --> 00:29:17,750  
right close that alright so on view

679

00:29:14,900 --> 00:29:20,019  
space what you can do is you can go and

680

00:29:17,750 --> 00:29:22,730  
you can actually look at these images

681

00:29:20,019 --> 00:29:24,289  
alright so you can go here and you can

682

00:29:22,730 --> 00:29:25,460  
on the front page there's the whirlpool

683

00:29:24,289 --> 00:29:27,009  
which I show I think this is the

684

00:29:25,460 --> 00:29:29,690  
whirlpool or it's the pinwheel on kintel



685  
00:29:27,009 --> 00:29:31,490  
which you can you saw an image earlier

686  
00:29:29,690 --> 00:29:33,740  
if it's the whirlpool you can slide it

687  
00:29:31,490 --> 00:29:37,460  
across and these are the actual

688  
00:29:33,740 --> 00:29:39,740  
astronomical images ok this is x-ray and

689  
00:29:37,460 --> 00:29:41,569  
visible but let's do better this is all

690  
00:29:39,740 --> 00:29:44,120  
free by the way this view space if you

691  
00:29:41,569 --> 00:29:47,029  
go to the Interactive's here's an

692  
00:29:44,119 --> 00:29:48,409  
interactive of what the world a cartoon

693  
00:29:47,029 --> 00:29:54,649  
of what the world looks like in visible

694  
00:29:48,410 --> 00:29:57,410  
light infrared radio microwave you can

695  
00:29:54,650 --> 00:30:01,820  
see there are different sources for each

696  
00:29:57,410 --> 00:30:03,798  
of these ultraviolet x-ray and gamma-ray

697  
00:30:01,819 --> 00:30:06,019  
I also want to point out that there's

698  
00:30:03,798 --> 00:30:08,960  
labels here so you can turn on and see

699  
00:30:06,019 --> 00:30:10,730  
what things are this is a nice thing to

700  
00:30:08,960 --> 00:30:14,120  
show off if you want to do a quick

701  
00:30:10,730 --> 00:30:15,319  
demonstration but let's do star

702  
00:30:14,119 --> 00:30:19,389  
formation because it has lots of

703  
00:30:15,319 --> 00:30:21,619  
beautiful dust so here is visible right

704  
00:30:19,390 --> 00:30:22,370  
this gets you an idea of the power of

705  
00:30:21,619 --> 00:30:24,168  
multi-wavelength

706  
00:30:22,369 --> 00:30:26,239  
astronomy and the detectors on all of

707  
00:30:24,169 --> 00:30:28,640  
our telescopes so this is a visible

708  
00:30:26,240 --> 00:30:30,710  
light with Hubble if you scroll over to

709  
00:30:28,640 --> 00:30:32,570  
near-infrared this is what Hubble looks

710  
00:30:30,710 --> 00:30:35,298  
like it has near infrared capability and

711  
00:30:32,569 --> 00:30:37,189  
you can actually see inside those dust

712  
00:30:35,298 --> 00:30:40,730  
pillars and you can see stars being born

713

00:30:37,190 --> 00:30:43,490  
in the dust if you go to the further

714  
00:30:40,730 --> 00:30:48,380  
into the infrared that dust actually

715  
00:30:43,490 --> 00:30:50,660  
starts to glow ok and the I believe this

716  
00:30:48,380 --> 00:30:52,490  
is Herschel Space Telescope with this

717  
00:30:50,660 --> 00:30:55,009  
image the dust starts to glow because

718  
00:30:52,490 --> 00:30:56,659  
the dust is being heated by stars so the

719  
00:30:55,009 --> 00:30:58,879  
dust is glowing there you go in the

720  
00:30:56,659 --> 00:31:02,390  
other direction you go to x-ray what you

721  
00:30:58,880 --> 00:31:05,150  
find are the hot stars the

722  
00:31:02,390 --> 00:31:07,040  
carving away at that dust so that if

723  
00:31:05,150 --> 00:31:10,100  
you've recognized this image here

724  
00:31:07,039 --> 00:31:11,629  
invisible we we typically sometimes it's

725  
00:31:10,099 --> 00:31:14,949  
the Eagle Nebula we sometimes call these

726  
00:31:11,630 --> 00:31:16,730  
the pillars of creation they're not

727  
00:31:14,950 --> 00:31:19,370

going to be there forever

728

00:31:16,730 --> 00:31:21,019

in fact they're being constantly eroded

729

00:31:19,369 --> 00:31:22,909

by the hot young stars that were born

730

00:31:21,019 --> 00:31:25,250

from that nebula that are releasing all

731

00:31:22,910 --> 00:31:28,370

that ionizing flux and eroding it away

732

00:31:25,250 --> 00:31:29,900

and so you can see that in x-ray and

733

00:31:28,369 --> 00:31:32,750

then there's a nice multi-wavelength

734

00:31:29,900 --> 00:31:35,960

where you can put the x-ray visible and

735

00:31:32,750 --> 00:31:37,549

Infrared together okay so there's a lot

736

00:31:35,960 --> 00:31:40,420

of lot of things you can explore in view

737

00:31:37,549 --> 00:31:46,789

space I encourage you to to check it out

738

00:31:40,420 --> 00:31:49,460

let's go back to the slide but this is

739

00:31:46,789 --> 00:31:52,129

this is another one I wanted to show you

740

00:31:49,460 --> 00:31:54,079

this is another interactive I told you

741

00:31:52,130 --> 00:31:56,270

there would be Interactive's even though

742  
00:31:54,079 --> 00:31:59,179  
it's really me just interacting but you

743  
00:31:56,269 --> 00:32:00,109  
know I should have we should have said

744  
00:31:59,180 --> 00:32:03,259  
you know bring your and bring your

745  
00:32:00,109 --> 00:32:04,789  
computers but this is all online as well

746  
00:32:03,259 --> 00:32:06,049  
so if you see this and you want to go on

747  
00:32:04,789 --> 00:32:08,450  
and explore with this or you want to

748  
00:32:06,049 --> 00:32:09,710  
share it with others please do I want to

749  
00:32:08,450 --> 00:32:11,420  
show you a really cool thing that we

750  
00:32:09,710 --> 00:32:14,809  
just started doing it's called NASA's

751  
00:32:11,420 --> 00:32:17,090  
asteroid challenges basically what we do

752  
00:32:14,809 --> 00:32:18,440  
is we allow we have it in the summer

753  
00:32:17,089 --> 00:32:19,490  
which we just finished we'll have

754  
00:32:18,440 --> 00:32:20,930  
another one in the winter and then

755  
00:32:19,490 --> 00:32:24,259  
another one in the summer and so on and

756  
00:32:20,930 --> 00:32:26,269  
what we do is we provide users the we

757  
00:32:24,259 --> 00:32:27,410  
provide anyone the ability with just

758  
00:32:26,269 --> 00:32:29,629  
their computer and an internet

759  
00:32:27,410 --> 00:32:31,340  
connection to go on and to use

760  
00:32:29,630 --> 00:32:34,130  
ground-based telescopes to take their

761  
00:32:31,339 --> 00:32:37,609  
own images and we provide the free

762  
00:32:34,130 --> 00:32:38,750  
online software with tutorials it's it's

763  
00:32:37,609 --> 00:32:41,359  
relatively simple and I'll walk through

764  
00:32:38,750 --> 00:32:43,390  
an example of it here for you to put

765  
00:32:41,359 --> 00:32:46,459  
together your own astronomical images

766  
00:32:43,390 --> 00:32:49,370  
astrophotography if you will okay we

767  
00:32:46,460 --> 00:32:51,319  
also provide the NASA data Ament much of

768  
00:32:49,369 --> 00:32:53,569  
the NASA data for those objects so you

769  
00:32:51,319 --> 00:32:54,799  
can make you see those beautiful you

770

00:32:53,569 --> 00:32:55,789  
know Frank is always up here at the

771  
00:32:54,799 --> 00:32:58,399  
beginning of every public lecture

772  
00:32:55,789 --> 00:32:59,990  
showing you those beautiful releases

773  
00:32:58,400 --> 00:33:02,330  
that we provide that that Space

774  
00:32:59,990 --> 00:33:03,620  
Telescope produces or NASA produces you

775  
00:33:02,329 --> 00:33:06,980  
can create your own version of those

776  
00:33:03,619 --> 00:33:08,419  
same objects with the same data so let

777  
00:33:06,980 --> 00:33:11,960  
me show you what that looks like real

778  
00:33:08,420 --> 00:33:12,650  
quick so if you go to ask for photo

779  
00:33:11,960 --> 00:33:15,470  
challenge

780  
00:33:12,650 --> 00:33:16,220  
let's I'm just going to show you okay so

781  
00:33:15,470 --> 00:33:17,960  
if you go to Mike

782  
00:33:16,220 --> 00:33:19,640  
Observatory that's the robotic telescope

783  
00:33:17,960 --> 00:33:21,650  
you can observe the object and do it

784  
00:33:19,640 --> 00:33:25,280

yourself but let's just go to the NASA

785

00:33:21,650 --> 00:33:27,980

data one and I just want to show you how

786

00:33:25,279 --> 00:33:29,720

it works so and there's there's a

787

00:33:27,980 --> 00:33:31,700

step-by-step guide but basically what

788

00:33:29,720 --> 00:33:34,730

you do is you open up this tool this is

789

00:33:31,700 --> 00:33:36,529

us this is a pared down version of the

790

00:33:34,730 --> 00:33:39,679

same tool that astronomers use for their

791

00:33:36,529 --> 00:33:41,538

research by the way okay we paired it

792

00:33:39,679 --> 00:33:44,390

down though and what you can do is on

793

00:33:41,538 --> 00:33:49,220

this tool you go over to images and you

794

00:33:44,390 --> 00:33:51,710

say okay I really want the Chandra x-ray

795

00:33:49,220 --> 00:33:54,558

of the Whirlpool Galaxy okay

796

00:33:51,710 --> 00:33:57,169

it puts it up there alright it doesn't

797

00:33:54,558 --> 00:33:59,599

seem like much but if you step through

798

00:33:57,169 --> 00:34:01,820

it there will be a hint that this is in



799

00:33:59,599 --> 00:34:03,889  
a linear scale of brightness and for

800

00:34:01,819 --> 00:34:07,819  
astronomical images it tends to help to

801

00:34:03,890 --> 00:34:09,440  
put it in a log scale there we go you

802

00:34:07,819 --> 00:34:13,579  
can mess with the controls on the side

803

00:34:09,440 --> 00:34:15,710  
until you can see it better so you can

804

00:34:13,579 --> 00:34:18,469  
kind of see it there you can add color

805

00:34:15,710 --> 00:34:20,570  
to it so I want I want x-ray high-energy

806

00:34:18,469 --> 00:34:24,168  
I want it to be blue so I'm going to

807

00:34:20,570 --> 00:34:30,379  
color it blue and I want to go to click

808

00:34:24,168 --> 00:34:32,480  
this RGB mode again it is all all on on

809

00:34:30,378 --> 00:34:35,628  
the tutorial so you can do it all right

