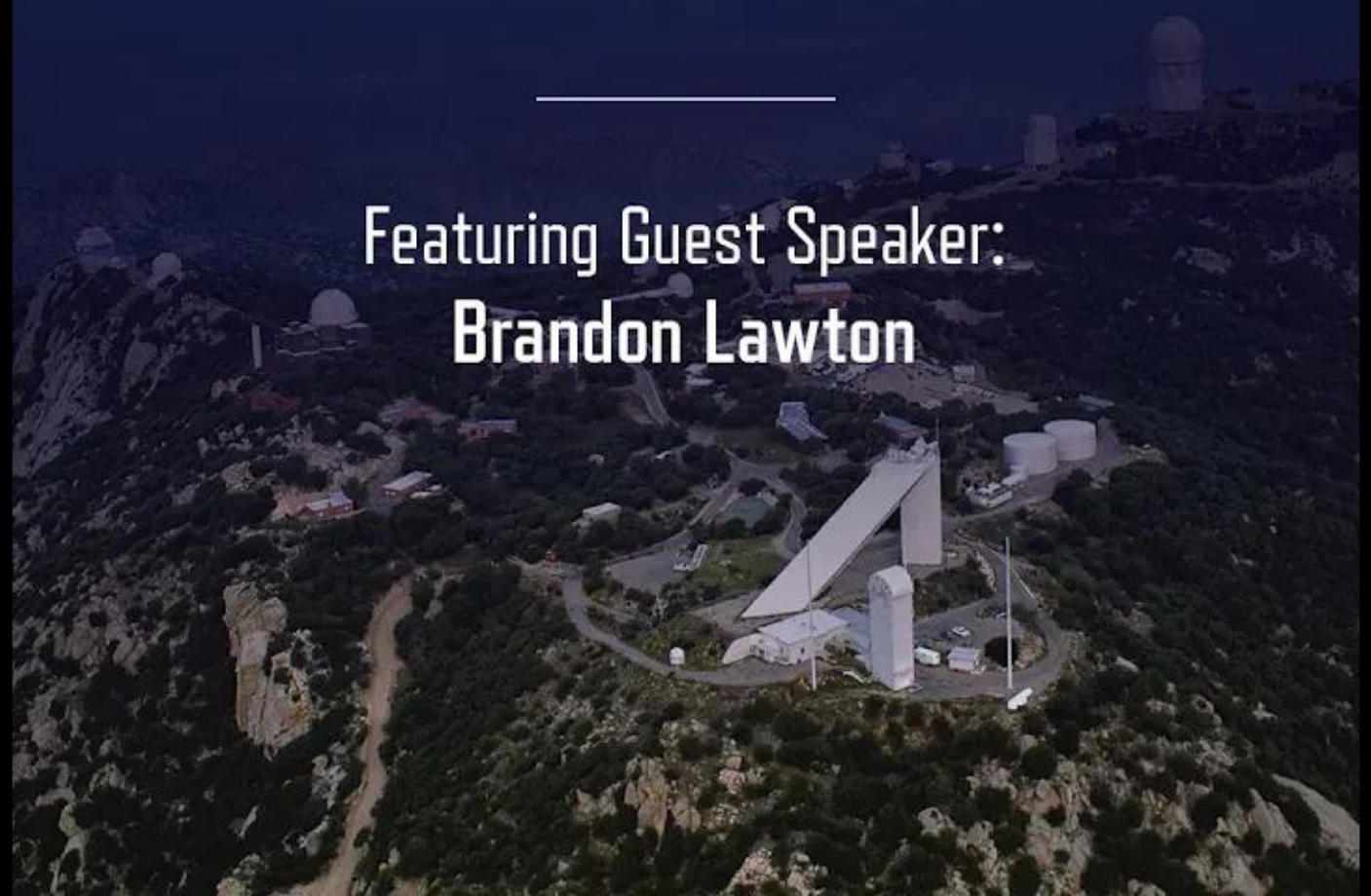
PUBLIC LECTURE SERIES

The Astronomer's Toolkit

Featuring Guest Speaker:

Brandon Lawton



1
00:00:05,960 --> 00:00:04,039
good evening ladies and gentlemen and

2
00:00:08,360 --> 00:00:05,970
welcome to the Space Telescope public

3
00:00:10,250 --> 00:00:08,370
lecture series it is my pleasure to be

4
00:00:13,549 --> 00:00:10,260
your host I am dr. Frank summers of the

5
00:00:16,640 --> 00:00:13,559
office of public outreach and when you

6
00:00:18,470 --> 00:00:16,650
came in hopefully you can picked up one

7
00:00:20,750 --> 00:00:18,480
of our pretty pictures this is a brand

8
00:00:23,570 --> 00:00:20,760
new pretty picture on that we haven't

9
00:00:27,859 --> 00:00:23,580
given out before it is the southern Crab

10
00:00:30,859 --> 00:00:27,869
Nebula which I don't guess you could see

11
00:00:39,740 --> 00:00:30,869
a crab there I see more of a tick to be

12
00:00:41,750 --> 00:00:39,750
honest with you now this is a special

13
00:00:44,900 --> 00:00:41,760

image this was one that we released for

14
00:00:48,920 --> 00:00:44,910
Hubble's 29th anniversary and you'll see

15
00:00:51,040 --> 00:00:48,930
on the back that it's not a full-color

16
00:00:54,650 --> 00:00:51,050
image it's actually composed of several

17
00:00:57,380 --> 00:00:54,660
spectral lines put together okay so

18
00:00:59,029 --> 00:00:57,390
these are the spectral lines that were

19
00:01:01,310 --> 00:00:59,039
used to put it together so it's not how

20
00:01:03,170 --> 00:01:01,320
it would look to the human eye it's how

21
00:01:05,390 --> 00:01:03,180
it looks in these specific spectral

22
00:01:07,520 --> 00:01:05,400
lines that Hubble observed and of course

23
00:01:09,200 --> 00:01:07,530
astronomers use these spectral lines to

24
00:01:11,270 --> 00:01:09,210
pull out different physical

25
00:01:13,399 --> 00:01:11,280
characteristics of the object under

26
00:01:15,140 --> 00:01:13,409
study and I'm assuming that the text

27
00:01:17,330 --> 00:01:15,150
from the back tells you all about that

28
00:01:21,230 --> 00:01:17,340
you didn't get one there are some extra

29
00:01:24,440 --> 00:01:21,240
on you can get on your way out please

30
00:01:27,080 --> 00:01:24,450
silence your electronics actually I know

31
00:01:29,120 --> 00:01:27,090
what I did not silence my electronics

32
00:01:32,120 --> 00:01:29,130
you know and that would be embarrassing

33
00:01:38,060 --> 00:01:32,130
so airplane mode there we go

34
00:01:40,490 --> 00:01:38,070
okay let's see what else uh tonight yes

35
00:01:42,350 --> 00:01:40,500
we have the astronomers talking this is

36
00:01:44,270 --> 00:01:42,360
gonna be an interesting talk it's a

37
00:01:45,649 --> 00:01:44,280
different kind of talk than we then we

38
00:01:47,270 --> 00:01:45,659

usually give we use to talk about all

39
00:01:50,270 --> 00:01:47,280
this science stuff and everything right

40
00:01:53,030 --> 00:01:50,280
here but we also have these wonderful

41
00:01:54,620 --> 00:01:53,040
talks about how we create science and

42
00:01:58,179 --> 00:01:54,630
Brandon's gonna do some stuff with

43
00:02:01,819 --> 00:01:58,189
hopefully a live demo yep live demo here

44
00:02:05,300 --> 00:02:01,829
okay he's gonna walk the tightrope let's

45
00:02:08,109 --> 00:02:05,310
see next month we have black holes and

46
00:02:10,729 --> 00:02:08,119
gravitational waves always a very

47
00:02:13,670 --> 00:02:10,739
popular topic from emmanuel Bertie

48
00:02:16,849 --> 00:02:13,680
across the street at Johns Hopkins no

49
00:02:19,130 --> 00:02:16,859
we have our infamous TBA who appears

50
00:02:21,170 --> 00:02:19,140
every now and then but always cancels

51
00:02:23,720 --> 00:02:21,180
before it's time for TBA to give the

52
00:02:26,780 --> 00:02:23,730
talk which means I will have somebody

53
00:02:29,089 --> 00:02:26,790
filled in that slot you never try and

54
00:02:31,220 --> 00:02:29,099
ask people to commit to talks in August

55
00:02:33,530 --> 00:02:31,230
over over summer break right so now it's

56
00:02:35,360 --> 00:02:33,540
September I can get their attention and

57
00:02:38,539 --> 00:02:35,370
I'll be able to fill that one in in

58
00:02:40,429 --> 00:02:38,549
December we have a very long title red

59
00:02:42,589 --> 00:02:40,439
and brown doors understanding our

60
00:02:45,410 --> 00:02:42,599
smallest and closest sub stellar

61
00:02:47,020 --> 00:02:45,420
neighbors okay this is understanding the

62
00:02:50,629 --> 00:02:47,030
stars around us that happen to be

63
00:02:51,979 --> 00:02:50,639

relatively small stars okay all right if

64
00:02:54,470 --> 00:02:51,989
you would like to know all about that

65
00:02:56,929 --> 00:02:54,480
you can go to our website and if you

66
00:02:59,869 --> 00:02:56,939
remember we changed our website over the

67
00:03:02,149 --> 00:02:59,879
summer we are now holding it and we're

68
00:03:04,280 --> 00:03:02,159
not posting it mainly on we sit still on

69
00:03:08,449 --> 00:03:04,290
hubble site but our prime hosting site

70
00:03:10,849 --> 00:03:08,459
port is now stsci edu and we have a nice

71
00:03:13,059 --> 00:03:10,859
shortened public - lectures all right

72
00:03:15,830 --> 00:03:13,069
something even I could remember okay so

73
00:03:19,610 --> 00:03:15,840
this end so here is our website for the

74
00:03:22,759 --> 00:03:19,620
public lecture series and we have the

75
00:03:25,309 --> 00:03:22,769
links to the web casts here we have the

76
00:03:28,550 --> 00:03:25,319
sign up for the email stuff here we have

77
00:03:29,809 --> 00:03:28,560
information across here we also have you

78
00:03:31,909 --> 00:03:29,819
scroll down because these are now

79
00:03:33,830 --> 00:03:31,919
optimized for phones all the websites

80
00:03:35,300 --> 00:03:33,840
are now optimized for looking at it on

81
00:03:37,339 --> 00:03:35,310
your phone these days so you got to do

82
00:03:38,659 --> 00:03:37,349
lots of scrolling but you get down and

83
00:03:41,449 --> 00:03:38,669
you can see of course our upcoming

84
00:03:43,599 --> 00:03:41,459
lectures as well as below that we have a

85
00:03:46,520 --> 00:03:43,609
complete listing of the past lectures

86
00:03:49,399 --> 00:03:46,530
plus we improve the individual lecture

87
00:03:52,960 --> 00:03:49,409
pages so that we have full information

88
00:03:56,179 --> 00:03:52,970

on them we have links to the whoops

89
00:04:00,319 --> 00:03:56,189
wrong one there we go

90
00:04:05,240 --> 00:04:00,329
links to the STScI webcast here links to

91
00:04:07,369 --> 00:04:05,250
the YouTube webcast down here okay and I

92
00:04:10,339 --> 00:04:07,379
know that semi gratuitous use of this

93
00:04:12,530 --> 00:04:10,349
little spotlight feature but the folks

94
00:04:14,869 --> 00:04:12,540
on that well online webcast cannot see

95
00:04:17,080 --> 00:04:14,879
my laser pointer if I use that so that's

96
00:04:20,449 --> 00:04:17,090
why I'm using the special spotlight

97
00:04:22,430 --> 00:04:20,459
feature here all right okay

98
00:04:25,190 --> 00:04:22,440
email the announcements you can sign up

99
00:04:26,480 --> 00:04:25,200
on our website or just if you want to

100
00:04:27,350 --> 00:04:26,490
write it down and hand it to me at the

101
00:04:29,959 --> 00:04:27,360
end of lecture

102
00:04:32,450 --> 00:04:29,969
can put you in there you only get two or

103
00:04:33,920 --> 00:04:32,460
three left messages per month if you

104
00:04:37,999 --> 00:04:33,930
have comments or questions public

105
00:04:40,159 --> 00:04:38,009
lecture at STScI dot edu if you'd like

106
00:04:42,920 --> 00:04:40,169
to follow us on social media especially

107
00:04:45,969 --> 00:04:42,930
those of you on the webcast we have

108
00:04:49,129 --> 00:04:45,979
Facebook Twitter YouTube and Instagram

109
00:04:51,439 --> 00:04:49,139
myself I sometimes am on Facebook or

110
00:04:53,450 --> 00:04:51,449
Twitter although I will admit I took the

111
00:04:55,730 --> 00:04:53,460
entire month of August off from social

112
00:04:57,770 --> 00:04:55,740
media it was actually kind of refreshing

113
00:05:00,709 --> 00:04:57,780

I'll be back now that it now that the

114
00:05:02,899 --> 00:05:00,719
fall is hit tonight we also have the

115
00:05:04,519 --> 00:05:02,909
observatory the weather is very much

116
00:05:07,339 --> 00:05:04,529
permitting it looks very clear outside

117
00:05:09,439 --> 00:05:07,349
so after the lecture the Maryland Space

118
00:05:11,629 --> 00:05:09,449
Grant observatory staff I'll have

119
00:05:13,189 --> 00:05:11,639
everybody meet down here and they can

120
00:05:15,980 --> 00:05:13,199
take some people across the street to do

121
00:05:17,480 --> 00:05:15,990
the observing also if you can't make it

122
00:05:20,600 --> 00:05:17,490
tonight or you want to come some other

123
00:05:22,670 --> 00:05:20,610
time MB dot space grant that Ord they

124
00:05:25,760 --> 00:05:22,680
have the observatory status on there

125
00:05:27,080 --> 00:05:25,770
every Friday evening by 5 or 6 p.m. they

126
00:05:29,029 --> 00:05:27,090
will post whether or not they're going

127
00:05:33,499 --> 00:05:29,039
to be open that evening and you can go

128
00:05:37,309 --> 00:05:33,509
do it then all right now our news from

129
00:05:40,490 --> 00:05:37,319
the universe for September 2019 and I

130
00:05:43,820 --> 00:05:40,500
only have one story for you tonight and

131
00:05:48,140 --> 00:05:43,830
they are i dropping images of Jupiter

132
00:05:50,930 --> 00:05:48,150
okay so we take pictures of Jupiter when

133
00:05:53,499 --> 00:05:50,940
it's at conjunction okay and we got

134
00:05:57,740 --> 00:05:53,509
another really good one

135
00:05:59,809 --> 00:05:57,750
just a few days ago okay this is our

136
00:06:02,390 --> 00:05:59,819
image of Jupiter at conjunction this

137
00:06:05,179 --> 00:06:02,400
year and it's really you know like

138
00:06:07,219 --> 00:06:05,189

Jupiter always is it's gorgeous although

139
00:06:09,829 --> 00:06:07,229
you know you look at it you go alright

140
00:06:12,769 --> 00:06:09,839
well Hubble's taken pictures of Jupiter

141
00:06:15,679 --> 00:06:12,779
since the 1990s okay

142
00:06:19,629 --> 00:06:15,689
I mean what's here that we haven't seen

143
00:06:24,019 --> 00:06:19,639
already but we've seen it so many times

144
00:06:27,110 --> 00:06:24,029
but that's actually the point is that

145
00:06:30,890 --> 00:06:27,120
Hubble can observe it year after year

146
00:06:35,990 --> 00:06:30,900
after year okay so look at the two no

147
00:06:37,550 --> 00:06:36,000
2019 okay here is our 2014 image all

148
00:06:40,339 --> 00:06:37,560
right and if I blink back and forth I go

149
00:06:41,270 --> 00:06:40,349
here and I go here they don't look all

150
00:06:44,810 --> 00:06:41,280
that different

151
00:06:48,920 --> 00:06:44,820
right but by tracking it over the years

152
00:06:52,730 --> 00:06:48,930
we can see that the Great Red Spot on

153
00:06:54,650 --> 00:06:52,740
Jupiter is shrieking so here is a

154
00:06:57,530 --> 00:06:54,660
picture whoops sorry

155
00:07:03,860 --> 00:06:57,540
here's a picture from 1995 up here and

156
00:07:05,840 --> 00:07:03,870
then 2009 and 2014 and when you compare

157
00:07:09,379 --> 00:07:05,850
them you can see that the Great Red Spot

158
00:07:12,800 --> 00:07:09,389
is actually shrinking it's getting

159
00:07:15,020 --> 00:07:12,810
smaller at one time it was estimated to

160
00:07:18,440 --> 00:07:15,030
be three times the size of our planet

161
00:07:20,570 --> 00:07:18,450
and now it's down to about one time the

162
00:07:23,600 --> 00:07:20,580
size of our planet okay so by looking

163
00:07:26,510 --> 00:07:23,610

over the course of the long numbers of

164
00:07:29,810 --> 00:07:26,520
years we can see that we can also see

165
00:07:32,350 --> 00:07:29,820
other changes so we follow these white

166
00:07:35,420 --> 00:07:32,360
ovals these were these smaller storms

167
00:07:40,610 --> 00:07:35,430
and from 97 they're worth these three fa

168
00:07:44,990 --> 00:07:40,620
de and BC in 98 de and BC combined to

169
00:07:49,100 --> 00:07:45,000
make de and in 2000 F a and B II

170
00:07:52,130 --> 00:07:49,110
combined to make ba oval ba 3 white

171
00:07:55,360 --> 00:07:52,140
storms that combine to form oval be a in

172
00:08:01,460 --> 00:07:55,370
2000 and then a few years later that

173
00:08:04,100 --> 00:08:01,470
oval turned red and became Red Spot jr.

