1
00:00:00,000 --> 00:00:04,049
ladies and gentlemen and welcome to the

2
00:00:02,009 --> 00:00:06,809
Space Telescope public lecture series

3
00:00:04,049 --> 00:00:08,400
I'm your host dr. Frank summers and I'm

4
00:00:06,809 --> 00:00:12,119
gonna show you something new with our

5
00:00:08,400 --> 00:00:12,839
new remote alright let's see I got this

6
00:00:12,119 --> 00:00:15,808
oh there we go

7
00:00:12,839 --> 00:00:18,089
that's me dr. Frank summers this is a

8
00:00:15,808 --> 00:00:20,579
special remote that I can use to

9
00:00:18,089 --> 00:00:23,820
highlight sections on screen our

10
00:00:20,579 --> 00:00:26,909
webcasting audience does not get to see

11
00:00:23,820 --> 00:00:28,740
the laser pointer when we use the laser

12
00:00:26,910 --> 00:00:30,899
pointer so I'm trying out this for the

13
00:00:28,739 --> 00:00:32,308
first time tonight and if it works

14
00:00:30,899 --> 00:00:34,229
successfully maybe we'll be able to get

15
00:00:32,308 --> 00:00:36,058
our speakers to use it in the future and

16
00:00:34,229 --> 00:00:39,148
the webcasting audience will see all of

17
00:00:36,058 --> 00:00:41,519
our highlights let's see when you came

18
00:00:39,149 --> 00:00:44,579
in there are images on the table

19
00:00:41,520 --> 00:00:50,100
tonight's image is of the ring nebula

20
00:00:44,579 --> 00:00:52,590
NGC 67 20 and the ring nebula is one of

21
00:00:50,100 --> 00:00:55,140
the most beautiful planetary nebula has

22
00:00:52,590 --> 00:00:58,649
nothing to do with planets that's just a

23
00:00:55,140 --> 00:01:01,590
name that unfortunately stuck it is a

24
00:00:58,649 --> 00:01:03,629
dying star if you want to understand it

25
00:01:01,590 --> 00:01:06,390
well you could turn over on the back and

26
00:01:03,628 --> 00:01:08,519
you can see that we have a collection a

27
00:01:06,390 --> 00:01:11,728
few paragraphs that can tell you about

28
00:01:08,519 --> 00:01:13,890
it as well as up here in the upper right

29

00:01:11,728 --> 00:01:15,569
hand corner there are comparisons to

30
00:01:13,890 --> 00:01:18,719
other planetary nebulae

31
00:01:15,569 --> 00:01:20,938
planetary nebulae have some really

32
00:01:18,719 --> 00:01:25,228
really cool shapes it's well worth

33
00:01:20,938 --> 00:01:28,349
investigating we have to do our reminder

34
00:01:25,228 --> 00:01:30,390
please silence your phones we don't want

35
00:01:28,349 --> 00:01:32,789
them going off during the lecture thank

36
00:01:30,390 --> 00:01:35,219
you very much because tonight's lecture

37
00:01:32,790 --> 00:01:37,170
is one you are definitely want going to

38
00:01:35,219 --> 00:01:40,319
want to listen closely to it's called

39
00:01:37,170 --> 00:01:43,530
our colorful universe translating cosmic

40
00:01:40,319 --> 00:01:47,908
light by our very own master image

41
00:01:43,530 --> 00:01:52,049
processor Joseph de Pascua upcoming we

42
00:01:47,909 --> 00:01:55,170
have an August tiny stellar Islands in a

43
00:01:52,049 --> 00:01:57,719

big old universe this will be a talk

44
00:01:55,170 --> 00:01:59,490
about dwarf galaxies okay and dwarf

45
00:01:57,718 --> 00:02:01,349
galaxies you might think ah who cares

46
00:01:59,489 --> 00:02:03,478
about them you know if snow white wake

47
00:02:01,349 --> 00:02:06,118
may care about the Seven Dwarfs but why

48
00:02:03,478 --> 00:02:08,550
would we care about dwarf galaxies well

49
00:02:06,118 --> 00:02:09,840
they are the most numerous type of

50
00:02:08,550 --> 00:02:12,000
galaxies in the universe they're

51
00:02:09,840 --> 00:02:13,740
actually extremely important to

52
00:02:12,000 --> 00:02:16,949
understand to understand how

53
00:02:13,740 --> 00:02:18,270
universe developed and September Brandon

54
00:02:16,949 --> 00:02:20,969
Lawton is going to talk about the

55
00:02:18,270 --> 00:02:22,830
astronomers toolkit he's decided he

56
00:02:20,969 --> 00:02:25,129
wants to talk to you about all the

57
00:02:22,830 --> 00:02:28,410
various tools astronomers use to

58
00:02:25,129 --> 00:02:29,789
investigate the universe and that should

59
00:02:28,409 --> 00:02:35,009
be fun in September right after Labor

60
00:02:29,789 --> 00:02:38,669
Day and in October a perennial fun topic

61
00:02:35,009 --> 00:02:40,769
black holes and gravitational waves we

62
00:02:38,669 --> 00:02:43,459
have learned so much about this

63
00:02:40,770 --> 00:02:46,770
brand-new gravitational wave astronomy

64
00:02:43,460 --> 00:02:47,939
and Emanuel barity from across the

65
00:02:46,770 --> 00:02:51,000
street at Johns Hopkins will be

66
00:02:47,939 --> 00:02:53,189
discussing that if you want to find out

67
00:02:51,000 --> 00:02:55,439
about things you go to our website and

68
00:02:53,189 --> 00:02:58,800
you will find that our website has a

69
00:02:55,439 --> 00:03:02,879
brand new look it doesn't have

70
00:02:58,800 --> 00:03:05,760
unfortunately a short URL so if you want

71
00:03:02,879 --> 00:03:07,889
to go to the website it's HTTP hollow

72
00:03:05,759 --> 00:03:11,759
site org resources - gallery learning -

73
00:03:07,889 --> 00:03:13,379
resources public - lecture - series easy

74
00:03:11,759 --> 00:03:16,379
to remember right take a picture of the

75
00:03:13,379 --> 00:03:17,340
screen oh if you put into your favorite

76
00:03:16,379 --> 00:03:20,609
search engine

77
00:03:17,340 --> 00:03:25,140
Hubble public lectures you should end up

78
00:03:20,610 --> 00:03:28,740
at this webpage okay we have on it our

79
00:03:25,139 --> 00:03:32,219
list of our upcoming lectures we have

80
00:03:28,740 --> 00:03:34,770
the link to our past lectures all right

81
00:03:32,219 --> 00:03:36,870
so if you want to go to our past public

82
00:03:34,770 --> 00:03:39,420
lectures as well as our YouTube playlist

83
00:03:36,870 --> 00:03:41,759
and our webcasting archive where you can

84
00:03:39,419 --> 00:03:43,799
watch them we also have the lecture

85
00:03:41,759 --> 00:03:46,289
announcements email list where you can

86

00:03:43,800 --> 00:03:48,210
enter your email address and subscribe

87
00:03:46,289 --> 00:03:50,519
to the lecture announcements it's

88
00:03:48,210 --> 00:03:52,740
basically two emails a month reminding

89
00:03:50,520 --> 00:03:54,590
you of the upcoming lectures and telling

90
00:03:52,740 --> 00:03:58,950
you where the webcasts are posted

91
00:03:54,590 --> 00:04:01,050
finally they have a new setup for

92
00:03:58,949 --> 00:04:04,889
presenting the lectures this for example

93
00:04:01,050 --> 00:04:07,980
was last month's lecture by Christopher

94
00:04:04,889 --> 00:04:09,929
Britt and it includes the you know the

95
00:04:07,979 --> 00:04:12,840
basic information he now includes the

96
00:04:09,930 --> 00:04:15,480
description okay as well as link to the

97
00:04:12,840 --> 00:04:19,230
webcast on the SDSU IO site and they'll

98
00:04:15,479 --> 00:04:22,319
link to the webcast on YouTube okay

99
00:04:19,230 --> 00:04:26,430
so they have new stuff on our website

100
00:04:22,319 --> 00:04:27,540

for you to look at and get all the

101
00:04:26,430 --> 00:04:31,379
information about our

102
00:04:27,540 --> 00:04:33,990
what series okay the email I showed you

103
00:04:31,379 --> 00:04:35,490
how to sign up the website if you find

104
00:04:33,990 --> 00:04:37,319
yourself that you do not want to do that

105
00:04:35,490 --> 00:04:39,509
and you want to just write it down on a

106
00:04:37,319 --> 00:04:42,329
piece of paper and hand it to me that'll

107
00:04:39,509 --> 00:04:44,069
work as well those who have comments and

108
00:04:42,329 --> 00:04:48,449
questions can send them to public

109
00:04:44,069 --> 00:04:51,269
lecture at STScI dot edu if you like

110
00:04:48,449 --> 00:04:52,769
social media we have social media for

111
00:04:51,269 --> 00:04:54,779
the Hubble Space Telescope for the

112
00:04:52,769 --> 00:04:56,459
upcoming James Webb Space Telescope and

113
00:04:54,779 --> 00:04:59,369
for our Institute the Space Telescope

114
00:04:56,459 --> 00:05:03,029
Science Institute on Facebook Twitter

115
00:04:59,370 --> 00:05:05,220
YouTube and Instagram and if you care

116
00:05:03,029 --> 00:05:07,709
about what I might want to tweet it out

117
00:05:05,220 --> 00:05:09,600
I'm on Facebook and Twitter but I will

118
00:05:07,709 --> 00:05:12,359
warn you I only do that occasionally

119
00:05:09,600 --> 00:05:15,540
because I get very busy my job and I

120
00:05:12,360 --> 00:05:18,569
enjoy my job and I don't do as much

121
00:05:15,540 --> 00:05:20,340
social media as perhaps I should the

122
00:05:18,569 --> 00:05:23,610
Observatory across the street at Johns

123
00:05:20,339 --> 00:05:25,109
Hopkins will not be open tonight they

124
00:05:23,610 --> 00:05:28,680
said it was looking like there could be

125
00:05:25,110 --> 00:05:30,300
showers and thundershowers and things

126
00:05:28,680 --> 00:05:32,759
were not set up properly for it to

127
00:05:30,300 --> 00:05:35,460
handle this and so there will be no

128
00:05:32,759 --> 00:05:38,279
observatory tonight however I always

129
00:05:35,459 --> 00:05:40,139
note that they do have open houses on

130
00:05:38,279 --> 00:05:42,179
Friday evenings if you go to the

131
00:05:40,139 --> 00:05:44,610
Maryland Space Grant Observatory website

132
00:05:42,180 --> 00:05:47,459
you can see the observatory status right

133
00:05:44,610 --> 00:05:50,520
there okay that Observatory status will

134
00:05:47,459 --> 00:05:52,469
be updated on Friday evenings about 6:00

135
00:05:50,519 --> 00:05:54,479
p.m. they tell me if they're going to be

136
00:05:52,470 --> 00:05:58,470
open so you can come down and see it

137
00:05:54,480 --> 00:06:00,780
then alright well we took all a long

138
00:05:58,470 --> 00:06:03,660
time here doing some some extra stuff

139
00:06:00,779 --> 00:06:06,629
here tonight so I have my news from the

140
00:06:03,660 --> 00:06:08,310