810

00:34:32,480 --> 00:34:36,800  
now let's let's do Spitzer let's look at

811

00:34:35,628 --> 00:34:38,628  
the dust because that's what we're

812

00:34:36,800 --> 00:34:41,839  
really interested in yeah

813  
00:34:38,628 --> 00:34:43,878  
all right again do you log you can look

814  
00:34:41,838 --> 00:34:46,820  
at the dust I'm gonna go ahead and color

815  
00:34:43,878 --> 00:34:48,440  
that red by the way I'm doing the

816  
00:34:46,820 --> 00:34:50,179  
typical color scheme that astronomers

817  
00:34:48,440 --> 00:34:52,338  
would use where high energy is blue low

818  
00:34:50,179 --> 00:34:55,338  
energy is red but in you can do any

819  
00:34:52,338 --> 00:34:57,409  
color scheme you want it's all up to you

820  
00:34:55,338 --> 00:35:02,599  
alright and then we're gonna do a Hubble

821  
00:34:57,409 --> 00:35:11,739  
let's do a Hubble green and we will

822  
00:35:02,599 --> 00:35:11,740  
color it green and alright alright so

823  
00:35:13,440 --> 00:35:21,579  
alright so there's a Hubble green let me

824  
00:35:17,260 --> 00:35:25,030  
see here there we go and then you can

825  
00:35:21,579 --> 00:35:27,009  
combine them together and you get this

826  
00:35:25,030 --> 00:35:31,120  
and let me zoom out so you can see the

827

00:35:27,010 --> 00:35:34,330  
whole thing you get this beautiful now

828  
00:35:31,119 --> 00:35:35,589  
in this the red this and this it

829  
00:35:34,329 --> 00:35:37,630  
explains there's videos here on what

830  
00:35:35,590 --> 00:35:40,329  
these colors actually mean but the red

831  
00:35:37,630 --> 00:35:43,900  
is the dust okay that's being heated by

832  
00:35:40,329 --> 00:35:46,420  
stars okay and that's the Spitzer

833  
00:35:43,900 --> 00:35:48,010  
infrared the blue is the high-energy

834  
00:35:46,420 --> 00:35:51,210  
stuff that's coming from high energy

835  
00:35:48,010 --> 00:35:54,970  
sources like black holes or neutron

836  
00:35:51,210 --> 00:35:56,559  
stars okay that's what blue is and then

837  
00:35:54,969 --> 00:35:58,000  
green which unfortunately didn't look

838  
00:35:56,559 --> 00:36:00,429  
like it didn't come through very much on

839  
00:35:58,000 --> 00:36:02,440  
here but green from Hubble would be the

840  
00:36:00,429 --> 00:36:05,739  
typical stellar population the normal

841  
00:36:02,440 --> 00:36:06,970

stars okay and so there's other there's

842

00:36:05,739 --> 00:36:08,829

other wavelengths in here you can mess

843

00:36:06,969 --> 00:36:11,109

with but it's a fun way of just getting

844

00:36:08,829 --> 00:36:12,819

into the astrophotography and I should

845

00:36:11,110 --> 00:36:17,980

mention that I talked about how these

846

00:36:12,820 --> 00:36:19,600

detectors are pixelated right there

847

00:36:17,980 --> 00:36:20,980

actually pixels if you zoom in far

848

00:36:19,599 --> 00:36:25,360

enough you can start to see the pixels

849

00:36:20,980 --> 00:36:28,750

of the image okay right alright so that

850

00:36:25,360 --> 00:36:30,070

is that is what we call NASA's

851

00:36:28,750 --> 00:36:34,619

astrophotography challenge and we're

852

00:36:30,070 --> 00:36:37,710

coming up with a nice image in the and

853

00:36:34,619 --> 00:36:40,960

for the winter I also want to show you

854

00:36:37,710 --> 00:36:42,220

we have we have images from astronomer

855

00:36:40,960 --> 00:36:43,659

or we have videos from astronomers

856  
00:36:42,219 --> 00:36:46,449  
explaining what the different types of

857  
00:36:43,659 --> 00:36:47,829  
light tell you and then I also want to

858  
00:36:46,449 --> 00:36:50,279  
show you that from the summer challenge

859  
00:36:47,829 --> 00:36:52,869  
for the Whirlpool Galaxy we also

860  
00:36:50,280 --> 00:36:56,080  
highlight some really standout entries

861  
00:36:52,869 --> 00:36:58,509  
okay we highlight standout entries and

862  
00:36:56,079 --> 00:37:01,119  
scientists actually provide commentary

863  
00:36:58,510 --> 00:37:04,390  
on why they're so beautiful so if you

864  
00:37:01,119 --> 00:37:06,219  
also want yourself or anyone you know to

865  
00:37:04,389 --> 00:37:07,900  
take part in this we'll be doing it

866  
00:37:06,219 --> 00:37:09,819  
through December through January in the

867  
00:37:07,900 --> 00:37:12,460  
winter you can make your own beautiful

868  
00:37:09,820 --> 00:37:14,710  
images you can submit it and we'll

869  
00:37:12,460 --> 00:37:16,119  
highlight the standout entries and it's

870  
00:37:14,710 --> 00:37:19,690  
something that you can show off to

871  
00:37:16,119 --> 00:37:22,779  
others okay so this is sort of the this

872  
00:37:19,690 --> 00:37:24,070  
is a very similar process to how

873  
00:37:22,780 --> 00:37:26,680  
astronomers put together basically

874  
00:37:24,070 --> 00:37:29,920  
images and I believe Jody Pasquale

875  
00:37:26,679 --> 00:37:31,750  
he had a talk a few months ago so it was

876  
00:37:29,920 --> 00:37:35,110  
probably along these lines about how he

877  
00:37:31,750 --> 00:37:41,110  
puts his images together yeah all right

878  
00:37:35,110 --> 00:37:44,760  
okay all right let's go ahead and move

879  
00:37:41,110 --> 00:37:46,809  
along here all right

880  
00:37:44,760 --> 00:37:51,310  
all right I want to talk a little bit

881  
00:37:46,809 --> 00:37:53,320  
about photometry now all right so with

882  
00:37:51,309 --> 00:37:55,029  
the digital detectors it's possible to

883  
00:37:53,320 --> 00:37:57,700  
do what's called photometry which

884

00:37:55,030 --> 00:37:59,769  
basically is just counting the photons

885  
00:37:57,699 --> 00:38:02,799  
counting how many photons hit the

886  
00:37:59,769 --> 00:38:04,539  
detector and this is a tool and a

887  
00:38:02,800 --> 00:38:07,570  
technique that has been incredibly

888  
00:38:04,539 --> 00:38:09,699  
important in astronomy I'm highlighting

889  
00:38:07,570 --> 00:38:11,710  
Henrietta Leavitt here she did

890  
00:38:09,699 --> 00:38:15,399  
groundbreaking reefs were Kahn this at

891  
00:38:11,710 --> 00:38:18,429  
Harvard in fact they named a law after

892  
00:38:15,400 --> 00:38:21,460  
her Levitz law she this is a paper from

893  
00:38:18,429 --> 00:38:23,079  
1912 that she produced this was this is

894  
00:38:21,460 --> 00:38:24,789  
basically looking at those variable

895  
00:38:23,079 --> 00:38:27,429  
stars which I talked about earlier stars

896  
00:38:24,789 --> 00:38:32,679  
that vary in the night and what she

897  
00:38:27,429 --> 00:38:36,250  
noticed is that the if you look at a

898  
00:38:32,679 --> 00:38:37,539

stars period how much it brightens and

899

00:38:36,250 --> 00:38:39,280

fades and brightens and fades for

900

00:38:37,539 --> 00:38:42,670

certain kinds of stars if you look at

901

00:38:39,280 --> 00:38:45,550

that period and you also measure the

902

00:38:42,670 --> 00:38:47,860

brightness changes okay there's a

903

00:38:45,550 --> 00:38:50,650

relationship there and that's very

904

00:38:47,860 --> 00:38:52,960

important because this was really the

905

00:38:50,650 --> 00:38:56,920

first what we call standard candle for

906

00:38:52,960 --> 00:38:58,780

astronomy which means that if we can

907

00:38:56,920 --> 00:39:00,309

measure the period which is a pretty

908

00:38:58,780 --> 00:39:02,680

simple measurement you just measure the

909

00:39:00,309 --> 00:39:03,789

period of a star going getting brighter

910

00:39:02,679 --> 00:39:06,039

and fainter if you can measure that

911

00:39:03,789 --> 00:39:08,590

period you can just use this chart to

912

00:39:06,039 --> 00:39:11,039

calculate how bright it really is its



913  
00:39:08,590 --> 00:39:13,539  
intrinsic luminosity how bright it is

914  
00:39:11,039 --> 00:39:15,250  
right that's like if someone handed you

915  
00:39:13,539 --> 00:39:16,690  
a light bulb and you didn't know how

916  
00:39:15,250 --> 00:39:17,050  
bright it was and they told you it's 60

917  
00:39:16,690 --> 00:39:18,940  
watts

918  
00:39:17,050 --> 00:39:21,700  
okay well now you know something right

919  
00:39:18,940 --> 00:39:24,070  
so we know we now know these are called

920  
00:39:21,699 --> 00:39:25,480  
Cepheid variables we now know how bright

921  
00:39:24,070 --> 00:39:27,490  
they can be if we look at their periods

922  
00:39:25,480 --> 00:39:32,940  
this is an incredibly important

923  
00:39:27,489 --> 00:39:35,799  
discovery and here's why at the time and

924  
00:39:32,940 --> 00:39:40,450  
you know the late you know I'm sorry

925  
00:39:35,800 --> 00:39:42,970  
around night between 1919 12 to 19 to

926  
00:39:40,449 --> 00:39:44,348  
or so there's this there's this in even

927  
00:39:42,969 --> 00:39:45,399  
earlier there's this big debate in

928  
00:39:44,349 --> 00:39:47,920  
astronomy

929  
00:39:45,400 --> 00:39:50,889  
about these nebulae this they saw in the

930  
00:39:47,920 --> 00:39:52,240  
universe were they inside of our own

931  
00:39:50,889 --> 00:39:54,219  
Milky Way galaxy or did they exist

932  
00:39:52,239 --> 00:39:57,699  
outside of our Milky Way galaxy this is

933  
00:39:54,219 --> 00:39:59,559  
called the great debate okay and the

934  
00:39:57,699 --> 00:40:01,719  
great debate was actually was an actual

935  
00:39:59,559 --> 00:40:04,690  
essentially a debate that was held in

936  
00:40:01,719 --> 00:40:07,899  
nineteen in 1920 almost a hundred years

937  
00:40:04,690 --> 00:40:09,099  
ago and there was people you know there

938  
00:40:07,900 --> 00:40:10,809  
were two astronomers going back and

939  
00:40:09,099 --> 00:40:13,240  
forth and they couldn't resolve it but

940  
00:40:10,809 --> 00:40:16,299  
lo and behold Edwin Hubble using

941

00:40:13,239 --> 00:40:20,348  
Henrietta Leavitt Sturtevant's discovery of being