174
00:08:06,920 --> 00:08:04,110
we saw for the first time ever the

175
00:08:10,790 --> 00:08:06,930
formation of a red spot so we're getting

176
00:08:13,730 --> 00:08:10,800
to see changes like this okay and that

177
00:08:15,710 --> 00:08:13,740
is why this latest image is not just

178
00:08:18,469 --> 00:08:15,720
some random image that we do but it's

179
00:08:20,930 --> 00:08:18,479
part of a very dedicated program and

180
00:08:23,330 --> 00:08:20,940
that program is called opal the outer

181
00:08:26,000 --> 00:08:23,340
planets atmospheres Legacy Program

182
00:08:29,570 --> 00:08:26,010
because this is one of the things Hubble

183
00:08:31,940 --> 00:08:29,580
really can do is look at these planets

184
00:08:35,149 --> 00:08:31,950
for years upon years and follow the

185
00:08:36,890 --> 00:08:35,159
transitions so this is what Jupiter

186
00:08:39,680 --> 00:08:36,900
looked like this is a full global map of

187
00:08:43,670 --> 00:08:39,690
Jupiter taking my Hubble in 2015 by the

188
00:08:46,760 --> 00:08:43,680

opal program okay and then this is what

189
00:08:51,130 --> 00:08:46,770
it looks like in 2019 alright and we

190
00:08:55,160 --> 00:08:51,140
could we go back and forth 2015-2019

191
00:08:57,740 --> 00:08:55,170
you'll notice that this central band

192
00:08:59,270 --> 00:08:57,750
here look at that color along the

193
00:09:02,750 --> 00:08:59,280
central band that orange is color there

194
00:09:04,940 --> 00:09:02,760
I go back it's more of a whitish color

195
00:09:07,400 --> 00:09:04,950
one of the things they noted in this

196
00:09:11,210 --> 00:09:07,410
year's image was that the aerosols at

197
00:09:13,640 --> 00:09:11,220
higher altitude along the equatorial

198
00:09:15,980 --> 00:09:13,650
belt seemed to be activated and you

199
00:09:16,550 --> 00:09:15,990
getting a submit bit of a no more orange

200
00:09:19,820 --> 00:09:16,560
color

201
00:09:23,090 --> 00:09:19,830
we're also noting that yes the Great Red

202
00:09:26,990 --> 00:09:23,100
Spot has continued to shrink okay so

203
00:09:29,530 --> 00:09:27,000
that is a small Great Red Spot it's only

204
00:09:33,380 --> 00:09:29,540
the size of our entire planet okay

205
00:09:36,140 --> 00:09:33,390
that's that small but what do you notice

206
00:09:41,030 --> 00:09:36,150
even more even more

207
00:09:45,650 --> 00:09:41,040
you notice that Red Spot jr. is no

208
00:09:49,430 --> 00:09:45,660
longer red red we saw the first time the

209
00:09:52,760 --> 00:09:49,440
formation of a red spot and now our red

210
00:09:56,570 --> 00:09:52,770
spot has dropped out and has become a

211
00:09:59,660 --> 00:09:56,580
white oval again so when I said these

212
00:10:01,550 --> 00:09:59,670
were i dropping images i actually was

213
00:10:05,060 --> 00:10:01,560

talking about somebody's been using eye

214
00:10:10,400 --> 00:10:05,070
drops on jupiter because we all know

215
00:10:12,440 --> 00:10:10,410
that it gets the red out okay I wish it

216
00:10:15,560 --> 00:10:12,450
were that easy of an explanation okay

217
00:10:19,070 --> 00:10:15,570
we're losing the Great Red Spot the

218
00:10:23,180 --> 00:10:19,080
grand spot jr. has gone away and we do

219
00:10:25,910 --> 00:10:23,190
not know for sure why okay we do not

220
00:10:26,690 --> 00:10:25,920
know why we're losing the red in Jupiter

221
00:10:28,580 --> 00:10:26,700
all right

222
00:10:31,070 --> 00:10:28,590
but that's why we're doing this ople

223
00:10:33,170 --> 00:10:31,080
program so that we'll have the data to

224
00:10:35,720 --> 00:10:33,180
study these effects and then make better

225
00:10:38,060 --> 00:10:35,730
and better hypotheses all right I'm

226
00:10:42,460 --> 00:10:38,070
gonna leave you with one final image

227
00:10:46,130 --> 00:10:42,470
that's not Hubble but oh is it just

228
00:10:49,160 --> 00:10:46,140
gorgeous this is from the Juno mission

229
00:10:51,740 --> 00:10:49,170
in 2017 it's a close-up of one of those

230
00:10:54,350 --> 00:10:51,750
white ovals and look at all the

231
00:10:56,870 --> 00:10:54,360
hydrodynamics going on in here okay this

232
00:10:59,900 --> 00:10:56,880
is the kind of stuff I just love okay

233
00:11:02,330 --> 00:10:59,910
those beautiful natural swirls that come

234
00:11:05,180 --> 00:11:02,340
about in Jupiter's atmosphere are just

235
00:11:06,380 --> 00:11:05,190
amazing so I don't use this term well

236
00:11:07,980 --> 00:11:06,390
first of all to show you that it's

237
00:11:09,600 --> 00:11:07,990
really gorgeous could I love it

238
00:11:12,360 --> 00:11:09,610

but also to remind you that you need

239
00:11:14,730 --> 00:11:12,370
those missions that go to the planets to

240
00:11:16,710 --> 00:11:14,740
see these great details but they can

241
00:11:18,060 --> 00:11:16,720
only be there for a few years we've got

242
00:11:21,030 --> 00:11:18,070
Galileo jew-jew

243
00:11:22,470 --> 00:11:21,040
we had Galileo Juno is there now we have

244
00:11:24,840 --> 00:11:22,480
these missions that can go to the

245
00:11:27,660 --> 00:11:24,850
planets for a few years but the value of

246
00:11:30,720 --> 00:11:27,670
Hubble is that it's been up there for 29

247
00:11:33,000 --> 00:11:30,730
years now and it can see the longer-term

248
00:11:34,740 --> 00:11:33,010
effects you can get the details with the

249
00:11:37,470 --> 00:11:34,750
space missions you get the long-term

250
00:11:40,620 --> 00:11:37,480
effects over over decades with the

251
00:11:44,120 --> 00:11:40,630
Hubble Space Telescope okay all right

252
00:11:46,710 --> 00:11:44,130
and now we move to our featured speaker

253
00:11:49,760 --> 00:11:46,720
we are very happy to have here tonight

254
00:11:51,960 --> 00:11:49,770
dr. Brandon Lawton he is an

255
00:11:54,180 --> 00:11:51,970
astrophysicist in the office of public

256
00:11:55,800 --> 00:11:54,190
outreach whose research if you guys

257
00:12:01,020 --> 00:11:55,810
remember he has come here and talked

258
00:12:03,120 --> 00:12:01,030
about studies dust in galaxies the dust

259
00:12:05,430 --> 00:12:03,130
clouds are incredibly important because

260
00:12:08,190 --> 00:12:05,440
they're from which the stuff from which

261
00:12:09,420 --> 00:12:08,200
stars actually form it's dark and

262
00:12:11,100 --> 00:12:09,430
visible light so people don't pay as

263
00:12:12,840 --> 00:12:11,110

much attention to it but when we have

264
00:12:14,760 --> 00:12:12,850
Brandon around he always makes sure we

265
00:12:16,890 --> 00:12:14,770
remember that the dust is really the

266
00:12:21,080 --> 00:12:16,900
most important stuff all right

267
00:12:25,290 --> 00:12:21,090
[Laughter]

268
00:12:27,600 --> 00:12:25,300
however he is an astronomer in the

269
00:12:30,090 --> 00:12:27,610
office of public outreach and in that

270
00:12:32,730 --> 00:12:30,100
process we do a tremendous number of

271
00:12:35,040 --> 00:12:32,740
activities with students with teachers

272
00:12:37,770 --> 00:12:35,050
with the general public in which we

273
00:12:40,500 --> 00:12:37,780
explain how astronomers learn what we

274
00:12:43,110 --> 00:12:40,510
learn and he decided the other day last

275
00:12:44,550 --> 00:12:43,120
time the last time I chatted with him to

276
00:12:46,980 --> 00:12:44,560
do this he decided all right I'm gonna

277
00:12:49,080 --> 00:12:46,990
take that and show off the astronomers

278
00:12:54,160 --> 00:12:49,090
toolkit so ladies and gentlemen dr.