universe for july 2019 but i'm only

141
00:06:06,629 --> 00:06:09,000
going to give you a one-story here

142
00:06:08,310 --> 00:06:12,870
tonight okay

143

00:06:09,000 --> 00:06:15,800
and our only story for tonight is the

144
00:06:12,870 --> 00:06:19,980
intriguing atmosphere of a mini Neptune

145
00:06:15,800 --> 00:06:22,350
alright so in our solar system we have

146
00:06:19,980 --> 00:06:24,900
our earth here on the left and we have

147
00:06:22,350 --> 00:06:27,390
Neptune on the right and these are kind

148
00:06:24,899 --> 00:06:29,729
of roughly to scale or as as simple as

149
00:06:27,389 --> 00:06:32,990
two scales I can make it very quickly in

150
00:06:29,730 --> 00:06:35,400
PowerPoint and so Neptune's diameter is

151
00:06:32,990 --> 00:06:38,879
3.9 x earth it's about four times the

152
00:06:35,399 --> 00:06:41,189
size of Earth and it's math is 17 and a

153
00:06:38,879 --> 00:06:45,420
half 17.15 times

154
00:06:41,189 --> 00:06:47,579
earth okay so Neptune is a giant planet

155
00:06:45,420 --> 00:06:50,129
and some people have tied up call it a

156
00:06:47,579 --> 00:06:52,829
gas giant but actually if you're a real

157
00:06:50,129 --> 00:06:56,279

astronomer you call it an ice giant

158
00:06:52,829 --> 00:06:58,979
because Neptune is 30 times further away

159
00:06:56,279 --> 00:07:01,649
from the Sun than Earth it formed out

160
00:06:58,980 --> 00:07:05,069
beyond what we call the frost line and

161
00:07:01,649 --> 00:07:08,039
it formed with a lot of ices falling

162
00:07:05,069 --> 00:07:11,099
onto it okay so the atma the composition

163
00:07:08,040 --> 00:07:12,300
of Neptune's atmosphere contains a lot

164
00:07:11,100 --> 00:07:15,180
more heavy elements than it otherwise

165
00:07:12,300 --> 00:07:17,160
would if it had formed closer in where

166
00:07:15,180 --> 00:07:20,220
Jupiter and Saturn form and those are

167
00:07:17,160 --> 00:07:24,030
commonly called gas giants okay that's

168
00:07:20,220 --> 00:07:29,970
important because this discovery is

169
00:07:24,029 --> 00:07:33,329
about a planet called GJ 3470 B okay

170
00:07:29,970 --> 00:07:36,570
and this is a what we call a mini

171
00:07:33,329 --> 00:07:39,240
Neptune it's mass is twelve point six

172
00:07:36,569 --> 00:07:41,430
times earth so it's not quite as big as

173
00:07:39,240 --> 00:07:44,009
in up tune but it's much bigger than an

174
00:07:41,430 --> 00:07:47,310
earth alright we often have has anybody

175
00:07:44,009 --> 00:07:49,949
heard the phrase super earth okay yeah

176
00:07:47,310 --> 00:07:52,350
okay that is super earth generally we

177
00:07:49,949 --> 00:07:54,750
think of those up to five six seven

178
00:07:52,350 --> 00:07:56,250
maybe eight times the mass of Earth so

179
00:07:54,750 --> 00:07:58,139
this is sort of larger than a super

180
00:07:56,250 --> 00:07:58,980
earth but it's smaller than a full-size

181
00:07:58,139 --> 00:08:00,959
Neptune

182
00:07:58,980 --> 00:08:03,270
so it's it's starting into that

183
00:08:00,959 --> 00:08:05,159
in-between phase okay is it an

184
00:08:03,269 --> 00:08:08,430
earth-like object is a Neptune sized

185
00:08:05,160 --> 00:08:10,230
object at 13 times earth I considered

186
00:08:08,430 --> 00:08:11,668
more of a Neptune Neptune objects what I

187
00:08:10,230 --> 00:08:14,910
call it a mini I would call it a mini

188
00:08:11,668 --> 00:08:18,240
Neptune all right and they have measured

189
00:08:14,910 --> 00:08:20,880
the atmosphere of this object to have a

190
00:08:18,240 --> 00:08:23,220
hydrogen helium atmosphere with a rock

191
00:08:20,879 --> 00:08:26,579
and ice core and at first that's not

192
00:08:23,220 --> 00:08:29,700
really surprising but let's go a little

193
00:08:26,579 --> 00:08:34,879
further this planet has been discovered

194
00:08:29,699 --> 00:08:38,129
around a red dwarf star GJ 3470 okay and

195
00:08:34,879 --> 00:08:42,029
where as I told you that our Neptune is

196
00:08:38,129 --> 00:08:44,970
out beyond this frost line out at 38 30

197
00:08:42,029 --> 00:08:47,549
astronomical units this one in is in so

198
00:08:44,970 --> 00:08:53,100
close that it orbits around its star

199
00:08:47,549 --> 00:08:54,750
every 3.3 days okay it orbits this red

200

00:08:53,100 --> 00:08:58,560
dwarf star in three

201
00:08:54,750 --> 00:09:00,029
days furthermore it's not situated like

202
00:08:58,559 --> 00:09:01,559
this from our point of view it's

203
00:09:00,029 --> 00:09:04,230
actually situated from our point of view

204
00:09:01,559 --> 00:09:06,899
where it passes in front of its star and

205
00:09:04,230 --> 00:09:09,659
behind its star and in front of its star

206
00:09:06,899 --> 00:09:11,490
and behind a star when it passes in

207
00:09:09,659 --> 00:09:13,740
front of its star it's called a transit

208
00:09:11,490 --> 00:09:16,919
when it passes behind the star is called

209
00:09:13,740 --> 00:09:18,810
an eclipse all right and the Hubble

210
00:09:16,919 --> 00:09:21,479
Space Telescope and the Spitzer Space

211
00:09:18,809 --> 00:09:26,009
Telescope have been observing this

212
00:09:21,480 --> 00:09:28,529
planet star combination during let's see

213
00:09:26,009 --> 00:09:32,069
what's the notes they see like 20 a

214
00:09:28,529 --> 00:09:32,759

transits and 12 eclipses or is it the

215
00:09:32,070 --> 00:09:34,440
vice-versa

216
00:09:32,759 --> 00:09:38,009
all right so you put the two together

217
00:09:34,440 --> 00:09:41,480
you've got this net 2 mini Neptune sized

218
00:09:38,009 --> 00:09:46,350
planet passing in front of the red dwarf

219
00:09:41,480 --> 00:09:49,500
and in these transits and eclipses you

220
00:09:46,350 --> 00:09:51,990
can take it when it's in front and when

221
00:09:49,500 --> 00:09:55,230
it's not in front subtract off the

222
00:09:51,990 --> 00:09:57,570
spectra and get the atmosphere of the

223
00:09:55,230 --> 00:09:59,700
mini Neptune now we've done this for a

224
00:09:57,570 --> 00:10:05,490
lot of hot Jupiters we may have done it

225
00:09:59,700 --> 00:10:06,839
for a few seconds this is they claim one

226
00:10:05,490 --> 00:10:09,060
of the first time that's been done for a

227
00:10:06,839 --> 00:10:10,589
mini Neptune this is one of the smallest

228
00:10:09,059 --> 00:10:14,099
objects from which we're measuring the

229
00:10:10,589 --> 00:10:15,330
atmosphere now I said hydrogen helium

230
00:10:14,100 --> 00:10:17,159
atmosphere doesn't shouldn't surprise

231
00:10:15,330 --> 00:10:18,780
you much right because hydrogen and

232
00:10:17,159 --> 00:10:22,620
helium are the dominant elements in the

233
00:10:18,779 --> 00:10:26,129
universe however this atmosphere is

234
00:10:22,620 --> 00:10:29,669
really just hydrogen helium it doesn't

235
00:10:26,129 --> 00:10:32,730
contain the water vapor and the methane

236
00:10:29,669 --> 00:10:35,370
that you would expect for a Neptune if

237
00:10:32,730 --> 00:10:37,589
it was normal Neptune it formed out

238
00:10:35,370 --> 00:10:40,649
beyond the frost line and then it you

239
00:10:37,589 --> 00:10:42,780
know migrates inward due to

240
00:10:40,649 --> 00:10:45,209
gravitational interactions ok

241
00:10:42,779 --> 00:10:47,279
planets we don't expect Jupiter's and

242
00:10:45,210 --> 00:10:49,800
Neptune's to form close to their star

243
00:10:47,279 --> 00:10:52,110
they only form way out here and so if it

244
00:10:49,799 --> 00:10:53,549
migrates inward it should still at least

245
00:10:52,110 --> 00:10:55,169
keep its chemical composition in its

246
00:10:53,549 --> 00:10:57,629
atmosphere and there should be water

247
00:10:55,169 --> 00:11:00,120
vapor there should be methane they found

248
00:10:57,629 --> 00:11:04,080
no evidence of such and as such it's a

249
00:11:00,120 --> 00:11:07,740
weird an odd object how does it form a

250
00:11:04,080 --> 00:11:08,430
13 earth mass object without having a

251
00:11:07,740 --> 00:11:10,860
good

252
00:11:08,429 --> 00:11:13,759
of heavier elements in its atmosphere

253
00:11:10,860 --> 00:11:16,710
and that's the conundrum now they make a

254
00:11:13,759 --> 00:11:20,039
speculation that saying well perhaps it

255
00:11:16,710 --> 00:11:24,060
actually formed in situ okay that it

256
00:11:20,039 --> 00:11:26,279
formed in close to its star which I as

257

00:11:24,059 --> 00:11:27,629
an astronomer start to actually laughed

258
00:11:26,279 --> 00:11:29,789
at when it was brought up in the news

259
00:11:27,629 --> 00:11:33,240
meeting it's like come on

260
00:11:29,789 --> 00:11:35,639
you cannot form a giant planet in next

261
00:11:33,240 --> 00:11:39,120
to the star okay that's just not

262
00:11:35,639 --> 00:11:41,490
possible as far as I know maybe they

263
00:11:39,120 --> 00:11:44,460
know something I don't know but what

264
00:11:41,490 --> 00:11:47,519
they've speculated is that the rock and

265
00:11:44,460 --> 00:11:50,370
ice core formed first like a earth size

266
00:11:47,519 --> 00:11:53,340
a very large earth type rocky planet and

267
00:11:50,370 --> 00:11:55,139
that the hydrogen helium atmosphere then

268
00:11:53,340 --> 00:11:58,470
accreted onto it and that would have

269
00:11:55,139 --> 00:12:00,029
gone much larger except that this was

270
00:11:58,470 --> 00:12:02,129
late in the late in the stage and it

271
00:12:00,029 --> 00:12:04,589

only was able to pull in the hydrogen

272
00:12:02,129 --> 00:12:06,330
helium it wasn't out far enough for the

273
00:12:04,590 --> 00:12:07,889
ices to accrete that would have given

274
00:12:06,330 --> 00:12:11,759
the heavy elements in the atmosphere

275
00:12:07,889 --> 00:12:14,699
I consider that a bit speculative but it

276
00:12:11,759 --> 00:12:17,700
does make for an intriguing object that

277
00:12:14,700 --> 00:12:20,580
one of the first small small Neptune

278
00:12:17,700 --> 00:12:23,550
type objects that we measure doesn't

279
00:12:20,580 --> 00:12:27,030