942  
00:40:16,300 --> 00:40:23,829  
able to calculate the brightness of a

943  
00:40:20,349 --> 00:40:26,289  
Cepheid variable took observations of a

944  
00:40:23,829 --> 00:40:28,480  
Cepheid variable from and around the

945  
00:40:26,289 --> 00:40:30,369  
Andromeda nebula he called it Andromeda

946  
00:40:28,480 --> 00:40:33,490  
nebula which we now know to be the

947  
00:40:30,369 --> 00:40:35,980  
Andromeda galaxy and he calculated its

948  
00:40:33,489 --> 00:40:38,828  
intrinsic brightness and if you know if

949  
00:40:35,980 --> 00:40:41,170  
you know how bright it should be and you

950  
00:40:38,829 --> 00:40:44,500  
know how bright it appears to you you

951  
00:40:41,170 --> 00:40:46,389  
know how far away it is okay and he was

952  
00:40:44,500 --> 00:40:48,250  
able to determine that Andromeda was

953  
00:40:46,389 --> 00:40:49,809  
actually way outside of our galaxy and

954  
00:40:48,250 --> 00:40:51,818  
that broke the great debate that

955  
00:40:49,809 --> 00:40:53,739

basically answered it to us where the

956

00:40:51,818 --> 00:40:56,440

Milky Way wasn't the entire universe all

957

00:40:53,739 --> 00:40:59,139

these galaxies were outside of our

958

00:40:56,440 --> 00:41:00,909

universe I mean outside of our galaxy

959

00:40:59,139 --> 00:41:02,379

all these other galaxies were outside of

960

00:41:00,909 --> 00:41:06,449

our own galaxy the universe was a much

961

00:41:02,380 --> 00:41:11,890

bigger place than we had thought before

962

00:41:06,449 --> 00:41:15,098

all right so today what does that mean

963

00:41:11,889 --> 00:41:17,230

well we're still using this tool this

964

00:41:15,099 --> 00:41:19,720

technique we're still using this

965

00:41:17,230 --> 00:41:21,219

photometer E and watching these variable

966

00:41:19,719 --> 00:41:24,219

stars and in fact you may have heard a

967

00:41:21,219 --> 00:41:27,759

lot of press over the last six months or

968

00:41:24,219 --> 00:41:29,549

so over this new debate over the Hubble

969

00:41:27,760 --> 00:41:30,700

constant the expansion of the universe

970  
00:41:29,550 --> 00:41:34,539  
okay

971  
00:41:30,699 --> 00:41:36,969  
and so this using this tool and

972  
00:41:34,539 --> 00:41:39,699  
technique astronomers using the Hubble

973  
00:41:36,969 --> 00:41:41,318  
Space Telescope observed a lot of

974  
00:41:39,699 --> 00:41:43,449  
Cepheid variables which this is supposed

975  
00:41:41,318 --> 00:41:45,460  
to represent a blow-up of Cepheid

976  
00:41:43,449 --> 00:41:46,989  
variables around the Magellanic Clouds

977  
00:41:45,460 --> 00:41:51,909  
and they observed these Cepheid

978  
00:41:46,989 --> 00:41:53,709  
variables and they came to a very they

979  
00:41:51,909 --> 00:41:54,279  
observe the Cepheid variables and they

980  
00:41:53,710 --> 00:41:55,630  
it was a

981  
00:41:54,280 --> 00:41:59,170  
they were Alette they are able to come

982  
00:41:55,630 --> 00:42:02,349  
up to a very good estimation of how fast

983  
00:41:59,170 --> 00:42:05,019  
the universe is expanding by looking at

984  
00:42:02,349 --> 00:42:06,759  
those Cepheid variables okay okay so

985  
00:42:05,019 --> 00:42:10,000  
these are a standard candle and you can

986  
00:42:06,760 --> 00:42:11,260  
use them you can use them as a distance

987  
00:42:10,000 --> 00:42:13,510  
ladder to understand how fast the

988  
00:42:11,260 --> 00:42:16,930  
universe is expanding with time the

989  
00:42:13,510 --> 00:42:20,500  
problem is is that it it significantly

990  
00:42:16,929 --> 00:42:22,059  
defers from the result of another space

991  
00:42:20,500 --> 00:42:24,099  
telescope called Planck that looks at

992  
00:42:22,059 --> 00:42:26,769  
the early universe looks at the

993  
00:42:24,099 --> 00:42:28,539  
conditions of the early universe you

994  
00:42:26,769 --> 00:42:31,179  
know twelve thirteen billion years ago

995  
00:42:28,539 --> 00:42:33,309  
on we think we understand the physics

996  
00:42:31,179 --> 00:42:35,619  
firm since then if you just play the

997  
00:42:33,309 --> 00:42:38,409  
movie forward the expansion rate at the

998

00:42:35,619 --> 00:42:40,900  
current time should be X but they but it

999  
00:42:38,409 --> 00:42:42,489  
that they're X doesn't match their value

1000  
00:42:40,900 --> 00:42:44,410  
basically there's a discrepancy between

1001  
00:42:42,489 --> 00:42:45,849  
what they think the expansion rate of

1002  
00:42:44,409 --> 00:42:48,579  
the universe is right now and what it

1003  
00:42:45,849 --> 00:42:50,860  
currently is and this is turning out to

1004  
00:42:48,579 --> 00:42:52,900  
be actually a modern-day debate that's

1005  
00:42:50,860 --> 00:42:54,550  
turning into a big thing because they've

1006  
00:42:52,900 --> 00:42:58,480  
gotten their airs down quite small and

1007  
00:42:54,550 --> 00:43:01,720  
they think that there may be new physics

1008  
00:42:58,480 --> 00:43:03,400  
here okay so I want to point this out to

1009  
00:43:01,719 --> 00:43:05,769  
you because these tools and techniques

1010  
00:43:03,400 --> 00:43:08,800  
that were you know first really started

1011  
00:43:05,769 --> 00:43:12,369  
from Henrietta Leavitt and the computers

1012  
00:43:08,800 --> 00:43:14,380

at Harvard back in the early 1900s those

1013

00:43:12,369 --> 00:43:17,529

techniques are still being perfected and

1014

00:43:14,380 --> 00:43:19,510

used today to find new clues to the to

1015

00:43:17,530 --> 00:43:22,300

the physics of our universe in the

1016

00:43:19,510 --> 00:43:24,630

present day of course now we have

1017

00:43:22,300 --> 00:43:27,580

Hubble's so so that that's a big help

1018

00:43:24,630 --> 00:43:29,680

all right okay

1019

00:43:27,579 --> 00:43:32,250

this idea of photometry is also used to

1020

00:43:29,679 --> 00:43:36,909

find alien worlds around other stars

1021

00:43:32,250 --> 00:43:41,230

exoplanets okay so you can use this same

1022

00:43:36,909 --> 00:43:42,879

technique let me see where you this is

1023

00:43:41,230 --> 00:43:46,480

what the Kepler space telescope did

1024

00:43:42,880 --> 00:43:49,119

Kepler was launched in 2009 I believe

1025

00:43:46,480 --> 00:43:50,740

and it stared at a blank patch of sky or

1026

00:43:49,119 --> 00:43:52,839

not a blank it stared at this patch of



1027  
00:43:50,739 --> 00:43:54,639  
sky definitely not blank there's a lot

1028  
00:43:52,840 --> 00:43:56,980  
of stars in this patch of sky but it

1029  
00:43:54,639 --> 00:43:59,589  
stared at it for many years and it just

1030  
00:43:56,980 --> 00:44:01,449  
looked for the dimming of basically the

1031  
00:43:59,590 --> 00:44:04,329  
photometry the dimming of the star over

1032  
00:44:01,449 --> 00:44:05,649  
of all those stars over time and it

1033  
00:44:04,329 --> 00:44:08,078  
looked at about a hundred and fifty

1034  
00:44:05,650 --> 00:44:10,900  
thousand stars looked for the dimming

1035  
00:44:08,079 --> 00:44:12,670  
and if those if the dimming kept

1036  
00:44:10,900 --> 00:44:13,869  
repeating they could use they could

1037  
00:44:12,670 --> 00:44:16,088  
infer that there perhaps there is a

1038  
00:44:13,869 --> 00:44:19,088  
planet going around the star and in our

1039  
00:44:16,088 --> 00:44:20,978  
line of sight blocking that star okay so

1040  
00:44:19,088 --> 00:44:22,808  
this is called the transit technique but

1041  
00:44:20,978 --> 00:44:24,728  
really it's basically photometry it's

1042  
00:44:22,809 --> 00:44:26,920  
basically just measuring how the Stars

1043  
00:44:24,728 --> 00:44:29,288  
dim with time and brighten with time

1044  
00:44:26,920 --> 00:44:30,849  
although in this case it's not because

1045  
00:44:29,289 --> 00:44:32,709  
unlike the Cepheid variable where the

1046  
00:44:30,849 --> 00:44:34,568  
star itself was physically dimming and

1047  
00:44:32,708 --> 00:44:36,639  
brightening in this case it's because

1048  
00:44:34,568 --> 00:44:40,329  
there's a planet coming in front and

1049  
00:44:36,639 --> 00:44:42,129  
behind the star okay and so because of

1050  
00:44:40,329 --> 00:44:44,229  
this technique which is a relatively new

1051  
00:44:42,130 --> 00:44:45,969  
technique of using where we use

1052  
00:44:44,228 --> 00:44:49,808  
photometry the Kepler space telescope

1053  
00:44:45,969 --> 00:44:52,509  
has found over 2,000 planets around

1054  
00:44:49,809 --> 00:44:54,339  
other stars but this technique we're

1055

00:44:52,509 --> 00:44:59,228  
still using it here is the test space

1056  
00:44:54,338 --> 00:45:02,469  
telescope and test was launched in 2018

1057  
00:44:59,228 --> 00:45:05,428  
and Tess has about a 400 times larger

1058  
00:45:02,469 --> 00:45:08,289  
search area than Kepler so it's going to

1059  
00:45:05,429 --> 00:45:09,429  
do exoplanet detections and the

1060  
00:45:08,289 --> 00:45:11,499  
basically the same way but it's

1061  
00:45:09,429 --> 00:45:13,719  
estimated to find many more what's

1062  
00:45:11,498 --> 00:45:16,298  
exciting about Tess is that it's going

1063  
00:45:13,719 --> 00:45:18,869  
to look at four exoplanets that are

1064  
00:45:16,298 --> 00:45:21,268  
closer to us a lot of Kepler's

1065  
00:45:18,869 --> 00:45:23,559  
exoplanets that discovered are quite far

1066  
00:45:21,268 --> 00:45:25,058  
but Tess is going to look for some that

1067  
00:45:23,559 --> 00:45:29,469  
are closer including this system which

1068  
00:45:25,059 --> 00:45:35,709  
was just released this summer with a

1069  
00:45:29,469 --> 00:45:37,749

very nice name GJ 3 5 7 GJ 3 5 7 is only

1070

00:45:35,708 --> 00:45:40,838

30 31 light-years away from us it's very

1071

00:45:37,748 --> 00:45:42,759

close as far as star systems go

1072

00:45:40,838 --> 00:45:47,199

and they just and test discovered this

1073

00:45:42,759 --> 00:45:51,579

inner 1 3 5 7 B around this small little

1074

00:45:47,199 --> 00:45:53,528

M dwarf star and test discovered that

1075

00:45:51,579 --> 00:45:55,449

and then once test discovered that what

1076

00:45:53,528 --> 00:45:57,608

happened was astronomers around the

1077

00:45:55,449 --> 00:45:59,588

world decided that they would look back

1078

00:45:57,608 --> 00:46:01,449

at all the archival data of that star

1079

00:45:59,588 --> 00:46:03,670

from other Telegram based telescopes in

1080

00:46:01,449 --> 00:46:07,059

the hid going back all the way through

1081

00:46:03,670 --> 00:46:09,880

the late 1990s and they realized that

1082

00:46:07,059 --> 00:46:11,410

they had and that data these two EXO

1083

00:46:09,880 --> 00:46:13,599

other exoplanets that had never been

1084  
00:46:11,409 --> 00:46:15,548  
detected it lived in that data but they

1085  
00:46:13,599 --> 00:46:18,670  
didn't know it and they didn't know how

1086  
00:46:15,548 --> 00:46:21,759  
to look for it until Tess found that

1087  
00:46:18,670 --> 00:46:23,590  
first one there these are all

1088  
00:46:21,760 --> 00:46:27,310  
super-earths size so larger than earth

1089  
00:46:23,590 --> 00:46:30,010  
that 3 5 7 B is much too close to the

1090  
00:46:27,309 --> 00:46:32,289  
star to be habitable but you see this

1091  
00:46:30,010 --> 00:46:37,600  
blue region called the habitable zone 3

1092  
00:46:32,289 --> 00:46:39,550  
5 7 D is potentially habitable follow-up

1093  
00:46:37,599 --> 00:46:42,519  
missions will have to explore the

1094  
00:46:39,550 --> 00:46:45,760  
habitability of that exoplanet but it's

1095  
00:46:42,519 --> 00:46:49,539  
about it's about 6 times the mass of our

1096  
00:46:45,760 --> 00:46:53,560  
earth it's called a super earth ok so

1097  
00:46:49,539 --> 00:46:56,079  
this so photometry is a very is a very

1098  
00:46:53,559 --> 00:47:01,090  
powerful tool that you can actually do

1099  
00:46:56,079 --> 00:47:03,179  
yourself with this with this online tool

1100  
00:47:01,090 --> 00:47:06,070  
called do-it-yourself planet search

1101  
00:47:03,179 --> 00:47:08,139  
what's really cool about this tool is is

1102  
00:47:06,070 --> 00:47:09,670  
that you yourself can do the same

1103  
00:47:08,139 --> 00:47:15,460  
techniques that astronomers do and you

1104  
00:47:09,670 --> 00:47:16,840  
can discover exoplanets ok and the way

1105  
00:47:15,460 --> 00:47:18,280  
it worked and by the way I know you're

1106  
00:47:16,840 --> 00:47:20,740  
like I'm never gonna remember all these

1107  
00:47:18,280 --> 00:47:22,570  
tools I'll give you one URL at the end

1108  
00:47:20,739 --> 00:47:26,379  
that you can find everything at or one

1109  
00:47:22,570 --> 00:47:27,940  
place you can look the DIY planet search

1110  
00:47:26,380 --> 00:47:29,890  
is a nice tool where you can basically

1111  
00:47:27,940 --> 00:47:32,920  
do the same processes that astronomers

1112

00:47:29,889 --> 00:47:34,569  
do with photometry so basically what you

1113  
00:47:32,920 --> 00:47:36,820  
do is you first choose a target

1114  
00:47:34,570 --> 00:47:38,620  
there are many targets you can choose

1115  
00:47:36,820 --> 00:47:40,930  
these and I should say these are known

1116  
00:47:38,619 --> 00:47:43,719  
exoplanets so you're going to get a

1117  
00:47:40,929 --> 00:47:45,069  
result if you do it correctly ok these

1118  
00:47:43,719 --> 00:47:48,699  
are known exoplanets that we've

1119  
00:47:45,070 --> 00:47:50,320  
discovered so you're going to get a

1120  
00:47:48,699 --> 00:47:52,419  
result so if you if you want to do this

1121  
00:47:50,320 --> 00:47:55,240  
you can observe anytime you can also go

1122  
00:47:52,420 --> 00:47:57,820  
back in the past and observe that's nice

1123  
00:47:55,239 --> 00:47:59,979  
if you want something right now you

1124  
00:47:57,820 --> 00:48:02,680  
don't have to wait for it I went ahead

1125  
00:47:59,980 --> 00:48:08,260  
and did that because we aren't going to

1126  
00:48:02,679 --> 00:48:10,059

wait several days and let me show you

1127

00:48:08,260 --> 00:48:14,830

what I did so I just want to bring this

1128

00:48:10,059 --> 00:48:17,440

up so that you can see let me see it's

1129

00:48:14,829 --> 00:48:20,079

this one yeah alright so what you can do

1130

00:48:17,440 --> 00:48:22,360

is you can bring up an image so

1131

00:48:20,079 --> 00:48:23,769

basically you can do you can observe the

1132

00:48:22,360 --> 00:48:25,510

the telescope's this is the same

1133

00:48:23,769 --> 00:48:27,639

microbes orbit Ori telescopes by the way

1134

00:48:25,510 --> 00:48:30,190

that I showed you earlier ok they

1135

00:48:27,639 --> 00:48:31,750

observe they're just 6-inch ground-based

1136

00:48:30,190 --> 00:48:34,369

telescopes but they can still detect

1137

00:48:31,750 --> 00:48:37,000

exoplanets which is amazing

1138

00:48:34,369 --> 00:48:40,279

so if you hit view you come up with a

1139

00:48:37,000 --> 00:48:41,869

region of the night sky and there's

1140

00:48:40,280 --> 00:48:43,460

instructions on how to do this but I'll



1141  
00:48:41,869 --> 00:48:45,079  