279
00:13:05,090 --> 00:13:00,760
which one are you it's number very wet

280
00:13:06,460 --> 00:13:05,100
Thank You Brad thank you got a fan club

281
00:13:10,550 --> 00:13:06,470
in here

282
00:13:14,750 --> 00:13:10,560
it should be one thank you okay now we

283
00:13:17,840 --> 00:13:14,760
have to know that was some of my dust

284
00:13:21,490 --> 00:13:17,850
you saw there that was yes all right

285
00:13:24,440 --> 00:13:21,500
thank you so much Frank all right so I

286
00:13:25,840 --> 00:13:24,450
started here like Frank said about ten

287
00:13:30,050 --> 00:13:25,850
years ago I was a postdoctoral

288
00:13:31,310 --> 00:13:30,060

researcher here working in dust now now

289
00:13:35,000 --> 00:13:31,320
I work in the office public outreach

290
00:13:36,500 --> 00:13:35,010
since about 2011 and we're gonna talk a

291
00:13:38,060 --> 00:13:36,510
little bit about the astronomers toolkit

292
00:13:39,260 --> 00:13:38,070
this is going to be a little bit of a

293
00:13:42,320 --> 00:13:39,270
whirlwind I'm it because astronomers

294
00:13:45,470 --> 00:13:42,330
have lots of tools as is all scientists

295
00:13:47,360 --> 00:13:45,480
all engineers do right but I want to

296
00:13:50,060 --> 00:13:47,370
also show you some things that you can

297
00:13:52,760 --> 00:13:50,070
take back with you that you can do on

298
00:13:57,770 --> 00:13:52,770
your own all right let's go to the next

299
00:14:03,560 --> 00:13:57,780
first a little bit more about me so I

300
00:14:06,020 --> 00:14:03,570
grew up in Washington State and I you

301
00:14:07,460 --> 00:14:06,030
know I grew up and I I have a similar

302
00:14:09,680 --> 00:14:07,470
sort of story that a lot of Sun

303
00:14:10,790 --> 00:14:09,690
astronomers do in scientists do they you

304
00:14:12,080 --> 00:14:10,800
know you look through the telescope for

305
00:14:13,910 --> 00:14:12,090
the first time and you see something

306
00:14:15,620 --> 00:14:13,920
like Saturn and it sticks with you right

307
00:14:17,570 --> 00:14:15,630
you just you just fall in love with the

308
00:14:19,490 --> 00:14:17,580
night sky and my neighbor had this

309
00:14:21,560 --> 00:14:19,500
telescope and I saw Saturn through it

310
00:14:22,910 --> 00:14:21,570
and I was I was stuck and then my

311
00:14:24,710 --> 00:14:22,920
parents you know growing in Washington

312
00:14:26,510 --> 00:14:24,720
we didn't do a lot of trips around the

313
00:14:27,710 --> 00:14:26,520

country but we did save up because I

314
00:14:29,540 --> 00:14:27,720
really wanted to go to the Kennedy Space

315
00:14:31,940 --> 00:14:29,550
Center as a kid so we went there and

316
00:14:35,270 --> 00:14:31,950
that was an amazing trip and it meant a

317
00:14:38,330 --> 00:14:35,280
lot to me and really my love first for

318
00:14:40,970 --> 00:14:38,340
astronomy was born quite early but it

319
00:14:42,200 --> 00:14:40,980
wasn't really until I was an

320
00:14:44,150 --> 00:14:42,210
undergraduate at the University of

321
00:14:47,480 --> 00:14:44,160
Washington which is that middle picture

322
00:14:49,340 --> 00:14:47,490
there where I really got to do sort of a

323
00:14:52,130 --> 00:14:49,350
participatory sport that is science that

324
00:14:53,540 --> 00:14:52,140
is astronomy okay you can really the

325
00:14:55,250 --> 00:14:53,550
best way to learn and the best way to

326
00:14:56,840 --> 00:14:55,260
appreciate anything is really to get in

327
00:14:58,670 --> 00:14:56,850
there and try to do some of it you're

328
00:15:01,460 --> 00:14:58,680
gonna make a lot of mistakes I certainly

329
00:15:03,740 --> 00:15:01,470
did but it's a lot of fun and so what I

330
00:15:05,420 --> 00:15:03,750
what I was able to do is at this - -

331
00:15:07,070 --> 00:15:05,430
Rodge Observatory in the mountains of

332
00:15:09,020 --> 00:15:07,080
the Cascade Mountains in washing

333
00:15:11,210 --> 00:15:09,030
State I got to spend entire summers up

334
00:15:14,330 --> 00:15:11,220
there basically by myself just taking

335
00:15:16,040 --> 00:15:14,340
images of the night sky I I was lucky to

336
00:15:18,560 --> 00:15:16,050
work on a research project with

337
00:15:20,600 --> 00:15:18,570
Professor Paulus Cody there and

338
00:15:21,500 --> 00:15:20,610

professor Chris Stubbs on variable stars

339
00:15:25,190 --> 00:15:21,510
and I'll talk a little bit about

340
00:15:26,840 --> 00:15:25,200
variable stars later in this talk but I

341
00:15:28,790 --> 00:15:26,850
got it I got to do what's called

342
00:15:30,860 --> 00:15:28,800
differential photometry and I'll explain

343
00:15:32,480 --> 00:15:30,870
what that means later on these stars

344
00:15:34,130 --> 00:15:32,490
that vary over the course of night and

345
00:15:36,680 --> 00:15:34,140
it's a lot of fun to just be out there

346
00:15:39,770 --> 00:15:36,690
and doing science and then I took that

347
00:15:41,990 --> 00:15:39,780
to my graduate work in New Mexico that's

348
00:15:44,030 --> 00:15:42,000
the far right you can see the big

349
00:15:46,370 --> 00:15:44,040
telescope in the lower right is a 3.5

350
00:15:49,100 --> 00:15:46,380
meter telescope at Apache point

351
00:15:50,990 --> 00:15:49,110
observatory and that's where I fell in

352
00:15:55,010 --> 00:15:51,000
love with dust it's very dusty in the

353
00:15:57,290 --> 00:15:55,020
southwest so it makes a lot of sense but

354
00:15:59,690 --> 00:15:57,300
I did a lot of research on dust and I

355
00:16:02,780 --> 00:15:59,700
did research on some very intim attic

356
00:16:06,740 --> 00:16:02,790
mysterious things which I'll talk about

357
00:16:08,570 --> 00:16:06,750
as well in this talk okay so let's go

358
00:16:10,730 --> 00:16:08,580
ahead and move on I think a little

359
00:16:13,880 --> 00:16:10,740
history though to set the stage right

360
00:16:15,410 --> 00:16:13,890
because we have this toolkit but science

361
00:16:17,870 --> 00:16:15,420
is always built on the people that have

362
00:16:19,850 --> 00:16:17,880
come before us and humans have had

363
00:16:21,980 --> 00:16:19,860

observatories for thousands of years

364
00:16:26,690 --> 00:16:21,990
okay so on the left there is an

365
00:16:29,330 --> 00:16:26,700
observatory and from in Portugal it's

366
00:16:32,120 --> 00:16:29,340
about 6,000 years old and it was

367
00:16:34,130 --> 00:16:32,130
actually partly a crypt as well but it's

368
00:16:36,010 --> 00:16:34,140
an observatory and the hypothesis for

369
00:16:39,230 --> 00:16:36,020
this Observatory is is that it allowed

370
00:16:42,440 --> 00:16:39,240
the people the nomads of the time and

371
00:16:47,810 --> 00:16:42,450
Portugal to go inside there and look out

372
00:16:49,640 --> 00:16:47,820
that viewing window to see stars before

373
00:16:51,770 --> 00:16:49,650
the Sun had set and they would look for

374
00:16:53,120 --> 00:16:51,780
stars that would signal the change of

375
00:16:54,470 --> 00:16:53,130
the seasons so they knew when to go to

376
00:16:56,960 --> 00:16:54,480
the mountains with their herds or

377
00:17:00,560 --> 00:16:56,970
whatever they were doing so they they

378
00:17:03,410 --> 00:17:00,570
really needed that interior cavern of

379
00:17:04,760 --> 00:17:03,420
rocks there to block out the Sun so they

380
00:17:06,800 --> 00:17:04,770
could see the earliest point at which

381
00:17:09,199 --> 00:17:06,810
those stars in this case they think it's

382
00:17:11,420 --> 00:17:09,209
Aldebaran but the Stars as they were

383
00:17:13,040 --> 00:17:11,430
coming as they were coming up that

384
00:17:15,949 --> 00:17:13,050
signified spring or fall or

385
00:17:17,480 --> 00:17:15,959
what-have-you so and of course we all

386
00:17:19,880 --> 00:17:17,490
know that there is sundials and the

387
00:17:20,840 --> 00:17:19,890
Egyptians and cultures across the world

388
00:17:23,000 --> 00:17:20,850

have had observe

389
00:17:24,559 --> 00:17:23,010
tory's where people have observed the

390
00:17:27,289 --> 00:17:24,569
night sky looked at the positions of the

391
00:17:28,789 --> 00:17:27,299
stars and so on so this is really a

392
00:17:31,430 --> 00:17:28,799
human endeavor that's going on for

393
00:17:33,409 --> 00:17:31,440
thousands of years fast forward many

394
00:17:36,620 --> 00:17:33,419
thousands of years to just about 400

395
00:17:38,659 --> 00:17:36,630
years ago and you have a picture there

396
00:17:42,200 --> 00:17:38,669
painting of Tycho Brahe he in the late

397
00:17:44,810 --> 00:17:42,210
1500s who we didn't have telescopes yet

398
00:17:46,279 --> 00:17:44,820
right that wasn't in our toolkit but

399
00:17:51,350 --> 00:17:46,289
what he had was he had an observatory

400
00:17:52,669 --> 00:17:51,360
and he had he had helped perfect some of

401
00:17:55,430 --> 00:17:52,679
the instruments of measuring very

402
00:17:57,320 --> 00:17:55,440
precise angles of the sky so for example

403
00:17:59,000 --> 00:17:57,330
sextant sand quadrants and things like

404
00:18:00,500 --> 00:17:59,010
that so that he could measure the

405
00:18:03,169 --> 00:18:00,510
positions of celestial objects

406
00:18:05,299 --> 00:18:03,179
incredibly accurately as well as have

407
00:18:07,130 --> 00:18:05,309
clocks that had hours and seconds and so

408
00:18:08,810 --> 00:18:07,140
on so he knew exactly when those

409
00:18:11,659 --> 00:18:08,820
celestial objects were in that exact

410
00:18:14,810 --> 00:18:11,669
part of the sky and that was incredibly

411
00:18:17,149 --> 00:18:14,820
helpful because his assistant Johann

412
00:18:18,799 --> 00:18:17,159
Kepler used that very detailed

413
00:18:21,470 --> 00:18:18,809

information to come up with the

414
00:18:23,870 --> 00:18:21,480
Keplerian basically the Kepler in laws

415
00:18:26,419 --> 00:18:23,880
if you will the mote but that basically

416
00:18:29,299 --> 00:18:26,429
told us how the celestial or how the

417
00:18:31,669 --> 00:18:29,309
planets went around the Sun so his

418
00:18:34,100 --> 00:18:31,679
positions were incredibly detailed

419
00:18:35,270 --> 00:18:34,110
incredibly valuable for the time and it

420
00:18:39,159 --> 00:18:35,280
really pushed the field of astronomy

421
00:18:43,820 --> 00:18:39,169
forward but of course the telescope

422
00:18:44,960 --> 00:18:43,830
helped us a great deal so it's it's

423
00:18:46,460 --> 00:18:44,970
probably the most well known in our

424
00:18:47,990 --> 00:18:46,470
toolkit I'm sure everyone's aware that

425
00:18:49,960 --> 00:18:48,000
we use telescopes right so here's a

426
00:18:52,250 --> 00:18:49,970
here's a painting of Galileo Galilei

427
00:18:55,850 --> 00:18:52,260
with a tellus I think this is when he's

428
00:18:58,760 --> 00:18:55,860
showing the the Catholic Church his his

429
00:19:01,460 --> 00:18:58,770
observations that's what it's portraying

430
00:19:03,140 --> 00:19:01,470
there but this was basically built from

431
00:19:07,100 --> 00:19:03,150
the spyglass which was thought to be

432
00:19:09,860 --> 00:19:07,110
invented in 1608 and Galileo took that

433
00:19:12,470 --> 00:19:09,870
invention and tried to better it in some

434
00:19:14,779 --> 00:19:12,480
ways and he basically used it then to

435
00:19:17,240 --> 00:19:14,789
build a telescope to look up at the

436
00:19:19,279 --> 00:19:17,250
night sky in 1609 is when he did that

437
00:19:21,200 --> 00:19:19,289
okay so you can see we're progressing

438
00:19:23,720 --> 00:19:21,210

and the toolkit here we have telescopes

439
00:19:25,940 --> 00:19:23,730
now and now we just jump all the way to

440
00:19:28,850 --> 00:19:25,950
Hubble right so now we have telescopes

441
00:19:31,490 --> 00:19:28,860
where where we're not just using lenses

442
00:19:34,540 --> 00:19:31,500
like Galileo used for the optics where

443
00:19:36,640 --> 00:19:34,550
the where the glass lens collects

444
00:19:38,680 --> 00:19:36,650
redirects the light to a focus where

445
00:19:41,410 --> 00:19:38,690
your eyeball is so you can see it but

446
00:19:44,140 --> 00:19:41,420
now we have these telescopes on the

447
00:19:46,800 --> 00:19:44,150
ground and in space that use mirrors to

448
00:19:49,660 --> 00:19:46,810
reflect the light to a focus and

449
00:19:51,220 --> 00:19:49,670
sensitive detectors to capture it thank

450
00:19:53,290 --> 00:19:51,230
goodness we don't need somebody peering

451
00:19:56,590 --> 00:19:53,300
through an eyepiece up there in space

452
00:19:59,080 --> 00:19:56,600
that would be very very painful so so

453
00:20:00,790 --> 00:19:59,090
we've really moved along with our

454
00:20:04,390 --> 00:20:00,800
technology so let's talk a little bit

455
00:20:06,970 --> 00:20:04,400
about telescopes before we move on I

456
00:20:08,500 --> 00:20:06,980
want to remind you all and I'm sure many

457
00:20:10,690 --> 00:20:08,510
of you are aware of this already that

458
00:20:12,880 --> 00:20:10,700
the light that we see with our eyes

459
00:20:14,650 --> 00:20:12,890
makes up a very small part of what's

460
00:20:16,840 --> 00:20:14,660
called the electromagnetic spectrum the

461
00:20:18,610 --> 00:20:16,850
light that we can see right and that's

462
00:20:20,140 --> 00:20:18,620
noted in the middle there the visible

463
00:20:21,580 --> 00:20:20,150

light there's a whole host of

464
00:20:25,060 --> 00:20:21,590
wavelengths or types of light that our

465
00:20:26,920 --> 00:20:25,070
eyes cannot see so those include higher

466
00:20:29,170 --> 00:20:26,930
energy light like gamma rays and x-rays

467
00:20:31,510 --> 00:20:29,180
and ultraviolet rays and lower energy

468
00:20:35,020 --> 00:20:31,520
light like infrared microwave and radio

469
00:20:37,120 --> 00:20:35,030
okay and our toolkit if we really wanted

470
00:20:39,430 --> 00:20:37,130
to understand the universe our toolkit

471
00:20:41,770 --> 00:20:39,440
needs to expand to be able to observe

472
00:20:43,630 --> 00:20:41,780
those wavelengths of light so we needed

473
00:20:46,780 --> 00:20:43,640
to build special telescopes that can

474
00:20:50,530 --> 00:20:46,790
capture and detect and record those

475
00:20:52,360 --> 00:20:50,540
wavelengths so all these telescopes nASA

476
00:20:55,570 --> 00:20:52,370
has well hopefully two telescopes up

477
00:20:57,040 --> 00:20:55,580
there a large region what reason why we

478
00:20:58,960 --> 00:20:57,050
have so many telescopes is because we

479
00:21:01,660 --> 00:20:58,970
need special technology to observe those

480
00:21:03,190 --> 00:21:01,670
different wavelengths this also shows

481
00:21:05,860 --> 00:21:03,200
you why we need to put telescopes in

482
00:21:08,020 --> 00:21:05,870
space for many wavelengths right so the

483
00:21:11,230 --> 00:21:08,030
colored lines show you how far down that

484
00:21:14,170 --> 00:21:11,240
wavelength reaches to the surface okay

485
00:21:16,360 --> 00:21:14,180
so thankfully gamma rays and x-rays

486
00:21:18,250 --> 00:21:16,370
don't make it to the surface it's a good

487
00:21:19,660 --> 00:21:18,260
thing all right but if we do in

488
00:21:21,130 --> 00:21:19,670

astronomy if we do want to understand

489
00:21:22,900 --> 00:21:21,140
the highest energy sources in the

490
00:21:24,670 --> 00:21:22,910
universe it means we have to put our

491
00:21:27,510 --> 00:21:24,680
telescopes out there above the

492
00:21:29,380 --> 00:21:27,520
atmosphere where we can detect it

493
00:21:30,700 --> 00:21:29,390
visible light does reach it to the

494
00:21:32,020 --> 00:21:30,710
surface we have lots of optical

495
00:21:33,310 --> 00:21:32,030
ground-based telescopes but there's a

496
00:21:35,950 --> 00:21:33,320
reason why we would still want to put

497
00:21:37,540 --> 00:21:35,960
something like Hubble in space and it's

498
00:21:39,190 --> 00:21:37,550
because our atmosphere acts like a fit

499
00:21:41,170 --> 00:21:39,200
like a like a fishbowl like we're

500
00:21:43,750 --> 00:21:41,180
underwater right the atmosphere blurs

501
00:21:44,830 --> 00:21:43,760
the light as it comes from space so if

502
00:21:47,290 --> 00:21:44,840
you can get above the blurring

503
00:21:48,380 --> 00:21:47,300
atmosphere right then you have a more

504
00:21:50,810 --> 00:21:48,390
clear vision

505
00:21:53,270 --> 00:21:50,820
of the universe and likewise you can see

506
00:21:55,130 --> 00:21:53,280
that you know for radio it's it's quite

507
00:21:56,510 --> 00:21:55,140
lucky you can have a lot of wavelengths

508
00:21:57,980 --> 00:21:56,520
reach the ground I want to point out

509
00:22:00,110 --> 00:21:57,990
this this is a very interesting NASA

510
00:22:01,850 --> 00:22:00,120
mission called Sofia where they actually

511
00:22:05,990 --> 00:22:01,860
just put a giant telescope in the side

512
00:22:08,090 --> 00:22:06,000
of a of a plane a jetliner and they fly

513
00:22:10,669 --> 00:22:08,100

that around to get some of the infrared

514
00:22:12,799 --> 00:22:10,679
wavelengths so they open up the entire

515
00:22:16,610 --> 00:22:12,809
side of the JAL the jetliner and they

516
00:22:18,500 --> 00:22:16,620
they observe okay so our toolkit is

517
00:22:21,100 --> 00:22:18,510
greatly expanded from the early days of

518
00:22:23,930 --> 00:22:21,110
Galileo where he just had his nice

519
00:22:26,720 --> 00:22:23,940
refracting telescope too now a whole

520
00:22:28,700 --> 00:22:26,730
suite of telescopes but of course

521
00:22:31,340 --> 00:22:28,710
telescopes aren't just the lenses in the

522
00:22:33,320 --> 00:22:31,350
mirrors they're also the other things on

523
00:22:35,960 --> 00:22:33,330
there that let us record the data right

524
00:22:37,640 --> 00:22:35,970
so telescopes capture the light but we

525
00:22:40,760 --> 00:22:37,650
need Oh some way to record it we don't

526
00:22:42,680 --> 00:22:40,770
we you know we used to use our eyes for

527
00:22:46,180 --> 00:22:42,690
a while we use photographic plates but

528
00:22:50,030 --> 00:22:46,190
now we use something called C CDs

529
00:22:54,500 --> 00:22:50,040
charged couple devices which were first

530
00:22:56,870 --> 00:22:54,510
invented in 1969 by Bell Labs now C CDs

531
00:22:59,210 --> 00:22:56,880
are a wonderful invention because

532
00:23:01,520 --> 00:22:59,220
they're very set they're quite sensitive

533
00:23:02,840 --> 00:23:01,530
to light and you can actually count the

534
00:23:04,909 --> 00:23:02,850
photons of light that come in the way

535
00:23:08,180 --> 00:23:04,919
they work is there I kind of like to use

536
00:23:10,010 --> 00:23:08,190
an analogy where I pray you know you can

537
00:23:13,640 --> 00:23:10,020
pretend like if if someone asks you okay

538
00:23:15,530 --> 00:23:13,650

it's stormy outside and you want to play

539
00:23:17,480 --> 00:23:15,540
a game capture is you have these all

540
00:23:19,070 --> 00:23:17,490
these buckets capture as much rain as

541
00:23:21,200 --> 00:23:19,080
you can what would you do

542
00:23:22,549 --> 00:23:21,210
okay you could try to get one big bucket

543
00:23:25,850 --> 00:23:22,559
or you could try to get a bunch of

544
00:23:27,710 --> 00:23:25,860
smaller buckets right telescopes are

545
00:23:29,360 --> 00:23:27,720
like big light collecting buckets okay

546
00:23:31,400 --> 00:23:29,370
they collect all those raindrops but we

547
00:23:33,440 --> 00:23:31,410
still need to count those raindrops the

548
00:23:35,990 --> 00:23:33,450
CCD detectors does that for us

549
00:23:38,240 --> 00:23:36,000
see CDs are basically have these little

550
00:23:40,730 --> 00:23:38,250
little little buckets in themselves

551
00:23:42,409 --> 00:23:40,740
these little pixels and a photon of

552
00:23:44,419 --> 00:23:42,419
light will hit that particular pixel and

553
00:23:47,000 --> 00:23:44,429
release electrons and we can count those

554
00:23:49,250 --> 00:23:47,010
electrons so it's like it's like a grid

555
00:23:51,530 --> 00:23:49,260
of little traps that basically collect

556
00:23:54,530 --> 00:23:51,540
the pixels and you get images like you

557
00:23:57,590 --> 00:23:54,540
see on the right so this detector here

558
00:24:00,799 --> 00:23:57,600
is the ACS detector that's on Hubble

559
00:24:02,180 --> 00:24:00,809
it's over 10 years now and it captured

560
00:24:06,529 --> 00:24:02,190
that image on the right of the world

561
00:24:09,169 --> 00:24:06,539
whole galaxy now the ACS detector is 16

562
00:24:11,960 --> 00:24:09,179
megapixels 16 million pixels in that

563
00:24:13,220 --> 00:24:11,970

detector which is quite amazing given it

564
00:24:15,799 --> 00:24:13,230
was over 10 years ago that it was

565
00:24:18,289 --> 00:24:15,809
launched on Hubble of course now you can

566
00:24:19,879 --> 00:24:18,299
buy a camera a digital camera that has

567
00:24:23,450 --> 00:24:19,889
twice that if you want to spend the

568
00:24:25,460 --> 00:24:23,460
money our phones are getting to the

569
00:24:29,509 --> 00:24:25,470
point where they're getting not too far

570
00:24:32,960 --> 00:24:29,519
from this 8 10 12 megapixels okay so

571
00:24:34,940 --> 00:24:32,970
this is an amazing instrument but the

572
00:24:37,549 --> 00:24:34,950
toolkit if we want to do more we have to

573
00:24:40,960 --> 00:24:37,559
do better we have to expand our tools so

574
00:24:43,669 --> 00:24:40,970
we have these C CDs these digital tools

575
00:24:45,980 --> 00:24:43,679
what can we do well here is I like to

576
00:24:48,259 --> 00:24:45,990
think one of the best examples of what

577
00:24:53,299 --> 00:24:48,269
we can do currently with our detectors

578
00:24:55,190 --> 00:24:53,309
this is another ACS the the ACS is that

579
00:24:57,080 --> 00:24:55,200
camera I showed you that it stands for

580
00:25:01,669 --> 00:24:57,090
advanced camera for surveys it's on the

581
00:25:03,499 --> 00:25:01,679
Hubble Space Telescope this is over 400

582
00:25:08,419 --> 00:25:03,509
pointings of the Hubble Space Telescope

583
00:25:11,090 --> 00:25:08,429
to make this image this mosaic of our

584