have the characteristic atmosphere we

280
00:12:23,549 --> 00:12:30,569
expect for a Neptune sized object okay

281
00:12:27,029 --> 00:12:32,429
so to be continued as we study this more

282
00:12:30,570 --> 00:12:36,510
with both Hubble and Spitzer and

283
00:12:32,429 --> 00:12:39,599
upcoming space telescopes all right okay

284
00:12:36,509 --> 00:12:42,600
now we move on to our speaker for

285
00:12:39,600 --> 00:12:45,570
tonight and our speaker for tonight is

286
00:12:42,600 --> 00:12:47,279
Joseph de Pascua he got his degree in

287
00:12:45,570 --> 00:12:50,940
astronomy and astrophysics from

288
00:12:47,279 --> 00:12:53,490
Villanova University and then spent 15

289
00:12:50,940 --> 00:12:56,970
years up in Boston at the Chandra x-ray

290
00:12:53,490 --> 00:12:59,940
Center where he became an absolute

291
00:12:56,970 --> 00:13:02,930
expert in astronomical image processing

292
00:12:59,940 --> 00:13:05,700
in data processing in visualization

293
00:13:02,929 --> 00:13:08,059
anything uh taking the universe and

294
00:13:05,700 --> 00:13:10,830
making it understandable and

295
00:13:08,059 --> 00:13:12,539
contributing to press releases I think

296
00:13:10,830 --> 00:13:15,840
Joe can do it okay because when he got

297
00:13:12,539 --> 00:13:18,120
here the first project I worked with him

298
00:13:15,840 --> 00:13:20,100
on I said here try something like this

299
00:13:18,120 --> 00:13:22,080
and I've never gotten anybody in this

300
00:13:20,100 --> 00:13:24,330
building to be able to

301
00:13:22,080 --> 00:13:26,100
to really jump in when you were working

302
00:13:24,330 --> 00:13:27,600
on the candle stuff together and he just

303
00:13:26,100 --> 00:13:31,170
jumped in as a tall figure it out

304
00:13:27,600 --> 00:13:33,300
mayhem he figured it out so he's been

305
00:13:31,169 --> 00:13:36,569
very impressive in his few years here

306
00:13:33,299 --> 00:13:38,370
and he is now our lead image processor

307
00:13:36,570 --> 00:13:40,710
and he's here to talk to you about our

308
00:13:38,370 --> 00:13:50,060
colorful universe translating cosmic

309
00:13:40,710 --> 00:14:08,970
light everyone Joseph de Pascua whoops

310
00:13:50,059 --> 00:14:10,049
what number you want oh well thank you

311
00:14:08,970 --> 00:14:12,060
Frank for that introduction

312
00:14:10,049 --> 00:14:13,620
it was nice and thank you everyone for

313
00:14:12,059 --> 00:14:16,829
being here tonight it's really it's

314

00:14:13,620 --> 00:14:18,480
great to see such a full audience and hi

315
00:14:16,830 --> 00:14:24,210
to everyone out on the Internet as well

316
00:14:18,480 --> 00:14:26,539
I think my family's on - so our cult for

317
00:14:24,210 --> 00:14:29,070
universe translating cosmic light is

318
00:14:26,539 --> 00:14:31,740
intentionally vague enough title that I

319
00:14:29,070 --> 00:14:34,620
can sort of cover whatever I want which

320
00:14:31,740 --> 00:14:36,690
I like what I would like to do though is

321
00:14:34,620 --> 00:14:38,009
to talk a little bit about the the

322
00:14:36,690 --> 00:14:40,290
methods that I use for processing

323
00:14:38,009 --> 00:14:42,210
astronomical data but I want to frame it

324
00:14:40,289 --> 00:14:44,189
in the context of the history of our

325
00:14:42,210 --> 00:14:46,050
understanding of light and so we're

326
00:14:44,190 --> 00:14:48,530
gonna spend the first maybe third of the

327
00:14:46,049 --> 00:14:50,579
talk talking about the history of light

328
00:14:48,529 --> 00:14:52,679

and before I get into that I want to

329
00:14:50,580 --> 00:14:54,509
talk a little bit about just light in

330
00:14:52,679 --> 00:14:56,489
general I mean it's the dominant way

331
00:14:54,509 --> 00:14:59,250
that we experience our world our eyes

332
00:14:56,490 --> 00:15:02,460
are constantly flooded with light but

333
00:14:59,250 --> 00:15:04,200
imagine oh so light carries information

334
00:15:02,460 --> 00:15:05,820
we're surrounded by information imagine

335
00:15:04,200 --> 00:15:07,580
if our eyes were actually sensitive to

336
00:15:05,820 --> 00:15:10,410
light beyond the visible wavelengths

337
00:15:07,580 --> 00:15:13,050
this is a conceptual visualization

338
00:15:10,409 --> 00:15:15,959
showing what it might look like to be

339
00:15:13,049 --> 00:15:18,000
able to see cellphone tower signals in a

340
00:15:15,960 --> 00:15:19,710
city so if our eyes were sensitive to

341
00:15:18,000 --> 00:15:22,440
this kind of light we would just see the

342
00:15:19,710 --> 00:15:23,759
city blanketed in light every one of

343
00:15:22,440 --> 00:15:24,990
these buildings basically has a cell

344
00:15:23,759 --> 00:15:29,669
tower above and it's emitting signals

345
00:15:24,990 --> 00:15:31,289
all the time we're imagine being able to

346
00:15:29,669 --> 00:15:33,899
see Wi-Fi signals this is a

347
00:15:31,289 --> 00:15:35,849
visualization of why free Wi-Fi signals

348
00:15:33,899 --> 00:15:37,110
on the National Mall and that

349
00:15:35,850 --> 00:15:38,940
being on the National Mall sitting on a

350
00:15:37,110 --> 00:15:42,600
park bench and just seeing this swirling

351
00:15:38,940 --> 00:15:44,819
around you it would be overwhelming for

352
00:15:42,600 --> 00:15:48,810
sure very glad that our eyes are

353
00:15:44,818 --> 00:15:50,278
sensitive just a visible light of course

354
00:15:48,809 --> 00:15:54,088
we all know we've heard about the speed

355
00:15:50,278 --> 00:15:56,610
of light 186,000 miles per second or 3

356
00:15:54,089 --> 00:15:59,190
times 10 to the 8 meters per second in

357
00:15:56,610 --> 00:16:01,889
our light bubble of Earth that seems

358
00:15:59,190 --> 00:16:04,050
instantaneous right that's the speed of

359
00:16:01,889 --> 00:16:06,060
light travels around the earth seven and

360
00:16:04,049 --> 00:16:08,519
a half times in one second and so in our

361
00:16:06,059 --> 00:16:10,828
experiential life on this planet light

362
00:16:08,519 --> 00:16:13,379
is instant but as soon as we leave that

363
00:16:10,828 --> 00:16:17,008
light bubble that speed limit becomes

364
00:16:13,379 --> 00:16:18,778
important for example Jupiter which is

365
00:16:17,009 --> 00:16:20,699
up if the clouds clear tonight when we

366
00:16:18,778 --> 00:16:22,110
leave the light that isn't currently

367
00:16:20,698 --> 00:16:24,479
reflecting off of Jupiter as I'm

368
00:16:22,110 --> 00:16:27,419
speaking right now we'll be hitting

369
00:16:24,480 --> 00:16:29,699
earth when you leave here tonight so

370
00:16:27,419 --> 00:16:31,049
keep an eye out when you go outside

371

00:16:29,698 --> 00:16:35,309
for Jupiter it'll be the big bright

372
00:16:31,049 --> 00:16:36,958
thing in the southeast sky and this of

373
00:16:35,309 --> 00:16:38,489
course this speed limit to light gets

374
00:16:36,958 --> 00:16:41,818
even more significant as we move away

375
00:16:38,490 --> 00:16:44,339
from our solar system as a species our

376
00:16:41,818 --> 00:16:45,750
humanity has been generating radio

377
00:16:44,339 --> 00:16:48,600
signals for about a hundred years and

378
00:16:45,750 --> 00:16:51,500
that basically creates a light bubble

379
00:16:48,600 --> 00:16:53,970
around our solar system that's been

380
00:16:51,500 --> 00:16:56,278
expanding into our galaxy for a hundred

381
00:16:53,970 --> 00:16:58,379
years but on a galactic scale it's

382
00:16:56,278 --> 00:17:00,688
pretty insignificant if I were to ask

383
00:16:58,379 --> 00:17:02,100
you to draw a circle on this this is a

384
00:17:00,688 --> 00:17:06,000
visualization of the Milky Way galaxy

385
00:17:02,100 --> 00:17:09,630

and somewhere in here is a circle that

386
00:17:06,000 --> 00:17:12,029
shows how much light has moved through

387
00:17:09,630 --> 00:17:13,530
our galaxy in a hundred years you might

388
00:17:12,029 --> 00:17:17,178
think it would be something like this

389
00:17:13,529 --> 00:17:22,949
but no it's that little dot right there

390
00:17:17,179 --> 00:17:24,509
zoom in on that so when people say why

391
00:17:22,949 --> 00:17:25,500
can't we send a probe up into space to

392
00:17:24,509 --> 00:17:29,879
be able to take a picture of the Milky

393
00:17:25,500 --> 00:17:30,990
Way from above that's why and that's to

394
00:17:29,880 --> 00:17:33,419
me I can travel at the speed of light

395
00:17:30,990 --> 00:17:35,370
which is not possible of course it would

396
00:17:33,419 --> 00:17:38,970
take millions of years generations to be

397
00:17:35,369 --> 00:17:41,609
able to do something like that but now

398
00:17:38,970 --> 00:17:43,460
moving on into the history of light this

399
00:17:41,609 --> 00:17:46,109
is what I call a crash course in light

400
00:17:43,460 --> 00:17:47,759
and I'm by no means an expert in this

401
00:17:46,109 --> 00:17:49,750
but there are a few key concepts that I

402
00:17:47,759 --> 00:17:52,569
want to touch on before we dive into the

403
00:17:49,750 --> 00:17:54,130
processing part of this so we've known

404
00:17:52,569 --> 00:17:55,419
about and have been studying light for

405
00:17:54,130 --> 00:17:57,280
thousands of years going all the way

406
00:17:55,420 --> 00:17:58,750
back to Chinese and ancient Greek

407
00:17:57,279 --> 00:18:02,259
philosophers of course the ancient

408
00:17:58,750 --> 00:18:04,839
Greeks had this idea called EXO was an

409
00:18:02,259 --> 00:18:06,549
EXO mission or extra mission the extra

410
00:18:04,839 --> 00:18:08,379
mission theory of light which was that

411
00:18:06,549 --> 00:18:10,659
our eyes were actually emitting light

412
00:18:08,380 --> 00:18:12,460
rays and so the light that we saw was

413
00:18:10,660 --> 00:18:15,120
actually bounced off of objects from our

414
00:18:12,460 --> 00:18:17,140
eyes of course we know that's not true

415
00:18:15,119 --> 00:18:19,599
what the Greek philosophers gave us

416
00:18:17,140 --> 00:18:21,580
though was really a scientific method a