just walk you through real quick the

1142  
00:48:43,460 --> 00:48:47,449  
first thing that any astronomer needs to

1143  
00:48:45,079 --> 00:48:50,869  
do is to find their star one of these

1144  
00:48:47,449 --> 00:48:55,039  
stars has an exoplanet going around it

1145  
00:48:50,869 --> 00:48:57,250  
which one is it that one you're you're

1146  
00:48:55,039 --> 00:49:02,029  
right you're right

1147  
00:48:57,250 --> 00:49:04,190  
right right well right it's the one with

1148  
00:49:02,030 --> 00:49:06,920  
the yellow circle on it right yes that's

1149  
00:49:04,190 --> 00:49:08,659  
it that's it so there's a finder chart

1150  
00:49:06,920 --> 00:49:11,599  
right there's a finder chart here that

1151  
00:49:08,659 --> 00:49:14,509  
lets you find your star so the process

1152  
00:49:11,599 --> 00:49:16,730  
is you first calibrate your image and

1153  
00:49:14,510 --> 00:49:19,100  
what that means is that you subtract off

1154  
00:49:16,730 --> 00:49:20,719  
what's called the dark noise or the dark

1155  
00:49:19,099 --> 00:49:22,219  
current from the chip all these CCD

1156  
00:49:20,719 --> 00:49:24,259  
chips have these interesting noise

1157  
00:49:22,219 --> 00:49:25,579  
features first thing you do is you

1158  
00:49:24,260 --> 00:49:27,500  
subtract that off because that's just

1159  
00:49:25,579 --> 00:49:30,590  
noise so you click calibrate it does it

1160  
00:49:27,500 --> 00:49:33,800  
for you and then you bring up your

1161  
00:49:30,590 --> 00:49:36,920  
finder chart and you try to find out

1162  
00:49:33,800 --> 00:49:38,600  
where it is and you see these two stars

1163  
00:49:36,920 --> 00:49:39,110  
they're looking awful lot like these two

1164  
00:49:38,599 --> 00:49:41,960  
stars

1165  
00:49:39,110 --> 00:49:43,190  
if you ever observe it in the night sky

1166  
00:49:41,960 --> 00:49:44,599  
if you've ever done observing with your

1167  
00:49:43,190 --> 00:49:46,639  
own telescope you'd know the idea of

1168  
00:49:44,599 --> 00:49:48,549  
star hopping where you try to find the

1169

00:49:46,639 --> 00:49:51,379  
bright ones and you sort of hop around

1170  
00:49:48,550 --> 00:49:55,400  
and then the yellow one which is that

1171  
00:49:51,380 --> 00:49:56,599  
one is our target star right so let me

1172  
00:49:55,400 --> 00:49:58,940  
close that because I know what the

1173  
00:49:56,599 --> 00:50:00,829  
answers are alright so basically you put

1174  
00:49:58,940 --> 00:50:03,440  
your little cursor here and you click on

1175  
00:50:00,829 --> 00:50:05,029  
this and when you click on it what it's

1176  
00:50:03,440 --> 00:50:08,000  
doing is it's basically saying it's

1177  
00:50:05,030 --> 00:50:10,760  
going to count up all the photons or all

1178  
00:50:08,000 --> 00:50:12,110  
the light within that circle that's what

1179  
00:50:10,760 --> 00:50:13,490  
that circle is this like your bucket

1180  
00:50:12,110 --> 00:50:16,640  
it's going to count all the light in

1181  
00:50:13,489 --> 00:50:19,009  
that circle it asks for two comparison

1182  
00:50:16,639 --> 00:50:20,329  
stars because we're looking for a star

1183  
00:50:19,010 --> 00:50:21,860

that varies with time and you need to

1184

00:50:20,329 --> 00:50:24,670

compare it with a star that doesn't vary

1185

00:50:21,860 --> 00:50:28,070

with time as to get sort of a relative

1186

00:50:24,670 --> 00:50:29,420

measurement so the finer chart tells you

1187

00:50:28,070 --> 00:50:31,670

where these are but I'll just click them

1188

00:50:29,420 --> 00:50:32,869

here there's a comparison and then they

1189

00:50:31,670 --> 00:50:36,619

just want you to click on a couple of

1190

00:50:32,869 --> 00:50:38,659

dark patches of sky because the dark sky

1191

00:50:36,619 --> 00:50:39,739

could actually have some small amount of

1192

00:50:38,659 --> 00:50:43,789

brightness that you might want to

1193

00:50:39,739 --> 00:50:45,109

subtract off okay all the instructions

1194

00:50:43,789 --> 00:50:47,960

walk you through that and then when you

1195

00:50:45,110 --> 00:50:52,130

hit calculate and record

1196

00:50:47,960 --> 00:50:54,588

you are going to it'll tell you okay

1197

00:50:52,130 --> 00:50:57,410

relative brightness measurement so it's

1198  
00:50:54,588 --> 00:50:59,838  
about 80% as bright as the average of

1199  
00:50:57,409 --> 00:51:01,279  
those two stars what's important is you

1200  
00:50:59,838 --> 00:51:02,719  
do this as you can see with the

1201  
00:51:01,280 --> 00:51:05,480  
checkmarks with enough of those

1202  
00:51:02,719 --> 00:51:08,059  
observations of that same star and you

1203  
00:51:05,480 --> 00:51:10,099  
graph the brightness it'll graph it for

1204  
00:51:08,059 --> 00:51:13,480  
you and you can start to see although

1205  
00:51:10,099 --> 00:51:16,490  
it's noisy you can start to see a trend

1206  
00:51:13,480 --> 00:51:18,440  
where there's a dip where in here is

1207  
00:51:16,489 --> 00:51:20,868  
where the the transiting planet must be

1208  
00:51:18,440 --> 00:51:22,490  
in front of the star right now again

1209  
00:51:20,869 --> 00:51:24,108  
this is pretty powerful because this is

1210  
00:51:22,489 --> 00:51:26,059  
only a six inch telescope these are

1211  
00:51:24,108 --> 00:51:27,889  
pretty small telescopes there but

1212  
00:51:26,059 --> 00:51:29,719  
they're pretty powerful the idea that

1213  
00:51:27,889 --> 00:51:31,759  
with a six inch telescope you can

1214  
00:51:29,719 --> 00:51:34,669  
actually discover a planet around

1215  
00:51:31,760 --> 00:51:37,220  
another world it's quite amazing and in

1216  
00:51:34,670 --> 00:51:39,530  
fact if you go onto this tool you will

1217  
00:51:37,219 --> 00:51:40,969  
there's opportunities to to work with

1218  
00:51:39,530 --> 00:51:43,310  
others in the community that used this

1219  
00:51:40,969 --> 00:51:47,539  
tool to pull your your answers together

1220  
00:51:43,309 --> 00:51:49,940  
to get even more accurate data so this

1221  
00:51:47,539 --> 00:51:52,130  
is oh this is a fun tool that gets into

1222  
00:51:49,940 --> 00:51:55,429  
photometry that you that we would happy

1223  
00:51:52,130 --> 00:51:57,849  
for you to share with others I want to

1224  
00:51:55,429 --> 00:52:04,250  
also just make a couple other points

1225  
00:51:57,849 --> 00:52:06,019  
about other tools we work and a learning

1226

00:52:04,250 --> 00:52:08,150  
program called NASA's Universal learning

1227  
00:52:06,019 --> 00:52:10,460  
this is a NASA program where a Space

1228  
00:52:08,150 --> 00:52:12,139  
Telescope is is a member but we have

1229  
00:52:10,460 --> 00:52:14,240  
partners across the country including at

1230  
00:52:12,139 --> 00:52:15,739  
Sonoma State University and they're

1231  
00:52:14,239 --> 00:52:17,479  
leading this effort called the global

1232  
00:52:15,739 --> 00:52:20,750  
telescope Network where you can

1233  
00:52:17,480 --> 00:52:22,579  
basically do what we just did with that

1234  
00:52:20,750 --> 00:52:24,800  
but with even larger telescopes

1235  
00:52:22,579 --> 00:52:27,170  
ground-based telescopes and even do more

1236  
00:52:24,800 --> 00:52:29,030  
you can do exoplanets just like we just

1237  
00:52:27,170 --> 00:52:31,159  
did there you could do variable stars

1238  
00:52:29,030 --> 00:52:33,560  
like Henrietta Leavitt was doing an

1239  
00:52:31,159 --> 00:52:35,779  
Edwin Hubble was doing okay so there's

1240  
00:52:33,559 --> 00:52:38,420

there's online tools that you can do and

1241  
00:52:35,780 --> 00:52:42,349  
learn about with the global telescope

1242  
00:52:38,420 --> 00:52:44,088  
network likewise there's a project

1243  
00:52:42,349 --> 00:52:47,059  
that's coming out very soon that we're

1244  
00:52:44,088 --> 00:52:50,239  
excited to share with you it's called

1245  
00:52:47,059 --> 00:52:53,599  
the exoplanet transit survey this is

1246  
00:52:50,239 --> 00:52:58,250  
aimed at amateur astronomers and smaller

1247  
00:52:53,599 --> 00:53:00,619  
colleges universities basically you can

1248  
00:52:58,250 --> 00:53:01,639  
you can observe high-priority transiting

1249  
00:53:00,619 --> 00:53:03,200  
exoplanets

1250  
00:53:01,639 --> 00:53:06,318  
discovered by Kepler tests and other

1251  
00:53:03,199 --> 00:53:07,879  
surveys this is getting more into doing

1252  
00:53:06,318 --> 00:53:10,219  
actual I mean this is really getting

1253  
00:53:07,880 --> 00:53:11,650  
into actual science here so the whole

1254  
00:53:10,219 --> 00:53:14,298  
point of this is to pool together



1255  
00:53:11,650 --> 00:53:17,539  
ground-based telescopes small large

1256  
00:53:14,298 --> 00:53:20,210  
whatever they are and to do things like

1257  
00:53:17,539 --> 00:53:20,960  
follow up on potential tests discoveries

1258  
00:53:20,210 --> 00:53:22,369  
okay

1259  
00:53:20,960 --> 00:53:24,949  
so test is going to do a lot of

1260  
00:53:22,369 --> 00:53:26,690  
discoveries but they're not test is only

1261  
00:53:24,949 --> 00:53:29,239  
going to maybe visit a few some of those

1262  
00:53:26,690 --> 00:53:31,130  
may be one visit or one pass so there

1263  
00:53:29,239 --> 00:53:32,809  
might be uncertain so if you follow up

1264  
00:53:31,130 --> 00:53:34,930  
with these ground base you might

1265  
00:53:32,809 --> 00:53:39,920  
actually be able to confirm that there's

1266  
00:53:34,929 --> 00:53:41,690  
possibly an exoplanet there okay and so

1267  
00:53:39,920 --> 00:53:44,389  
this is something that's that's going to

1268  
00:53:41,690 --> 00:53:46,999  
be out in the next hopefully next

1269  
00:53:44,389 --> 00:53:48,739  
several months so keep that in mind

1270  
00:53:46,998 --> 00:53:51,618  
again this is a NASA's Universal

1271  
00:53:48,739 --> 00:53:53,509  
Learning Program I will and this is done

1272  
00:53:51,619 --> 00:53:57,220  
with our partners at at NASA's Jet

1273  
00:53:53,509 --> 00:53:59,568  
Propulsion Laboratory I encourage you to

1274  
00:53:57,219 --> 00:54:01,038  
an off point this again at the end go to

1275  
00:53:59,568 --> 00:54:02,869  
NASA's Universal learning site all of

1276  
00:54:01,039 --> 00:54:05,710  
the activities that I show you will be

1277  
00:54:02,869 --> 00:54:10,099  
there all right

1278  
00:54:05,710 --> 00:54:11,539  
spectroscopy probably I this I'm biased

1279  
00:54:10,099 --> 00:54:15,588  
but I think this is the most powerful

1280  
00:54:11,539 --> 00:54:16,640  
tool in our toolkit so how are we doing

1281  
00:54:15,588 --> 00:54:19,239  
on time we're just getting to the

1282  
00:54:16,639 --> 00:54:20,838  
punchline we all right okay all right

1283

00:54:19,239 --> 00:54:23,900  
all right

1284  
00:54:20,838 --> 00:54:27,038  
so spectroscopy and you got a nice

1285  
00:54:23,900 --> 00:54:30,170  
Luthor that showcases some spectroscopy

1286  
00:54:27,039 --> 00:54:31,549  
you know they say a picture is worth a

1287  
00:54:30,170 --> 00:54:33,309  
thousand words sometimes they say a

1288  
00:54:31,548 --> 00:54:35,748  
spectrum is worth a thousand pictures

1289  
00:54:33,309 --> 00:54:38,329  
spectroscopy really has a lot of

1290  
00:54:35,748 --> 00:54:40,129  
information in it what is spectroscopy

1291  
00:54:38,329 --> 00:54:42,079  
well spectroscopy is just breaking up

1292  
00:54:40,130 --> 00:54:46,430  
the light you get into the component

1293  
00:54:42,079 --> 00:54:49,278  
colors okay a lot of people credit Isaac

1294  
00:54:46,429 --> 00:54:50,899  
Newton was sort of the invention of the

1295  
00:54:49,278 --> 00:54:52,579  
the field of spectroscopy although

1296  
00:54:50,900 --> 00:54:56,028  
others were doing spectroscopy before

1297  
00:54:52,579 --> 00:54:58,849

him in the 1600s and in fact the Romans

1298

00:54:56,028 --> 00:55:01,818

were breaking up light with with glass

1299

00:54:58,849 --> 00:55:06,579

and seeing rainbows but Isaac Newton in

1300

00:55:01,818 --> 00:55:09,619

his optics book that came out in 1704

1301

00:55:06,579 --> 00:55:12,109

basically put together the fact that you

1302

00:55:09,619 --> 00:55:13,400

can actually break up white light into

1303

00:55:12,108 --> 00:55:14,748

the component colors and put the

1304

00:55:13,400 --> 00:55:15,200

component colors back together again in

1305

00:55:14,748 --> 00:55:17,259

white light

1306

00:55:15,199 --> 00:55:19,789

so he basically showed with his

1307

00:55:17,260 --> 00:55:22,010

experiments that that white light was

1308

00:55:19,789 --> 00:55:24,949

really comprised of those of those

1309

00:55:22,010 --> 00:55:26,750

colors of the rainbow alright so you can

1310

00:55:24,949 --> 00:55:28,429

see him with the prism there and that

1311

00:55:26,750 --> 00:55:33,409

pick in that painting breaking up the

1312  
00:55:28,429 --> 00:55:36,230  
light alright so let's go ahead and do a

1313  
00:55:33,409 --> 00:55:39,048  
demo I have this up here this is uh this

1314  
00:55:36,230 --> 00:55:40,429  
is sort of an idea there's a lot of

1315  
00:55:39,048 --> 00:55:44,000  
stuff on here all I want to get across

1316  
00:55:40,429 --> 00:55:45,199  
is is it in most cases on a telescope if

1317  
00:55:44,000 --> 00:55:46,818  
you have as if you're trying to take a

1318  
00:55:45,199 --> 00:55:48,858  
spectrum of an object if you're trying

1319  
00:55:46,818 --> 00:55:51,949  
to break the light up of an object you

1320  
00:55:48,858 --> 00:55:54,409  
have you want to you want to only get

1321  
00:55:51,949 --> 00:55:56,179  
the target usually right so you have a

1322  
00:55:54,409 --> 00:55:58,730  
star or you have a galaxy or something

1323  
00:55:56,179 --> 00:56:01,009  
and so you need some way of preventing

1324  
00:55:58,730 --> 00:56:03,769  
all the other light from the image from

1325  
00:56:01,010 --> 00:56:05,680  
getting into your great getting into

1326  
00:56:03,769 --> 00:56:08,719  
this grating is essentially a prism you

1327  
00:56:05,679 --> 00:56:10,308  
only want your target to be broken up

1328  
00:56:08,719 --> 00:56:12,199  
into a spectrum that's not always the

1329  
00:56:10,309 --> 00:56:13,819  
case there are others there are other

1330  
00:56:12,199 --> 00:56:15,649  
spec there are other spectrographs on

1331  
00:56:13,818 --> 00:56:17,210  
our two instruments things that are

1332  
00:56:15,650 --> 00:56:19,220  
things like all like ia fuse and other

1333  
00:56:17,210 --> 00:56:21,309  
things that that you can basically get a

1334  
00:56:19,219 --> 00:56:24,259  
spectrum of the entire field if you will

1335  
00:56:21,309 --> 00:56:26,540  
but the idea is is that you take the

1336  
00:56:24,260 --> 00:56:27,890  
light from a source you you pass it

1337  
00:56:26,539 --> 00:56:30,588  
through in this case it's a grating but

1338  
00:56:27,889 --> 00:56:32,179  
it acts like a prism you break up you

1339  
00:56:30,588 --> 00:56:34,369  
bend the colors of light and then you

1340