00:25:13,669 --> 00:25:11,100
nearby Andromeda galaxy and this doesn't

585
00:25:16,399 --> 00:25:13,679
do it justice you if you actually

586
00:25:17,810 --> 00:25:16,409
download the full image and you can do

587
00:25:20,029 --> 00:25:17,820
this on you can do this online if you

588
00:25:21,919 --> 00:25:20,039

download the full image there's over a

589
00:25:24,590 --> 00:25:21,929
hundred million stars that you can make

590
00:25:26,090 --> 00:25:24,600
out in this image okay this is only

591
00:25:28,399 --> 00:25:26,100
about a third of the Andromeda galaxy

592
00:25:30,409 --> 00:25:28,409
our nearby galaxies right so this is

593
00:25:33,830 --> 00:25:30,419
taking our detector technology and

594
00:25:36,320 --> 00:25:33,840
stepping across this galaxy and putting

595
00:25:38,600 --> 00:25:36,330
it together and and I should I should

596
00:25:40,549 --> 00:25:38,610
also mention that along with detectors

597
00:25:44,840 --> 00:25:40,559
our space telescopes have filters on

598
00:25:46,820 --> 00:25:44,850
them okay now if you want to study an

599
00:25:48,710 --> 00:25:46,830
object across all the colors you might

600
00:25:50,480 --> 00:25:48,720
you you might want to use filters to

601
00:25:51,830 --> 00:25:50,490
just study one color at a time and

602
00:25:53,930 --> 00:25:51,840
that's what Hubble has and all these

603
00:25:56,629 --> 00:25:53,940
telescopes have these filters so to make

604
00:25:58,639 --> 00:25:56,639
this image it used multiple filters it

605
00:26:01,580 --> 00:25:58,649
and that it had you know essentially red

606
00:26:03,830 --> 00:26:01,590
green blue filters essentially and and

607
00:26:06,049 --> 00:26:03,840
then you can study them individually to

608
00:26:08,389 --> 00:26:06,059
see where the blue objects are which

609
00:26:10,879 --> 00:26:08,399
tend to be in this case new forming

610
00:26:13,639 --> 00:26:10,889
stars the red tends to be indications of

611
00:26:15,310 --> 00:26:13,649
older stars you might find dust the best

612
00:26:17,340 --> 00:26:15,320
thing in the universe

613
00:26:19,960 --> 00:26:17,350

but when you have the different filters

614
00:26:22,270 --> 00:26:19,970
right then you can study the pieces of

615
00:26:25,330 --> 00:26:22,280
the galaxy so filters in combination

616
00:26:27,190 --> 00:26:25,340
with these digital detectors allow us to

617
00:26:29,290 --> 00:26:27,200
study galaxies in greater detail than

618
00:26:30,880 --> 00:26:29,300
we've ever been able to do before so

619
00:26:33,670 --> 00:26:30,890
we're able to piece together essentially

620
00:26:35,950 --> 00:26:33,680
the history of our closest neighbor a

621
00:26:39,160 --> 00:26:35,960
big galaxy our closest big galaxy

622
00:26:40,750 --> 00:26:39,170
neighbor the Andromeda galaxy and so

623
00:26:42,760 --> 00:26:40,760
it's an amazing but let's do better and

624
00:26:43,750 --> 00:26:42,770
we're going to do better in the

625
00:26:47,410 --> 00:26:43,760
mid-2020s

626
00:26:50,920 --> 00:26:47,420
when w first launches okay w first is

627
00:26:54,610 --> 00:26:50,930
the wide field imaging Survey telescope

628
00:26:58,270 --> 00:26:54,620
and well I'm sorry wide field Infrared

629
00:27:00,850 --> 00:26:58,280
Survey telescope and it's imaging is

630
00:27:05,740 --> 00:27:00,860
going to be amazing so here again is

631
00:27:08,050 --> 00:27:05,750
this 411 pointings of Hubble this this

632
00:27:10,750 --> 00:27:08,060
is by the way a ground-based image of

633
00:27:13,680 --> 00:27:10,760
the Andromeda galaxy and then overlaid

634
00:27:17,740 --> 00:27:13,690
is the Hubble 411 much higher resolution

635
00:27:20,650 --> 00:27:17,750
okay and then here is the footprint of

636
00:27:22,630 --> 00:27:20,660
the detector on the W first telescope

637
00:27:25,240 --> 00:27:22,640
the wide field imager over a hundred

638
00:27:27,730 --> 00:27:25,250

times the field of view the same quality

639
00:27:32,350 --> 00:27:27,740
level of data as the Hubble okay

640
00:27:34,860 --> 00:27:32,360
so instead of instead of 16 megapixels

641
00:27:38,620 --> 00:27:34,870
we're talking like 288 megapixels camera

642
00:27:41,440 --> 00:27:38,630
okay so we're really gonna get big

643
00:27:45,460 --> 00:27:41,450
images of the sky with this - with this

644
00:27:47,590 --> 00:27:45,470
telescope okay so our toolkit is always

645
00:27:48,820 --> 00:27:47,600
increasing but I need to put a caveat

646
00:27:50,500 --> 00:27:48,830
that the reason that the toolkit is

647
00:27:52,720 --> 00:27:50,510
increasing or the reason why we're

648
00:27:55,080 --> 00:27:52,730
making our tools better is not because

649
00:27:58,630 --> 00:27:55,090
we can but it's because each generation

650
00:28:02,080 --> 00:27:58,640
of telescope or instrument before has

651
00:28:03,670 --> 00:28:02,090
given us mysteries that then dictate the

652
00:28:05,560 --> 00:28:03,680
kind of technology we need to solve

653
00:28:08,560 --> 00:28:05,570
those mysteries it's a never-ending

654
00:28:11,620 --> 00:28:08,570
science is a never-ending exploration so

655
00:28:13,450 --> 00:28:11,630
Hubble and other telescopes have have

656
00:28:15,010 --> 00:28:13,460
discovered amazing things but I've also

657
00:28:17,860 --> 00:28:15,020
to have also led us with a lot of

658
00:28:19,210 --> 00:28:17,870
mysteries and W first is going to be one

659
00:28:21,730 --> 00:28:19,220
of those missions that's really designed

660
00:28:23,800 --> 00:28:21,740
to understand some of those mysteries in

661
00:28:28,210 --> 00:28:23,810
particular I should mention the mystery

662
00:28:32,740 --> 00:28:31,269
alright this is one of those little

663
00:28:35,619 --> 00:28:32,750

places where I just wanted to take a

664
00:28:38,830 --> 00:28:35,629
quick break and let me see if you can

665
00:28:41,139 --> 00:28:38,840
see this and do an interactive I wanted

666
00:28:43,360 --> 00:28:41,149
to point you to a resource

667
00:28:50,560 --> 00:28:43,370
it's called Hubbell site I mean it's

668
00:28:53,049 --> 00:28:50,570
called view space let me see ok all

669
00:28:55,899 --> 00:28:53,059
right close that alright so on view

670
00:28:58,169 --> 00:28:55,909
space what you can do is you can go and

671
00:29:00,879 --> 00:28:58,179
you can actually look at these images

672
00:29:02,440 --> 00:29:00,889
alright so you can go here and you can

673
00:29:03,610 --> 00:29:02,450
on the front page there's the whirlpool

674
00:29:05,190 --> 00:29:03,620
which I show I think this is the

675
00:29:07,840 --> 00:29:05,200
whirlpool or it's the pinwheel on kintel

676
00:29:09,759 --> 00:29:07,850
which you can you saw an image earlier

677
00:29:11,919 --> 00:29:09,769
if it's the whirlpool you can slide it

678
00:29:15,639 --> 00:29:11,929
across and these are the actual

679
00:29:17,919 --> 00:29:15,649
astronomical images ok this is x-ray and

680
00:29:19,869 --> 00:29:17,929
visible but let's do better this is all

681
00:29:22,269 --> 00:29:19,879
free by the way this new space if you go

682
00:29:25,180 --> 00:29:22,279
to the Interactive's here's an

683
00:29:26,590 --> 00:29:25,190
interactive of what the world a cartoon

684
00:29:32,799 --> 00:29:26,600
of what the world looks like in visible

685
00:29:35,529 --> 00:29:32,809
light infrared radio microwave you can

686
00:29:40,060 --> 00:29:35,539
see there are different sources for each

687
00:29:41,950 --> 00:29:40,070
of these ultraviolet x-ray and gamma ray

688
00:29:44,169 --> 00:29:41,960

I also want to point out that there's

689
00:29:47,019 --> 00:29:44,179
labels here so you can turn on and see

690
00:29:48,879 --> 00:29:47,029
what things are this is a nice thing to

691
00:29:52,299 --> 00:29:48,889
show off if you want to do a quick

692
00:29:53,470 --> 00:29:52,309
demonstration but let's do star

693
00:29:57,539 --> 00:29:53,480
formation because it has lots of

694
00:29:59,769 --> 00:29:57,549
beautiful dust so here is visible right

695
00:30:01,269 --> 00:29:59,779
this gets you an idea of the power of

696
00:30:03,580 --> 00:30:01,279
multi-wavelength astronomy and the

697
00:30:05,980 --> 00:30:03,590
detectors on all of our telescopes so

698
00:30:08,200 --> 00:30:05,990
this is a visible light with Hubble if

699
00:30:09,580 --> 00:30:08,210
you scroll over to near-infrared this is

700
00:30:11,919 --> 00:30:09,590
what Hubble looks like it has near

701
00:30:14,289 --> 00:30:11,929
infrared capability and you can actually

702
00:30:17,619 --> 00:30:14,299
see inside those dust pillars and you

703
00:30:19,769 --> 00:30:17,629
can see stars being born in the dust if

704
00:30:24,450 --> 00:30:19,779
you go to the further into the infrared

705
00:30:27,490 --> 00:30:24,460
that dust actually starts to glow ok and

706
00:30:29,769 --> 00:30:27,500
the I believe this is Herschel Space

707
00:30:31,360 --> 00:30:29,779
Telescope with this image the dust

708
00:30:33,940 --> 00:30:31,370
starts to glow because the dust is being

709
00:30:35,379 --> 00:30:33,950
heated by stars so the dust is glowing

710
00:30:39,430 --> 00:30:35,389
there you go in the other direction you

711
00:30:42,220 --> 00:30:39,440
go to x-ray what you find are the hot

712
00:30:44,890 --> 00:30:42,230
stars that are carving away at that dust

713
00:30:47,980 --> 00:30:44,900

so that if you've recognized this image

714
00:30:49,660 --> 00:30:47,990
here invisible we we typically sometimes

715
00:30:52,300 --> 00:30:49,670
it's the Eagle Nebula we sometimes call

716
00:30:55,240 --> 00:30:52,310
these the pillars of creation they're

717
00:30:57,970 --> 00:30:55,250
not going to be there forever in fact

718
00:30:59,530 --> 00:30:57,980
they're being constantly eroded by the

719
00:31:01,090 --> 00:30:59,540
hot young stars that were born from that

720
00:31:05,080 --> 00:31:01,100
nebula that are releasing all that

721
00:31:07,150 --> 00:31:05,090
ionizing flux and eroding it away and so

722
00:31:08,410 --> 00:31:07,160
you can see that in x-ray and then

723
00:31:10,900 --> 00:31:08,420
there's a nice multi-wavelength where

724
00:31:14,140 --> 00:31:10,910
you can put the x-ray visible and

725
00:31:15,700 --> 00:31:14,150
Infrared together okay so there's a lot

726
00:31:18,600 --> 00:31:15,710
of lot of things you can explore in view

727
00:31:24,970 --> 00:31:18,610
space I encourage you to to check it out

728
00:31:27,640 --> 00:31:24,980
let's go back to the slide but this is

729
00:31:30,280 --> 00:31:27,650
this is another one I wanted to show you

730
00:31:32,230 --> 00:31:30,290
this is another interactive I told you

731
00:31:34,420 --> 00:31:32,240
there would be interactive even though

732
00:31:37,330 --> 00:31:34,430
it's really me just interacting but you

733
00:31:38,290 --> 00:31:37,340
know I should have we should have said

734
00:31:41,410 --> 00:31:38,300
you know bring your and bring your

735
00:31:42,970 --> 00:31:41,420
computers but this is all online as well

736
00:31:44,200 --> 00:31:42,980
so if you see this and you want to go on

737
00:31:46,600 --> 00:31:44,210
and explore with this or you want to

738
00:31:47,860 --> 00:31:46,610

share it with others please do I want to

739
00:31:49,570 --> 00:31:47,870
show you a really cool thing that we

740
00:31:52,600 --> 00:31:49,580
just started doing it's called NASA's

741
00:31:55,060 --> 00:31:52,610
asteroid oach Allen jiz basically what

742
00:31:56,590 --> 00:31:55,070
we do is we allow we have it in the

743
00:31:57,640 --> 00:31:56,600
summer which we just finished we'll have

744
00:31:59,110 --> 00:31:57,650
another one in the winter and then

745
00:32:02,410 --> 00:31:59,120
another one in the summer and so on and

746
00:32:04,420 --> 00:32:02,420
what we do is we provide users the we

747
00:32:05,560 --> 00:32:04,430
provide anyone the ability with just

748
00:32:07,780 --> 00:32:05,570
their computer and an internet

749
00:32:09,490 --> 00:32:07,790
connection to go on and to use

750
00:32:12,280 --> 00:32:09,500
ground-based telescopes to take their

751
00:32:15,760 --> 00:32:12,290
own images and we provide the free

752
00:32:16,900 --> 00:32:15,770
online software with tutorials it's it's

753
00:32:19,510 --> 00:32:16,910
relatively simple and I'll walk through

754
00:32:21,430 --> 00:32:19,520
an example of it here for you to put

755
00:32:24,610 --> 00:32:21,440
together your own astronomical images

756
00:32:27,550 --> 00:32:24,620
Astro photography if you will okay we

757
00:32:29,470 --> 00:32:27,560
also provide the NASA datum it much of

758
00:32:31,720 --> 00:32:29,480
the NASA data for those objects so you

759
00:32:32,950 --> 00:32:31,730
can make you see those beautiful you

760
00:32:33,940 --> 00:32:32,960
know Frank is always up here at the

761
00:32:36,550 --> 00:32:33,950
beginning of every public lecture

762
00:32:38,140 --> 00:32:36,560
showing you those beautiful releases

763
00:32:40,480 --> 00:32:38,150

that we provide that that Space

764
00:32:41,770 --> 00:32:40,490
Telescope produces or NASA produces you

765
00:32:45,130 --> 00:32:41,780
can create your own version of those

766
00:32:46,570 --> 00:32:45,140
same objects with the same data so let

767
00:32:50,140 --> 00:32:46,580
me show you what that looks like real

768
00:32:50,800 --> 00:32:50,150
quick so if you go to ask for photo

769
00:32:53,620 --> 00:32:50,810
challenge

770
00:32:55,180 --> 00:32:53,630
let's I'm just going to show you okay so

771
00:32:55,900 --> 00:32:55,190
if you go to micro Observatory that's

772
00:32:57,670 --> 00:32:55,910
the robotic tell

773
00:32:59,590 --> 00:32:57,680
scope you can observe the object and do

774
00:33:02,080 --> 00:32:59,600
it yourself but let's just go to the

775
00:33:06,040 --> 00:33:02,090
NASA data one and I just want to show

776
00:33:07,870 --> 00:33:06,050
you how it works so and there's there's

777
00:33:09,850 --> 00:33:07,880
a step-by-step guide but basically what

778
00:33:12,880 --> 00:33:09,860
you do is you open up this tool this is

779
00:33:14,680 --> 00:33:12,890
us this is a pared down version of the

780
00:33:17,080 --> 00:33:14,690
same tool that astronomers use for their

781
00:33:18,910 --> 00:33:17,090
research by the way okay

782
00:33:21,760 --> 00:33:18,920
we paired it down though and what you

783
00:33:24,510 --> 00:33:21,770
can do is on this tool you go over to

784
00:33:28,630 --> 00:33:24,520
images and you say okay I really want

785
00:33:29,860 --> 00:33:28,640
the Chandra x-ray of the Whirlpool

786
00:33:32,710 --> 00:33:29,870
Galaxy okay

787
00:33:35,350 --> 00:33:32,720
it puts it up there alright it doesn't

788
00:33:37,750 --> 00:33:35,360

seem like much but if you step through

789
00:33:40,000 --> 00:33:37,760
it there will be a hint that this is in

790
00:33:42,040 --> 00:33:40,010
a linear scale of brightness and for

791
00:33:44,970 --> 00:33:42,050
astronomical images it tends to help to

792
00:33:47,290 --> 00:33:44,980
put it in a log scale there we go

793
00:33:51,640 --> 00:33:47,300
you can mess with the controls on the

794
00:33:53,560 --> 00:33:51,650
side until you can see it better so you

795
00:33:55,990 --> 00:33:53,570
can kind of see it there you can add

796
00:33:58,510 --> 00:33:56,000
color to it so I want I want x-ray

797
00:34:01,840 --> 00:33:58,520
high-energy I want it to be blue so I'm

798
00:34:05,010 --> 00:34:01,850
going to color it blue and I want to go

799
00:34:10,240 --> 00:34:05,020
to click this RGB mode again it is all

800
00:34:13,360 --> 00:34:10,250
all on on the tutorial so you can do it

801
00:34:14,500 --> 00:34:13,370
all right now let's let's do Spitzer

802
00:34:17,230 --> 00:34:14,510
let's look at the dust because that's

803
00:34:18,070 --> 00:34:17,240
what we're really interested in yeah all

804
00:34:21,040 --> 00:34:18,080
right

805
00:34:24,190 --> 00:34:21,050
again do log you can look at the dust

806
00:34:25,630 --> 00:34:24,200
I'm gonna go ahead and color that red by

807
00:34:27,130 --> 00:34:25,640
the way I'm doing the typical color

808
00:34:29,080 --> 00:34:27,140
scheme that astronomers would use where

809
00:34:31,270 --> 00:34:29,090
high energy as blue low energy is red

810
00:34:34,570 --> 00:34:31,280
but in you can do any color scheme you

811
00:34:35,980 --> 00:34:34,580
want it's all up to you all right and

812
00:34:42,490 --> 00:34:35,990
then we're gonna do a Hubble let's do a

813
00:34:51,600 --> 00:34:42,500

Hubble green and we will color it green

814
00:34:59,740 --> 00:34:55,419
alright so there's a Hubble green let me

815
00:35:03,190 --> 00:34:59,750
see here there we go and then you can

816
00:35:05,170 --> 00:35:03,200
combine them together and you get this

817
00:35:09,280 --> 00:35:05,180
and let me zoom out so you can see the

818
00:35:12,490 --> 00:35:09,290
whole thing you get this beautiful now

819
00:35:13,750 --> 00:35:12,500
in this the red this and at this it

820
00:35:15,790 --> 00:35:13,760
explains there's videos here on what

821
00:35:17,590 --> 00:35:15,800
these colors actually mean but the red

822
00:35:21,280 --> 00:35:17,600
is the dust okay

823
00:35:23,650 --> 00:35:21,290
that's being heated by stars okay and

824
00:35:25,780 --> 00:35:23,660
that's the Spitzer infrared the blue is

825
00:35:28,350 --> 00:35:25,790
the high-energy stuff that's coming from

826
00:35:32,440 --> 00:35:28,360
high energy sources like black holes or

827
00:35:34,150 --> 00:35:32,450
neutron stars okay that's what blue is

828
00:35:35,650 --> 00:35:34,160
and then green which unfortunately

829
00:35:37,510 --> 00:35:35,660
didn't looks like it didn't come through

830
00:35:40,180 --> 00:35:37,520
very much on here but Green from Hubble

831
00:35:43,210 --> 00:35:40,190
would be the typical stellar population

832
00:35:44,680 --> 00:35:43,220
the normal stars okay and so there's

833
00:35:46,420 --> 00:35:44,690
other there's other wavelengths in here

834
00:35:48,190 --> 00:35:46,430
you can mess with but it's a fun way of

835
00:35:50,500 --> 00:35:48,200
just getting into the astrophotography

836
00:35:55,990 --> 00:35:50,510
and I should mention that I talked about

837
00:35:57,790 --> 00:35:56,000
how these detectors are pixelated right

838
00:35:59,200 --> 00:35:57,800

there actually pixels if you zoom in far

839
00:36:03,520 --> 00:35:59,210
enough you can start to see the pixels

840
00:36:06,880 --> 00:36:03,530
of the image okay right alright so that

841
00:36:08,230 --> 00:36:06,890
is that is what we call a NASA's

842
00:36:12,780 --> 00:36:08,240
astrophotography challenge and we're

843
00:36:15,870 --> 00:36:12,790
coming up with a nice image in the and

844
00:36:19,090 --> 00:36:15,880
for the winter I also want to show you

845
00:36:20,380 --> 00:36:19,100
we have we have images from astronomer

846
00:36:21,790 --> 00:36:20,390
or we have videos from astronomers

847
00:36:24,610 --> 00:36:21,800
explaining what the different types of

848
00:36:26,230 --> 00:36:24,620
light tell you and then I also want to

849
00:36:28,410 --> 00:36:26,240
show you that from the summer challenge

850
00:36:31,030 --> 00:36:28,420
for the Whirlpool Galaxy we also

851
00:36:34,240 --> 00:36:31,040
highlight some really standout entries

852
00:36:36,670 --> 00:36:34,250
okay we highlight standout entries and

853
00:36:39,280 --> 00:36:36,680
scientists actually provide commentary

854
00:36:42,550 --> 00:36:39,290
on why they're so beautiful so if you

855
00:36:44,380 --> 00:36:42,560
also want yourself or anyone you know to

856
00:36:46,060 --> 00:36:44,390
take part in this will be doing it

857
00:36:47,980 --> 00:36:46,070
through December through January in the

858
00:36:50,620 --> 00:36:47,990
winter you can make your own beautiful

859
00:36:52,840 --> 00:36:50,630
images you can submit it and we'll

860
00:36:53,920 --> 00:36:52,850
highlight the standout entries and it's

861
00:36:57,850 --> 00:36:53,930
something that you can show off to

862
00:37:00,940 --> 00:36:57,860
others okay so this is sort of the this

863
00:37:02,200 --> 00:37:00,950

is a very similar process to how

864
00:37:04,750 --> 00:37:02,210
astronomers put together basically

865
00:37:08,079 --> 00:37:04,760
images and I believe Joe de Pasquale

866
00:37:09,880 --> 00:37:08,089
he had a talk a few months ago so it was

867
00:37:13,270 --> 00:37:09,890
probably along these lines about how he

868
00:37:19,240 --> 00:37:13,280
puts his images together yeah all right

869
00:37:24,430 --> 00:37:19,250
okay all right let's go ahead and move

870
00:37:26,130 --> 00:37:24,440
along here all right all right I want to

871
00:37:30,609 --> 00:37:26,140
talk a little bit about photometry now

872
00:37:31,900 --> 00:37:30,619
all right so with the digital detectors

873
00:37:33,849 --> 00:37:31,910
it's possible to do what's called

874
00:37:36,880 --> 00:37:33,859
photometry which basically is just

875
00:37:40,390 --> 00:37:36,890
counting the photons counting how many

876
00:37:41,920 --> 00:37:40,400
photons hit the detector and this is a

877
00:37:45,310 --> 00:37:41,930
tool and a technique that has been

878
00:37:47,620 --> 00:37:45,320
incredibly important in astronomy I'm

879
00:37:49,870 --> 00:37:47,630
highlighting Henrietta Leavitt here she

880
00:37:53,560 --> 00:37:49,880
did groundbreaking research on this at

881
00:37:56,680 --> 00:37:53,570
Harvard in fact they named a law after

882
00:37:59,620 --> 00:37:56,690
her Levitz law she this is a paper from

883
00:38:01,240 --> 00:37:59,630
1912 that she produced this was this is

884
00:38:02,950 --> 00:38:01,250
basically looking at those variable

885
00:38:05,560 --> 00:38:02,960
stars which I talked about earlier stars

886
00:38:10,839 --> 00:38:05,570
that vary in the night and what she

887
00:38:14,380 --> 00:38:10,849
noticed is that the if you look at a

888
00:38:15,670 --> 00:38:14,390

star's period how much it brightens and

889
00:38:17,440 --> 00:38:15,680