417
00:18:19,599 --> 00:18:24,459
way of analytically thinking about

418
00:18:21,579 --> 00:18:26,649
things moving on through the Islamic

419
00:18:24,460 --> 00:18:28,450
civilization European enlightenment up

420
00:18:26,650 --> 00:18:31,120
to the discovery of the visible spectrum

421
00:18:28,450 --> 00:18:33,759
with Isaac Newton in 1666 this is where

422
00:18:31,119 --> 00:18:39,279
we finally started to realize that light

423
00:18:33,759 --> 00:18:41,680
is made up of component colors and then

424
00:18:39,279 --> 00:18:43,450
moving beyond visible light William

425
00:18:41,680 --> 00:18:46,990
Herschel discovered infrared light in

426
00:18:43,450 --> 00:18:48,100
1800 he was doing an experiment where he

427
00:18:46,990 --> 00:18:50,740
was actually measuring the temperature

428

00:18:48,099 --> 00:18:54,639
of colors of light so building on the

429
00:18:50,740 --> 00:18:56,529
work of Newton he was able to use a

430
00:18:54,640 --> 00:18:57,940
prism to it break down light into its

431
00:18:56,529 --> 00:18:59,200
component colors and then he was

432
00:18:57,940 --> 00:19:01,029
actually just using the thermometer to

433
00:18:59,200 --> 00:19:03,670
measure the temperature of the light and

434
00:19:01,029 --> 00:19:05,829
what he noticed was blue light was

435
00:19:03,670 --> 00:19:07,750
cooler than redder light and so as he

436
00:19:05,829 --> 00:19:09,789
went from blue to red the temperature

437
00:19:07,750 --> 00:19:12,299
was going up but then as he went just

438
00:19:09,789 --> 00:19:14,200
beyond read the thermometer kept rising

439
00:19:12,299 --> 00:19:16,569
so what's going on here there's nothing

440
00:19:14,200 --> 00:19:17,710
there that you can see but the

441
00:19:16,569 --> 00:19:18,939
thermometer is rising there must be

442
00:19:17,710 --> 00:19:20,980

something there that's causing it to

443
00:19:18,940 --> 00:19:22,269
rise that's actually infrared light

444
00:19:20,980 --> 00:19:25,140
there's light there that our eyes are

445
00:19:22,269 --> 00:19:26,920
not sensitive to and now we can thank

446
00:19:25,140 --> 00:19:28,900
William Herschel for discovering

447
00:19:26,920 --> 00:19:31,750
infrared light if you have a cell phone

448
00:19:28,900 --> 00:19:33,940
with face ID that's how it works it uses

449
00:19:31,750 --> 00:19:35,769
infrared light to project something onto

450
00:19:33,940 --> 00:19:37,690
your face that basically creates a grid

451
00:19:35,769 --> 00:19:40,450
the phone recognizes your face in that

452
00:19:37,690 --> 00:19:45,279
grid and then unlocks your phone so you

453
00:19:40,450 --> 00:19:47,799
can check Facebook moving on into

454
00:19:45,279 --> 00:19:51,849
spectroscopy Joseph von Fraunhofer in

455
00:19:47,799 --> 00:19:54,339
1814 he develops a method for

456
00:19:51,849 --> 00:19:57,730
analytically looking at the spectrum

457
00:19:54,339 --> 00:19:59,769
that's generated from a prism and also

458
00:19:57,730 --> 00:20:01,089
discovers the the dark absorption lines

459
00:19:59,769 --> 00:20:02,589
that we see you if you look at a solar

460
00:20:01,089 --> 00:20:03,939
spectrum you see all these dark lines in

461
00:20:02,589 --> 00:20:06,128
there and that's caused by

462
00:20:03,940 --> 00:20:08,440
atoms and molecules in the solar

463
00:20:06,128 --> 00:20:10,568
atmosphere absorbing light at specific

464
00:20:08,440 --> 00:20:13,538
frequencies and so this is where we

465
00:20:10,568 --> 00:20:19,479
start to move from qualitative to

466
00:20:13,538 --> 00:20:22,749
quantitative analysis of light building

467
00:20:19,479 --> 00:20:24,548
on even further James Clerk Maxwell and

468
00:20:22,749 --> 00:20:26,709
this is a really pivotal moment in our

469
00:20:24,548 --> 00:20:28,269
understanding of light he discovers this

470
00:20:26,709 --> 00:20:29,409
connection studying electricity and

471
00:20:28,269 --> 00:20:32,769
magnetism and he discovers this

472
00:20:29,409 --> 00:20:34,329
connection with with light where these

473
00:20:32,769 --> 00:20:36,128
fields these oscillating fields of

474
00:20:34,328 --> 00:20:38,578
electricity and magnetism are moving at

475
00:20:36,128 --> 00:20:40,598
what is known as the speed of light see

476
00:20:38,578 --> 00:20:42,158
and so this is the first time that we

477
00:20:40,598 --> 00:20:43,598
draw this connection that light that we

478
00:20:42,159 --> 00:20:47,459
see with our eyes is actually the same

479
00:20:43,598 --> 00:20:53,528
thing as electromagnetic spectrum and

480
00:20:47,459 --> 00:20:56,859
that was in 1860 in 1895 Wilhelm

481
00:20:53,528 --> 00:21:00,269
roentgen discovers x-rays because he's

482
00:20:56,858 --> 00:21:00,269
being irradiated right before our eyes

483
00:21:01,419 --> 00:21:06,759
he was experimenting with vacuum tubes

484
00:21:03,969 --> 00:21:08,859
in the lab and and discovered this there

485

00:21:06,759 --> 00:21:11,169
was a he had a tube shining and across

486
00:21:08,858 --> 00:21:15,249
the room there was this material that

487
00:21:11,169 --> 00:21:16,659
was tough blow to fluorescing and it was

488
00:21:15,249 --> 00:21:18,969
basically x-rays were being shot across

489
00:21:16,659 --> 00:21:22,359
the room hitting this this piece of film

490
00:21:18,969 --> 00:21:23,469
and lighting it up and then from that he

491
00:21:22,358 --> 00:21:26,108
goes on to become the father at

492
00:21:23,469 --> 00:21:29,078
diagnostic radiology and he also wins

493
00:21:26,108 --> 00:21:36,338
the first Nobel Prize in 1901 which is

494
00:21:29,078 --> 00:21:39,249
really cool and you may may notice that

495
00:21:36,338 --> 00:21:41,708
the name Rankin may sound familiar his

496
00:21:39,249 --> 00:21:43,509
name became synonymous with x-rays so he

497
00:21:41,709 --> 00:21:45,459
called it x-rays but then people

498
00:21:43,509 --> 00:21:46,808
especially in Germany called them wrong

499
00:21:45,459 --> 00:21:49,859

can raise and if you've watched

500
00:21:46,808 --> 00:21:49,858
Chernobyl you've heard that a lot

501
00:21:51,388 --> 00:21:57,278
building on the work of Maxwell in the

502
00:21:53,919 --> 00:21:59,349
Einstein era Einstein discovers in 1905

503
00:21:57,278 --> 00:22:00,759
the photoelectric effect and this is

504
00:21:59,348 --> 00:22:02,468
where we start to have an understanding

505
00:22:00,759 --> 00:22:05,469
of light as both a wave and a particle

506
00:22:02,469 --> 00:22:08,229
the wave particle duality of light

507
00:22:05,469 --> 00:22:14,769
Einstein also wins a Nobel Prize very

508
00:22:08,229 --> 00:22:15,940
cool for this work in 1921 so now with

509
00:22:14,769 --> 00:22:18,159
this sort of rudimentary understanding

510
00:22:15,940 --> 00:22:19,830
of our history of understanding

511
00:22:18,159 --> 00:22:21,580
we now have a framework for

512
00:22:19,829 --> 00:22:23,109
understanding how light is paved the

513
00:22:21,579 --> 00:22:26,019
wave this understanding is paved the way

514
00:22:23,109 --> 00:22:27,939
for astronomical spectroscopy which is

515
00:22:26,019 --> 00:22:31,589
now taking astronomy into a quantitative

516
00:22:27,940 --> 00:22:34,119
realm and allows astronomers to start to

517
00:22:31,589 --> 00:22:37,209
qualify stars by the nature of their

518
00:22:34,118 --> 00:22:39,398
light we can we can classify them that

519
00:22:37,210 --> 00:22:41,169
way and so as I mentioned before this is

520
00:22:39,398 --> 00:22:42,969
a this is a really detailed solar

521
00:22:41,169 --> 00:22:44,739
spectrum here and all of these dark

522
00:22:42,970 --> 00:22:46,690
lines here are caused by atoms and

523
00:22:44,739 --> 00:22:48,489
molecules in the solar atmosphere and

524
00:22:46,690 --> 00:22:52,480
using this information this is how we

525
00:22:48,489 --> 00:22:54,909
can classify stars but there are other

526
00:22:52,480 --> 00:22:58,389
ways that we get information from stars

527
00:22:54,909 --> 00:23:00,519
notably just by their light and there's

528
00:22:58,388 --> 00:23:02,199
a really great example of how just just

529
00:23:00,519 --> 00:23:05,169
measuring light and its intensity is

530
00:23:02,200 --> 00:23:07,600
really important not even 100 years ago

531
00:23:05,169 --> 00:23:10,419
we had this concept of the size of our

532
00:23:07,599 --> 00:23:12,368
universe that was was completely

533
00:23:10,419 --> 00:23:13,389
different than what we think today there

534
00:23:12,368 --> 00:23:15,038
was something called the great debate

535
00:23:13,388 --> 00:23:18,908
between Harlow Shapley and Herbert

536
00:23:15,038 --> 00:23:21,339
Curtis in 1920 where Shapley was on the

537
00:23:18,909 --> 00:23:22,350
side of saying that our universe was the

538
00:23:21,339 --> 00:23:24,398
Milky Way galaxy

539
00:23:22,349 --> 00:23:26,259
everything the entirety of the universe

540
00:23:24,398 --> 00:23:27,579
when we look up in the sky was contained

541
00:23:26,259 --> 00:23:30,249
within the hundred thousand light years

542

00:23:27,579 --> 00:23:33,398
or so of the Milky Way and Herbert

543
00:23:30,249 --> 00:23:34,629
Curtis was arguing that observational

544
00:23:33,398 --> 00:23:37,329
astronomers were looking up in the night

545
00:23:34,628 --> 00:23:40,058
sky and seeing what they called spiral

546
00:23:37,329 --> 00:23:41,829
nebulae now Herbert Curtis theorized

547
00:23:40,058 --> 00:23:44,470
that these spiral nebulae were actually

548
00:23:41,829 --> 00:23:46,689
Island universes or other galaxies in

549
00:23:44,470 --> 00:23:50,679
their own right much further distant

550
00:23:46,690 --> 00:23:52,269
from the Milky Way and so this was this

551
00:23:50,679 --> 00:23:55,480
is kind of what the state of the art was

552
00:23:52,269 --> 00:23:59,339
not in 1920 but one of the first hand

553
00:23:55,480 --> 00:23:59,339
drawings of the Whirlpool Galaxy

554
00:24:00,450 --> 00:24:06,399