00:56:32,179 --> 00:56:49,480  
put it on a detector your CCD chip and

1341  
00:56:34,369 --> 00:56:55,660  
you read it on yeah yeah yeah yeah yeah

1342  
00:56:49,480 --> 00:56:55,659  
yeah it is just just imagine that it's

1343  
00:56:55,960 --> 00:57:04,068  
alright Theatre of the mind people all

1344  
00:56:58,489 --> 00:57:05,419  
right ok thank you Frank but what's

1345  
00:57:04,068 --> 00:57:07,250  
powerful about spectroscopy why

1346  
00:57:05,420 --> 00:57:08,298  
spectroscopy is so powerful there's so

1347  
00:57:07,250 --> 00:57:10,159  
many things you can learn about an

1348  
00:57:08,298 --> 00:57:12,469  
object with a spectrum ok you can learn

1349  
00:57:10,159 --> 00:57:14,239  
in this case we're showing you one

1350  
00:57:12,469 --> 00:57:15,739  
example you can learn the composition of

1351  
00:57:14,239 --> 00:57:18,919  
the object what the object is made out

1352  
00:57:15,739 --> 00:57:20,989  
of you can learn how far away an object

1353  
00:57:18,920 --> 00:57:23,659  
is you can learn how fast it's moving

1354  
00:57:20,989 --> 00:57:25,548

through space you can learn the

1355

00:57:23,659 --> 00:57:27,379

temperature of an object there's so many

1356

00:57:25,548 --> 00:57:28,789

things that a spectrum can give you if

1357

00:57:27,380 --> 00:57:33,200

you if you

1358

00:57:28,789 --> 00:57:34,699

if you take a spectrum so with that let

1359

00:57:33,199 --> 00:57:38,679

me go ahead and switch over we're gonna

1360

00:57:34,699 --> 00:57:40,759

try something we've see if this works

1361

00:57:38,679 --> 00:57:47,239

all right we're gonna go ahead and do a

1362

00:57:40,760 --> 00:57:47,960

demo here and before we turn though

1363

00:57:47,239 --> 00:57:50,449

there we go

1364

00:57:47,960 --> 00:57:56,420

before we turn the lights off I need to

1365

00:57:50,449 --> 00:57:58,009

switch it over see if you can see I want

1366

00:57:56,420 --> 00:58:02,480

you to see what I can see on my screen

1367

00:57:58,010 --> 00:58:07,040

here there we go all right okay all

1368

00:58:02,480 --> 00:58:10,099

right now what I have up here in the



1369  
00:58:07,039 --> 00:58:11,900  
front is I have a camera with us with

1370  
00:58:10,099 --> 00:58:13,819  
essentially a prism or a grating in it

1371  
00:58:11,900 --> 00:58:15,920  
that's going to be our spectrograph and

1372  
00:58:13,820 --> 00:58:18,440  
then I have these tubes that are filled

1373  
00:58:15,920 --> 00:58:20,300  
with an element okay and I'm going to

1374  
00:58:18,440 --> 00:58:21,860  
heat up I'm going to turn this on and

1375  
00:58:20,300 --> 00:58:24,980  
it's going to heat the element the gas

1376  
00:58:21,860 --> 00:58:26,840  
in this and it's going to give off very

1377  
00:58:24,980 --> 00:58:29,210  
specific colors that are associated with

1378  
00:58:26,840 --> 00:58:32,240  
that gas okay essentially it's going to

1379  
00:58:29,210 --> 00:58:33,800  
give off a spectrum it's it's what we

1380  
00:58:32,239 --> 00:58:37,009  
call we sometimes call it a spectral

1381  
00:58:33,800 --> 00:58:38,420  
fingerprint so let me go ahead and turn

1382  
00:58:37,010 --> 00:58:40,690  
that on okay you can go ahead and turn

1383  
00:58:38,420 --> 00:58:44,510  
the lights off now yeah Thank You Thomas

1384  
00:58:40,690 --> 00:58:48,950  
all right turn that on all right good

1385  
00:58:44,510 --> 00:58:51,410  
okay so when you look at this screen

1386  
00:58:48,949 --> 00:58:54,409  
all right so there there's the tube you

1387  
00:58:51,409 --> 00:58:56,719  
see it bright that sort of hashed bar is

1388  
00:58:54,409 --> 00:58:58,639  
essentially the amount where I want the

1389  
00:58:56,719 --> 00:59:00,230  
light to come through so I don't want to

1390  
00:58:58,639 --> 00:59:02,119  
include all this other stuff in the

1391  
00:59:00,230 --> 00:59:04,250  
spectrum and then here's actually where

1392  
00:59:02,119 --> 00:59:06,559  
it breaks it apart and then you can see

1393  
00:59:04,250 --> 00:59:09,409  
over here it graphs it for you so these

1394  
00:59:06,559 --> 00:59:12,049  
are nanometers these are essentially the

1395  
00:59:09,409 --> 00:59:14,299  
wavelength of light and this is

1396  
00:59:12,050 --> 00:59:17,000  
intensity or how bright the light is

1397

00:59:14,300 --> 00:59:20,210  
and you'll notice that a few lines

1398  
00:59:17,000 --> 00:59:22,159  
really stick out okay and those are the

1399  
00:59:20,210 --> 00:59:24,019  
fingerprints that tell us what this

1400  
00:59:22,159 --> 00:59:28,129  
element is does anyone know what's in

1401  
00:59:24,019 --> 00:59:29,780  
this - how many chemical how many

1402  
00:59:28,130 --> 00:59:32,140  
chemistry of spectroscopy is do we have

1403  
00:59:29,780 --> 00:59:32,140  
in the room

1404  
00:59:32,298 --> 00:59:38,099  
all right God all right well luckily

1405  
00:59:36,088 --> 00:59:39,808  
people have done this in the laboratory

1406  
00:59:38,099 --> 00:59:42,390  
for a long time and they have the

1407  
00:59:39,809 --> 00:59:45,390  
answers for us so let me go ahead and

1408  
00:59:42,389 --> 00:59:49,409  
show you I'm going to over plot a line

1409  
00:59:45,389 --> 00:59:51,150  
here hydrogen lines and what you'll

1410  
00:59:49,409 --> 00:59:54,210  
notice is these are called the hydrogen

1411  
00:59:51,150 --> 00:59:56,910

bomber lines but they mark them so this

1412  
00:59:54,210 --> 01:00:00,088  
is called hydrogen alpha hydrogen beta

1413  
00:59:56,909 --> 01:00:01,618  
and so on there's one there it turns out

1414  
01:00:00,088 --> 01:00:03,838  
you don't really see these because the

1415  
01:00:01,619 --> 01:00:07,440  
sensitivity the check the chip drops off

1416  
01:00:03,838 --> 01:00:09,210  
over in the and the violet and so we

1417  
01:00:07,440 --> 01:00:12,119  
don't really the chip can't detect those

1418  
01:00:09,210 --> 01:00:14,670  
colors this is all noise over here by

1419  
01:00:12,119 --> 01:00:17,010  
the way so you can ignore this but here

1420  
01:00:14,670 --> 01:00:18,809  
between here and here is essentially

1421  
01:00:17,010 --> 01:00:22,740  
what the chip somewhere around here is

1422  
01:00:18,809 --> 01:00:26,819  
what the chip can see so that tells us

1423  
01:00:22,739 --> 01:00:28,798  
that we have hydrogen hydrogen lines so

1424  
01:00:26,818 --> 01:00:30,420  
when an astronomer is doing this and

1425  
01:00:28,798 --> 01:00:34,380  
this is actually a lot of what I did for

1426  
01:00:30,420 --> 01:00:37,980  
my PhD work is we we get a spectrum from

1427  
01:00:34,380 --> 01:00:40,530  
an object okay and it's a mystery right

1428  
01:00:37,980 --> 01:00:44,010  
and so you create these line lists like

1429  
01:00:40,530 --> 01:00:47,819  
we have here this is hydrogen bomber but

1430  
01:00:44,010 --> 01:00:49,500  
you know if I also clicked on h2o water

1431  
01:00:47,818 --> 01:00:54,199  
that's what the that's what the water

1432  
01:00:49,500 --> 01:00:56,639  
lines would be or neon or so on right

1433  
01:00:54,199 --> 01:00:57,929  
you can see it gets quite complicated if

1434  
01:00:56,639 --> 01:00:59,909  
your object has a lot of different

1435  
01:00:57,929 --> 01:01:01,409  
elements in it but that's where that's

1436  
01:00:59,909 --> 01:01:05,368  
that's that's where you make your money

1437  
01:01:01,409 --> 01:01:07,348  
right all right so that's hydrogen

1438  
01:01:05,369 --> 01:01:09,059  
bomber but let's let's actually take a

1439  
01:01:07,349 --> 01:01:15,079  
let me turn that off for a second and

1440  
01:01:09,059 --> 01:01:18,450  
let me overlay on here a reference star

1441  
01:01:15,079 --> 01:01:23,519  
I'm gonna do this is this is the

1442  
01:01:18,449 --> 01:01:24,750  
spectrum of a star an a0 star this is

1443  
01:01:23,519 --> 01:01:27,329  
basically if you've heard of the star

1444  
01:01:24,750 --> 01:01:30,809  
Vega this is equivalent to Vega what

1445  
01:01:27,329 --> 01:01:32,609  
you'll notice you notice that those we

1446  
01:01:30,809 --> 01:01:35,339  
call these emission lines the hot gas

1447  
01:01:32,608 --> 01:01:36,750  
from the tube ISM is creating these

1448  
01:01:35,338 --> 01:01:38,608  
emission lines these spectral

1449  
01:01:36,750 --> 01:01:41,909  
fingerprints you'll notice that they

1450  
01:01:38,608 --> 01:01:44,400  
overlap directly with these dips that

1451  
01:01:41,909 --> 01:01:48,449  
you see in the Stars spectrum

1452  
01:01:44,400 --> 01:01:51,568  
okay it turns out that four stars they

1453  
01:01:48,449 --> 01:01:53,489  
have these outer atmospheres okay

1454

01:01:51,568 --> 01:01:55,949  
so this this hot gas is emitting these

1455  
01:01:53,489 --> 01:02:00,000  
signature stars have these cooler

1456  
01:01:55,949 --> 01:02:02,460  
atmospheres where they absorb the

1457  
01:02:00,000 --> 01:02:05,608  
photons of specific from specific

1458  
01:02:02,460 --> 01:02:07,889  
elements so this star has an outer

1459  
01:02:05,608 --> 01:02:12,088  
atmosphere of hydrogen and we know that

1460  
01:02:07,889 --> 01:02:14,009  
because it's absorbing hydrogen because

1461  
01:02:12,088 --> 01:02:18,358  
there is less hydrogen that that line is

1462  
01:02:14,010 --> 01:02:20,309  
associate with hydrogen and so we can

1463  
01:02:18,358 --> 01:02:22,139  
actually use these are called absorption

1464  
01:02:20,309 --> 01:02:24,660  
lines so whether there are being emitted

1465  
01:02:22,139 --> 01:02:30,960  
from a hot gas like that tube or whether

1466  
01:02:24,659 --> 01:02:33,420  
the gas is absorbing photons the gas is

1467  
01:02:30,960 --> 01:02:36,028  
cooler and absorbing photons you can

1468  
01:02:33,420 --> 01:02:37,048

still do doesn't matter if it's emission

1469

01:02:36,028 --> 01:02:40,619

or absorption you can determine that

1470

01:02:37,048 --> 01:02:42,869

hydrogen is there right so this is

1471

01:02:40,619 --> 01:02:44,548

actually one of the ways in which they

1472

01:02:42,869 --> 01:02:46,559

did the stellar classifications of stars

1473

01:02:44,548 --> 01:02:49,679

so if you ever wondered why stars have

1474

01:02:46,559 --> 01:02:52,500

these weird classifications of Oh be a

1475

01:02:49,679 --> 01:02:55,980

FG whatever if you've ever heard of that

1476

01:02:52,500 --> 01:02:57,389

it actually initially came from using

1477

01:02:55,980 --> 01:02:58,920

spectroscopy and looking at the

1478

01:02:57,389 --> 01:03:01,920

strengths of the hydrogen Balmer lines

1479

01:02:58,920 --> 01:03:03,930

some a stars have very strong hydrogen

1480

01:03:01,920 --> 01:03:08,460

bomber lines they have very strong

1481

01:03:03,929 --> 01:03:10,528

hydrogen presence present in the Balmer

1482

01:03:08,460 --> 01:03:12,028

series and I keep saying bomber because



1483  
01:03:10,528 --> 01:03:15,358  
there's different kinds of hydrogen

1484  
01:03:12,028 --> 01:03:17,400  
hydrogen lines let me go ahead and do

1485  
01:03:15,358 --> 01:03:23,788  
another example let's go ahead and turn

1486  
01:03:17,400 --> 01:03:29,660  
that alright actually let me go ahead

1487  
01:03:23,789 --> 01:03:32,990  
and turn on see this is a star this is a

1488  
01:03:29,659 --> 01:03:36,659  
g25 star so this is a star like our Sun

1489  
01:03:32,989 --> 01:03:38,608  
so our Sun has a spectrum like this this

1490  
01:03:36,659 --> 01:03:40,679  
is a cool our Sun is a cooler star than

1491  
01:03:38,608 --> 01:03:42,179  
the a star and as you get cooler and

1492  
01:03:40,679 --> 01:03:44,399  
cooler stars you're gonna notice that

1493  
01:03:42,179 --> 01:03:45,778  
the spectrum looks a little Messier but

1494  
01:03:44,400 --> 01:03:48,389  
it's actually because there's a lot more

1495  
01:03:45,778 --> 01:03:50,278  
features that you see okay so it gets

1496  
01:03:48,389 --> 01:03:52,078  
actually quite complicated it's hard to

1497  
01:03:50,278 --> 01:03:53,460  
see but there is hydrogen there you can

1498  
01:03:52,079 --> 01:03:57,059  
see that it matches up with that and

1499  
01:03:53,460 --> 01:03:58,289  
there's hydrogen there but there's

1500  
01:03:57,059 --> 01:04:01,619  
something else that's really

1501  
01:03:58,289 --> 01:04:02,278  
cool that I want to show you let's take

1502  
01:04:01,619 --> 01:04:08,880  
off

1503  
01:04:02,278 --> 01:04:18,929  
let's take hydrogen out let's put in a

1504  
01:04:08,880 --> 01:04:21,239  
different element all right all right

1505  
01:04:18,929 --> 01:04:24,660  
you can see this has a lot more lines

1506  
01:04:21,239 --> 01:04:29,519  
right this has this spec this spectrum

1507  
01:04:24,659 --> 01:04:31,739  
is quite quite busier but you'll notice

1508  
01:04:29,518 --> 01:04:34,798  
that there are some features that that

1509  
01:04:31,739 --> 01:04:38,099  
do overlap with this sun-like star

1510  
01:04:34,798 --> 01:04:40,739  
spectrum don't nominally this this sort

1511

01:04:38,099 --> 01:04:42,298  
of yellow line here you kind of you kind

1512  
01:04:40,739 --> 01:04:47,699  
of see it dip up there and in fact I

1513  
01:04:42,298 --> 01:04:54,949  
could if I see if I can make this work

1514  
01:04:47,699 --> 01:04:58,289  
I might be able to not sure all right

1515  
01:04:54,949 --> 01:05:02,278  
there was some way that I forgot how of

1516  
01:04:58,289 --> 01:05:03,419  
zooming in anyway look at the mouse look

1517  
01:05:02,278 --> 01:05:07,469  
at the mouse it'll tell you where it is

1518  
01:05:03,418 --> 01:05:10,108  
all right so there is a dip there and it

1519  
01:05:07,469 --> 01:05:13,369  
turns out that does anyone know what's

1520  
01:05:10,108 --> 01:05:16,188  
at around five hundred and eighty-eight

1521  
01:05:13,369 --> 01:05:19,919  
nanometers

1522  
01:05:16,188 --> 01:05:22,558  
what was it not sodium although that

1523  
01:05:19,918 --> 01:05:25,078  
color looks very similar to it's

1524  
01:05:22,559 --> 01:05:27,599  
actually helium this is a helium

1525  
01:05:25,079 --> 01:05:30,179

spectrum and it turns out that this is

1526

01:05:27,599 --> 01:05:32,249

how helium was discovered because helium

1527

01:05:30,179 --> 01:05:34,858

is very rare on the earth it's a very

1528

01:05:32,248 --> 01:05:37,708

light gas helium was first discovered in

1529

01:05:34,858 --> 01:05:42,748

the Sun and and this was the line that

1530

01:05:37,708 --> 01:05:46,228

we discovered helium this 588 nanometer

1531

01:05:42,748 --> 01:05:47,639

line so using spectroscopy you know we

1532

01:05:46,228 --> 01:05:49,498

didn't we're doing a lot of things but

1533

01:05:47,639 --> 01:05:54,568

we're also you know filling in the

1534

01:05:49,498 --> 01:05:56,478

periodic table and that was actually

1535

01:05:54,568 --> 01:06:02,938

done in eight let me see if I did yeah

1536

01:05:56,478 --> 01:06:04,519

1868 all right so see we could play with

1537

01:06:02,938 --> 01:06:06,940

this all day but it's getting late

1538

01:06:04,519 --> 01:06:09,978

[Laughter]