fades and brightens and fades for

890
00:38:20,800 --> 00:38:17,450
certain kinds of stars if you look at

891
00:38:23,680 --> 00:38:20,810
that period and you also measure the

892
00:38:26,020 --> 00:38:23,690
brightness changes okay there's a

893
00:38:28,809 --> 00:38:26,030
relationship there and that's very

894
00:38:31,089 --> 00:38:28,819
important because this was really the

895
00:38:35,079 --> 00:38:31,099
first what we call standard candle for

896
00:38:36,940 --> 00:38:35,089
astronomy which means that if we can

897
00:38:38,470 --> 00:38:36,950
measure the period which is a pretty

898
00:38:40,839 --> 00:38:38,480
simple measurement you just measure the

899
00:38:41,920 --> 00:38:40,849
period of a star going getting brighter

900
00:38:44,200 --> 00:38:41,930
and fainter if you can measure that

901
00:38:46,750 --> 00:38:44,210
period you can just use this chart to

902
00:38:49,200 --> 00:38:46,760
calculate how bright it really is its

903
00:38:51,700 --> 00:38:49,210
intrinsic luminosity how bright it is

904
00:38:53,380 --> 00:38:51,710
right that's like if someone handed you

905
00:38:54,849 --> 00:38:53,390
a light bulb and you didn't know how

906
00:38:55,180 --> 00:38:54,859
bright it was and they told you it's 60

907
00:38:57,130 --> 00:38:55,190
watts

908
00:38:59,829 --> 00:38:57,140
okay well now you know something right

909
00:39:02,230 --> 00:38:59,839
so we know we now know these are called

910
00:39:03,640 --> 00:39:02,240
Cepheid variables we now know how bright

911
00:39:05,650 --> 00:39:03,650
they can be if we look at their periods

912
00:39:11,069 --> 00:39:05,660
this is an incredibly important

913
00:39:13,960 --> 00:39:11,079

discovery and here's why at the time and

914
00:39:18,430 --> 00:39:13,970
you know the late you know I'm sorry

915
00:39:20,710 --> 00:39:18,440
around night between 1919 12 to 19

916
00:39:22,540 --> 00:39:20,720
20 or so there is this there is this in

917
00:39:25,420 --> 00:39:22,550
even earlier there's this big debate an

918
00:39:28,870 --> 00:39:25,430
astronomy about these nebulae that they

919
00:39:30,370 --> 00:39:28,880
saw in the universe were they inside of

920
00:39:31,780 --> 00:39:30,380
our own Milky Way galaxy or did they

921
00:39:34,859 --> 00:39:31,790
exist outside of our Milky Way galaxy

922
00:39:37,480 --> 00:39:34,869
this is called the great debate okay and

923
00:39:39,520 --> 00:39:37,490
the great debate was actually was an

924
00:39:42,430 --> 00:39:39,530
actual essentially a debate that was

925
00:39:45,280 --> 00:39:42,440
held in nineteen in 1920 almost a

926
00:39:46,540 --> 00:39:45,290
hundred years ago and there was people

927
00:39:47,859 --> 00:39:46,550
you know there were two astronomers

928
00:39:49,960 --> 00:39:47,869
going back and forth and they couldn't

929
00:39:52,450 --> 00:39:49,970
resolve it but lo and behold Edwin

930
00:39:57,010 --> 00:39:52,460
Hubble using Henrietta Leavitt Stu

931
00:40:00,490 --> 00:39:57,020
scurry of being able to calculate the

932
00:40:03,760 --> 00:40:00,500
brightness of a Cepheid variable took

933
00:40:05,710 --> 00:40:03,770
observations of a Cepheid variable from

934
00:40:08,109 --> 00:40:05,720
and around the andromeda nebula he

935
00:40:10,809 --> 00:40:08,119
called it Andromeda nebula which we now

936
00:40:13,059 --> 00:40:10,819
know to be the Andromeda galaxy and he

937
00:40:15,490 --> 00:40:13,069
calculated its intrinsic brightness and

938
00:40:17,680 --> 00:40:15,500

if you know if you know how bright it

939
00:40:20,260 --> 00:40:17,690
should be and you know how bright it

940
00:40:23,410 --> 00:40:20,270
appears to you you know how far away it

941
00:40:25,450 --> 00:40:23,420
is okay and he was able to determine

942
00:40:27,579 --> 00:40:25,460
that Andromeda was actually way outside

943
00:40:29,290 --> 00:40:27,589
of our galaxy and that broke the great

944
00:40:31,120 --> 00:40:29,300
debate that basically answered it to us

945
00:40:34,329 --> 00:40:31,130
where the Milky Way wasn't the entire

946
00:40:37,150 --> 00:40:34,339
universe all these galaxies were outside

947
00:40:38,680 --> 00:40:37,160
of our universe I mean outside of our

948
00:40:40,089 --> 00:40:38,690
galaxy all these other galaxies were

949
00:40:42,910 --> 00:40:40,099
outside of our own galaxy the universe

950
00:40:49,450 --> 00:40:42,920
was a much bigger place than we had

951
00:40:52,329 --> 00:40:49,460
thought before all right so today what

952
00:40:54,910 --> 00:40:52,339
does that mean well we're still using

953
00:40:57,309 --> 00:40:54,920
this tool this technique we're still

954
00:40:58,900 --> 00:40:57,319
using this photometer E and watching

955
00:41:00,930 --> 00:40:58,910
these variable stars and in fact you may

956
00:41:05,140 --> 00:41:00,940
have heard a lot of press over the last

957
00:41:07,450 --> 00:41:05,150
six months or so over this new debate

958
00:41:12,099 --> 00:41:07,460
over the Hubble constant the expansion

959
00:41:14,859 --> 00:41:12,109
of the universe okay and so this using

960
00:41:15,569 --> 00:41:14,869
this tool and technique astronomers

961
00:41:18,609 --> 00:41:15,579
using the Hubble Space Telescope

962
00:41:20,290 --> 00:41:18,619
observed a lot of Cepheid variables

963
00:41:22,930 --> 00:41:20,300

which this is supposed to represent a

964
00:41:23,770 --> 00:41:22,940
blow-up of Cepheid variables around the

965
00:41:25,569 --> 00:41:23,780
Magellanic Clouds

966
00:41:31,000 --> 00:41:25,579
and they observe these Cepheid variables

967
00:41:32,320 --> 00:41:31,010
and they came to a very they observe the

968
00:41:33,790 --> 00:41:32,330
Cepheid variables and they it was a

969
00:41:37,330 --> 00:41:33,800
they were Alette they are able to come

970
00:41:40,510 --> 00:41:37,340
up to a very good estimation of how fast

971
00:41:43,150 --> 00:41:40,520
the universe is expanding by looking at

972
00:41:44,920 --> 00:41:43,160
those Cepheid variables okay okay so

973
00:41:48,130 --> 00:41:44,930
these are a standard candle and you can

974
00:41:49,420 --> 00:41:48,140
use them you can use them as a distance

975
00:41:51,670 --> 00:41:49,430
ladder to understand how fast the

976
00:41:55,090 --> 00:41:51,680
universe is expanding with time the

977
00:41:58,660 --> 00:41:55,100
problem is is that it it significantly

978
00:42:00,220 --> 00:41:58,670
defers from the result of another space

979
00:42:02,260 --> 00:42:00,230
telescope called Planck that looks at

980
00:42:04,930 --> 00:42:02,270
the early universe looks at the

981
00:42:06,670 --> 00:42:04,940
conditions of the early universe you

982
00:42:09,340 --> 00:42:06,680
know twelve thirteen billion years ago

983
00:42:11,470 --> 00:42:09,350
on we think we understand the physics

984
00:42:13,780 --> 00:42:11,480
form since then if you just play the

985
00:42:16,540 --> 00:42:13,790
movie forward the expansion rate at the

986
00:42:19,060 --> 00:42:16,550
current time should be x but they but it

987
00:42:20,650 --> 00:42:19,070
that they're x doesn't match their value

988
00:42:22,570 --> 00:42:20,660

basically there's a discrepancy between

989
00:42:24,010 --> 00:42:22,580
what they think the expansion rate of

990
00:42:26,710 --> 00:42:24,020
the universe is right now and what it

991
00:42:29,020 --> 00:42:26,720
currently is and this is turning out to

992
00:42:31,060 --> 00:42:29,030
be actually a modern-day debate that's

993
00:42:32,710 --> 00:42:31,070
turning into a big thing because they've

994
00:42:36,610 --> 00:42:32,720
gotten their airs down quite small and

995
00:42:39,850 --> 00:42:36,620
they think that there may be new physics

996
00:42:41,560 --> 00:42:39,860
here okay so I want to point this out to

997
00:42:43,930 --> 00:42:41,570
you because these tools and techniques

998
00:42:46,960 --> 00:42:43,940
that were you know first really started

999
00:42:49,810 --> 00:42:46,970
from Henrietta Leavitt and the computers

1000
00:42:51,820 --> 00:42:49,820
at Harvard back in the early 1900s

1001
00:42:54,370 --> 00:42:51,830
those techniques are still being

1002
00:42:56,380 --> 00:42:54,380
perfected and used today to find new

1003
00:43:00,130 --> 00:42:56,390
clues to the to the physics of our

1004
00:43:01,990 --> 00:43:00,140
universe in the present day of course

1005
00:43:03,010 --> 00:43:02,000
now we have Hubble's so so that that's a

1006
00:43:07,120 --> 00:43:03,020
big help

1007
00:43:09,550 --> 00:43:07,130
all right okay this idea of photometry

1008
00:43:14,470 --> 00:43:09,560
is also used to find alien worlds around

1009
00:43:18,400 --> 00:43:14,480
other stars exoplanets okay so you can

1010
00:43:20,320 --> 00:43:18,410
use this same technique let me see where

1011
00:43:22,650 --> 00:43:20,330
you this is what the Kepler space

1012
00:43:26,230 --> 00:43:22,660
telescope did Kepler was launched in

1013
00:43:28,240 --> 00:43:26,240

2009 I believe and it stared at a blank

1014
00:43:30,400 --> 00:43:28,250
patch of sky or not a blank it stared at

1015
00:43:31,990 --> 00:43:30,410
this patch of sky definitely not blank

1016
00:43:33,940 --> 00:43:32,000
there's a lot of stars in this patch of

1017
00:43:36,610 --> 00:43:33,950
sky but it stared at it for many years

1018
00:43:38,860 --> 00:43:36,620
and it just looked for the dimming of

1019
00:43:41,050 --> 00:43:38,870
basically the photometry at the dimming

1020
00:43:43,390 --> 00:43:41,060
of the star over of all those stars over

1021
00:43:45,820 --> 00:43:43,400
time and it looked at about a hundred

1022
00:43:46,210 --> 00:43:45,830
and fifty thousand stars looked for the

1023
00:43:50,830 --> 00:43:46,220
dimming

1024
00:43:52,030 --> 00:43:50,840
repeating they could use they could

1025
00:43:54,220 --> 00:43:52,040
infer that there perhaps there is a

1026
00:43:57,250 --> 00:43:54,230
planet going around the star and in our

1027
00:43:59,140 --> 00:43:57,260
line of sight blocking that star okay so

1028
00:44:00,970 --> 00:43:59,150
this is called the transit technique but

1029
00:44:02,890 --> 00:44:00,980
really it's basically photometry it's

1030
00:44:05,050 --> 00:44:02,900
basically just measuring how the Stars

1031
00:44:07,420 --> 00:44:05,060
dim with time and brighten with time

1032
00:44:08,980 --> 00:44:07,430
although in this case it's not because

1033
00:44:10,870 --> 00:44:08,990
unlike the Cepheid variable where the

1034
00:44:12,730 --> 00:44:10,880
star itself was physically dimming and

1035
00:44:14,800 --> 00:44:12,740
brightening in this case it's because

1036
00:44:18,370 --> 00:44:14,810
there's a planet coming in front and

1037
00:44:20,200 --> 00:44:18,380
behind the star okay and so because of

1038
00:44:23,470 --> 00:44:20,210

this technique which is a relatively new

1039
00:44:25,900 --> 00:44:23,480
technique of using we use photometry the

1040
00:44:29,830 --> 00:44:25,910
Kepler space telescope has found over

1041
00:44:31,450 --> 00:44:29,840
2,000 planets around other stars but

1042
00:44:35,650 --> 00:44:31,460
this technique we're still using it here

1043
00:44:39,550 --> 00:44:35,660
is the test space telescope and test was

1044
00:44:41,710 --> 00:44:39,560
launched in 2018 and Tess has about a

1045
00:44:45,730 --> 00:44:41,720
400 times larger search area than Kepler

1046
00:44:47,560 --> 00:44:45,740
so it's going to do exoplanet detection

1047
00:44:49,660 --> 00:44:47,570
and the basically the same way but it's

1048
00:44:51,820 --> 00:44:49,670
estimated to find many more what's

1049
00:44:54,460 --> 00:44:51,830
exciting about Tess is that it's going

1050
00:44:57,030 --> 00:44:54,470
to look at four exoplanets that are

1051
00:44:59,430 --> 00:44:57,040
closer to us a lot of Kepler's

1052
00:45:01,690 --> 00:44:59,440
exoplanets that discovered are quite far

1053
00:45:03,220 --> 00:45:01,700
but Tess is going to look for some that

1054
00:45:07,630 --> 00:45:03,230
are closer including this system which

1055
00:45:13,840 --> 00:45:07,640
was just released this summer with a

1056
00:45:15,910 --> 00:45:13,850
very nice name GJ 3 5 7 GJ 3 5 7 is only

1057
00:45:19,360 --> 00:45:15,920
30 31 light-years away from us it's very

1058
00:45:22,960 --> 00:45:19,370
close as far as star systems go and they

1059
00:45:25,930 --> 00:45:22,970
just stand test discover this inner 1 3

1060
00:45:30,100 --> 00:45:25,940
5 7 be around this small little m dwarf

1061
00:45:32,080 --> 00:45:30,110
star and test discovered that and then

1062
00:45:34,870 --> 00:45:32,090
once test discovered that what happened

1063
00:45:36,250 --> 00:45:34,880

was astronomers around the world decided

1064
00:45:38,230 --> 00:45:36,260
that they would look back at all the

1065
00:45:39,850 --> 00:45:38,240
archival data of that star from other

1066
00:45:42,070 --> 00:45:39,860
Telegram based telescopes in the hid

1067
00:45:45,640 --> 00:45:42,080
going back all the way through the late

1068
00:45:48,220 --> 00:45:45,650
1990s and they realized that they had

1069
00:45:49,840 --> 00:45:48,230
and that data these two EXO other

1070
00:45:52,030 --> 00:45:49,850
exoplanets that had never been detected

1071
00:45:53,980 --> 00:45:52,040
it lived in that data but they didn't

1072
00:45:57,340 --> 00:45:53,990
know it and they didn't know how to look

1073
00:45:59,920 --> 00:45:57,350
for it until Tess found that first one

1074
00:46:01,750 --> 00:45:59,930
there these are all

1075
00:46:05,470 --> 00:46:01,760
super-earths size so larger than earth

1076
00:46:08,170 --> 00:46:05,480
that 3 5 7 B is much too close to the

1077
00:46:10,450 --> 00:46:08,180
star to be habitable but you see this

1078
00:46:15,760 --> 00:46:10,460
blue region called the habitable zone 3

1079
00:46:17,710 --> 00:46:15,770
5 7 D is potentially habitable follow-up

1080
00:46:20,680 --> 00:46:17,720
missions will have to explore the

1081
00:46:23,890 --> 00:46:20,690
habitability of that exoplanet but it's

1082
00:46:27,700 --> 00:46:23,900
about it's about 6 times the mass of our

1083
00:46:31,720 --> 00:46:27,710
earth it's called a super earth ok so

1084
00:46:34,240 --> 00:46:31,730
this so photometry is a very is a very

1085
00:46:39,220 --> 00:46:34,250
powerful tool that you can actually do

1086
00:46:41,339 --> 00:46:39,230
yourself with this with this online tool

1087
00:46:44,230 --> 00:46:41,349
called do-it-yourself planet search

1088
00:46:46,299 --> 00:46:44,240

what's really cool about this tool is is

1089
00:46:47,799 --> 00:46:46,309
that you yourself can do the same

1090
00:46:53,620 --> 00:46:47,809
techniques that astronomers do and you

1091
00:46:55,000 --> 00:46:53,630
can discover exoplanets ok and the way

1092
00:46:56,470 --> 00:46:55,010
it worked and by the way I know you're

1093
00:46:58,779 --> 00:46:56,480
like I'm never gonna remember all these

1094
00:47:00,700 --> 00:46:58,789
tools I'll give you one URL at the end

1095
00:47:04,539 --> 00:47:00,710
that you can find everything at or one

1096
00:47:06,069 --> 00:47:04,549
place you can look the DIY planet search

1097
00:47:08,019 --> 00:47:06,079
is a nice tool where you can basically

1098
00:47:11,079 --> 00:47:08,029
do the same processes that astronomers

1099
00:47:12,609 --> 00:47:11,089
do with photometry so basically what you

1100
00:47:14,980 --> 00:47:12,619
do is you first choose a target

1101
00:47:16,779 --> 00:47:14,990
there are many targets you can choose

1102
00:47:19,089 --> 00:47:16,789
these and I should say these are known

1103
00:47:21,849 --> 00:47:19,099
exoplanets so you're going to get a

1104
00:47:23,200 --> 00:47:21,859
result if you do it correctly ok these

1105
00:47:26,859 --> 00:47:23,210
are known exoplanets that we've

1106
00:47:28,450 --> 00:47:26,869
discovered so you're going to get a

1107
00:47:30,579 --> 00:47:28,460
result so if you if you want to do this

1108
00:47:33,370 --> 00:47:30,589
you can observe anytime you can also go

1109
00:47:35,980 --> 00:47:33,380
back in the past and observe that's nice

1110
00:47:38,109 --> 00:47:35,990
if you want something right now you

1111
00:47:38,859 --> 00:47:38,119
don't have to wait for it I went ahead

1112
00:47:41,440 --> 00:47:38,869
and did that

1113
00:47:47,260 --> 00:47:41,450

because we aren't going to wait several

1114
00:47:50,829 --> 00:47:47,270
days and let me show you what I did so I

1115
00:47:54,130 --> 00:47:50,839
just want to bring this up so that you

1116
00:47:56,170 --> 00:47:54,140
can see let me see it's this one yeah

1117
00:47:59,140 --> 00:47:56,180
alright so what you can do is you can

1118
00:48:01,240 --> 00:47:59,150
bring up an image so basically you can

1119
00:48:02,740 --> 00:48:01,250
do you can observe the the telescope's

1120
00:48:04,150 --> 00:48:02,750
this is the same micro Observatory

1121
00:48:07,059 --> 00:48:04,160
telescopes by the way that I showed you

1122
00:48:09,220 --> 00:48:07,069
earlier ok they observe they're just

1123
00:48:10,809 --> 00:48:09,230
6-inch ground-based telescopes but they

1124
00:48:12,730 --> 00:48:10,819
can still detect exoplanets which is

1125
00:48:15,150 --> 00:48:12,740
amazing so

1126
00:48:18,430 --> 00:48:15,160
if you hit view you come up with a

1127
00:48:20,020 --> 00:48:18,440
region of the night sky and there's

1128
00:48:21,609 --> 00:48:20,030
instructions on how to do this but I'll

1129
00:48:23,230 --> 00:48:21,619
just walk you through real quick the

1130
00:48:25,600 --> 00:48:23,240
first thing that any astronomer needs to

1131
00:48:29,020 --> 00:48:25,610
do is to find their star one of these

1132
00:48:33,190 --> 00:48:29,030
stars has an exoplanet going around it

1133
00:48:38,310 --> 00:48:33,200
which one is it that one you're you're

1134
00:48:40,510 --> 00:48:38,320
right you're right right right well

1135
00:48:43,030 --> 00:48:40,520
right it's the one with the yellow

1136
00:48:43,570 --> 00:48:43,040
circle on it right yes that's it that's

1137
00:48:45,790 --> 00:48:43,580
it

1138
00:48:47,350 --> 00:48:45,800

so there's a finder chart right there's

1139
00:48:51,310 --> 00:48:47,360
a finder chart here that lets you find

1140
00:48:53,260 --> 00:48:51,320
your star so the process is you first

1141
00:48:55,870 --> 00:48:53,270
calibrate your image and what that means

1142
00:48:57,670 --> 00:48:55,880
is that you subtract off what's called

1143
00:48:59,590 --> 00:48:57,680
the dark noise or the dark current from

1144
00:49:02,080 --> 00:48:59,600
the chip all these CCD chips have these

1145
00:49:03,340 --> 00:49:02,090
interesting noise features first thing

1146
00:49:05,260 --> 00:49:03,350
you do is you subtract that off because

1147
00:49:08,560 --> 00:49:05,270
that's just noise so you click calibrate

1148
00:49:11,770 --> 00:49:08,570
it does it for you and then you bring up

1149
00:49:14,710 --> 00:49:11,780
your finder chart and you try to find

1150
00:49:16,390 --> 00:49:14,720
out where it is and you see these two

1151
00:49:17,260 --> 00:49:16,400
stars they're looking awful that like

1152
00:49:20,109 --> 00:49:17,270
these two stars

1153
00:49:21,340 --> 00:49:20,119
if you ever observe it in the night sky

1154
00:49:23,020 --> 00:49:21,350
if you've ever done observing with your

1155
00:49:24,970 --> 00:49:23,030
own telescope you know the idea of star

1156
00:49:28,330 --> 00:49:24,980
hopping where you try to find the bright

1157
00:49:31,000 --> 00:49:28,340
ones and you sort of hop around and then

1158
00:49:34,060 --> 00:49:31,010
the yellow one which is that one is our

1159
00:49:35,590 --> 00:49:34,070
target star right so let me close that

1160
00:49:37,720 --> 00:49:35,600
because I know what the answers are all

1161
00:49:39,790 --> 00:49:37,730
right so basically you put your little

1162
00:49:42,070 --> 00:49:39,800
cursor here and you click on this and

1163
00:49:43,690 --> 00:49:42,080

when you click on it what it's doing is

1164
00:49:46,330 --> 00:49:43,700
it's basically saying it's going to

1165
00:49:48,910 --> 00:49:46,340
count up all the photons or all the

1166
00:49:50,260 --> 00:49:48,920
light within that circle that's what

1167
00:49:51,640 --> 00:49:50,270
that circle is this like your bucket

1168
00:49:54,790 --> 00:49:51,650
it's going to count all the light in

1169
00:49:57,160 --> 00:49:54,800
that circle it asks for two comparison

1170
00:49:58,480 --> 00:49:57,170
stars because we're looking for a star

1171
00:50:00,010 --> 00:49:58,490
that varies with time and you need to

1172
00:50:02,820 --> 00:50:00,020
compare it with a star that doesn't vary

1173
00:50:06,220 --> 00:50:02,830
with time as a to get sort of a relative

1174
00:50:07,570 --> 00:50:06,230
measurement so the finer chart tells you

1175
00:50:09,820 --> 00:50:07,580
where these are but I'll just click them

1176
00:50:11,020 --> 00:50:09,830
here there's a comparison and then they

1177
00:50:14,770 --> 00:50:11,030
just want you to click on a couple of

1178
00:50:16,840 --> 00:50:14,780
dark patches of sky because the dark sky

1179
00:50:17,920 --> 00:50:16,850
could actually have some small amount of

1180
00:50:21,940 --> 00:50:17,930
brightness that you might want to

1181
00:50:23,260 --> 00:50:21,950
subtract off okay all the instructions

1182
00:50:26,210 --> 00:50:23,270
walk you through that and then when you

1183
00:50:30,260 --> 00:50:26,220
hit calculate and record you

1184
00:50:32,720 --> 00:50:30,270
are going to it'll tell you okay

1185
00:50:35,570 --> 00:50:32,730
relative brightness measurement so it's

1186
00:50:38,000 --> 00:50:35,580
about 80% as bright as the average of

1187
00:50:39,440 --> 00:50:38,010
those two stars what's important is you

1188
00:50:40,850 --> 00:50:39,450

do this as you can see with the

1189
00:50:43,640 --> 00:50:40,860
checkmarks with enough of those

1190
00:50:46,220 --> 00:50:43,650
observations of that same star and you

1191
00:50:48,350 --> 00:50:46,230
graph the brightness it'll graph it for