of course light was the answer to

555
00:24:02,710 --> 00:24:09,509
figuring out the distance and and the

556
00:24:06,398 --> 00:24:11,678

true size of the universe and this was

557
00:24:09,509 --> 00:24:13,210
through the importance of Cepheid

558
00:24:11,679 --> 00:24:15,999
variable stars these are a type of star

559
00:24:13,210 --> 00:24:18,100
that pulsate with a known frequency that

560
00:24:15,999 --> 00:24:20,278
is directly related to their luminosity

561
00:24:18,099 --> 00:24:22,178
the amount of light they give off

562
00:24:20,278 --> 00:24:24,190
Henrietta Leavitt at the Harvard

563
00:24:22,179 --> 00:24:25,210
Observatory discovered this they call it

564
00:24:24,190 --> 00:24:28,659
appears she call it a period-luminosity

565
00:24:25,210 --> 00:24:30,399
relationship and so if you are able to

566
00:24:28,659 --> 00:24:31,539
accurately measure the period of

567
00:24:30,398 --> 00:24:33,158
pulsations of a Steffie

568
00:24:31,538 --> 00:24:35,200
variable star and you're able to

569
00:24:33,159 --> 00:24:38,739
determine the distance to the star very

570
00:24:35,200 --> 00:24:40,269
accurately and just to give you a sort

571
00:24:38,739 --> 00:24:42,579
of a down-to-earth example of how this

572
00:24:40,269 --> 00:24:45,220
works let's consider the 100 watt light

573
00:24:42,579 --> 00:24:47,378
bulb its absolute magnitude or its

574
00:24:45,220 --> 00:24:49,600
intrinsic brightness is 100 watts it's

575
00:24:47,378 --> 00:24:51,908
printed right on it its apparent

576
00:24:49,599 --> 00:24:54,069
magnitude is the brightness that you

577
00:24:51,909 --> 00:24:57,009
would measure from a distance to that

578
00:24:54,069 --> 00:24:59,589
light bulb okay and that has a very

579
00:24:57,009 --> 00:25:01,589
well-known relationship where the light

580
00:24:59,589 --> 00:25:03,638
falls off as a 1 over R squared

581
00:25:01,589 --> 00:25:05,858
relationship so as you go away from the

582
00:25:03,638 --> 00:25:08,678
light bulb that the brightness is

583
00:25:05,858 --> 00:25:11,858
dropping significantly and this way in

584
00:25:08,679 --> 00:25:14,639
this way and the true equation here this

585
00:25:11,858 --> 00:25:16,658
is how you can just derive the distance

586
00:25:14,638 --> 00:25:19,959
once you've measured that apparent

587
00:25:16,659 --> 00:25:21,999
magnitude and if you know the absolute

588
00:25:19,960 --> 00:25:27,970
magnitude then you can determine the

589
00:25:21,999 --> 00:25:29,618
distance to that bulb so this period

590
00:25:27,970 --> 00:25:31,690
luminosity function is essential in

591
00:25:29,618 --> 00:25:36,308
understanding the distances to the

592
00:25:31,690 --> 00:25:38,528
Cepheid variable stars so combined with

593
00:25:36,308 --> 00:25:39,700
their apparent magnitude we can now get

594
00:25:38,528 --> 00:25:41,259
an accurate distance measurement and

595
00:25:39,700 --> 00:25:44,889
that's exactly how this debate was

596
00:25:41,259 --> 00:25:46,868
finally settled in 1923 Edwin Hubble was

597
00:25:44,888 --> 00:25:50,798
observing Cepheid variable stars in the

598
00:25:46,868 --> 00:25:55,509
Andromeda nebula when he discovered this

599

00:25:50,798 --> 00:25:57,249
variable clearly denoted as var and

600
00:25:55,509 --> 00:25:59,319
using the the period-luminosity

601
00:25:57,249 --> 00:26:01,058
relationship he was able to determine an

602
00:25:59,319 --> 00:26:03,460
accurate distance to the Andromeda

603
00:26:01,058 --> 00:26:06,098
galaxy which was two and a half million

604
00:26:03,460 --> 00:26:08,858
light-years which was way further than

605
00:26:06,098 --> 00:26:10,089
the understanding of the size of the

606
00:26:08,858 --> 00:26:11,949
Milky Way galaxy at that time which was

607
00:26:10,089 --> 00:26:13,868
about a hundred thousand light years so

608
00:26:11,950 --> 00:26:15,819
a completely blew open our concept of

609
00:26:13,868 --> 00:26:20,319
the size of the universe just through

610
00:26:15,819 --> 00:26:22,178
measuring the brightness of light back

611
00:26:20,319 --> 00:26:24,189
in 2011 the Hubble Space Telescope

612
00:26:22,179 --> 00:26:26,048
actually went and looked at that same

613
00:26:24,190 --> 00:26:27,669

exact variable star and we measured a

614
00:26:26,048 --> 00:26:32,648
very accurate light curve and working

615
00:26:27,669 --> 00:26:34,570
with ground-based astronomers we have we

616
00:26:32,648 --> 00:26:36,158
determined a period of 31.4 days for

617
00:26:34,569 --> 00:26:40,148
that particular Cepheid variable star

618
00:26:36,159 --> 00:26:42,220
and so forth at work and for his many

619
00:26:40,148 --> 00:26:44,348
other contributions to our understanding

620
00:26:42,220 --> 00:26:45,400
of the event universe we named our

621
00:26:44,348 --> 00:26:49,119
favorite Space Telescope

622
00:26:45,400 --> 00:26:50,530
after Edwin Hubble the Hubble Space

623
00:26:49,119 --> 00:26:53,079
Telescope is arguably the greatest

624
00:26:50,529 --> 00:26:55,690
scientific endeavor of in the history of

625
00:26:53,079 --> 00:26:57,519
humanity for the last 29 years it has

626
00:26:55,690 --> 00:26:59,980
been providing us with breathtaking

627
00:26:57,519 --> 00:27:03,869
views of the cosmos and groundbreaking

628
00:26:59,980 --> 00:27:05,950
science thanks in no small part to the

629
00:27:03,869 --> 00:27:08,589
courageous men and women of the

630
00:27:05,950 --> 00:27:10,750
astronaut program who went up in four

631
00:27:08,589 --> 00:27:11,980
Shuttle missions servicing missions to

632
00:27:10,750 --> 00:27:15,009
make sure that Hubble was working in

633
00:27:11,980 --> 00:27:16,809
tip-top shape Hubble has become

634
00:27:15,009 --> 00:27:17,829
synonymous with astronomy and has

635
00:27:16,809 --> 00:27:19,569
literally transformed our understanding

636
00:27:17,829 --> 00:27:21,009
of the universe but also our

637
00:27:19,569 --> 00:27:23,710
understanding of what the universe looks

638
00:27:21,009 --> 00:27:26,019
like I think of these images as cosmic

639
00:27:23,710 --> 00:27:27,390
landscapes and as an image processor I

640
00:27:26,019 --> 00:27:29,500
approach them as a photographer would

641
00:27:27,390 --> 00:27:31,660
trying to pull out as much detail as

642
00:27:29,500 --> 00:27:34,660
possible while respecting the inherent

643
00:27:31,660 --> 00:27:36,130
data indeed the further we look the

644
00:27:34,660 --> 00:27:40,870
deeper we look with Hubble the deeper it

645
00:27:36,130 --> 00:27:42,250
gets and now I'd like to actually

646
00:27:40,869 --> 00:27:45,129
explore a little further some of the

647
00:27:42,250 --> 00:27:47,349
sorry some of the photographic concepts

648
00:27:45,130 --> 00:27:48,790
that I was talking about here the visual

649
00:27:47,349 --> 00:27:50,829
principles that that are sort of a

650
00:27:48,789 --> 00:27:52,299
guiding force in the work that I do when

651
00:27:50,829 --> 00:27:54,129
I'm taking the data from the telescope

652
00:27:52,299 --> 00:27:56,500
and turning it into press release

653
00:27:54,130 --> 00:27:57,880
imagery and so the three three key

654
00:27:56,500 --> 00:28:00,369
concepts that I always try to keep in

655
00:27:57,880 --> 00:28:05,110
mind are tonality color and Composition

656

00:28:00,369 --> 00:28:07,869
in these images so starting with

657
00:28:05,109 --> 00:28:10,750
tonality when we get the data from the

658
00:28:07,869 --> 00:28:12,489
telescope it comes down it looks

659
00:28:10,750 --> 00:28:14,200
basically just black and that's because

660
00:28:12,490 --> 00:28:17,140
the sensors the detectors on the

661
00:28:14,200 --> 00:28:19,210
telescope are very sensitive to light in

662
00:28:17,140 --> 00:28:22,720
a way that our eyes are not there's a

663
00:28:19,210 --> 00:28:24,400
huge dynamic range meaning that the the

664
00:28:22,720 --> 00:28:27,700
darkest darks and the brightest brights

665
00:28:24,400 --> 00:28:30,160
there's just a huge range of intensity

666
00:28:27,700 --> 00:28:31,690
values between the two much more than

667
00:28:30,160 --> 00:28:33,400
our eyes could see or much more that can

668
00:28:31,690 --> 00:28:35,860
even be displayed on an on a computer

669
00:28:33,400 --> 00:28:37,660
screen and so we have to scale that data

670
00:28:35,859 --> 00:28:39,849

so the first step is to be able to pull

671
00:28:37,660 --> 00:28:41,769
out the details of the data and so in

672
00:28:39,849 --> 00:28:44,409
this this is a linear scaling of an

673
00:28:41,769 --> 00:28:46,150
image we're using a linear scale you

674
00:28:44,410 --> 00:28:48,430
basically just see the brightest points

675
00:28:46,150 --> 00:28:49,690
so the Stars the Centers of the galaxies

676
00:28:48,430 --> 00:28:52,390
those are the things that are showing up

677
00:28:49,690 --> 00:28:53,740
when you do a linear scale now if you

678
00:28:52,390 --> 00:28:56,080
want to pull out more detail and see

679
00:28:53,740 --> 00:28:58,329
stuff that's that's darker than those

680
00:28:56,079 --> 00:28:59,129
bright point sources you need to ramp it

681
00:28:58,329 --> 00:29:01,619
up you need to

682
00:28:59,130 --> 00:29:04,470
that black level and just squish it up

683
00:29:01,619 --> 00:29:05,969
there and so now you can actually see

684
00:29:04,470 --> 00:29:07,679
some of that faint detail in that faint

685
00:29:05,970 --> 00:29:09,690
structure and the galaxies the the dust

686
00:29:07,679 --> 00:29:11,910
structure but because we stayed with a

687
00:29:09,690 --> 00:29:13,410
linear scaling we've sacrificed the

688
00:29:11,910 --> 00:29:14,970
cores of the galaxies and the cores of

689
00:29:13,410 --> 00:29:17,460
these bright stars now they're all blown

690
00:29:14,970 --> 00:29:20,190
out and we've we've lost we've lost data

691
00:29:17,460 --> 00:29:22,319
by doing this this is a completely

692
00:29:20,190 --> 00:29:25,350
saturated to white so you've lost that