1539

01:06:06,940 --> 01:06:11,210

but actually if you're interested after

1540  
01:06:09,978 --> 01:06:12,528  
we're done if you want to come up and

1541  
01:06:11,210 --> 01:06:16,239  
take a look at it - I'm happy to show

1542  
01:06:12,528 --> 01:06:19,460  
you this or any any of the other tools

1543  
01:06:16,239 --> 01:06:20,630  
alright so let's go ahead and I'm gonna

1544  
01:06:19,460 --> 01:06:27,739  
go ahead and go through a few more

1545  
01:06:20,630 --> 01:06:29,719  
things and then we'll wrap up all right

1546  
01:06:27,739 --> 01:06:34,159  
I have to do this again

1547  
01:06:29,719 --> 01:06:36,519  
look at my dust yes it's the best all

1548  
01:06:34,159 --> 01:06:39,768  
right okay

1549  
01:06:36,518 --> 01:06:43,149  
alright so this is what I studied as a

1550  
01:06:39,768 --> 01:06:45,018  
graduate student and this this is

1551  
01:06:43,150 --> 01:06:46,818  
something called the diffuse Center

1552  
01:06:45,018 --> 01:06:50,149  
seller bands there's probably ten people

1553  
01:06:46,818 --> 01:06:52,670  
in the world that study this I'm only

1554  
01:06:50,150 --> 01:06:56,450  
slightly exaggerating but it's a very

1555  
01:06:52,670 --> 01:06:59,059  
difficult mystery these are this is a

1556  
01:06:56,449 --> 01:07:01,098  
sort of a more modern-day absorption

1557  
01:06:59,059 --> 01:07:04,369  
profile look of it each of those dips

1558  
01:07:01,099 --> 01:07:06,979  
are absorption features that are called

1559  
01:07:04,369 --> 01:07:11,059  
that a few Center solar bands they were

1560  
01:07:06,978 --> 01:07:14,088  
first discovered around 1919 by Mary Lea

1561  
01:07:11,059 --> 01:07:16,759  
Hager she was a graduate student of Lick

1562  
01:07:14,088 --> 01:07:20,420  
Observatory and there the longest

1563  
01:07:16,759 --> 01:07:21,949  
spectroscopic mystery in astronomy we

1564  
01:07:20,420 --> 01:07:24,650  
don't know what these are these are

1565  
01:07:21,949 --> 01:07:27,248  
absorption features from things that we

1566  
01:07:24,650 --> 01:07:31,249  
can identify in the interstellar medium

1567  
01:07:27,248 --> 01:07:34,608  
so we know it's coming from the space in

1568

01:07:31,248 --> 01:07:35,988  
between stars because of the way the

1569  
01:07:34,608 --> 01:07:37,818  
features look they don't look like

1570  
01:07:35,989 --> 01:07:39,769  
they're coming from around stars they're

1571  
01:07:37,818 --> 01:07:41,659  
not don't have this sort of spectrum

1572  
01:07:39,768 --> 01:07:42,379  
that you would expect if they were near

1573  
01:07:41,659 --> 01:07:43,848  
a star

1574  
01:07:42,380 --> 01:07:46,640  
they look like they're coming they're

1575  
01:07:43,849 --> 01:07:47,979  
from the space between stars but we

1576  
01:07:46,639 --> 01:07:52,728  
don't know what they are

1577  
01:07:47,978 --> 01:07:55,248  
okay so it's been a it's been a mystery

1578  
01:07:52,728 --> 01:07:58,218  
and there's actually over 400 of these

1579  
01:07:55,248 --> 01:08:00,679  
absorption profiles now so we don't know

1580  
01:07:58,219 --> 01:08:02,139  
when married is Leah Hager discovered

1581  
01:08:00,679 --> 01:08:04,909  
him I believe she discovered two of them

1582  
01:08:02,139 --> 01:08:07,159

initially and now we know of over 400

1583

01:08:04,909 --> 01:08:09,558

and they're there throughout the visible

1584

01:08:07,159 --> 01:08:11,748

part of the spectrum and end close into

1585

01:08:09,559 --> 01:08:15,170

the near-infrared near infrareds here

1586

01:08:11,748 --> 01:08:18,079

visible spectrums here so that the kind

1587

01:08:15,170 --> 01:08:19,500

of light that our eyes can see right so

1588

01:08:18,079 --> 01:08:21,090

it's a big mystery

1589

01:08:19,500 --> 01:08:24,779

but we have made a little bit of headway

1590

01:08:21,090 --> 01:08:27,199

in the last year after all this time we

1591

01:08:24,779 --> 01:08:32,849

discovered what a few of them are and

1592

01:08:27,199 --> 01:08:36,899

they are buckyballs they are these

1593

01:08:32,850 --> 01:08:39,270

things called buckyballs bucky balls are

1594

01:08:36,899 --> 01:08:41,189

really interesting they're these organic

1595

01:08:39,270 --> 01:08:45,510

molecules these carbon and hydrogen

1596

01:08:41,189 --> 01:08:48,029

molecules these are these are sort of



1597  
01:08:45,510 --> 01:08:51,449  
carbon rings that fold over to make

1598  
01:08:48,029 --> 01:08:53,909  
these balls that you see here and there

1599  
01:08:51,449 --> 01:08:56,269  
are quite sturdy like this is a video I

1600  
01:08:53,909 --> 01:08:59,460  
can play and actually see if it plays

1601  
01:08:56,270 --> 01:09:00,840  
yeah see if I can do it anyway there's

1602  
01:08:59,460 --> 01:09:04,859  
some text there cuz I grabbed it from

1603  
01:09:00,840 --> 01:09:06,360  
the JPL site but now this isn't the

1604  
01:09:04,859 --> 01:09:08,670  
first time that we've discovered bucky

1605  
01:09:06,359 --> 01:09:10,710  
balls bucky balls were discovered in

1606  
01:09:08,670 --> 01:09:11,659  
space in 2010 from the Spitzer Space

1607  
01:09:10,710 --> 01:09:15,810  
Telescope

1608  
01:09:11,659 --> 01:09:18,180  
they found it from a star that was

1609  
01:09:15,810 --> 01:09:20,580  
that's been dying a planetary nebula and

1610  
01:09:18,180 --> 01:09:22,950  
that that was really interesting and

1611  
01:09:20,579 --> 01:09:24,119  
cool but the thing about planetary

1612  
01:09:22,949 --> 01:09:27,510  
nebula is is that there's a lot of

1613  
01:09:24,119 --> 01:09:29,939  
awesome dust there that shields these

1614  
01:09:27,510 --> 01:09:31,860  
molecules and prevents them from being

1615  
01:09:29,939 --> 01:09:34,109  
torn apart from the harsh radiation of

1616  
01:09:31,859 --> 01:09:37,049  
interstellar space from all these other

1617  
01:09:34,109 --> 01:09:39,779  
stars so we could explain that okay that

1618  
01:09:37,050 --> 01:09:42,869  
that makes sense there they these these

1619  
01:09:39,779 --> 01:09:45,000  
dying stars produce this the suit this

1620  
01:09:42,869 --> 01:09:48,000  
these bucky balls this carbonaceous

1621  
01:09:45,000 --> 01:09:50,729  
material and they're protected in this

1622  
01:09:48,000 --> 01:09:52,649  
planetary nebula phase but what's

1623  
01:09:50,729 --> 01:09:56,699  
interesting about this discovery from

1624  
01:09:52,649 --> 01:09:58,019  
Hubble just this year is that some of

1625

01:09:56,699 --> 01:10:00,750  
these bucky balls are actually an

1626  
01:09:58,020 --> 01:10:03,660  
interstellar space where we expected the

1627  
01:10:00,750 --> 01:10:06,239  
harsh radiation and interstellar space

1628  
01:10:03,659 --> 01:10:09,750  
to tear them apart but they seem to be

1629  
01:10:06,239 --> 01:10:12,269  
hearty enough to survive and in fact if

1630  
01:10:09,750 --> 01:10:14,970  
they're that hearty and in fact a common

1631  
01:10:12,270 --> 01:10:18,180  
belief or a common hypothesis I should

1632  
01:10:14,970 --> 01:10:20,060  
say for what a lot of the diffusive

1633  
01:10:18,180 --> 01:10:22,560  
solar bands are are sort of these

1634  
01:10:20,060 --> 01:10:25,400  
carbonaceous grains there are molecules

1635  
01:10:22,560 --> 01:10:28,500  
not grains these carbonaceous molecules

1636  
01:10:25,399 --> 01:10:30,359  
if that's true it tells us something

1637  
01:10:28,500 --> 01:10:31,859  
about the habitability of our universe

1638  
01:10:30,359 --> 01:10:32,429  
because they are quite common they're

1639  
01:10:31,859 --> 01:10:35,250

quiet you

1640

01:10:32,430 --> 01:10:38,490

ubiquitous and carbon and organic

1641

01:10:35,250 --> 01:10:41,130

molecules that carry carbon are what we

1642

01:10:38,489 --> 01:10:44,159

think are the precursors to what we need

1643

01:10:41,130 --> 01:10:46,710

for for the prebiotic molecules that

1644

01:10:44,159 --> 01:10:48,659

would later then form life so the idea

1645

01:10:46,710 --> 01:10:50,909

that the that the interstellar medium

1646

01:10:48,659 --> 01:10:54,329

that our galaxy could be filled with

1647

01:10:50,909 --> 01:10:56,479

these carbonaceous molecules potentially

1648

01:10:54,329 --> 01:10:59,159

even raining down on the early Earth

1649

01:10:56,479 --> 01:11:01,969

might be a source for how we got the

1650

01:10:59,159 --> 01:11:06,349

ingredients in the early and the early

1651

01:11:01,970 --> 01:11:09,180

days of the earth from when from when

1652

01:11:06,350 --> 01:11:12,110

who knows magic happens nobody knows

1653

01:11:09,180 --> 01:11:16,560

exactly how life left got it started but

1654  
01:11:12,109 --> 01:11:18,479  
it chemically but you have you know you

1655  
01:11:16,560 --> 01:11:20,970  
have some material there and and life

1656  
01:11:18,479 --> 01:11:25,319  
happens somehow so this is a big part of

1657  
01:11:20,970 --> 01:11:26,720  
that mystery and then I just want to I

1658  
01:11:25,319 --> 01:11:29,269  
want to I want to close by saying

1659  
01:11:26,720 --> 01:11:32,270  
something about the future so

1660  
01:11:29,270 --> 01:11:32,270  
spectroscopy

1661  
01:11:32,300 --> 01:11:37,289  
is while spectroscopy is going to be a

1662  
01:11:35,640 --> 01:11:39,150  
big part of our future and the James

1663  
01:11:37,289 --> 01:11:40,409  
Webb Space Telescope which I'm sure you

1664  
01:11:39,149 --> 01:11:43,049  
all aware launches in a couple of years

1665  
01:11:40,409 --> 01:11:46,279  
is going to be a spectroscopy machine it

1666  
01:11:43,050 --> 01:11:48,449  
is going to do so much with spectroscopy

1667  
01:11:46,279 --> 01:11:51,420  
that it's actually going to be hard

1668  
01:11:48,449 --> 01:11:54,210  
maybe to even handle all that amount of

1669  
01:11:51,420 --> 01:11:56,039  
data so one of it has several

1670  
01:11:54,210 --> 01:11:57,300  
spectrographs on it but I want to

1671  
01:11:56,039 --> 01:11:59,550  
highlight one of the most interesting

1672  
01:11:57,300 --> 01:12:02,520  
ones this is co this is an instrument

1673  
01:11:59,550 --> 01:12:05,180  
called near spec and it's a it's a new

1674  
01:12:02,520 --> 01:12:08,130  
technology for collecting spectra

1675  
01:12:05,180 --> 01:12:09,990  
basically what happens with near spec is

1676  
01:12:08,130 --> 01:12:13,529  
you it's you have these little shutters

1677  
01:12:09,989 --> 01:12:15,630  
okay on the camera and by the process of

1678  
01:12:13,529 --> 01:12:17,460  
using a magnet and electric charge they

1679  
01:12:15,630 --> 01:12:19,650  
can open and close these individual

1680  
01:12:17,460 --> 01:12:21,270  
shutters which are very tiny you know

1681  
01:12:19,649 --> 01:12:23,009  
we're talking about smaller than your

1682

01:12:21,270 --> 01:12:27,410  
hair or like these little shutters which

1683  
01:12:23,010 --> 01:12:31,530  
are very tiny and they can open up and

1684  
01:12:27,409 --> 01:12:33,119  
you can choose which objects on whatever

1685  
01:12:31,529 --> 01:12:34,590  
fuel do you want to take a spectrum of

1686  
01:12:33,119 --> 01:12:38,220  
so whatever is open you'll get a

1687  
01:12:34,590 --> 01:12:41,069  
spectrum of that okay so instead of the

1688  
01:12:38,220 --> 01:12:43,260  
current model where we have to carefully

1689  
01:12:41,069 --> 01:12:45,479  
pick one object in the field which is

1690  
01:12:43,260 --> 01:12:46,150  
the most common case one omlette onto

1691  
01:12:45,479 --> 01:12:47,919  
object in the

1692  
01:12:46,149 --> 01:12:50,439  
and we get a spectrum of it it's very

1693  
01:12:47,920 --> 01:12:54,550  
time you know it's very laborious it's

1694  
01:12:50,439 --> 01:12:56,739  
very time intensive we can just open the

1695  
01:12:54,550 --> 01:12:59,199  
shutters and just get a flood of spectra

1696  
01:12:56,739 --> 01:13:01,019

high resolution medium resolution really

1697

01:12:59,199 --> 01:13:03,069

high quality spectra from the universe

1698

01:13:01,020 --> 01:13:06,160

and so this is really going to change

1699

01:13:03,069 --> 01:13:09,750

the game for our understanding of galaxy

1700

01:13:06,159 --> 01:13:13,750

evolution and all sorts of things all

1701

01:13:09,750 --> 01:13:15,850

right and then I'm gonna fly through

1702

01:13:13,750 --> 01:13:17,979

these last bits quickly but I feel like

1703

01:13:15,850 --> 01:13:20,890

when you talk about tools and astronomy

1704

01:13:17,979 --> 01:13:25,209

you can't you cannot not talk about

1705

01:13:20,890 --> 01:13:27,490

these these these last few slides these

1706

01:13:25,210 --> 01:13:29,800

are also the area where in many cases I

1707

01:13:27,489 --> 01:13:33,670

am the least of an expert there's not a

1708

01:13:29,800 --> 01:13:36,400

lot of dust here but but I do want to I

1709

01:13:33,670 --> 01:13:38,649

do want to give it its due this is an

1710

01:13:36,399 --> 01:13:41,829

amazing era of astronomy that we live in



1711  
01:13:38,649 --> 01:13:44,679  
this multi messenger astronomy and what

1712  
01:13:41,829 --> 01:13:46,630  
do I mean by multi messenger it's an

1713  
01:13:44,680 --> 01:13:50,320  
interesting name that the astronomers

1714  
01:13:46,630 --> 01:13:52,480  
have given this field the idea that the

1715  
01:13:50,319 --> 01:13:54,579  
universe is sending us messages in a

1716  
01:13:52,479 --> 01:13:56,889  
bottle if you will but multi messenger

1717  
01:13:54,579 --> 01:14:01,750  
is essentially everything that I talked

1718  
01:13:56,890 --> 01:14:04,690  
about was using light okay you know as

1719  
01:14:01,750 --> 01:14:06,699  
astronomers unless we are lucky enough

1720  
01:14:04,689 --> 01:14:08,710  
to be a planetary astronomer we can't go

1721  
01:14:06,699 --> 01:14:11,079  
to the places that we study and take

1722  
01:14:08,710 --> 01:14:13,569  
samples of these objects right if

1723  
01:14:11,079 --> 01:14:15,189  
they're too far away all we have to

1724  
01:14:13,569 --> 01:14:17,739  
study are what the universe sends to us

1725  
01:14:15,189 --> 01:14:20,589  
right the messages that it sends to us

1726  
01:14:17,739 --> 01:14:22,809  
right and so for the longest time right

1727  
01:14:20,590 --> 01:14:24,789  
we used light you know started with

1728  
01:14:22,810 --> 01:14:27,070  
visible light then we moved across all

1729  
01:14:24,789 --> 01:14:29,050  
the types types of light but there are

1730  
01:14:27,069 --> 01:14:31,359  
other ways that the universe can give us

1731  
01:14:29,050 --> 01:14:33,550  
information okay so let's go through

1732  
01:14:31,359 --> 01:14:34,869  
those so of course we already talked

1733  
01:14:33,550 --> 01:14:36,970  