1192
00:50:51,640 --> 00:50:48,360
you and you can start to see although

1193
00:50:54,650 --> 00:50:51,650
it's noisy you can start to see a trend

1194
00:50:56,600 --> 00:50:54,660
where there's a dip where in here is

1195
00:50:59,000 --> 00:50:56,610
where the the transiting planet must be

1196
00:51:00,620 --> 00:50:59,010
in front of the star right now again

1197
00:51:02,240 --> 00:51:00,630
this is pretty powerful because this is

1198
00:51:04,220 --> 00:51:02,250
only a six inch telescope these are

1199
00:51:06,020 --> 00:51:04,230
pretty small telescopes there but

1200
00:51:07,910 --> 00:51:06,030
they're pretty powerful the idea that

1201
00:51:09,830 --> 00:51:07,920
with a six inch telescope you can

1202
00:51:12,830 --> 00:51:09,840
actually discover a planet around

1203
00:51:15,350 --> 00:51:12,840
another world it's quite amazing and in

1204
00:51:17,540 --> 00:51:15,360
fact if you go onto this tool you will

1205
00:51:19,130 --> 00:51:17,550
there's opportunities to to work with

1206
00:51:21,320 --> 00:51:19,140
others in the community that use this

1207
00:51:25,730 --> 00:51:21,330
tool to pull your your answers together

1208
00:51:28,100 --> 00:51:25,740
to get even more accurate data so this

1209
00:51:30,290 --> 00:51:28,110
is oh this is a fun tool that gets into

1210
00:51:33,590 --> 00:51:30,300
photometry that you that we would happy

1211
00:51:36,010 --> 00:51:33,600
for you to share with others I want to

1212
00:51:42,410 --> 00:51:36,020
also just make a couple other points

1213
00:51:44,150 --> 00:51:42,420

about other tools we work and a learning

1214
00:51:46,280 --> 00:51:44,160
program called NASA's Universal learning

1215
00:51:48,590 --> 00:51:46,290
this is a NASA program where a Space

1216
00:51:50,300 --> 00:51:48,600
Telescope is is a member but we have

1217
00:51:52,400 --> 00:51:50,310
partners across the country including at

1218
00:51:53,900 --> 00:51:52,410
Sonoma State University and they're

1219
00:51:55,610 --> 00:51:53,910
leading this effort called the global

1220
00:51:59,090 --> 00:51:55,620
telescope Network where you can

1221
00:52:00,740 --> 00:51:59,100
basically do what we just did with that

1222
00:52:02,930 --> 00:52:00,750
but with even larger telescopes

1223
00:52:05,210 --> 00:52:02,940
ground-based telescopes and even do more

1224
00:52:07,190 --> 00:52:05,220
you can do exoplanets just like we just

1225
00:52:09,320 --> 00:52:07,200
did there you could do variable stars

1226
00:52:11,720 --> 00:52:09,330
like Henrietta Leavitt was doing and

1227
00:52:13,910 --> 00:52:11,730
Edwin Hubble was doing okay so there's

1228
00:52:16,580 --> 00:52:13,920
there's online tools that you can do and

1229
00:52:20,480 --> 00:52:16,590
learn about with the global telescope

1230
00:52:22,250 --> 00:52:20,490
network likewise there's a project

1231
00:52:25,220 --> 00:52:22,260
that's coming out very soon that we're

1232
00:52:28,400 --> 00:52:25,230
excited to share with you it's called

1233
00:52:31,760 --> 00:52:28,410
the exoplanet transit survey this is

1234
00:52:36,410 --> 00:52:31,770
aimed at amateur astronomers and smaller

1235
00:52:38,750 --> 00:52:36,420
colleges universities basically you can

1236
00:52:39,800 --> 00:52:38,760
you can observe high-priority transiting

1237
00:52:41,360 --> 00:52:39,810
exoplanets

1238
00:52:44,480 --> 00:52:41,370

discovered by Kepler tests and other

1239
00:52:46,040 --> 00:52:44,490
surveys this is getting more into doing

1240
00:52:48,380 --> 00:52:46,050
actual I mean this is really getting

1241
00:52:49,810 --> 00:52:48,390
into actual science here so the whole

1242
00:52:52,460 --> 00:52:49,820
point of this is to pool together

1243
00:52:55,700 --> 00:52:52,470
ground-based telescopes small large

1244
00:52:58,370 --> 00:52:55,710
whatever they are and to do things like

1245
00:53:00,500 --> 00:52:58,380
follow up on potential tests discoveries

1246
00:53:03,110 --> 00:53:00,510
ok so test is going to do a lot of

1247
00:53:04,850 --> 00:53:03,120
discoveries but they're not test is only

1248
00:53:07,400 --> 00:53:04,860
going to maybe visit a few some of those

1249
00:53:09,290 --> 00:53:07,410
may be one visit or one pass so there

1250
00:53:10,940 --> 00:53:09,300
might be uncertain so if you follow up

1251
00:53:13,060 --> 00:53:10,950
with these ground base you might

1252
00:53:18,080 --> 00:53:13,070
actually be able to confirm that there's

1253
00:53:19,850 --> 00:53:18,090
possibly an exoplanet there okay and so

1254
00:53:22,430 --> 00:53:19,860
this is something that's that's going to

1255
00:53:25,160 --> 00:53:22,440
be out in the next hopefully next

1256
00:53:26,870 --> 00:53:25,170
several months so keep that in mind

1257
00:53:29,750 --> 00:53:26,880
again this is a NASA's Universal

1258
00:53:31,670 --> 00:53:29,760
learning program I will and this is done

1259
00:53:35,620 --> 00:53:31,680
with our partners at at NASA's Jet

1260
00:53:37,730 --> 00:53:35,630
Propulsion Laboratory I encourage you to

1261
00:53:39,470 --> 00:53:37,740
enough point this again at the end go to

1262
00:53:41,120 --> 00:53:39,480
NASA's Universal learning site all of

1263
00:53:43,840 --> 00:53:41,130

the activities that I show you will be

1264
00:53:48,230 --> 00:53:43,850
there all right

1265
00:53:49,700 --> 00:53:48,240
spectroscopy probably I this I'm biased

1266
00:53:53,750 --> 00:53:49,710
but I think this is the most powerful

1267
00:53:54,740 --> 00:53:53,760
tool in our toolkit so how are we doing

1268
00:53:57,230 --> 00:53:54,750
on time we're just getting to the

1269
00:53:59,000 --> 00:53:57,240
punchline we all right okay all right

1270
00:54:02,270 --> 00:53:59,010
all right

1271
00:54:05,200 --> 00:54:02,280
so spectroscopy and you got a nice loot

1272
00:54:08,330 --> 00:54:05,210
though that showcases some spectroscopy

1273
00:54:09,680 --> 00:54:08,340
you know they say a picture is worth a

1274
00:54:11,440 --> 00:54:09,690
thousand words sometimes they say a

1275
00:54:13,880 --> 00:54:11,450
spectrum is worth a thousand pictures

1276
00:54:14,950 --> 00:54:13,890
spectroscopy really has a lot of

1277
00:54:17,180 --> 00:54:14,960
information in it

1278
00:54:18,950 --> 00:54:17,190
what is spectroscopy well spectroscopy

1279
00:54:22,820 --> 00:54:18,960
is just breaking up the light you get

1280
00:54:25,660 --> 00:54:22,830
into the component colors okay a lot of

1281
00:54:28,190 --> 00:54:25,670
people credit Isaac Newton was sort of

1282
00:54:29,630 --> 00:54:28,200
the invention of the the field of

1283
00:54:33,050 --> 00:54:29,640
spectroscopy although others were doing

1284
00:54:34,940 --> 00:54:33,060
spectroscopy before him in the 1600s and

1285
00:54:37,520 --> 00:54:34,950
in fact the Romans were breaking up

1286
00:54:40,880 --> 00:54:37,530
light with with glass and seeing

1287
00:54:46,010 --> 00:54:40,890
rainbows but Isaac Newton in his optics

1288
00:54:48,400 --> 00:54:46,020

book that came out in 1704 basically put

1289
00:54:50,750 --> 00:54:48,410
together the fact that you can actually

1290
00:54:52,280 --> 00:54:50,760
break up white light into the component

1291
00:54:53,330 --> 00:54:52,290
colors and put the component colors back

1292
00:54:55,400 --> 00:54:53,340
together again in white lie

1293
00:54:57,950 --> 00:54:55,410
so he basically showed with his

1294
00:55:00,170 --> 00:54:57,960
experiments that that white light was

1295
00:55:03,110 --> 00:55:00,180
really comprised of those of those

1296
00:55:04,910 --> 00:55:03,120
colors of the rainbow alright so you can

1297
00:55:06,560 --> 00:55:04,920
see him with the prism there and that

1298
00:55:11,570 --> 00:55:06,570
pick in that painting breaking up the

1299
00:55:14,390 --> 00:55:11,580
light alright so let's go ahead and do a

1300
00:55:17,210 --> 00:55:14,400
demo I have this up here this is uh this

1301
00:55:18,530 --> 00:55:17,220
is sort of an idea there's a lot of

1302
00:55:22,130 --> 00:55:18,540
stuff on here all I want to get across

1303
00:55:23,360 --> 00:55:22,140
is that in most cases on a telescope if

1304
00:55:24,980 --> 00:55:23,370
you have as if you're trying to take a

1305
00:55:27,020 --> 00:55:24,990
spectrum of an object if you're trying

1306
00:55:30,140 --> 00:55:27,030
to break the light up of an object you

1307
00:55:32,570 --> 00:55:30,150
have you want to you want to only get

1308
00:55:34,340 --> 00:55:32,580
the target usually right so you have a

1309
00:55:36,890 --> 00:55:34,350
star or you have a galaxy or something

1310
00:55:39,200 --> 00:55:36,900
and so you need some way of preventing

1311
00:55:41,930 --> 00:55:39,210
all the other light from the image from

1312
00:55:43,750 --> 00:55:41,940
getting into your great getting into

1313
00:55:46,880 --> 00:55:43,760

this grating is essentially a prism you

1314
00:55:48,470 --> 00:55:46,890
only want your target to be broken up

1315
00:55:50,330 --> 00:55:48,480
into a spectrum that's not always the

1316
00:55:51,980 --> 00:55:50,340
case there are others there are other

1317
00:55:53,810 --> 00:55:51,990
spec there are other spectrographs on

1318
00:55:55,370 --> 00:55:53,820
our two instruments things that are

1319
00:55:57,380 --> 00:55:55,380
things I call like a fuse and other

1320
00:55:59,470 --> 00:55:57,390
things that that you can basically get a

1321
00:56:02,420 --> 00:55:59,480
spectrum of the entire field if you will

1322
00:56:04,700 --> 00:56:02,430
but the idea is is that you take the

1323
00:56:05,960 --> 00:56:04,710
light from a source you you pass it

1324
00:56:08,720 --> 00:56:05,970
through in this case it's a grating but

1325
00:56:10,250 --> 00:56:08,730
it acts like a prism you break up you

1326
00:56:12,500 --> 00:56:10,260
bend the colors of light and then you

1327
00:56:27,640 --> 00:56:12,510
put it on a detector your CCD chip and

1328
00:56:34,050 --> 00:56:27,650
you read it on yeah yeah yeah yeah yeah

1329
00:56:41,220 --> 00:56:36,660
all right Theatre of the mind people all

1330
00:56:43,290 --> 00:56:41,230
right okay thank you Frank

1331
00:56:45,270 --> 00:56:43,300
but what's powerful about spectroscopy

1332
00:56:46,440 --> 00:56:45,280
why spectroscopy so powerful there are

1333
00:56:48,120 --> 00:56:46,450
so many things you can learn about an

1334
00:56:50,640 --> 00:56:48,130
object with a spectrum okay you can

1335
00:56:52,380 --> 00:56:50,650
learn in this case we're showing you one

1336
00:56:53,880 --> 00:56:52,390
example you can learn the composition of

1337
00:56:57,060 --> 00:56:53,890
the object what the object is made out

1338
00:56:59,160 --> 00:56:57,070

of you can learn how far away an object

1339
00:57:01,800 --> 00:56:59,170
is you can learn how fast it's moving

1340
00:57:03,720 --> 00:57:01,810
through space you can learn the

1341
00:57:05,520 --> 00:57:03,730
temperature of an object there's so many

1342
00:57:08,870 --> 00:57:05,530
things that a spectrum can give you if

1343
00:57:12,270 --> 00:57:08,880
you if you if you take a spectrum so

1344
00:57:15,330 --> 00:57:12,280
with that let me go ahead and switch

1345
00:57:18,510 --> 00:57:15,340
over we're gonna try something we've see

1346
00:57:24,960 --> 00:57:18,520
if this works all right we're gonna go

1347
00:57:26,880 --> 00:57:24,970
ahead and do a demo here and before we

1348
00:57:32,360 --> 00:57:26,890
turn though there we go before we turn

1349
00:57:38,370 --> 00:57:34,890
see if you can see I want you to see

1350
00:57:44,340 --> 00:57:38,380
what I can see on my screen here there

1351
00:57:46,830 --> 00:57:44,350
we go all right okay all right now what

1352
00:57:49,260 --> 00:57:46,840
I have up here in the front is I have a

1353
00:57:50,670 --> 00:57:49,270
camera with us with essentially a prism

1354
00:57:53,040 --> 00:57:50,680
or a grating in it that's going to be

1355
00:57:54,780 --> 00:57:53,050
our spectrograph and then I have these

1356
00:57:57,840 --> 00:57:54,790
tubes that are filled with an element

1357
00:57:59,130 --> 00:57:57,850
okay and I'm going to heat up I'm going

1358
00:58:01,320 --> 00:57:59,140
to turn this on and it's going to heat

1359
00:58:04,080 --> 00:58:01,330
the element the gas in this and it's

1360
00:58:06,360 --> 00:58:04,090
going to give off very specific colors

1361
00:58:07,650 --> 00:58:06,370
that are associated with that gas okay

1362
00:58:10,830 --> 00:58:07,660
essentially it's going to give off a

1363
00:58:13,580 --> 00:58:10,840

spectrum it's it's what we call we

1364
00:58:15,930 --> 00:58:13,590
sometimes call it a spectral fingerprint

1365
00:58:17,070 --> 00:58:15,940
so let me go ahead and turn that on okay

1366
00:58:20,430 --> 00:58:17,080
you can go ahead and turn the lights off

1367
00:58:22,680 --> 00:58:20,440
now yeah Thank You Thomas all right turn

1368
00:58:27,750 --> 00:58:22,690
that on all right good

1369
00:58:29,700 --> 00:58:27,760
okay so when you look at this screen all

1370
00:58:32,580 --> 00:58:29,710
right so there there's the tube you see

1371
00:58:34,890 --> 00:58:32,590
it bright that sort of hashed bar is

1372
00:58:36,780 --> 00:58:34,900
essentially the amount where I want the

1373
00:58:38,370 --> 00:58:36,790
light to come through so I don't want to

1374
00:58:40,290 --> 00:58:38,380
include all this other stuff in the

1375
00:58:42,390 --> 00:58:40,300
spectrum and then here's actually where

1376
00:58:44,730 --> 00:58:42,400
it breaks it apart and then you can see

1377
00:58:47,549 --> 00:58:44,740
over here it graphs it for you so these

1378
00:58:50,189 --> 00:58:47,559
are nanometers these are essentially

1379
00:58:52,439 --> 00:58:50,199
wavelength of light and this is

1380
00:58:55,140 --> 00:58:52,449
intensity or how bright the light is

1381
00:58:58,349 --> 00:58:55,150
and you'll notice that a few lines

1382
00:59:00,329 --> 00:58:58,359
really stick out okay and those are the

1383
00:59:02,160 --> 00:59:00,339
fingerprints that tell us what this

1384
00:59:06,269 --> 00:59:02,170
element is does anyone know what's in

1385
00:59:08,069 --> 00:59:06,279
this - how many chemical how many

1386
00:59:13,229 --> 00:59:08,079
chemistry spectroscopy is do we have in

1387
00:59:15,689 --> 00:59:13,239
the room all right

1388
00:59:17,670 --> 00:59:15,699

well luckily people have done this in

1389
00:59:20,339 --> 00:59:17,680
the laboratory for a long time and they

1390
00:59:21,630 --> 00:59:20,349
have the answers for us so let me go

1391
00:59:27,449 --> 00:59:21,640
ahead and show you I'm going to over

1392
00:59:28,979 --> 00:59:27,459
plot a line here hydrogen lines and what

1393
00:59:31,380 --> 00:59:28,989
you'll notice is these are called the

1394
00:59:34,109 --> 00:59:31,390
hydrogen bomber lines but they mark them

1395
00:59:36,539 --> 00:59:34,119
so this is called hydrogen alpha

1396
00:59:38,939 --> 00:59:36,549
hydrogen beta and so on there's one

1397
00:59:40,799 --> 00:59:38,949
there it turns out you don't really see

1398
00:59:43,549 --> 00:59:40,809
these because the sensitivity the check

1399
00:59:46,589 --> 00:59:43,559
the chip drops off over in the and the

1400
00:59:48,660 --> 00:59:46,599
violet and so we don't really the chip

1401
00:59:51,299 --> 00:59:48,670
can't detect those colors this is all

1402
00:59:53,489 --> 00:59:51,309
noise over here by the way so you can

1403
00:59:55,859 --> 00:59:53,499
ignore this but here between here and

1404
00:59:57,359 --> 00:59:55,869
here is essentially what the chip

1405
01:00:01,169 --> 00:59:57,369
somewhere around here is what the chip

1406
01:00:05,459 --> 01:00:01,179
can see so that tells us that we have

1407
01:00:07,079 --> 01:00:05,469
hydrogen hydrogen lines so when an

1408
01:00:08,969 --> 01:00:07,089
astronomer is doing this and this is

1409
01:00:12,660 --> 01:00:08,979
actually a lot of what I did for my PhD

1410
01:00:16,380 --> 01:00:12,670
work is we we get a spectrum from an

1411
01:00:18,839 --> 01:00:16,390
object okay and it's a mystery right and

1412
01:00:22,140 --> 01:00:18,849
so you create these line lists like we

1413
01:00:26,039 --> 01:00:22,150

have here this is hydrogen bomber but

1414
01:00:27,689 --> 01:00:26,049
you know if I also clicked on h2o water

1415
01:00:32,359 --> 01:00:27,699
that's what the that's what the water

1416
01:00:34,769 --> 01:00:32,369
lines would be or neon or so on right

1417
01:00:36,059 --> 01:00:34,779
you can see it gets quite complicated if

1418
01:00:38,069 --> 01:00:36,069
your object has a lot of different

1419
01:00:39,569 --> 01:00:38,079
elements in it but that's where that's

1420
01:00:43,529 --> 01:00:39,579
that's that's where you make your money

1421
01:00:45,509 --> 01:00:43,539
right all right so that's hydrogen

1422
01:00:47,219 --> 01:00:45,519
bomber but let's let's actually take a

1423
01:00:53,239 --> 01:00:47,229
let me turn that off for a second and

1424
01:00:56,609 --> 01:00:53,249
let me overlay on here a reference star

1425
01:01:01,410 --> 01:00:56,619
I'm gonna do this is this is the

1426
01:01:02,700 --> 01:01:01,420
spectrum of a star an a0 star

1427
01:01:04,460 --> 01:01:02,710
this is basically if you've heard of the

1428
01:01:07,970 --> 01:01:04,470
star Vega this is equivalent to Vega

1429
01:01:10,770 --> 01:01:07,980
what you'll notice you notice that those

1430
01:01:13,470 --> 01:01:10,780
we call these emission lines the hot gas

1431
01:01:14,910 --> 01:01:13,480
from the tube ISM is creating these

1432
01:01:16,770 --> 01:01:14,920
emission lines these spectral

1433
01:01:20,069 --> 01:01:16,780
fingerprints you'll notice that they

1434
01:01:23,819 --> 01:01:20,079
overlap directly with these dips that

1435
01:01:26,849 --> 01:01:23,829
you see in the star's spectrum okay it

1436
01:01:30,240 --> 01:01:26,859
turns out that four stars they have

1437
01:01:32,339 --> 01:01:30,250
these outer atmospheres okay so this

1438
01:01:34,740 --> 01:01:32,349

this hot gas is emitting these signature

1439
01:01:38,789 --> 01:01:34,750
stars have these cooler atmospheres

1440
01:01:42,270 --> 01:01:38,799
where they absorb the photons of

1441
01:01:44,789 --> 01:01:42,280
specific from specific elements so this

1442
01:01:48,710 --> 01:01:44,799
star has an outer atmosphere of hydrogen

1443
01:01:51,210 --> 01:01:48,720
and we know that because it's absorbing

1444
01:01:52,620 --> 01:01:51,220
hydrogen because there is less hydrogen

1445
01:01:57,299 --> 01:01:52,630
that that line is associate with

1446
01:01:59,339 --> 01:01:57,309
hydrogen and so we can actually use

1447
01:02:00,690 --> 01:01:59,349
these are called absorption lines so

1448
01:02:03,690 --> 01:02:00,700
whether they're are being emitted from a

1449
01:02:09,329 --> 01:02:03,700
hot gas like that - or whether the gas

1450
01:02:12,200 --> 01:02:09,339
is absorbing photons the gas is cooler

1451
01:02:14,250 --> 01:02:12,210
and absorbing photons you can still do

1452
01:02:15,210 --> 01:02:14,260
doesn't matter if the submission or

1453
01:02:18,539 --> 01:02:15,220
absorption you can determine that

1454
01:02:21,030 --> 01:02:18,549
hydrogen is there right so this is

1455
01:02:22,710 --> 01:02:21,040
actually one of the ways in which they

1456
01:02:24,690 --> 01:02:22,720
did the stellar classifications of stars

1457
01:02:28,740 --> 01:02:24,700
so if you ever wondered why stars have

1458
01:02:30,960 --> 01:02:28,750
these weird classifications of oba FG

1459
01:02:34,140 --> 01:02:30,970
whatever if you've ever heard of that it

1460
01:02:35,549 --> 01:02:34,150
actually initially came from using

1461
01:02:37,109 --> 01:02:35,559
spectroscopy and looking at the

1462
01:02:40,079 --> 01:02:37,119
strengths of the hydrogen Balmer lines

1463
01:02:42,089 --> 01:02:40,089

some a stars have very strong hydrogen

1464
01:02:46,620 --> 01:02:42,099
bomber lines they have very strong

1465
01:02:48,809 --> 01:02:46,630
hydrogen presence present in the Balmer

1466
01:02:50,190 --> 01:02:48,819
series and I keep saying bomber because

1467
01:02:53,520 --> 01:02:50,200
there's different kinds of hydrogen

1468
01:02:55,559 --> 01:02:53,530
hydrogen lines let me go ahead and do

1469
01:03:01,950 --> 01:02:55,569
another example let's go ahead and turn

1470
01:03:07,819 --> 01:03:01,960
that alright actually let me go ahead

1471
01:03:11,150 --> 01:03:07,829
and turn on see this is a star this is a

1472
01:03:14,850 --> 01:03:11,160
g25 star so this is a star like our Sun

1473
01:03:16,770 --> 01:03:14,860
so our Sun has a spectrum like this the

1474
01:03:18,930 --> 01:03:16,780
is a cool our son is a cooler star than

1475
01:03:20,340 --> 01:03:18,940
the a star and as you get cooler and

1476
01:03:22,560 --> 01:03:20,350
cooler stars you're gonna notice that

1477
01:03:24,030 --> 01:03:22,570
the spectrum looks a little Messier but

1478
01:03:26,550 --> 01:03:24,040
it's actually because there's a lot more

1479
01:03:28,440 --> 01:03:26,560
features that you see okay so it gets

1480
01:03:30,240 --> 01:03:28,450
actually quite complicated it's hard to

1481
01:03:31,620 --> 01:03:30,250
see but there is hydrogen there you can

1482
01:03:35,220 --> 01:03:31,630
see that it matches up with that and

1483
01:03:37,860 --> 01:03:35,230
there's hydrogen there but there's

1484
01:03:41,040 --> 01:03:37,870
something else that's really cool that I

1485
01:03:47,040 --> 01:03:41,050
want to show you let's take off let's

1486
01:03:57,000 --> 01:03:47,050
take hydrogen out let's put in a

1487
01:03:59,400 --> 01:03:57,010
different element all right all right

1488
01:04:02,790 --> 01:03:59,410

you can see this has a lot more lines

1489
01:04:07,560 --> 01:04:02,800
right this has this spec this spectrum

1490
01:04:09,900 --> 01:04:07,570
is quite quite busier but you'll notice

1491
01:04:12,960 --> 01:04:09,910
that there are some features that that

1492
01:04:16,260 --> 01:04:12,970