693
00:29:22,319 --> 00:29:27,359
data so we need to do a nonlinear

694
00:29:25,349 --> 00:29:30,209
transformation to the image to be able

695
00:29:27,359 --> 00:29:32,250
to recover the details in those cores

696
00:29:30,210 --> 00:29:34,710
but also be able to see the structure

697
00:29:32,250 --> 00:29:36,089
the faint structure in those galaxies so

698
00:29:34,710 --> 00:29:37,798
a nonlinear transformation like a

699
00:29:36,089 --> 00:29:40,288
logarithmic transformation onto the

700
00:29:37,798 --> 00:29:41,819
image will allow you to see the full

701
00:29:40,288 --> 00:29:44,970
range of brightness from darkest to

702
00:29:41,819 --> 00:29:47,220
bright without sacrificing anything so

703
00:29:44,970 --> 00:29:50,940
this is a key first step in in working

704
00:29:47,220 --> 00:29:52,529
on these these data and an example of a

705
00:29:50,940 --> 00:29:53,640
tool that you could use to do this kind

706
00:29:52,529 --> 00:29:55,649
of thing is this is called fits

707
00:29:53,640 --> 00:29:58,530
Liberator it's available for free from

708
00:29:55,650 --> 00:30:00,120
the Space Telescope org I don't actually

709
00:29:58,529 --> 00:30:01,889
use this tool I use something called pix

710
00:30:00,119 --> 00:30:05,069
insight if you're an astronaut odd refer

711
00:30:01,890 --> 00:30:06,419
you may be familiar with that basically

712
00:30:05,069 --> 00:30:08,369
all this does is it allows you to do

713

00:30:06,419 --> 00:30:10,130
that kind of transformation that kind of

714
00:30:08,369 --> 00:30:12,449
nonlinear transformation to your data

715
00:30:10,130 --> 00:30:14,070
you basically select the stretch

716
00:30:12,450 --> 00:30:16,019
function here so in this case it's an

717
00:30:14,069 --> 00:30:18,450
arc sine function which is a nonlinear

718
00:30:16,019 --> 00:30:19,970
transformation and then in here you see

719
00:30:18,450 --> 00:30:23,009
the histogram which is basically just

720
00:30:19,970 --> 00:30:25,339
showing you the intensity values from

721
00:30:23,009 --> 00:30:28,650
dark to bright across the whole image

722
00:30:25,339 --> 00:30:30,689
okay so there's a lot of really dark

723
00:30:28,650 --> 00:30:31,980
stuff and then a tip there's a long tail

724
00:30:30,690 --> 00:30:33,240
to the bright stuff so the brightest

725
00:30:31,980 --> 00:30:34,860
things are these stars and then

726
00:30:33,240 --> 00:30:37,500
everything else sort of shows up in the

727
00:30:34,859 --> 00:30:39,089

in the darkest range and so you can now

728
00:30:37,500 --> 00:30:40,859
stretch that out and then you can change

729
00:30:39,089 --> 00:30:42,980
your white and black points to suit your

730
00:30:40,859 --> 00:30:45,149
needs

731
00:30:42,980 --> 00:30:47,970
so now thinking about color and

732
00:30:45,150 --> 00:30:51,450
composite color this is how we get color

733
00:30:47,970 --> 00:30:52,950
from these images Hubble takes images in

734
00:30:51,450 --> 00:30:55,019
different filters and those filters

735
00:30:52,950 --> 00:30:57,840
allow certain wavelengths of light to

736
00:30:55,019 --> 00:31:00,029
pass through to create images specific

737
00:30:57,839 --> 00:31:01,980
to those wavelengths so when we look

738
00:31:00,029 --> 00:31:03,389
through color filters we see color but

739
00:31:01,980 --> 00:31:05,548
Hubble's detectors see in black and

740
00:31:03,390 --> 00:31:06,780
white and so the images that we get from

741
00:31:05,548 --> 00:31:09,418
the telescope are black and white

742
00:31:06,779 --> 00:31:12,539
we need to apply color after the fact to

743
00:31:09,419 --> 00:31:14,070
make a color image and so for the exam

744
00:31:12,539 --> 00:31:16,730
that we were looking at this is Stefan's

745
00:31:14,069 --> 00:31:19,740
quintet this is what we call a natural

746
00:31:16,730 --> 00:31:23,099
broadband color the three filters that

747
00:31:19,740 --> 00:31:24,779
are here are basically red green and

748
00:31:23,099 --> 00:31:26,490
blue essentially since the sensitivity

749
00:31:24,779 --> 00:31:29,579
of our eyes that's why we call it

750
00:31:26,490 --> 00:31:30,990
natural color each filter covers a sort

751
00:31:29,579 --> 00:31:32,970
of a broad wavelength range

752
00:31:30,990 --> 00:31:36,599
corresponding to blue light green light

753
00:31:32,970 --> 00:31:38,220
and red light so we take these data

754
00:31:36,599 --> 00:31:40,289
we've scaled them now appropriately with

755
00:31:38,220 --> 00:31:42,630
a nonlinear transformation now we apply

756
00:31:40,289 --> 00:31:45,720
color to them according to their

757
00:31:42,630 --> 00:31:47,970
wavelengths in the filters and then we

758
00:31:45,720 --> 00:31:48,630
combine them together in image editing

759
00:31:47,970 --> 00:31:52,769
software

760
00:31:48,630 --> 00:31:55,200
maybe Photoshop and you get this now

761
00:31:52,769 --> 00:31:58,829
this isn't the end of the story this is

762
00:31:55,200 --> 00:32:00,690
where the the more subjective aesthetics

763
00:31:58,829 --> 00:32:03,149
come into play so the photographer's eye

764
00:32:00,690 --> 00:32:06,029
becomes important here to be able to

765
00:32:03,150 --> 00:32:08,700
notice if there's a color cast in this

766
00:32:06,029 --> 00:32:10,170
image if there are things that are that

767
00:32:08,700 --> 00:32:11,430
need to be cleaned up a lot of times

768
00:32:10,170 --> 00:32:14,910
there are artifacts in these images

769
00:32:11,430 --> 00:32:16,799
there are cosmic rays there are ghosts

770

00:32:14,910 --> 00:32:17,910
from reflect internal reflections of the

771
00:32:16,799 --> 00:32:19,440
telescope and all these things have to

772
00:32:17,910 --> 00:32:22,920
be taken out of the image for for a

773
00:32:19,440 --> 00:32:25,140
press release and so after cleaning all

774
00:32:22,920 --> 00:32:27,660
that up and adjusting contrast and

775
00:32:25,140 --> 00:32:31,110
tonality we get we arrive at the the

776
00:32:27,660 --> 00:32:32,700
clean press release image using the the

777
00:32:31,109 --> 00:32:35,189
full tonal range and preserving as much

778
00:32:32,700 --> 00:32:37,890
of the color to show off all of the

779
00:32:35,190 --> 00:32:39,600
important structures in the image so for

780
00:32:37,890 --> 00:32:42,150
example that the galaxy the foreground

781
00:32:39,599 --> 00:32:44,579
galaxy here these bright red regions are

782
00:32:42,150 --> 00:32:46,500
they're called h2 regions their pockets

783
00:32:44,579 --> 00:32:48,299
of hydrogen gas where stars are forming

784
00:32:46,500 --> 00:32:50,009

and we want to be able to see that

785
00:32:48,299 --> 00:32:53,399
clearly in the image and so it's

786
00:32:50,009 --> 00:32:55,740
processed to show that now looking at

787
00:32:53,400 --> 00:32:59,190
another type of image that Hubble will

788
00:32:55,740 --> 00:33:02,700
typically take data on is a narrowband

789
00:32:59,190 --> 00:33:04,019
image and now this is similar to what we

790
00:33:02,700 --> 00:33:06,450
were just talking about within the

791
00:33:04,019 --> 00:33:08,970
natural color only with narrow bands the

792
00:33:06,450 --> 00:33:11,250
filters that we use are looking at very

793
00:33:08,970 --> 00:33:14,120
specific wavelengths very small regions

794
00:33:11,250 --> 00:33:16,259
of the electromagnetic spectrum and

795
00:33:14,119 --> 00:33:17,789
we're taking an image and each one of

796
00:33:16,259 --> 00:33:20,099
those filters and now combining them

797
00:33:17,789 --> 00:33:22,319
together to make a color image but

798
00:33:20,099 --> 00:33:26,189
unlike before where we had the sort of

799
00:33:22,319 --> 00:33:28,289
natural transmen translation from

800
00:33:26,190 --> 00:33:30,299
red green and blue based on the filters

801
00:33:28,289 --> 00:33:32,609
in this case these filters that

802
00:33:30,299 --> 00:33:34,799
correspond to oxygen hydrogen and sulfur

803
00:33:32,609 --> 00:33:37,019
if I were to color them according to

804
00:33:34,799 --> 00:33:39,509
where they actually exist on the visible

805
00:33:37,019 --> 00:33:42,359
spectrum you would basically get cyan

806
00:33:39,509 --> 00:33:45,259
red and slightly more red which creates

807
00:33:42,359 --> 00:33:48,569
this image which is kind of ugly and

808
00:33:45,259 --> 00:33:50,099
doesn't actually tell you a lot it's

809
00:33:48,569 --> 00:33:51,960
it's aesthetically it's not very nice

810
00:33:50,099 --> 00:33:54,750
but it also doesn't really reveal the

811
00:33:51,960 --> 00:33:59,850
true beauty and the true depth of the

812
00:33:54,750 --> 00:34:02,339
data so instead of using the the colors

813
00:33:59,849 --> 00:34:04,819
as they're assigned in the spectrum we

814
00:34:02,339 --> 00:34:08,880
can apply this sort of RGB mentality to

815
00:34:04,819 --> 00:34:11,219
shift wavelengths shift the filters and

816
00:34:08,880 --> 00:34:12,480
apply blue green and red to these as

817
00:34:11,219 --> 00:34:14,039
well as long as it's chromatically

818
00:34:12,480 --> 00:34:15,960
ordered so that the shortest wavelengths

819
00:34:14,039 --> 00:34:18,889
get blue and the longest wavelengths get

820
00:34:15,960 --> 00:34:22,980
red and then green comes in the middle

821
00:34:18,889 --> 00:34:25,980
so now oxygen becomes pure blue hydrogen

822
00:34:22,980 --> 00:34:27,179
becomes green and sulfur stays red but

823
00:34:25,980 --> 00:34:29,090
when you combine them together this way

824
00:34:27,179 --> 00:34:31,410
you get this much more pleasing

825
00:34:29,090 --> 00:34:32,789
composite image that actually reveals

826
00:34:31,409 --> 00:34:34,619
more detail because you've now created

827

00:34:32,789 --> 00:34:36,570
an image that has a fuller color range

828
00:34:34,619 --> 00:34:39,299
in it it allows more of the data to show

829
00:34:36,570 --> 00:34:41,610
off I mean I would argue that the the

830
00:34:39,300 --> 00:34:44,610
wispy details surrounding the nebula