about light and so I won't

1734  
01:14:34,869 --> 01:14:39,099  
I won't spend any time on this but light

1735  
01:14:36,970 --> 01:14:41,530  
is the way that we've been studying the

1736  
01:14:39,100 --> 01:14:44,920  
universe the most but there's also

1737  
01:14:41,529 --> 01:14:47,380  
particles there's also matter mass okay

1738  
01:14:44,920 --> 01:14:49,539  
charged particles small things called

1739

01:14:47,380 --> 01:14:50,619  
neutrinos these are things that come

1740  
01:14:49,539 --> 01:14:52,869  
from

1741  
01:14:50,619 --> 01:14:57,069  
so high-energy events in the universe

1742  
01:14:52,869 --> 01:14:58,390  
that send us the data that get sent

1743  
01:14:57,069 --> 01:15:00,779  
throughout the universe and if we're

1744  
01:14:58,390 --> 01:15:04,920  
lucky we can capture them

1745  
01:15:00,779 --> 01:15:08,309  
this image here is of a tank underground

1746  
01:15:04,920 --> 01:15:12,539  
called super your super-kamiokande it's

1747  
01:15:08,310 --> 01:15:14,520  
in Japan and it's fill it gets filled

1748  
01:15:12,539 --> 01:15:16,859  
with 50,000 tons of purified water and

1749  
01:15:14,520 --> 01:15:19,200  
it has over 10,000 light sensors and

1750  
01:15:16,859 --> 01:15:21,059  
basically this entire purpose of this

1751  
01:15:19,199 --> 01:15:23,250  
mission of this tank this Observatory

1752  
01:15:21,060 --> 01:15:27,210  
this telescope for lack of a better word

1753  
01:15:23,250 --> 01:15:28,859

is to detect the some of the smallest

1754

01:15:27,210 --> 01:15:31,109

particles we could ever think of called

1755

01:15:28,859 --> 01:15:32,759

neutrinos and there are thousands of

1756

01:15:31,109 --> 01:15:34,469

neutrinos going through our body every

1757

01:15:32,760 --> 01:15:36,600

second they don't they're so small they

1758

01:15:34,470 --> 01:15:38,430

don't interact with matter at all okay

1759

01:15:36,600 --> 01:15:42,810

and they come from things like the Sun

1760

01:15:38,430 --> 01:15:44,100

and high energy events and so on but if

1761

01:15:42,810 --> 01:15:45,930

we can actually start detecting these

1762

01:15:44,100 --> 01:15:47,670

which we have we've started to be able

1763

01:15:45,930 --> 01:15:49,230

to detect these neutrinos it'll give us

1764

01:15:47,670 --> 01:15:50,819

insights into things like what's

1765

01:15:49,229 --> 01:15:54,899

happening in the center of the Sun that

1766

01:15:50,819 --> 01:15:56,819

we can't see with light okay so so

1767

01:15:54,899 --> 01:15:58,019

that's a very powerful tool and then

1768  
01:15:56,819 --> 01:16:00,929  
there's also gravitational wave

1769  
01:15:58,020 --> 01:16:02,340  
astronomy if you if you've been alive

1770  
01:16:00,930 --> 01:16:03,829  
the last couple years you probably have

1771  
01:16:02,340 --> 01:16:07,579  
heard of gravitational wave astronomy

1772  
01:16:03,829 --> 01:16:10,380  
this was a big deal these these

1773  
01:16:07,579 --> 01:16:13,559  
gravitational wave detectors you see the

1774  
01:16:10,380 --> 01:16:17,190  
to hear from LIGO one in Washington

1775  
01:16:13,560 --> 01:16:21,120  
State and the other one in Louisiana I

1776  
01:16:17,189 --> 01:16:23,069  
think Louisiana and essentially the idea

1777  
01:16:21,119 --> 01:16:24,779  
is is that if you have these really

1778  
01:16:23,069 --> 01:16:26,579  
massive objects like black holes or

1779  
01:16:24,779 --> 01:16:28,679  
neutron stars collide

1780  
01:16:26,579 --> 01:16:30,899  
they'll send ripples through space-time

1781  
01:16:28,680 --> 01:16:33,030  
and those ripples will come and they'll

1782  
01:16:30,899 --> 01:16:35,879  
interact with the earth that's a highly

1783  
01:16:33,029 --> 01:16:38,340  
exaggerated way of interacting by the

1784  
01:16:35,880 --> 01:16:40,460  
way it's not quite that bad but they'll

1785  
01:16:38,340 --> 01:16:44,480  
interact with the earth and as he as

1786  
01:16:40,460 --> 01:16:47,130  
space-time itself increases and expands

1787  
01:16:44,479 --> 01:16:50,099  
okay it'll pull these different lever

1788  
01:16:47,130 --> 01:16:51,900  
arms and there's lasers going through

1789  
01:16:50,100 --> 01:16:55,260  
these that estimate the distance and

1790  
01:16:51,899 --> 01:16:57,539  
they'll be able to tell the wiggling of

1791  
01:16:55,260 --> 01:16:59,280  
the earth as a gravitational wave goes

1792  
01:16:57,539 --> 01:17:01,109  
through and the fact that you have two

1793  
01:16:59,279 --> 01:17:02,250  
of them gives you some hope that you

1794  
01:17:01,109 --> 01:17:04,319  
actually might be able to pinpoint

1795  
01:17:02,250 --> 01:17:07,800  
roughly the source on the sky where they

1796

01:17:04,319 --> 01:17:09,449  
came from okay because one one might hit

1797  
01:17:07,800 --> 01:17:10,829  
this detector first before it hits the

1798  
01:17:09,449 --> 01:17:12,970  
other detector and so on you might be

1799  
01:17:10,829 --> 01:17:15,579  
able to triangulate a little bit

1800  
01:17:12,970 --> 01:17:21,159  
and so actually we've been able to do

1801  
01:17:15,579 --> 01:17:24,659  
that and so Lego now has discovered with

1802  
01:17:21,159 --> 01:17:28,149  
the gravitational wave detectors these

1803  
01:17:24,659 --> 01:17:30,579  
merging black holes and what's really

1804  
01:17:28,149 --> 01:17:32,109  
interesting is so the blue here are

1805  
01:17:30,579 --> 01:17:35,829  
although the gravitational wave

1806  
01:17:32,109 --> 01:17:38,679  
detection x' though the purple here were

1807  
01:17:35,829 --> 01:17:40,420  
detected by some signature of light

1808  
01:17:38,680 --> 01:17:43,240  
coming from the from them from the

1809  
01:17:40,420 --> 01:17:45,279  
merger but we're but with the

1810  
01:17:43,239 --> 01:17:46,779

gravitational wave we're probing larger

1811

01:17:45,279 --> 01:17:49,179

black holes and we were able to probe

1812

01:17:46,779 --> 01:17:51,369

before and learning more about them and

1813

01:17:49,180 --> 01:17:53,590

you can also do the same for neutron

1814

01:17:51,369 --> 01:17:56,470

stars so this is a neutron star

1815

01:17:53,590 --> 01:17:59,890

detection so neutron stars are the dense

1816

01:17:56,470 --> 01:18:06,369

cores of old stars and Frank's getting

1817

01:17:59,890 --> 01:18:08,440

up which tells me all right

1818

01:18:06,369 --> 01:18:12,039

well this is my last slide a nice time

1819

01:18:08,439 --> 01:18:13,719

all right I also I also I also have to

1820

01:18:12,039 --> 01:18:17,019

say something about tools there's a

1821

01:18:13,720 --> 01:18:18,640

whole field in theory and modeling every

1822

01:18:17,020 --> 01:18:20,860

every subject of astronomy and

1823

01:18:18,640 --> 01:18:24,070

astrophysics has theorists and has

1824

01:18:20,859 --> 01:18:26,439

modelers that work on on understanding



1825  
01:18:24,069 --> 01:18:28,689  
the basic physical concepts and I just

1826  
01:18:26,439 --> 01:18:32,259  
want to play this because it's beautiful

1827  
01:18:28,689 --> 01:18:34,629  
this is an illustrious simulation this

1828  
01:18:32,260 --> 01:18:36,789  
is essentially putting in the physics of

1829  
01:18:34,630 --> 01:18:38,260  
our known universe into this really

1830  
01:18:36,789 --> 01:18:40,630  
powerful computer simulation and

1831  
01:18:38,260 --> 01:18:44,590  
watching it play with time this purple

1832  
01:18:40,630 --> 01:18:47,289  
here this is basically looking at the 10

1833  
01:18:44,590 --> 01:18:49,239  
mega parsec view of our universe and

1834  
01:18:47,289 --> 01:18:51,159  
you're seeing dark matter here and

1835  
01:18:49,239 --> 01:18:53,679  
you're seeing all the gravity that's

1836  
01:18:51,159 --> 01:18:55,359  
condensing these proto galaxies together

1837  
01:18:53,680 --> 01:18:57,159  
and when they start to merge you know

1838  
01:18:55,359 --> 01:18:58,719  
you see these filaments and when these

1839  
01:18:57,159 --> 01:19:00,309  
galaxies start to merge you start

1840  
01:18:58,720 --> 01:19:02,289  
there's star formation happening and

1841  
01:19:00,310 --> 01:19:03,940  
then you're going to start seeing stars

1842  
01:19:02,289 --> 01:19:07,479  
blowing up in supernovae and giving

1843  
01:19:03,939 --> 01:19:08,739  
their gas back out into the material

1844  
01:19:07,479 --> 01:19:10,809  
between galaxies the intergalactic

1845  
01:19:08,739 --> 01:19:14,679  
medium so you can start seeing some

1846  
01:19:10,810 --> 01:19:16,810  
stars going on this by by doing

1847  
01:19:14,680 --> 01:19:19,300  
something like this we put our

1848  
01:19:16,810 --> 01:19:21,670  
understanding of the physics into these

1849  
01:19:19,300 --> 01:19:23,590  
computer models and then we compare what

1850  
01:19:21,670 --> 01:19:26,139  
we see in here with our observations and

1851  
01:19:23,590 --> 01:19:27,550  
if they don't match up it tells us that

1852  
01:19:26,139 --> 01:19:30,788  
either we're doing bad observations

1853

01:19:27,550 --> 01:19:32,559  
which I never believed or that there's

1854  
01:19:30,788 --> 01:19:35,198  
some fundamental misunderstanding of the

1855  
01:19:32,559 --> 01:19:37,269  
physics that we need to resolve okay

1856  
01:19:35,198 --> 01:19:40,719  
so that's a huge area so with that I'm

1857  
01:19:37,269 --> 01:19:42,729  
just going to leave up the the universal

1858  
01:19:40,719 --> 01:19:44,019  
learning a URL where you can get all of

1859  
01:19:42,729 --> 01:19:52,989  
our activities and I'll leave it open

1860  
01:19:44,019 --> 01:19:54,699  
for questions all right all right we

1861  
01:19:52,988 --> 01:19:56,738  
just have a short amount of time for

1862  
01:19:54,698 --> 01:19:58,478  
questions what so I have one that I saw

1863  
01:19:56,738 --> 01:20:03,488  
in the chat online which is what is an

1864  
01:19:58,479 --> 01:20:08,019  
absorption feature yeah so an absorption

1865  
01:20:03,488 --> 01:20:12,998  
feature is basically you have all these

1866  
01:20:08,019 --> 01:20:15,309  
photons going around and as as if a

1867  
01:20:12,998 --> 01:20:17,828

photon of that particular if of a light

1868

01:20:15,309 --> 01:20:19,570

of that particular color say that that

1869

01:20:17,828 --> 01:20:21,668

yellow color I showed you from helium if

1870

01:20:19,569 --> 01:20:25,630

a photon that has that particular color

1871

01:20:21,668 --> 01:20:29,559

interacts with cooler gas made of helium

1872

01:20:25,630 --> 01:20:31,359

it's going to get absorbed okay so then

1873

01:20:29,559 --> 01:20:32,979

you're gonna see an absorption feature

1874

01:20:31,359 --> 01:20:34,688

is essentially a dip in the amount of

1875

01:20:32,979 --> 01:20:36,849

light that you see so you have the

1876

01:20:34,689 --> 01:20:38,769

Starlight in the example I showed and

1877

01:20:36,849 --> 01:20:41,288

it's bright and then there'll be a dip

1878

01:20:38,769 --> 01:20:44,530

because that photon that was trying to

1879

01:20:41,288 --> 01:20:46,509

reach us that basically got stopped

1880

01:20:44,529 --> 01:20:48,279

okay it couldn't reach us so you're

1881

01:20:46,510 --> 01:20:54,010

tellin what's there by telling what's

1882  
01:20:48,279 --> 01:20:59,889  
not there yeah okay yeah yeah questions

1883  
01:20:54,010 --> 01:21:01,059  
oh all the way in the back hold up for

1884  
01:20:59,889 --> 01:21:04,149  
the microphone so the online audience

1885  
01:21:01,059 --> 01:21:08,199  
can hear there you go hello I've heard a

1886  
01:21:04,149 --> 01:21:11,050  
lot of talk today about the different

1887  
01:21:08,198 --> 01:21:14,879  
telescopes that we've been putting out

1888  
01:21:11,050 --> 01:21:17,260  
in space and they all kind of observe

1889  
01:21:14,880 --> 01:21:19,059  
sort of passively as it were all that

1890  
01:21:17,260 --> 01:21:21,489  
all the electromagnetic radiation from

1891  
01:21:19,059 --> 01:21:25,929  
the universe I'm wondering are there any

1892  
01:21:21,488 --> 01:21:26,978  
other devices out there like I remember

1893  
01:21:25,929 --> 01:21:28,809  
the Magellan machine used synthetic

1894  
01:21:26,979 --> 01:21:30,369  
aperture radar is there any other

1895  
01:21:28,809 --> 01:21:34,329  
synthetic aperture radar that uses

1896  
01:21:30,368 --> 01:21:35,248  
active detections right now or in the

1897  
01:21:34,328 --> 01:21:37,988  
future

1898  
01:21:35,248 --> 01:21:40,000  
now when you mean active detection so

1899  
01:21:37,988 --> 01:21:43,299  
maybe transmitting something

1900  
01:21:40,000 --> 01:21:45,340  
something back I see well the distances

1901  
01:21:43,300 --> 01:21:49,539  
in the universe are so vast certainly

1902  
01:21:45,340 --> 01:21:53,500  
that you know I know the SETI project

1903  
01:21:49,539 --> 01:21:55,210  
sent a message with radio but in terms

1904  
01:21:53,500 --> 01:21:57,489  
of anything back from that one yeah we

1905  
01:21:55,210 --> 01:21:59,439  
haven't heard anything back we have used

1906  
01:21:57,489 --> 01:22:02,590  
laser off the moon

1907  
01:21:59,439 --> 01:22:04,449  
yeah and radar off Venus right okay any

1908  
01:22:02,590 --> 01:22:09,250  
others like that and the other planets

1909  
01:22:04,449 --> 01:22:12,909  
uh I'm not sure if there's been any

1910

01:22:09,250 --> 01:22:14,140  
other any other from the planets yeah I

1911  
01:22:12,909 --> 01:22:16,510  
mean that's that's the only hope you

1912  
01:22:14,140 --> 01:22:21,010  
have though is see I generally forget

1913  
01:22:16,510 --> 01:22:22,869  
that we have the solar system so that

1914  
01:22:21,010 --> 01:22:24,579  
you're reminded there is some dust in

1915  
01:22:22,869 --> 01:22:27,970  
the solar so there is some there is so

1916  
01:22:24,579 --> 01:22:29,409  
you just don't love it but now that's a

1917  
01:22:27,970 --> 01:22:31,869  
good point so that is another way of

1918  
01:22:29,409 --> 01:22:37,239  
getting information from objects in the

1919  
01:22:31,869 --> 01:22:39,550  
solar system yeah thank you yeah oh wait

1920  
01:22:37,239 --> 01:22:40,719  
grant we got it okay we have an online

1921  
01:22:39,550 --> 01:22:44,230  
audience that needs to hear your

1922  
01:22:40,720 --> 01:22:45,880  
wonderful question yes it won't make it

1923  
01:22:44,229 --> 01:22:51,269  
to the microphones yes you can chop the

1924  
01:22:45,880 --> 01:22:55,239

Antartica we don't what he was joking

1925

01:22:51,270 --> 01:22:58,410

what you called us a must be incredibly

1926

01:22:55,239 --> 01:23:02,979

variable throughout the universe but

1927

01:22:58,409 --> 01:23:04,989

what's it like what's dust like it

1928