do overlap with this sun-like star

1493
01:04:18,930 --> 01:04:16,270
spectrum don't nominally this this sort

1494
01:04:20,430 --> 01:04:18,940
of yellow line here you kind of you kind

1495
01:04:25,860 --> 01:04:20,440
of see a dip up there and in fact I

1496
01:04:33,050 --> 01:04:25,870
could if I see if I can make this work I

1497
01:04:36,420 --> 01:04:33,060
might be able to not sure all right

1498
01:04:39,660 --> 01:04:36,430
there was some way but I forgot how of

1499
01:04:41,460 --> 01:04:39,670
assuming it anyway look at the mouse

1500
01:04:44,880 --> 01:04:41,470
look at the mouse it'll tell you where

1501
01:04:47,850 --> 01:04:44,890
it is all right so there is a dip there

1502
01:04:55,440 --> 01:04:47,860
and it turns out that does anyone know

1503
01:04:58,650 --> 01:04:55,450
what's at around 588 nanometers what was

1504
01:05:01,760 --> 01:04:58,660
it not sodium although that color looks

1505
01:05:04,950 --> 01:05:01,770
very similar to it's actually helium

1506
01:05:06,450 --> 01:05:04,960
this is a helium spectrum and it turns

1507
01:05:09,300 --> 01:05:06,460
out that this is how helium was

1508
01:05:10,970 --> 01:05:09,310
discovered because helium is very rare

1509
01:05:13,350 --> 01:05:10,980
on the earth it's a very light gas

1510
01:05:16,280 --> 01:05:13,360
helium was first discovered in the Sun

1511
01:05:20,910 --> 01:05:16,290
and and this was the line that

1512
01:05:24,360 --> 01:05:20,920
rediscovered helium this 588 nanometer

1513
01:05:25,800 --> 01:05:24,370

line so using spectroscopy you know we

1514
01:05:27,660 --> 01:05:25,810
didn't we're doing a lot of things but

1515
01:05:30,540 --> 01:05:27,670
we're also you know filling in the

1516
01:05:40,260 --> 01:05:33,780
and that was actually done in eight let

1517
01:05:42,120 --> 01:05:40,270
me see if either 1868 all right so see

1518
01:05:47,610 --> 01:05:42,130
we could play with this all day but it's

1519
01:05:48,930 --> 01:05:47,620
getting late but actually if you're

1520
01:05:50,220 --> 01:05:48,940
interested after we're done if you want

1521
01:05:52,230 --> 01:05:50,230
to come up and take a look at it - I'm

1522
01:05:56,040 --> 01:05:52,240
happy to show you this or any any of the

1523
01:05:58,320 --> 01:05:56,050
other tools alright so let's go ahead

1524
01:06:04,730 --> 01:05:58,330
and I'm gonna go ahead and go through a

1525
01:06:12,860 --> 01:06:08,310
all right I have to do this again look

1526
01:06:17,670 --> 01:06:12,870
at my dust yes it's the best alright

1527
01:06:21,450 --> 01:06:17,680
okay alright so this is what I studied

1528
01:06:23,160 --> 01:06:21,460
as a graduate student and this this is

1529
01:06:24,960 --> 01:06:23,170
something called that a few centers

1530
01:06:28,260 --> 01:06:24,970
other bands there's probably ten people

1531
01:06:30,840 --> 01:06:28,270
in the world that study this I'm only

1532
01:06:34,590 --> 01:06:30,850
slightly exaggerating but it's a very

1533
01:06:37,200 --> 01:06:34,600
difficult mystery these are this is a

1534
01:06:39,270 --> 01:06:37,210
sort of a more modern-day absorption

1535
01:06:42,540 --> 01:06:39,280
profile look of it each of those dips

1536
01:06:45,120 --> 01:06:42,550
are absorption features that are called

1537
01:06:49,200 --> 01:06:45,130
the diffuse center solar bands they were

1538
01:06:52,230 --> 01:06:49,210

first discovered around 1919 by Mary Lea

1539
01:06:54,900 --> 01:06:52,240
Hager she was a graduate student at Lick

1540
01:06:58,560 --> 01:06:54,910
Observatory and there the longest

1541
01:07:00,090 --> 01:06:58,570
spectroscopic mystery in astronomy we

1542
01:07:02,790 --> 01:07:00,100
don't know what these are these are

1543
01:07:05,390 --> 01:07:02,800
absorption features from things that we

1544
01:07:09,390 --> 01:07:05,400
can identify in the interstellar medium

1545
01:07:12,750 --> 01:07:09,400
so we know it's coming from the space in

1546
01:07:14,160 --> 01:07:12,760
between stars because of the way the

1547
01:07:15,990 --> 01:07:14,170
features look they don't look like

1548
01:07:17,910 --> 01:07:16,000
they're coming from around stars they're

1549
01:07:19,830 --> 01:07:17,920
not don't have this sort of spectrum

1550
01:07:20,550 --> 01:07:19,840
that you would expect if they were near

1551
01:07:21,990 --> 01:07:20,560
a star

1552
01:07:24,780 --> 01:07:22,000
they look like they're coming they're

1553
01:07:29,640 --> 01:07:24,790
from the space between stars but we

1554
01:07:31,200 --> 01:07:29,650
don't know what they are okay so it's

1555
01:07:34,290 --> 01:07:31,210
been a it's been a mystery and there's

1556
01:07:37,350 --> 01:07:34,300
actually over 400 of these absorption

1557
01:07:39,000 --> 01:07:37,360
profiles now so we don't know when

1558
01:07:40,280 --> 01:07:39,010
married is Lea Hager discovered him I

1559
01:07:42,839 --> 01:07:40,290
believe she discovered two of them

1560
01:07:45,599 --> 01:07:42,849
initially and now we know of over four

1561
01:07:47,819 --> 01:07:45,609
and there throughout the visible part of

1562
01:07:49,890 --> 01:07:47,829
the spectrum and in close into the

1563
01:07:53,309 --> 01:07:49,900

near-infrared near infrareds here

1564
01:07:56,219 --> 01:07:53,319
visible spectrums here so that the kind

1565
01:07:58,679 --> 01:07:56,229
of light that our eyes can see right so

1566
01:08:00,289 --> 01:07:58,689
it's a big mystery but we have made a

1567
01:08:03,989 --> 01:08:00,299
little bit of headway in the last year

1568
01:08:09,679 --> 01:08:03,999
after all this time we discovered what a

1569
01:08:16,470 --> 01:08:13,640
they are these things called bucky balls

1570
01:08:18,689 --> 01:08:16,480
bucky balls are really interesting there

1571
01:08:23,189 --> 01:08:18,699
are these organic molecules these carbon

1572
01:08:25,950 --> 01:08:23,199
and hydrogen molecules these are these

1573
01:08:27,859 --> 01:08:25,960
are sort of carbon rings that fold over

1574
01:08:31,649 --> 01:08:27,869
to make these balls that you see here

1575
01:08:33,899 --> 01:08:31,659
and there are quite sturdy like this is

1576
01:08:37,410 --> 01:08:33,909
a video I can play actually see if it

1577
01:08:38,549 --> 01:08:37,420
plays yeah see if I can do it anyway

1578
01:08:42,510 --> 01:08:38,559
there's some text there because I

1579
01:08:43,709 --> 01:08:42,520
grabbed it from the JPL site but now

1580
01:08:45,870 --> 01:08:43,719
this isn't the first time that we've

1581
01:08:48,390 --> 01:08:45,880
discovered bucky balls bucky balls were

1582
01:08:49,829 --> 01:08:48,400
discovered in space in 2010 from the

1583
01:08:54,359 --> 01:08:49,839
Spitzer Space Telescope

1584
01:08:56,309 --> 01:08:54,369
they found it from a star that was there

1585
01:08:58,769 --> 01:08:56,319
that's been dying a planetary nebula and

1586
01:09:01,049 --> 01:08:58,779
that that was really interesting and

1587
01:09:02,280 --> 01:09:01,059
cool but the thing about planetary

1588
01:09:05,640 --> 01:09:02,290

nebula is is that there's a lot of

1589
01:09:08,069 --> 01:09:05,650
awesome dust there that shields these

1590
01:09:10,019 --> 01:09:08,079
molecules and prevents them from being

1591
01:09:12,120 --> 01:09:10,029
torn apart from the harsh radiation of

1592
01:09:15,209 --> 01:09:12,130
interstellar space from all these other

1593
01:09:17,549 --> 01:09:15,219
stars so we could explain that okay that

1594
01:09:20,399 --> 01:09:17,559
that makes sense they're they these

1595
01:09:23,160 --> 01:09:20,409
these dying stars produce this the suit

1596
01:09:26,160 --> 01:09:23,170
this these bucky balls this carbonaceous

1597
01:09:28,859 --> 01:09:26,170
material and they're protected in this

1598
01:09:30,809 --> 01:09:28,869
planetary nebula phase but what's

1599
01:09:34,829 --> 01:09:30,819
interesting about this discovery from

1600
01:09:36,180 --> 01:09:34,839
Hubble just this year is that some of

1601
01:09:38,879 --> 01:09:36,190
these bucky balls are actually an

1602
01:09:41,789 --> 01:09:38,889
interstellar space where we expected the

1603
01:09:44,430 --> 01:09:41,799
harsh radiation and interstellar space

1604
01:09:47,879 --> 01:09:44,440
to tear them apart but they seem to be

1605
01:09:50,399 --> 01:09:47,889
hearty enough to survive and in fact if

1606
01:09:53,129 --> 01:09:50,409
they're that hearty and in fact a common

1607
01:09:56,040 --> 01:09:53,139
belief or a common hypothesis I should

1608
01:09:57,870 --> 01:09:56,050
say for what a lot of

1609
01:10:00,240 --> 01:09:57,880
a few sonís other bands are are sort of

1610
01:10:02,879 --> 01:10:00,250
these carbonaceous grains there are

1611
01:10:06,450 --> 01:10:02,889
molecules not grains these carbonaceous

1612
01:10:08,069 --> 01:10:06,460
molecules if that's true it tells us

1613
01:10:09,899 --> 01:10:08,079

something about the habitability of our

1614
01:10:11,609 --> 01:10:09,909
universe because they are quite common

1615
01:10:14,459 --> 01:10:11,619
they're quite ubiquitous ubiquitous and

1616
01:10:17,100 --> 01:10:14,469
carbon and organic molecules that carry

1617
01:10:20,790 --> 01:10:17,110
carbon are what we think are the

1618
01:10:22,649 --> 01:10:20,800
precursors to what we need for for the

1619
01:10:25,919 --> 01:10:22,659
prebiotic molecules that would later

1620
01:10:27,720 --> 01:10:25,929
than form life so the idea that the that

1621
01:10:30,560 --> 01:10:27,730
the interstellar medium there a galaxy

1622
01:10:33,149 --> 01:10:30,570
could be filled with these carbonaceous

1623
01:10:36,780 --> 01:10:33,159
molecules potentially even raining down

1624
01:10:39,149 --> 01:10:36,790
on the early Earth might be a source for

1625
01:10:42,990 --> 01:10:39,159
how we got the ingredients in the early

1626
01:10:46,649 --> 01:10:43,000
and the early days of the earth from

1627
01:10:49,319 --> 01:10:46,659
when from when who knows magic happens

1628
01:10:53,490 --> 01:10:49,329
nobody knows exactly how life left got

1629
01:10:55,890 --> 01:10:53,500
it started but chemically but you have

1630
01:10:58,649 --> 01:10:55,900
you know you have some material there

1631
01:11:03,060 --> 01:10:58,659
and life happens somehow so this is a

1632
01:11:04,470 --> 01:11:03,070
big part of that mystery and then I just

1633
01:11:07,649 --> 01:11:04,480
want to I want to I want to close by

1634
01:11:13,260 --> 01:11:07,659
saying something about the future so

1635
01:11:14,669 --> 01:11:13,270
spectroscopy is well spectroscopy is

1636
01:11:17,010 --> 01:11:14,679
going to be a big part of our future and

1637
01:11:18,330 --> 01:11:17,020
the James Webb Space Telescope which I'm

1638
01:11:20,010 --> 01:11:18,340

sure you all aware launches in a couple

1639
01:11:22,919 --> 01:11:20,020
of years is going to be a spectroscopy

1640
01:11:26,250 --> 01:11:22,929
machine it is going to do so much with

1641
01:11:29,100 --> 01:11:26,260
spectroscopy that it's actually going to

1642
01:11:32,339 --> 01:11:29,110
be hard maybe to even handle all that

1643
01:11:34,200 --> 01:11:32,349
amount of data so one of it has several

1644
01:11:35,430 --> 01:11:34,210
spectrographs on it but I want to

1645
01:11:37,740 --> 01:11:35,440
highlight one of the most interesting

1646
01:11:40,649 --> 01:11:37,750
ones this is co this is an instrument

1647
01:11:43,339 --> 01:11:40,659
called near spec and it's a it's a new

1648
01:11:46,260 --> 01:11:43,349
technology for collecting spectra

1649
01:11:48,419 --> 01:11:46,270
basically what happens with near spec is

1650
01:11:51,720 --> 01:11:48,429
you it's you have these little shutters

1651
01:11:53,790 --> 01:11:51,730
okay on the camera and by the process of

1652
01:11:55,620 --> 01:11:53,800
using a magnet and electric charge they

1653
01:11:57,780 --> 01:11:55,630
can open and close these individual

1654
01:11:59,430 --> 01:11:57,790
shutters which are very tiny you know

1655
01:12:01,140 --> 01:11:59,440
we're talking about smaller than your

1656
01:12:05,569 --> 01:12:01,150
hair like these little shutters which

1657
01:12:09,899 --> 01:12:05,579
are very tiny and they can open up and

1658
01:12:11,520 --> 01:12:09,909
you can choose which objects on whatever

1659
01:12:13,259 --> 01:12:11,530
you want to take a spectrum of so

1660
01:12:16,649 --> 01:12:13,269
whatever is open you'll get a spectrum

1661
01:12:19,439 --> 01:12:16,659
of that okay so instead of the current

1662
01:12:21,449 --> 01:12:19,449
model where we have to carefully pick

1663
01:12:24,089 --> 01:12:21,459

one object in the field which is the

1664
01:12:25,439 --> 01:12:24,099
most common case one omelet object in

1665
01:12:27,899 --> 01:12:25,449
the field and we get a spectrum of it

1666
01:12:31,020 --> 01:12:27,909
it's very time you know it's very

1667
01:12:33,839 --> 01:12:31,030
laborious it's very time intensive we

1668
01:12:35,969 --> 01:12:33,849
can just open the shutters and just get

1669
01:12:37,620 --> 01:12:35,979
a flood of spectra high resolution

1670
01:12:40,560 --> 01:12:37,630
medium resolution really high-quality

1671
01:12:42,149 --> 01:12:40,570
spectra from the universe and so this is

1672
01:12:45,120 --> 01:12:42,159
really going to change the game for our

1673
01:12:49,589 --> 01:12:45,130
understanding of galaxy evolution and

1674
01:12:52,169 --> 01:12:49,599
all sorts of things all right

1675
01:12:54,299 --> 01:12:52,179
and then I'm gonna fly through these

1676
01:12:56,159 --> 01:12:54,309
last bits quickly but I feel like when

1677
01:12:59,279 --> 01:12:56,169
you talk about tools in astronomy you

1678
01:13:03,540 --> 01:12:59,289
can't you cannot not talk about these

1679
01:13:05,969 --> 01:13:03,550
these these last few slides these are

1680
01:13:08,189 --> 01:13:05,979
also the area where in many cases I am

1681
01:13:12,000 --> 01:13:08,199
the least of an expert there's not a lot

1682
01:13:14,549 --> 01:13:12,010
of dust here but but I do want to I do

1683
01:13:16,919 --> 01:13:14,559
want to give it its due this is an

1684
01:13:19,979 --> 01:13:16,929
amazing era of astronomy that we live in

1685
01:13:22,830 --> 01:13:19,989
this multi messenger astronomy and what

1686
01:13:25,080 --> 01:13:22,840
do I mean by multi messenger it's an

1687
01:13:28,469 --> 01:13:25,090
interesting name that the astronomers

1688
01:13:30,629 --> 01:13:28,479

have given this field the idea that the

1689
01:13:32,729 --> 01:13:30,639
universe is sending us messages in a

1690
01:13:35,040 --> 01:13:32,739
bottle if you will but multi messenger

1691
01:13:39,929 --> 01:13:35,050
is essentially everything that I talked

1692
01:13:42,839 --> 01:13:39,939
about was using light okay you know as

1693
01:13:44,850 --> 01:13:42,849
astronomers unless we are lucky enough

1694
01:13:46,859 --> 01:13:44,860
to be a planetary astronomer we can't go

1695
01:13:49,229 --> 01:13:46,869
to the places that we study and take

1696
01:13:51,719 --> 01:13:49,239
samples of these objects right if

1697
01:13:53,339 --> 01:13:51,729
they're too far away all we have to

1698
01:13:55,770 --> 01:13:53,349
study are what the universe sends to us

1699
01:13:58,770 --> 01:13:55,780
right the messages that it sends to us

1700
01:14:00,959 --> 01:13:58,780
right and so for the longest time right

1701
01:14:02,939 --> 01:14:00,969
we've used light you know started with

1702
01:14:05,219 --> 01:14:02,949
visible light then we moved across all

1703
01:14:07,199 --> 01:14:05,229
the types types of light but there are

1704
01:14:09,810 --> 01:14:07,209
other ways that the universe can give us

1705
01:14:11,699 --> 01:14:09,820
information okay so let's go through

1706
01:14:13,140 --> 01:14:11,709
those so of course we already talked

1707
01:14:15,120 --> 01:14:13,150
about light and so I won't

1708
01:14:17,250 --> 01:14:15,130
I won't spend any time on this but light

1709
01:14:19,679 --> 01:14:17,260
is the way that we've been studying the

1710
01:14:23,040 --> 01:14:19,689
universe the most but there's also

1711
01:14:23,820 --> 01:14:23,050
particles there's also matter mass okay

1712
01:14:25,920 --> 01:14:23,830
charged part

1713
01:14:28,850 --> 01:14:25,930

chuckles small things called neutrinos

1714
01:14:31,320 --> 01:14:28,860
these are things that come from

1715
01:14:35,700 --> 01:14:31,330
high-energy events in the universe that

1716
01:14:36,960 --> 01:14:35,710
send us that get sent throughout the

1717
01:14:41,280 --> 01:14:36,970
universe and if we're lucky we can

1718
01:14:44,660 --> 01:14:41,290
capture them this image here is of a

1719
01:14:49,830 --> 01:14:44,670
tank underground called super your

1720
01:14:51,660 --> 01:14:49,840
super-kamiokande it's in Japan and it's

1721
01:14:54,180 --> 01:14:51,670
filled it gets filled with 50,000 tons

1722
01:14:56,370 --> 01:14:54,190
of purified water and it has over 10,000

1723
01:14:58,320 --> 01:14:56,380
light sensors and basically this entire

1724
01:15:00,900 --> 01:14:58,330
purpose of this mission of this tank

1725
01:15:04,800 --> 01:15:00,910
this Observatory this telescope for lack

1726
01:15:06,300 --> 01:15:04,810
of a better word is to detect the some

1727
01:15:08,730 --> 01:15:06,310
of the smallest particles we could ever

1728
01:15:10,530 --> 01:15:08,740
think of called neutrinos and there are

1729
01:15:12,060 --> 01:15:10,540
thousands of neutrinos coming through

1730
01:15:13,440 --> 01:15:12,070
our body every second they don't they're

1731
01:15:15,990 --> 01:15:13,450
so small they don't interact with matter

1732
01:15:18,030 --> 01:15:16,000
at all okay and they come from things

1733
01:15:21,750 --> 01:15:18,040
like the Sun and high-energy events and

1734
01:15:23,070 --> 01:15:21,760
so on but if we can actually start

1735
01:15:24,510 --> 01:15:23,080
detecting these which we have we've

1736
01:15:26,610 --> 01:15:24,520
started to be able to take these

1737
01:15:27,930 --> 01:15:26,620
neutrinos it'll give us insights into

1738
01:15:29,670 --> 01:15:27,940

things like what's happening in the

1739
01:15:33,750 --> 01:15:29,680
center of the Sun that we can't see with

1740
01:15:36,090 --> 01:15:33,760
light okay so so that's a very powerful

1741
01:15:38,880 --> 01:15:36,100
tool and then there's also gravitational

1742
01:15:40,350 --> 01:15:38,890
wave astronomy if you if you've been

1743
01:15:41,310 --> 01:15:40,360
alive the last couple years you probably

1744
01:15:44,270 --> 01:15:41,320
have heard of gravitational wave

1745
01:15:48,150 --> 01:15:44,280
astronomy this was a big deal these

1746
01:15:51,300 --> 01:15:48,160
these gravitational wave detectors you

1747
01:15:54,720 --> 01:15:51,310
see the to hear from LIGO one in

1748
01:15:57,590 --> 01:15:54,730
Washington State and the other one in

1749
01:16:00,720 --> 01:15:57,600
Louisiana I think Louisiana and

1750
01:16:02,310 --> 01:16:00,730
essentially the idea is is that if you

1751
01:16:04,710 --> 01:16:02,320
have these really massive objects like

1752
01:16:06,840 --> 01:16:04,720
black holes or neutron stars collide

1753
01:16:09,060 --> 01:16:06,850
they'll send ripples through space-time

1754
01:16:11,190 --> 01:16:09,070
and those ripples will come and they'll

1755
01:16:14,040 --> 01:16:11,200
interact with the earth that's a highly

1756
01:16:16,470 --> 01:16:14,050
exaggerated way of interacting by the

1757
01:16:18,620 --> 01:16:16,480
way it's not quite that bad but they'll

1758
01:16:22,640 --> 01:16:18,630
interact with the earth and as he as

1759
01:16:25,260 --> 01:16:22,650
space-time itself increases and expands

1760
01:16:28,260 --> 01:16:25,270
okay it'll pull these different lever

1761
01:16:30,060 --> 01:16:28,270
arms and there's lasers going through

1762
01:16:33,390 --> 01:16:30,070
these that estimate the distance and

1763
01:16:35,670 --> 01:16:33,400

they'll be able to tell the wiggling of

1764
01:16:36,839 --> 01:16:35,680
the earth as a gravitational wave goes

1765
01:16:38,790 --> 01:16:36,849
through and the

1766
01:16:40,200 --> 01:16:38,800
that you have two of them gives you some

1767
01:16:42,209 --> 01:16:40,210
hope that you actually might be able to

1768
01:16:44,100 --> 01:16:42,219
pinpoint roughly the source on the sky

1769
01:16:46,709 --> 01:16:44,110
where they came from okay

1770
01:16:48,240 --> 01:16:46,719
because one one might hit this detector

1771
01:16:49,169 --> 01:16:48,250
first before it hits the other detector

1772
01:16:52,859 --> 01:16:49,179
and so on you might be able to

1773
01:16:54,569 --> 01:16:52,869
triangulate a little bit and so actually

1774
01:16:59,459 --> 01:16:54,579
we've been able to do that and Seoul I

1775
01:17:02,810 --> 01:16:59,469
go now has discovered with the

1776
01:17:06,300 --> 01:17:02,820
gravitational wave detectors these

1777
01:17:08,729 --> 01:17:06,310
merging black holes and what's really

1778
01:17:10,290 --> 01:17:08,739
interesting is so the the blue here our

1779
01:17:13,979 --> 01:17:10,300
although the gravitational wave

1780
01:17:16,830 --> 01:17:13,989
detection x' though the purple here were

1781
01:17:18,569 --> 01:17:16,840
detected by some signature of light

1782
01:17:21,390 --> 01:17:18,579
coming from the from them from the

1783
01:17:23,430 --> 01:17:21,400
merger but we're but with the

1784
01:17:24,930 --> 01:17:23,440
gravitational wave we're probing larger

1785
01:17:27,359 --> 01:17:24,940
black holes and we were able to probe

1786
01:17:29,520 --> 01:17:27,369
before and learning more about them and

1787
01:17:31,740 --> 01:17:29,530
you can also do the same for neutron

1788
01:17:34,620 --> 01:17:31,750

stars so this is a neutron star

1789
01:17:38,040 --> 01:17:34,630
detection so neutron stars are the dense

1790
01:17:45,060 --> 01:17:38,050
cores of old stars and Frank's getting

1791
01:17:48,600 --> 01:17:45,070
up which tells me all right well this is

1792
01:17:50,729 --> 01:17:48,610
my last slide nice time all right I also