831
00:34:41,610 --> 00:34:48,390
here are much more apparent in the image

832
00:34:44,610 --> 00:34:49,620
that's RGB and of course this is the

833
00:34:48,389 --> 00:34:50,179
Eagle Nebula I probably should have led

834
00:34:49,619 --> 00:34:55,099
with that

835
00:34:50,179 --> 00:34:57,119
the famous pillars of creation image and

836
00:34:55,099 --> 00:35:00,599
then there's the post-processing steps

837
00:34:57,119 --> 00:35:03,059
so here is the that the basic color

838
00:35:00,599 --> 00:35:06,089
combination RG and B from those narrow

839
00:35:03,059 --> 00:35:06,659
band filters but that's not the end of

840
00:35:06,090 --> 00:35:09,390
the story

841
00:35:06,659 --> 00:35:10,710

we will now want to take away the color

842
00:35:09,389 --> 00:35:12,420
casts we want to do additional

843
00:35:10,710 --> 00:35:14,909
processing we want to brighten it we

844
00:35:12,420 --> 00:35:16,409
want to highlight different features the

845
00:35:14,909 --> 00:35:18,869
stars look a little strange let's take

846
00:35:16,409 --> 00:35:20,789
some of that red out of the stars let's

847
00:35:18,869 --> 00:35:23,460
emphasize the structure of the the

848
00:35:20,789 --> 00:35:25,650
pillars of creation themselves balance

849
00:35:23,460 --> 00:35:28,019
the color better pull out the shadow

850
00:35:25,650 --> 00:35:30,869
details as much as we can and then crop

851
00:35:28,019 --> 00:35:33,630
it and that's just work the composition

852
00:35:30,869 --> 00:35:35,639
comes into play these images are these

853
00:35:33,630 --> 00:35:37,140
are objects in space there's no up or

854
00:35:35,639 --> 00:35:39,289
down although astronomers will argue

855
00:35:37,139 --> 00:35:39,289
with that

856
00:35:39,610 --> 00:35:45,079
it must be Northup it doesn't have to be

857
00:35:42,920 --> 00:35:47,349
Northup it can be any orientation that

858
00:35:45,079 --> 00:35:49,849
works aesthetically if we want it to be

859
00:35:47,349 --> 00:35:53,059
so that's where the photographer's eye

860
00:35:49,849 --> 00:35:54,440
again comes into play so now I'd like to

861
00:35:53,059 --> 00:35:55,639
shift a little bit from what we've been

862
00:35:54,440 --> 00:35:58,159
talking about with Hubble into more

863
00:35:55,639 --> 00:35:59,779
multi-wavelength astronomy and before I

864
00:35:58,159 --> 00:36:01,250
do that I just want to give you a quick

865
00:35:59,780 --> 00:36:02,720
refresher on the electromagnetic

866
00:36:01,250 --> 00:36:04,039
spectrum I've been talking about it a

867
00:36:02,719 --> 00:36:06,739
lot but I never actually showed this

868
00:36:04,039 --> 00:36:07,789
this graph I'm sure most of you are

869
00:36:06,739 --> 00:36:10,039
familiar with the electromagnetic

870
00:36:07,789 --> 00:36:13,940
spectrum this is light in all its forms

871
00:36:10,039 --> 00:36:15,650
from the the lowest energy longest

872
00:36:13,940 --> 00:36:17,360
wavelengths up to the highest energy

873
00:36:15,650 --> 00:36:19,550
shortest wavelengths so radio microwave

874
00:36:17,360 --> 00:36:21,710
infrared visible light UV x-ray gamma

875
00:36:19,550 --> 00:36:23,720
ray it's all there this is everything

876
00:36:21,710 --> 00:36:24,980
all that we well not that all that we

877
00:36:23,719 --> 00:36:27,289
see all that we see is just that little

878
00:36:24,980 --> 00:36:28,699
bit in the middle and that's because our

879
00:36:27,289 --> 00:36:30,079
eyes have evolved on a planet that

880
00:36:28,699 --> 00:36:33,799
orbits a star that emits most of its

881
00:36:30,079 --> 00:36:35,539
light in the visible wavelengths so as

882
00:36:33,800 --> 00:36:36,590
I'm showing these images in the

883
00:36:35,539 --> 00:36:38,300
following slides I'm gonna have this

884

00:36:36,590 --> 00:36:40,970
handy little guide here to tell you

885
00:36:38,300 --> 00:36:42,830
which wavelengths of light are actually

886
00:36:40,969 --> 00:36:44,529
shown in that image and how they're

887
00:36:42,829 --> 00:36:46,610
colored so keep an eye out for that

888
00:36:44,530 --> 00:36:49,100
before I show the images that I want to

889
00:36:46,610 --> 00:36:53,059
just review quickly the NASA's Great

890
00:36:49,099 --> 00:36:55,219
observatories program this was NASA's

891
00:36:53,059 --> 00:36:58,429
attempt to to really broaden our

892
00:36:55,219 --> 00:36:59,809
horizons visually speaking to take in as

893
00:36:58,429 --> 00:37:02,899
much light as possible in all the

894
00:36:59,809 --> 00:37:04,369
different wavelength ranges and they

895
00:37:02,900 --> 00:37:05,900
have to be for most part they have to be

896
00:37:04,369 --> 00:37:09,650
space-based observatories because

897
00:37:05,900 --> 00:37:12,860
Earth's atmosphere is opaque to most of

898
00:37:09,650 --> 00:37:14,059

these high-energy most of the

899
00:37:12,860 --> 00:37:15,890
high-energy part of the electromagnetic

900
00:37:14,059 --> 00:37:18,049
spectrum gamma rays x-rays they're all

901
00:37:15,889 --> 00:37:21,949
and UV are mostly absorbed by our

902
00:37:18,050 --> 00:37:23,480
atmosphere which is good for us in the

903
00:37:21,949 --> 00:37:25,189
infrared is also mostly absorbed by the

904
00:37:23,480 --> 00:37:26,599
atmosphere and so we have to put these

905
00:37:25,190 --> 00:37:29,059
observatories up in space above our

906
00:37:26,599 --> 00:37:31,039
atmosphere of course with Hubble it's it

907
00:37:29,059 --> 00:37:32,840
really helps to have the telescope up in

908
00:37:31,039 --> 00:37:34,250
space because even though the atmosphere

909
00:37:32,840 --> 00:37:38,890
it lets visible light through it does

910
00:37:34,250 --> 00:37:41,090
distort it so NASA's Great observatories

911
00:37:38,889 --> 00:37:44,269
include the Compton gamma ray

912
00:37:41,090 --> 00:37:47,600
Observatory which was launched in 1991

913
00:37:44,269 --> 00:37:49,309
and operated until 2000 the Chandra

914
00:37:47,599 --> 00:37:51,860
x-ray Observatory which is this year

915
00:37:49,309 --> 00:37:52,969
celebrating 20 years in orbit Hubble

916
00:37:51,860 --> 00:37:55,910
Space Telescope which is

917
00:37:52,969 --> 00:37:58,429
29 years in orbit and the Spitzer Space

918
00:37:55,909 --> 00:38:00,769
Telescope which was launched in 2003 and

919
00:37:58,429 --> 00:38:05,779
is supposed to be shut down in January

920
00:38:00,769 --> 00:38:06,800
so why would why don't we want to look

921
00:38:05,780 --> 00:38:11,119
at the universe in multiple wavelengths

922
00:38:06,800 --> 00:38:13,640
I like to make this analogy to listening

923
00:38:11,119 --> 00:38:14,780
to an orchestra and imagine that you're

924
00:38:13,639 --> 00:38:17,659
listening to the orchestra but you can

925
00:38:14,780 --> 00:38:18,970
only hear a brass section it's gonna be

926
00:38:17,659 --> 00:38:21,199
a very different experience

927
00:38:18,969 --> 00:38:22,579
similarly when we're looking in space

928
00:38:21,199 --> 00:38:24,769
and we're trying to observe the universe

929
00:38:22,579 --> 00:38:26,989
and understand it it really helps to

930
00:38:24,769 --> 00:38:28,009
look and as many wavelengths as possible

931
00:38:26,989 --> 00:38:31,189
because there's a lot more information

932
00:38:28,010 --> 00:38:34,070
there so let's look at something in

933
00:38:31,190 --> 00:38:36,139
x-ray light now we're in high energies

934
00:38:34,070 --> 00:38:39,140
we shift it into high gear this is

935
00:38:36,139 --> 00:38:41,059
Cassiopeia A and it's an x-ray image in

936
00:38:39,139 --> 00:38:42,949
red green and blue so following a

937
00:38:41,059 --> 00:38:44,529
similar coloring pattern to what I

938
00:38:42,949 --> 00:38:47,299
showed you with the narrowband imaging

939
00:38:44,530 --> 00:38:49,700
now we're applying that concept to x-ray

940
00:38:47,300 --> 00:38:51,320
light we're breaking it down into low

941

00:38:49,699 --> 00:38:53,929
medium and high energy x-rays and

942
00:38:51,320 --> 00:38:55,580
applying red green and blue colors to

943
00:38:53,929 --> 00:38:57,799
those images and when you put that all

944
00:38:55,579 --> 00:39:01,130
together you get this amazing image of a

945
00:38:57,800 --> 00:39:02,900
supernova remnant where this bright spot

946
00:39:01,130 --> 00:39:05,180
here is a neutron star that's left over

947
00:39:02,900 --> 00:39:07,940
after the explosion a supernova of a

948
00:39:05,179 --> 00:39:10,730
star all of that material was blasted

949
00:39:07,940 --> 00:39:13,400
off into space and is emitting x-rays

950
00:39:10,730 --> 00:39:15,380
it's very hot and there are blast waves

951
00:39:13,400 --> 00:39:17,660
moving outward and there's one moving

952
00:39:15,380 --> 00:39:19,450
inwards called a reverse shock the

953
00:39:17,659 --> 00:39:21,739
highest-energy x-rays which are blue

954
00:39:19,449 --> 00:39:23,569
surrounds all of the material inside

955
00:39:21,739 --> 00:39:25,639

that's the shockwave moving out into

956
00:39:23,570 --> 00:39:27,950
space there's even this cool jet

957
00:39:25,639 --> 00:39:29,509
shooting out to the side here that's

958
00:39:27,949 --> 00:39:31,460
mostly green light that actually

959
00:39:29,510 --> 00:39:34,130
corresponds to iron that's emitting

960
00:39:31,460 --> 00:39:36,440
x-rays and that's a really interesting

961
00:39:34,130 --> 00:39:38,660
feature some somehow the star when it

962
00:39:36,440 --> 00:39:40,220
exploded preferentially shot material

963
00:39:38,659 --> 00:39:43,489
out in one direction and that became the

964
00:39:40,219 --> 00:39:45,739
jet moving in that direction but now we

965
00:39:43,489 --> 00:39:47,179
can apply this multi-wavelength concept

966
00:39:45,739 --> 00:39:50,118
to it and bring in Hubble Space

967
00:39:47,179 --> 00:39:52,489
Telescope data and if I take away the

968
00:39:50,119 --> 00:39:54,940
x-ray data we get a very different

969
00:39:52,489 --> 00:39:58,069