01:23:02,979 --> 01:23:09,459

obviously becomes dense enough to become

1929

01:23:04,989 --> 01:23:11,920

a star but but it just dust you know we

1930

01:23:09,460 --> 01:23:16,180

think of dust as what we think of as

1931

01:23:11,920 --> 01:23:19,449

dust yeah yes just money yeah if you're

1932

01:23:16,180 --> 01:23:21,730

in it I mean am I like in it or is it so

1933

01:23:19,449 --> 01:23:22,689

far apart each particle that I don't

1934

01:23:21,729 --> 01:23:27,099

even know

1935

01:23:22,689 --> 01:23:29,619

quite far apart but the studying of the

1936

01:23:27,100 --> 01:23:32,470

composition of dust itself and the sizes

1937

01:23:29,619 --> 01:23:34,029

of dust is its own field so dust comes

1938

01:23:32,470 --> 01:23:35,970

in a range of sizes and the actual



1939  
01:23:34,029 --> 01:23:39,429  
breakdown of where you go from being

1940  
01:23:35,970 --> 01:23:41,680  
molecules to being a dust grain is not

1941  
01:23:39,430 --> 01:23:43,390  
exactly defined it's its physical

1942  
01:23:41,680 --> 01:23:45,520  
properties that define that but you know

1943  
01:23:43,390 --> 01:23:46,990  
you start out with molecules and if you

1944  
01:23:45,520 --> 01:23:48,640  
get if you get large enough for the

1945  
01:23:46,989 --> 01:23:50,590  
molecules stick to dust grains you can

1946  
01:23:48,640 --> 01:23:52,480  
start to grow them dust grains can stick

1947  
01:23:50,590 --> 01:23:53,769  
together you can start to grow things of

1948  
01:23:52,479 --> 01:23:56,919  
course things can tear apart

1949  
01:23:53,769 --> 01:23:59,289  
dust grains it's this active process and

1950  
01:23:56,920 --> 01:24:00,190  
there's compositionally there's lots of

1951  
01:23:59,288 --> 01:24:02,319  
different kinds of dust there's

1952  
01:24:00,189 --> 01:24:04,839  
carbonaceous dusts there's silicate dust

1953  
01:24:02,319 --> 01:24:08,319  
there's Isis out there so sometimes dust

1954  
01:24:04,840 --> 01:24:10,110  
is covered in ice and chemically that

1955  
01:24:08,319 --> 01:24:12,689  
produces a lot of different

1956  
01:24:10,109 --> 01:24:15,038  
possibilities for what you can actually

1957  
01:24:12,689 --> 01:24:16,928  
create the types of molecules and things

1958  
01:24:15,038 --> 01:24:18,099  
you can actually create so a lot of

1959  
01:24:16,929 --> 01:24:20,828  
things are actually created on the

1960  
01:24:18,099 --> 01:24:22,480  
surface of dust grains themselves so

1961  
01:24:20,828 --> 01:24:24,399  
like what's the average density of an

1962  
01:24:22,479 --> 01:24:26,049  
interstellar dust cloud because you know

1963  
01:24:24,399 --> 01:24:28,149  
the air we're breathing now is billions

1964  
01:24:26,050 --> 01:24:29,590  
and trillions of particles per cubic

1965  
01:24:28,149 --> 01:24:31,149  
centimeter Oh certainly much less than

1966  
01:24:29,590 --> 01:24:34,389  
that I don't know it yeah it's like 10

1967

01:24:31,149 --> 01:24:35,888  
to the fifth yeah I don't I don't

1968  
01:24:34,389 --> 01:24:39,340  
actually recall the the actual density

1969  
01:24:35,889 --> 01:24:41,380  
of it but it's yeah so I mean even the

1970  
01:24:39,340 --> 01:24:43,090  
dust clouds that she's talking about are

1971  
01:24:41,380 --> 01:24:45,969  
way lower density than the air you're

1972  
01:24:43,090 --> 01:24:48,010  
breathing right now okay yeah well and

1973  
01:24:45,969 --> 01:24:49,809  
there's a there's there's a the thing is

1974  
01:24:48,010 --> 01:24:52,269  
there's also a range of densities of

1975  
01:24:49,809 --> 01:24:54,340  
dust clouds too right so so I mean we

1976  
01:24:52,269 --> 01:24:55,510  
have we have things like some of the

1977  
01:24:54,340 --> 01:24:58,989  
nebula that you look here but then

1978  
01:24:55,510 --> 01:25:01,719  
there's also dust clouds that are much

1979  
01:24:58,988 --> 01:25:03,399  
denser that in fact we typically

1980  
01:25:01,719 --> 01:25:05,019  
wouldn't use Hubble to go observe we

1981  
01:25:03,399 --> 01:25:06,788

would only see them in shadow anyway if

1982

01:25:05,019 --> 01:25:08,019

we do observe them they're there they

1983

01:25:06,788 --> 01:25:09,939

have interesting things like Bok

1984

01:25:08,019 --> 01:25:11,530

globules and things but they're they're

1985

01:25:09,939 --> 01:25:13,268

the places where we think the stars are

1986

01:25:11,529 --> 01:25:15,849

actually forming in and those are where

1987

01:25:13,269 --> 01:25:18,519

you have the densest places the densest

1988

01:25:15,849 --> 01:25:20,590

amount of dust is in those regions okay

1989

01:25:18,519 --> 01:25:22,929

you have an online question do neutrinos

1990

01:25:20,590 --> 01:25:25,269

pass through the entire Earth without

1991

01:25:22,929 --> 01:25:28,538

hitting anything because solid matter is

1992

01:25:25,269 --> 01:25:36,739

mostly empty space or because neutrinos

1993

01:25:28,538 --> 01:25:39,929

don't interact good that is a good price

1994

01:25:36,738 --> 01:25:42,178

question yeah remember when I put up

1995

01:25:39,929 --> 01:25:50,368

multi messenger and I said that I am NOT

1996  
01:25:42,179 --> 01:25:52,590  
an expert I'm not a yeah I think it

1997  
01:25:50,368 --> 01:25:54,688  
might be both right I mean it's sort of

1998  
01:25:52,590 --> 01:25:56,578  
both but I mean I if you just think

1999  
01:25:54,689 --> 01:25:58,619  
about you know the normal interaction of

2000  
01:25:56,578 --> 01:26:01,049  
a photon with things versus and oh yeah

2001  
01:25:58,618 --> 01:26:02,848  
I know things there you know really low

2002  
01:26:01,050 --> 01:26:05,248  
mass objects anyways both of them right

2003  
01:26:02,849 --> 01:26:06,659  
right and so I would say it's just

2004  
01:26:05,248 --> 01:26:09,448  
because neutrinos just don't interact

2005  
01:26:06,658 --> 01:26:11,549  
more would be more cuz you're comparing

2006  
01:26:09,448 --> 01:26:14,248  
it against something else that yeah also

2007  
01:26:11,550 --> 01:26:17,070  
yeah that's a great question that's know

2008  
01:26:14,248 --> 01:26:19,288  
I'm gonna do my homework yeah and you

2009  
01:26:17,069 --> 01:26:20,759  
know they aren't electrically charged so

2010  
01:26:19,288 --> 01:26:22,859  
there's very very little chance for them

2011  
01:26:20,760 --> 01:26:27,059  
to interaction to active as well all

2012  
01:26:22,859 --> 01:26:28,828  
right over here hey this is the best

2013  
01:26:27,059 --> 01:26:33,479  
astronomy lecture I've been to this

2014  
01:26:28,828 --> 01:26:35,069  
month this month all right well I got it

2015  
01:26:33,479 --> 01:26:38,400  
sorry it's only the third of the month

2016  
01:26:35,069 --> 01:26:41,308  
so oh my god five bucks and I just read

2017  
01:26:38,399 --> 01:26:45,198  
this recently the dust is is so

2018  
01:26:41,309 --> 01:26:48,748  
scattered at least in the solar system

2019  
01:26:45,198 --> 01:26:52,078  
that a spacecraft an average spacecraft

2020  
01:26:48,748 --> 01:26:55,010  
would encounter a dust particle every

2021  
01:26:52,078 --> 01:26:57,359  
three days does that sound about right

2022  
01:26:55,010 --> 01:26:59,820  
yeah I could yeah I could believe that

2023  
01:26:57,359 --> 01:27:02,339  
sure I mean that yeah it's it's it's

2024

01:26:59,819 --> 01:27:04,558  
it's not dense at all I mean you're not

2025  
01:27:02,340 --> 01:27:06,389  
yeah this this is the exact sort of

2026  
01:27:04,559 --> 01:27:08,369  
thing that that they have to think about

2027  
01:27:06,389 --> 01:27:10,618  
when they create when they when they're

2028  
01:27:08,368 --> 01:27:11,880  
building the spacecraft you know like

2029  
01:27:10,618 --> 01:27:14,130  
for example James Webb they're gonna

2030  
01:27:11,880 --> 01:27:15,929  
they're gonna Park it at the Lagrangian

2031  
01:27:14,130 --> 01:27:17,939  
a million miles away they have to have

2032  
01:27:15,929 --> 01:27:19,380  
you know they have some estimates of the

2033  
01:27:17,939 --> 01:27:22,229  
wear and tear on the spacecraft over

2034  
01:27:19,380 --> 01:27:24,719  
time as it interacts with dust grains or

2035  
01:27:22,229 --> 01:27:28,260  
other you know small particles that are

2036  
01:27:24,719 --> 01:27:30,389  
going through so yeah they it's

2037  
01:27:28,260 --> 01:27:32,189  
certainly not a bad enough issue that

2038  
01:27:30,389 --> 01:27:34,319

they're worried about it you know ending

2039

01:27:32,189 --> 01:27:37,439

a mission in a very short timeframe so

2040

01:27:34,319 --> 01:27:39,688

it's it's not very dense yeah but also

2041

01:27:37,439 --> 01:27:41,820

space is very big so if you actually

2042

01:27:39,689 --> 01:27:44,820

were to add up all that material over

2043

01:27:41,819 --> 01:27:47,880

all of that space it amounts for quite a

2044

01:27:44,819 --> 01:27:49,869

bit in terms of in you know bulk it

2045

01:27:47,880 --> 01:27:51,760

actually adds up to a lot if you

2046

01:27:49,869 --> 01:27:53,319

you know it's scattered throughout the

2047

01:27:51,760 --> 01:27:55,060

throughout the interstellar medium and

2048

01:27:53,319 --> 01:27:57,630

throughout the solar system so okay

2049

01:27:55,060 --> 01:27:57,630

thank you

2050

01:28:13,550 --> 01:28:20,400

back to the neutrino question who knows

2051

01:28:16,889 --> 01:28:22,828

don't interact or go pump it up anything

2052

01:28:20,399 --> 01:28:27,359

how then do we detect them for example



2053  
01:28:22,828 --> 01:28:29,908  
yo that cameo cap or Ice Cube how do we

2054  
01:28:27,359 --> 01:28:34,018  
detect them that's a great question

2055  
01:28:29,908 --> 01:28:37,379  
so they don't interact much but if one

2056  
01:28:34,019 --> 01:28:38,639  
in you know a hundred billion or

2057  
01:28:37,380 --> 01:28:40,739  
whatever I don't know what the exact

2058  
01:28:38,639 --> 01:28:42,809  
ratio is and does interact there is a

2059  
01:28:40,738 --> 01:28:46,348  
very small chance that it will inter it

2060  
01:28:42,809 --> 01:28:49,110  
will actually impact a water molecule

2061  
01:28:46,349 --> 01:28:52,710  
and when that does it's a very rare

2062  
01:28:49,109 --> 01:28:55,078  
event they they have those detectors

2063  
01:28:52,710 --> 01:28:58,380  
there to see the flash so it's a it's

2064  
01:28:55,078 --> 01:28:59,969  
incredibly rare but it it does happen

2065  
01:28:58,380 --> 01:29:02,788  
enough that they've been able to text

2066  
01:28:59,969 --> 01:29:05,939  
some so the scintillation very very

2067  
01:29:02,788 --> 01:29:08,279  
inefficient so the statistic I remember

2068  
01:29:05,939 --> 01:29:10,469  
from graduate school way back when was

2069  
01:29:08,279 --> 01:29:12,448  
that the original neutrino detector was

2070  
01:29:10,469 --> 01:29:14,819  
a swimming pool of carbon tetrachloride

2071  
01:29:12,448 --> 01:29:17,129  
cleaning fluid okay so take a swimming

2072  
01:29:14,819 --> 01:29:19,170  
pool of cleaning fluid okay shielded

2073  
01:29:17,130 --> 01:29:20,699  
from all other radiation and the

2074  
01:29:19,170 --> 01:29:23,630  
neutrinos that are passing through it

2075  
01:29:20,698 --> 01:29:25,738  
you get about one interaction per day

2076  
01:29:23,630 --> 01:29:27,420  
with a swimming pool of clean flu

2077  
01:29:25,738 --> 01:29:29,308  
because the the neutrinos would interact

2078  
01:29:27,420 --> 01:29:31,769  
with the cloak with the chlorine create

2079  
01:29:29,309 --> 01:29:34,230  
the rate is it's shrink of radiation and

2080  
01:29:31,769 --> 01:29:35,730  
then the the photomultipliers wouldn't

2081

01:29:34,229 --> 01:29:37,828  
be able to detect it that was the

2082  
01:29:35,729 --> 01:29:40,018  
original one this is the super camera

2083  
01:29:37,828 --> 01:29:43,738  
Conda is much much much much more

2084  
01:29:40,019 --> 01:29:45,750  
advanced alright I think we have one

2085  
01:29:43,738 --> 01:29:50,149  
more question who would like the last

2086  
01:29:45,750 --> 01:29:52,738  
question here all right there we go then

2087  
01:29:50,149 --> 01:29:55,319  
so there's been a in the news recently

2088  
01:29:52,738 --> 01:29:58,229  
about the mega constellations of

2089  
01:29:55,319 --> 01:30:00,359  
satellites and whatnot how's that going

2090  
01:29:58,229 --> 01:30:05,218  
to affect things is their fight green

2091  
01:30:00,359 --> 01:30:08,939  
can you subtract that out it's a very

2092  
01:30:05,219 --> 01:30:10,920  
good question I don't want to get on

2093  
01:30:08,939 --> 01:30:15,629  
anyone's bad side if they watch this on

2094  
01:30:10,920 --> 01:30:18,750  
it yeah it is actually a problem I mean

2095  
01:30:15,630 --> 01:30:22,409

these satellites these satellites are a

2096

01:30:18,750 --> 01:30:24,448

problem it I know you know we do want

2097

01:30:22,408 --> 01:30:28,769

of course 5g and we want all the

2098

01:30:24,448 --> 01:30:32,849

technology that comes with it but you

2099

01:30:28,770 --> 01:30:34,380

know it it essentially becomes next to

2100

01:30:32,850 --> 01:30:35,820

impossible if you get enough of them up

2101

01:30:34,380 --> 01:30:37,260

they're like what what happened if you

2102

01:30:35,819 --> 01:30:39,090

and if they just happen across your

2103

01:30:37,260 --> 01:30:41,010

field of view to actually subtract it

2104

01:30:39,090 --> 01:30:42,989

out it kind of just unless you happen to

2105

01:30:41,010 --> 01:30:48,510

get your targets like in between them so

2106

01:30:42,988 --> 01:30:51,149

it's very disruptive you know so who

2107

01:30:48,510 --> 01:30:52,889

knows maybe maybe they'll feel guilty

2108

01:30:51,149 --> 01:30:59,158

enough that they'll have fun Space

2109

01:30:52,889 --> 01:31:01,920

Telescope's more and all right huit 9:30

2110  
01:30:59,158 --> 01:31:03,809  
and I always cut off at 9:30 and brandon

2111  
01:31:01,920 --> 01:31:11,908  
has given you a ton of things to look

2112  
01:31:03,810 --> 01:31:14,010  
about do we have our Maryland spacecraft

2113  
01:31:11,908 --> 01:31:17,339  
server target person yes all right

2114  
01:31:14,010 --> 01:31:19,260  
Jacob our Alex Jacob Jacob's gonna come

2115  
01:31:17,340 --> 01:31:21,420  
down here over to my right if you would

2116  
01:31:19,260 --> 01:31:23,159  
like to go across the street to look

2117  
01:31:21,420 --> 01:31:26,429  
through the telescope with Jacob please

2118  
01:31:23,158 --> 01:31:28,500  
come down and join him otherwise we will

2119  
01:31:26,429 --> 01:31:31,219  
see you next month thank you all for

2120  
01:31:28,500 --> 01:31:31,219  
coming and good night

2121  
01:31:31,970 --> 01:31:35,369  
[Applause]