1793
01:17:52,560 --> 01:17:50,739
I also I also have to say something

1794
01:17:56,069 --> 01:17:52,570
about tools there's a whole field in

1795
01:17:57,800 --> 01:17:56,079
theory and modeling every every subject

1796
01:18:00,419 --> 01:17:57,810
of astronomy and astrophysics has

1797
01:18:03,060 --> 01:18:00,429
theorists and has modelers that work on

1798
01:18:05,129 --> 01:18:03,070
on understanding the basic physical

1799
01:18:07,589 --> 01:18:05,139
concepts and I just want to play this

1800
01:18:10,560 --> 01:18:07,599
because it's beautiful this is an

1801
01:18:12,810 --> 01:18:10,570
illustrious simulation this is

1802
01:18:14,939 --> 01:18:12,820
essentially putting in the physics of

1803
01:18:16,410 --> 01:18:14,949
our known universe into this really

1804
01:18:18,780 --> 01:18:16,420
powerful computer simulation and

1805
01:18:20,490 --> 01:18:18,790
watching it play with time this purple

1806
01:18:24,750 --> 01:18:20,500
here this is basically looking at the

1807
01:18:27,390 --> 01:18:24,760
are ten mega parsec view of our universe

1808
01:18:29,280 --> 01:18:27,400
and you're seeing dark matter here and

1809
01:18:31,680 --> 01:18:29,290
you're seeing all the gravity that's

1810
01:18:33,510 --> 01:18:31,690
condensing these proto galaxies together

1811
01:18:35,310 --> 01:18:33,520
and when they start to merge you know

1812
01:18:36,870 --> 01:18:35,320
you see these filaments and when these

1813
01:18:38,459 --> 01:18:36,880

galaxies start to merge you start

1814
01:18:40,439 --> 01:18:38,469
there's star formation happening and

1815
01:18:42,089 --> 01:18:40,449
then you're going to start seeing stars

1816
01:18:45,629 --> 01:18:42,099
blowing up in supernovae and giving

1817
01:18:46,890 --> 01:18:45,639
their gas back out into the material

1818
01:18:48,959 --> 01:18:46,900
between galaxies the intergalactic

1819
01:18:50,630 --> 01:18:48,969
medium so you can start seeing some

1820
01:18:54,830 --> 01:18:50,640
stars going on

1821
01:18:57,320 --> 01:18:54,840
this by doing something like this we put

1822
01:18:59,150 --> 01:18:57,330
our understanding of the physics into

1823
01:19:00,770 --> 01:18:59,160
these computer models and then we

1824
01:19:02,570 --> 01:19:00,780
compare what we see in here with our

1825
01:19:05,120 --> 01:19:02,580
observations and if they don't match up

1826
01:19:06,970 --> 01:19:05,130
it tells us that either we're doing bad

1827
01:19:09,410 --> 01:19:06,980
observations which I never believed or

1828
01:19:11,450 --> 01:19:09,420
that there's some fundamental

1829
01:19:14,120 --> 01:19:11,460
misunderstanding of the physics that we

1830
01:19:15,770 --> 01:19:14,130
need to resolve okay so that's a huge

1831
01:19:19,250 --> 01:19:15,780
area so with that I'm just going to

1832
01:19:21,020 --> 01:19:19,260
leave up the the universal learning law

1833
01:19:22,370 --> 01:19:21,030
URL where you can get all of our

1834
01:19:31,190 --> 01:19:22,380
activities and I'll leave it open for

1835
01:19:34,490 --> 01:19:31,200
questions all right all right we just

1836
01:19:36,110 --> 01:19:34,500
have four questions what so I have one

1837
01:19:40,760 --> 01:19:36,120
that I saw in the chat online which is

1838
01:19:43,720 --> 01:19:40,770

what is an absorption feature yeah

1839
01:19:47,270 --> 01:19:43,730
so an absorption feature is basically

1840
01:19:52,340 --> 01:19:47,280
you have all these photons going around

1841
01:19:54,650 --> 01:19:52,350
and as as if a photon of that particular

1842
01:19:57,080 --> 01:19:54,660
if of a light of that particular color

1843
01:19:59,060 --> 01:19:57,090
say that that yellow color I showed you

1844
01:20:01,610 --> 01:19:59,070
from helium if a photon that has that

1845
01:20:05,180 --> 01:20:01,620
particular color interacts with cooler

1846
01:20:08,420 --> 01:20:05,190
gas made of helium it's going to get

1847
01:20:10,190 --> 01:20:08,430
absorbed okay so then you're gonna see

1848
01:20:11,750 --> 01:20:10,200
an absorption feature is essentially a

1849
01:20:14,060 --> 01:20:11,760
dip in the amount of light that you see

1850
01:20:15,920 --> 01:20:14,070
so you have the Starlight than the

1851
01:20:18,380 --> 01:20:15,930
example I showed and it's bright and

1852
01:20:20,830 --> 01:20:18,390
then there'll be a dip because that

1853
01:20:23,570 --> 01:20:20,840
photon that was trying to reach us that

1854
01:20:25,370 --> 01:20:23,580
basically got stopped okay it couldn't

1855
01:20:29,200 --> 01:20:25,380
reach us so you're telling what's there

1856
01:20:33,590 --> 01:20:29,210
by telling what's not there yeah yeah

1857
01:20:38,720 --> 01:20:33,600
yeah questions oh all the way in the

1858
01:20:40,250 --> 01:20:38,730
back hold up for the microphone so the

1859
01:20:45,560 --> 01:20:40,260
online audience can hear there you go

1860
01:20:47,090 --> 01:20:45,570
hello I've heard a lot of talk today

1861
01:20:50,840 --> 01:20:47,100
about the different telescopes that

1862
01:20:54,830 --> 01:20:50,850
we've been putting out in space and they

1863
01:20:56,210 --> 01:20:54,840

all kind of observe sort of passively as

1864
01:20:57,830 --> 01:20:56,220
it were although all the electromagnetic

1865
01:21:02,750 --> 01:20:57,840
radiation from the universe I'm

1866
01:21:04,100 --> 01:21:02,760
wondering are there any other devices

1867
01:21:05,359 --> 01:21:04,110
out there like I remember

1868
01:21:06,950 --> 01:21:05,369
the Magellan mission used synthetic

1869
01:21:08,540 --> 01:21:06,960
aperture radar is there any other

1870
01:21:12,470 --> 01:21:08,550
synthetic aperture radar that uses

1871
01:21:13,390 --> 01:21:12,480
active detections right now or in the

1872
01:21:16,129 --> 01:21:13,400
future

1873
01:21:17,990 --> 01:21:16,139
now when you mean active detection so

1874
01:21:19,760 --> 01:21:18,000
maybe transmitting something turn

1875
01:21:22,250 --> 01:21:19,770
something back I see

1876
01:21:26,390 --> 01:21:22,260
well the distances in the universe are

1877
01:21:28,790 --> 01:21:26,400
so vast certainly that you know I know

1878
01:21:32,540 --> 01:21:28,800
the SETI project sent a message with

1879
01:21:33,830 --> 01:21:32,550
radio but in terms of anything back from

1880
01:21:37,609 --> 01:21:33,840
that one yeah we haven't heard anything

1881
01:21:40,729 --> 01:21:37,619
back we have used laser off the moon

1882
01:21:42,620 --> 01:21:40,739
yeah and radar off Venus right okay any

1883
01:21:45,609 --> 01:21:42,630
others like that and the other planets

1884
01:21:51,260 --> 01:21:47,689
I'm not sure if there's been any other

1885
01:21:52,340 --> 01:21:51,270
any other from the planets yeah I mean

1886
01:21:55,189 --> 01:21:52,350
that's that's the only hope you have

1887
01:21:59,300 --> 01:21:55,199
though is see I generally forget that we

1888
01:22:01,310 --> 01:21:59,310

have the solar system so that you're

1889
01:22:02,990 --> 01:22:01,320
reminded there is some dust in the solar

1890
01:22:06,260 --> 01:22:03,000
so there is some there is some just

1891
01:22:07,669 --> 01:22:06,270
don't love it but though that's a good

1892
01:22:10,129 --> 01:22:07,679
point so that is another way of getting

1893
01:22:16,820 --> 01:22:10,139
information from objects in the solar

1894
01:22:18,500 --> 01:22:16,830
system yeah thank you yeah oh wait okay

1895
01:22:21,950 --> 01:22:18,510
we have an online audience that needs to

1896
01:22:23,570 --> 01:22:21,960
hear your wonderful question yeah it

1897
01:22:27,080 --> 01:22:23,580
won't make it to the microphones yes you

1898
01:22:31,340 --> 01:22:27,090
can chop the end are together we don't

1899
01:22:35,209 --> 01:22:31,350
what he was joking what you called us

1900
01:22:39,649 --> 01:22:35,219
must be incredibly variable throughout

1901
01:22:42,379 --> 01:22:39,659
the universe but what's it like what's

1902
01:22:45,500 --> 01:22:42,389
dust like it obviously becomes dense

1903
01:22:48,620 --> 01:22:45,510
enough to become a star but but it just

1904
01:22:52,459 --> 01:22:48,630
dust yeah you know we think of dust is

1905
01:22:55,250 --> 01:22:52,469
what we think of as dust yeah yes just

1906
01:22:58,310 --> 01:22:55,260
money-spinner yet if you're in it I mean

1907
01:23:00,800 --> 01:22:58,320
am I like in it or is it so far apart

1908
01:23:04,520 --> 01:23:00,810
each particle that I don't even know

1909
01:23:07,220 --> 01:23:04,530
that white far apart but the studying of

1910
01:23:10,310 --> 01:23:07,230
the composition of dust itself and the

1911
01:23:12,229 --> 01:23:10,320
sizes of dust is its own field so dust

1912
01:23:14,140 --> 01:23:12,239
comes in a range of sizes and the actual

1913
01:23:16,669 --> 01:23:14,150

breakdown of where you go from being

1914
01:23:17,930 --> 01:23:16,679
molecules to being a dust to grain is

1915
01:23:20,240 --> 01:23:17,940
not exact

1916
01:23:22,040 --> 01:23:20,250
we defined its physical properties that

1917
01:23:24,530 --> 01:23:22,050
to find that but you know you start out

1918
01:23:26,030 --> 01:23:24,540
with molecules and if you get if you get

1919
01:23:27,530 --> 01:23:26,040
large enough for the molecules stick to

1920
01:23:29,330 --> 01:23:27,540
dust grains you can start to grow them

1921
01:23:31,160 --> 01:23:29,340
dust grains can stick together you can

1922
01:23:32,930 --> 01:23:31,170
start to grow things of course things

1923
01:23:35,890 --> 01:23:32,940
can tear apart dust grains it's this

1924
01:23:37,430 --> 01:23:35,900
active process and there's

1925
01:23:38,360 --> 01:23:37,440
compositionally there's lots of

1926
01:23:40,340 --> 01:23:38,370
different kinds of dust there's

1927
01:23:43,010 --> 01:23:40,350
carbonaceous dust there's silicate dust

1928
01:23:46,460 --> 01:23:43,020
there's Isis out there so sometimes dust

1929
01:23:48,140 --> 01:23:46,470
is covered in ice and chemically that

1930
01:23:50,770 --> 01:23:48,150
produces a lot of different

1931
01:23:53,210 --> 01:23:50,780
possibilities for what you can actually

1932
01:23:55,100 --> 01:23:53,220
create the types of molecules and things

1933
01:23:56,240 --> 01:23:55,110
you can actually create so a lot of

1934
01:23:59,000 --> 01:23:56,250
things are actually created on the

1935
01:24:00,620 --> 01:23:59,010
surface of dust grains themselves so

1936
01:24:02,540 --> 01:24:00,630
like what's the average density of an

1937
01:24:04,220 --> 01:24:02,550
interstellar dust cloud because you know

1938
01:24:06,080 --> 01:24:04,230

the air we're breathing now is billions

1939
01:24:07,760 --> 01:24:06,090
and trillions of particles per cubic

1940
01:24:09,290 --> 01:24:07,770
centimeter well certainly much less than

1941
01:24:12,410 --> 01:24:09,300
that I don't know it yeah it's like 10

1942
01:24:14,030 --> 01:24:12,420
to the fifth yeah I don't I don't

1943
01:24:17,480 --> 01:24:14,040
actually recall the the actual density

1944
01:24:19,550 --> 01:24:17,490
of it but it's yeah so I mean even the

1945
01:24:21,230 --> 01:24:19,560
dust clouds that she's talking about are

1946
01:24:24,110 --> 01:24:21,240
way lower density than the air you're

1947
01:24:26,150 --> 01:24:24,120
breathing right now okay yeah well and

1948
01:24:27,920 --> 01:24:26,160
there's a there's there's a the thing is

1949
01:24:30,410 --> 01:24:27,930
there's also a range of densities of

1950
01:24:32,510 --> 01:24:30,420
dust clouds too right so so I mean we

1951
01:24:33,650 --> 01:24:32,520
have we have things like some of the

1952
01:24:37,130 --> 01:24:33,660
nebula that you look here but then

1953
01:24:39,890 --> 01:24:37,140
there's also dust clouds that are much

1954
01:24:41,570 --> 01:24:39,900
denser that in fact we typically

1955
01:24:43,160 --> 01:24:41,580
wouldn't use Hubble to go observe we

1956
01:24:44,930 --> 01:24:43,170
would only see them in shadow anyway if

1957
01:24:46,370 --> 01:24:44,940
we do observe them they're there they

1958
01:24:48,290 --> 01:24:46,380
have interesting names like Bok globules

1959
01:24:49,670 --> 01:24:48,300
and things but they're they're the

1960
01:24:51,470 --> 01:24:49,680
places where we think the stars are

1961
01:24:53,990 --> 01:24:51,480
actually forming in and those are where

1962
01:24:56,660 --> 01:24:54,000
you have the densest places the densest

1963
01:24:58,730 --> 01:24:56,670

amount of dust is in those regions okay

1964
01:25:01,070 --> 01:24:58,740
you have an online question do neutrinos

1965
01:25:03,410 --> 01:25:01,080
pass through the entire Earth without

1966
01:25:06,950 --> 01:25:03,420
hitting anything because solid matter is

1967
01:25:14,890 --> 01:25:06,960
mostly empty space or because neutrinos

1968
01:25:18,080 --> 01:25:14,900
don't interact good that is a good price

1969
01:25:20,570 --> 01:25:18,090
question yeah remember when I put up

1970
01:25:28,550 --> 01:25:20,580
multi messenger and I said that I not an

1971
01:25:30,919 --> 01:25:28,560
expert I'm not a yeah I think it might

1972
01:25:33,410 --> 01:25:30,929
be both right I mean it's sort of both

1973
01:25:35,209 --> 01:25:33,420
but I mean I if you just think about you

1974
01:25:37,189 --> 01:25:35,219
know the normal interaction of a photon

1975
01:25:39,979 --> 01:25:37,199
with things versus and ya know things

1976
01:25:42,470 --> 01:25:39,989
they're you know really low mass objects

1977
01:25:43,970 --> 01:25:42,480
anyways both of them right right and so

1978
01:25:46,459 --> 01:25:43,980
I would say it's just because neutrinos

1979
01:25:48,080 --> 01:25:46,469
just don't interact more would be more

1980
01:25:50,180 --> 01:25:48,090
cuz you're comparing it against

1981
01:25:51,350 --> 01:25:50,190
something else that yeah also yeah

1982
01:25:54,290 --> 01:25:51,360
that's a great question

1983
01:25:56,840 --> 01:25:54,300
that's no I'm gonna do my homework yeah

1984
01:25:58,340 --> 01:25:56,850
and you know they aren't electrically

1985
01:25:59,959 --> 01:25:58,350
charged so there's very very little

1986
01:26:00,649 --> 01:25:59,969
chance for them to interaction to active

1987
01:26:05,240 --> 01:26:00,659
as well

1988
01:26:06,979 --> 01:26:05,250

all right over here hey this is the best

1989
01:26:11,629 --> 01:26:06,989
astronomy lecture I've been to this

1990
01:26:13,220 --> 01:26:11,639
month this month all right well I got it

1991
01:26:16,729 --> 01:26:13,230
sorry it's only the third of the month

1992
01:26:21,709 --> 01:26:16,739
so my god bucks and I just read this

1993
01:26:24,410 --> 01:26:21,719
recently the dust is is so scattered at

1994
01:26:27,620 --> 01:26:24,420
least in the solar system that a

1995
01:26:30,649 --> 01:26:27,630
spacecraft an average spacecraft would

1996
01:26:34,189 --> 01:26:30,659
encounter a dust particle every three

1997
01:26:35,510 --> 01:26:34,199
days does that sound about right yeah I

1998
01:26:37,910 --> 01:26:35,520
could yeah I could believe that

1999
01:26:40,520 --> 01:26:37,920
sure I mean that yeah it's it's it's

2000
01:26:42,709 --> 01:26:40,530
it's not dense at all I mean you're not

2001
01:26:44,570 --> 01:26:42,719
yeah this this is the exact sort of

2002
01:26:46,490 --> 01:26:44,580
thing that that they have to think about

2003
01:26:48,770 --> 01:26:46,500
when they create when they when they're

2004
01:26:50,030 --> 01:26:48,780
building the spacecraft you know like

2005
01:26:52,250 --> 01:26:50,040
for example James Webb they're gonna

2006
01:26:54,290 --> 01:26:52,260
they're gonna park it at the lagrangean

2007
01:26:56,090 --> 01:26:54,300
million miles away they have to have you

2008
01:26:57,530 --> 01:26:56,100
know they have some estimates of the

2009
01:27:00,379 --> 01:26:57,540
wear and tear on the spacecraft over

2010
01:27:02,810 --> 01:27:00,389
time as it interacts with dust grains or

2011
01:27:06,410 --> 01:27:02,820
other you know small particles that are

2012
01:27:08,540 --> 01:27:06,420
going through so yeah they it's

2013
01:27:10,340 --> 01:27:08,550

certainly not a bad enough issue that

2014
01:27:12,290 --> 01:27:10,350
they're worried about it you know ending

2015
01:27:15,560 --> 01:27:12,300
a mission in a very short timeframe so

2016
01:27:17,840 --> 01:27:15,570
it's it's not very dense yeah but also

2017
01:27:19,970 --> 01:27:17,850
space is very big so if you actually

2018
01:27:22,970 --> 01:27:19,980
were to add up all that material over

2019
01:27:26,030 --> 01:27:22,980
all of that space it amounts for quite a

2020
01:27:28,040 --> 01:27:26,040
bit in terms of in you know bulk it

2021
01:27:30,050 --> 01:27:28,050
actually adds up to a lot if you

2022
01:27:31,490 --> 01:27:30,060
you know it's scattered throughout the

2023
01:27:33,230 --> 01:27:31,500
throughout the interstellar medium and

2024
01:27:51,700 --> 01:27:33,240
throughout the solar system so okay

2025
01:27:58,040 --> 01:27:55,040
back to the neutrino question who knows

2026
01:28:00,560 --> 01:27:58,050
don't interact or you'll bump it up

2027
01:28:05,510 --> 01:28:00,570
anything how then do we detect them for

2028
01:28:08,320 --> 01:28:05,520
example yo cameo or Ice Cube how do we

2029
01:28:12,500 --> 01:28:08,330
detect them that's a great question so

2030
01:28:15,890 --> 01:28:12,510
they don't interact much but if one in

2031
01:28:17,690 --> 01:28:15,900
you know a hundred billion or whatever I

2032
01:28:19,460 --> 01:28:17,700
don't know what the exact ratio is and

2033
01:28:21,230 --> 01:28:19,470
does interact there is a very small

2034
01:28:24,770 --> 01:28:21,240
chance that it will inter it will

2035
01:28:27,410 --> 01:28:24,780
actually impact a water molecule and

2036
01:28:31,160 --> 01:28:27,420
when that does it's a very rare event

2037
01:28:33,800 --> 01:28:31,170
they they have those detectors there to

2038
01:28:37,160 --> 01:28:33,810

see the flash so it's a it's incredibly

2039
01:28:39,050 --> 01:28:37,170
rare but it it does happen enough that

2040
01:28:42,920 --> 01:28:39,060
they've been able to text some so the

2041
01:28:44,840 --> 01:28:42,930
simulation very very inefficient so the

2042
01:28:46,790 --> 01:28:44,850
statistic I remember from graduate

2043
01:28:48,650 --> 01:28:46,800
school way back when was that the

2044
01:28:50,600 --> 01:28:48,660
original neutrino detector was a

2045
01:28:52,970 --> 01:28:50,610
swimming pool of carbon tetrachloride

2046
01:28:55,280 --> 01:28:52,980
cleaning fluid okay so take a swimming

2047
01:28:57,350 --> 01:28:55,290
pool of cleaning fluid okay shielded

2048
01:28:58,850 --> 01:28:57,360
from all other radiation and the

2049
01:29:01,280 --> 01:28:58,860
neutrinos that are passing through it

2050
01:29:03,890 --> 01:29:01,290
you get about one per interaction per

2051
01:29:05,360 --> 01:29:03,900
day with a swimming pool of clean flu

2052
01:29:06,380 --> 01:29:05,370
because the the entry nose would

2053
01:29:09,200 --> 01:29:06,390
interact with the clock with the

2054
01:29:11,050 --> 01:29:09,210
chlorine create the rate is shrink of

2055
01:29:12,650 --> 01:29:11,060
radiation and then the the

2056
01:29:14,900 --> 01:29:12,660
photomultipliers wouldn't be able to

2057
01:29:17,360 --> 01:29:14,910
detect it that was the original one this

2058
01:29:21,260 --> 01:29:17,370
is the super camera Conda is much much

2059
01:29:23,300 --> 01:29:21,270
much much more advanced all right I

2060
01:29:25,550 --> 01:29:23,310
think we have one more question who

2061
01:29:29,840 --> 01:29:25,560
would like the last question there all

2062
01:29:32,450 --> 01:29:29,850
right there we go that so there's been a

2063
01:29:34,880 --> 01:29:32,460

in the news recently about the mega

2064
01:29:37,400 --> 01:29:34,890
constellations of satellites and whatnot

2065
01:29:39,650 --> 01:29:37,410
how's that going to affect things is

2066
01:29:46,520 --> 01:29:39,660
their fight green can you subtract that

2067
01:29:48,380 --> 01:29:46,530
out it's a very good question I don't

2068
01:29:52,940 --> 01:29:48,390
want to get on anyone's bad side if they

2069
01:29:54,830 --> 01:29:52,950
watch this on it yeah it is actually a

2070
01:29:58,550 --> 01:29:54,840
problem I mean these satellites these

2071
01:30:00,560 --> 01:29:58,560
satellites are a problem it I know you

2072
01:30:02,600 --> 01:30:00,570
know we do want

2073
01:30:06,920 --> 01:30:02,610
of course 5g and we want all the

2074
01:30:11,000 --> 01:30:06,930
technology that comes with it but you

2075
01:30:12,530 --> 01:30:11,010
know it it essentially becomes next to

2076
01:30:13,940 --> 01:30:12,540
impossible if you get enough of them up

2077
01:30:15,410 --> 01:30:13,950
they're like what what happened if you

2078
01:30:17,240 --> 01:30:15,420
and if they just happen across your

2079
01:30:19,160 --> 01:30:17,250
field of view to actually subtract it

2080
01:30:21,590 --> 01:30:19,170
out it kind of just unless you happen to

2081
01:30:26,660 --> 01:30:21,600
get your targets like in between them so

2082
01:30:29,300 --> 01:30:26,670
it's very disruptive you know so who

2083
01:30:31,040 --> 01:30:29,310
knows maybe maybe they'll feel guilty

2084
01:30:37,310 --> 01:30:31,050
enough that they'll fund Space

2085
01:30:40,070 --> 01:30:37,320
Telescope's more and all right huit 9:30

2086
01:30:41,990 --> 01:30:40,080
and I always cut off at 9:30 and brandon

2087
01:30:50,060 --> 01:30:42,000
has given you a ton of things to look

2088
01:30:52,160 --> 01:30:50,070

about do we have our Maryland spacecraft

2089
01:30:55,490 --> 01:30:52,170
server target person yes all right

2090
01:30:57,410 --> 01:30:55,500
Jacob our Alex Jacob Jacob's gonna come

2091
01:30:59,540 --> 01:30:57,420
down here over to my right if you would

2092
01:31:01,310 --> 01:30:59,550
like to go across the street to look

2093
01:31:04,580 --> 01:31:01,320
through the telescope with Jacob please

2094
01:31:06,650 --> 01:31:04,590
come down and join him otherwise we will