understanding of the supernova remnant

970
00:39:54,940 --> 00:39:59,539
most of what we're seeing here traces a

971
00:39:58,070 --> 00:40:02,180
lot of what we saw in the x-rays but

972
00:39:59,539 --> 00:40:04,699
leaves a lot out too this is oxygen

973
00:40:02,179 --> 00:40:06,259
mostly oxygen that's emitting it's

974
00:40:04,699 --> 00:40:11,269
radiating and visit

975
00:40:06,260 --> 00:40:14,900
wavelengths but also an x-ray we were

976
00:40:11,269 --> 00:40:16,369
back to the x-ray here's another one of

977
00:40:14,900 --> 00:40:21,079
my favorites this the Whirlpool Galaxy

978
00:40:16,369 --> 00:40:25,279
and what we're looking at here is the

979
00:40:21,079 --> 00:40:28,069
full color natural color broadband red

980
00:40:25,280 --> 00:40:31,730
green and blue optical image and x-rays

981
00:40:28,070 --> 00:40:33,230
overlaid in purple and now this is a

982
00:40:31,730 --> 00:40:34,880
this is of just a beautiful spiral

983
00:40:33,230 --> 00:40:36,530
galaxy that we many people are familiar

984
00:40:34,880 --> 00:40:38,930
with with that's been a very famous

985
00:40:36,530 --> 00:40:41,300
Hubble image full of these h2 regions

986
00:40:38,929 --> 00:40:43,789
these regions of star formation full of

987
00:40:41,300 --> 00:40:46,310
blue stars lots of intricate dust lanes

988
00:40:43,789 --> 00:40:48,679
moving out and it's spiral but when we

989
00:40:46,309 --> 00:40:51,619
look at it in the solely in x-rays we

990
00:40:48,679 --> 00:40:53,539
see a very different view mainly what

991
00:40:51,619 --> 00:40:56,089
we're looking at here is hot gas the hot

992
00:40:53,539 --> 00:40:58,059
gas between stars and all the points

993
00:40:56,090 --> 00:41:01,490
sources here most of those are actually

994
00:40:58,059 --> 00:41:04,699
black holes or x-ray binaries neutron

995
00:41:01,489 --> 00:41:06,559
saw our black hole binaries and of

996
00:41:04,699 --> 00:41:10,099
course there's the supermassive black

997
00:41:06,559 --> 00:41:11,360
hole at the center of the the Whirlpool

998

00:41:10,099 --> 00:41:12,980
Galaxy as well that we're seeing in

999
00:41:11,360 --> 00:41:14,300
x-ray light so all of this is this is

1000
00:41:12,980 --> 00:41:15,590
very high-energy phenomena that's

1001
00:41:14,300 --> 00:41:18,410
emitting x-rays and we're seeing that

1002
00:41:15,590 --> 00:41:20,030
here and now we can also apply the three

1003
00:41:18,409 --> 00:41:22,849
color method to this and get even more

1004
00:41:20,030 --> 00:41:24,560
information from the x-ray data and so

1005
00:41:22,849 --> 00:41:25,880
now we're seeing that most of that hot

1006
00:41:24,559 --> 00:41:28,070
gas that we're looking at is actually

1007
00:41:25,880 --> 00:41:29,720
emitting low-energy x-rays and it's

1008
00:41:28,070 --> 00:41:32,480
those point sources that are really the

1009
00:41:29,719 --> 00:41:38,089
really super energetic bright white

1010
00:41:32,480 --> 00:41:39,860
lights of this in this galaxy now moving

1011
00:41:38,090 --> 00:41:41,930
on so one of my favorite images that I

1012
00:41:39,860 --> 00:41:45,920

one of the first images I worked on when

1013
00:41:41,929 --> 00:41:48,289
I came over to space telescope the Crab

1014
00:41:45,920 --> 00:41:49,639
Nebula so this is a supernova remnant

1015
00:41:48,289 --> 00:41:52,489
another supernova remnant they're my

1016
00:41:49,639 --> 00:41:54,730
favorite in the constellation of Taurus

1017
00:41:52,489 --> 00:41:57,319
it's about 6,500 light years away and

1018
00:41:54,730 --> 00:41:58,550
this image is actually made up of five

1019
00:41:57,320 --> 00:42:00,260
different wavelengths of light

1020
00:41:58,550 --> 00:42:03,560
all combined together so now we're kind

1021
00:42:00,260 --> 00:42:05,840
of taking our concept of three color and

1022
00:42:03,559 --> 00:42:07,429
playing around with it and when I made

1023
00:42:05,840 --> 00:42:10,400
this image I really was thinking that

1024
00:42:07,429 --> 00:42:12,079
way I was like I have this concept for

1025
00:42:10,400 --> 00:42:14,809
how to put together images with three

1026
00:42:12,079 --> 00:42:16,670
with 3m and three component images red

1027
00:42:14,809 --> 00:42:18,619
green and blue how can we apply that to

1028
00:42:16,670 --> 00:42:20,059
something that has more more than three

1029
00:42:18,619 --> 00:42:23,089
channels to it

1030
00:42:20,059 --> 00:42:24,980
well basically I just took the color

1031
00:42:23,090 --> 00:42:27,340
wheel and broke it down I just divided

1032
00:42:24,980 --> 00:42:31,610
it by five and so then you get steps of

1033
00:42:27,340 --> 00:42:34,340
72 per color so the lowest wavelength

1034
00:42:31,610 --> 00:42:39,380
radio data gets read and then you move

1035
00:42:34,340 --> 00:42:41,800
up 72 color units into the green sort of

1036
00:42:39,380 --> 00:42:44,869
orangish green to get to infra red and

1037
00:42:41,800 --> 00:42:48,200
then optical and an ultraviolet and

1038
00:42:44,869 --> 00:42:50,299
x-ray so it's really basically a simple

1039
00:42:48,199 --> 00:42:53,210
application of this this idea of how to

1040
00:42:50,300 --> 00:42:55,340
apply color to the data and now we can

1041
00:42:53,210 --> 00:42:57,769
step through each one and see in the

1042
00:42:55,340 --> 00:42:59,630
Crab Nebula this is a neutron star

1043
00:42:57,769 --> 00:43:01,880
pulsar at the centre here again it's

1044
00:42:59,630 --> 00:43:03,559
another supernova remnant there's a disk

1045
00:43:01,880 --> 00:43:04,880
of material swirling around this and

1046
00:43:03,559 --> 00:43:07,489
this is again all x-rays are very

1047
00:43:04,880 --> 00:43:08,720
high-energy this material swirling

1048
00:43:07,489 --> 00:43:10,519
around the star there are jets coming

1049
00:43:08,719 --> 00:43:12,619
out of it and it's basically the heart

1050
00:43:10,519 --> 00:43:14,059
the engine of this whole supernova

1051
00:43:12,619 --> 00:43:17,089
remnant it's just a radiating everything

1052
00:43:14,059 --> 00:43:19,670
around it so as we step down an energy

1053
00:43:17,090 --> 00:43:22,100
shift in wavelengths now we're looking

1054
00:43:19,670 --> 00:43:24,980
at ultraviolet light and that starts to

1055

00:43:22,099 --> 00:43:28,279
show more of the interior of the nebulas

1056
00:43:24,980 --> 00:43:29,869
structure surrounding the Pulsar now

1057
00:43:28,280 --> 00:43:31,700
with Hubble and it's superb resolution

1058
00:43:29,869 --> 00:43:33,079
we're seeing filaments of material that

1059
00:43:31,699 --> 00:43:36,079
were ejected from that star and are

1060
00:43:33,079 --> 00:43:37,549
being irradiated by that core and you

1061
00:43:36,079 --> 00:43:40,429
can kind of see a ghost of that core

1062
00:43:37,550 --> 00:43:42,170
here this sort of ghostly glow in the

1063
00:43:40,429 --> 00:43:44,389
middle here that's again coming from

1064
00:43:42,170 --> 00:43:48,590
that neutron star and it's and it's

1065
00:43:44,389 --> 00:43:49,909
swirling disc of material as we shift

1066
00:43:48,590 --> 00:43:52,130
down to longer wavelengths lower

1067
00:43:49,909 --> 00:43:54,079
energies now we're looking at warm dust

1068
00:43:52,130 --> 00:43:56,300
so this is kind of tracing those

1069
00:43:54,079 --> 00:43:57,529

filaments as well and the only gets a

1070
00:43:56,300 --> 00:44:00,620
radio wavelengths we're actually looking

1071
00:43:57,530 --> 00:44:02,180
at more of we're getting an

1072
00:44:00,619 --> 00:44:04,279
understanding of the magnetic fields

1073
00:44:02,179 --> 00:44:06,469
that are constraining all of the

1074
00:44:04,280 --> 00:44:08,090
material in the supernova remnant and so

1075
00:44:06,469 --> 00:44:10,579
now this is a really great example of

1076
00:44:08,090 --> 00:44:12,350
why it matters to look at the universe

1077
00:44:10,579 --> 00:44:13,639
and multiple wavelengths having all of

1078
00:44:12,349 --> 00:44:14,779
this information and being able to see

1079
00:44:13,639 --> 00:44:16,609
it all at once gives you a much

1080
00:44:14,780 --> 00:44:19,510
different picture of what's happening

1081
00:44:16,610 --> 00:44:19,510
with this object

1082
00:44:21,539 --> 00:44:25,469
now here's a really good one I just put

1083
00:44:23,550 --> 00:44:28,230
this in here yesterday this is a press

1084
00:44:25,469 --> 00:44:31,259
release from yesterday of Etta karena

1085
00:44:28,230 --> 00:44:34,559
this is 7,500 light-years away in the

1086
00:44:31,260 --> 00:44:36,510
Carina constellation and basically

1087
00:44:34,559 --> 00:44:38,190
there's there was an explosion about 170

1088
00:44:36,510 --> 00:44:40,140
years ago and there's this sort of

1089
00:44:38,190 --> 00:44:41,730
bipolar outflow coming out there was

1090
00:44:40,139 --> 00:44:44,849
there was a triple star system we think

1091
00:44:41,730 --> 00:44:46,590
maybe one of the stars absorbed the

1092
00:44:44,849 --> 00:44:48,659
other star and created this explosion so

1093
00:44:46,590 --> 00:44:50,400
now there's a binary system in here the

1094
00:44:48,659 --> 00:44:51,899
really interesting thing about this new

1095
00:44:50,400 --> 00:44:55,099
image that just came out yesterday and

1096
00:44:51,900 --> 00:44:59,639
it's a celebration of the 4th of July

1097
00:44:55,099 --> 00:45:02,549
the blue data here this is all new this

1098
00:44:59,639 --> 00:45:05,069
was just taken last year and it's it's

1099
00:45:02,550 --> 00:45:06,660
highlighting magnesium and I should say

1100
00:45:05,070 --> 00:45:07,830
this is a just as just Hubble data this

1101
00:45:06,659 --> 00:45:09,739
is just an optical image we're not

1102
00:45:07,829 --> 00:45:12,449
looking at x-rays or anything like that

1103
00:45:09,739 --> 00:45:15,359
but this was the first time that we were

1104
00:45:12,449 --> 00:45:17,609
able to see material sort of between the

1105
00:45:15,360 --> 00:45:18,930
we call this the homunculus between the

1106
00:45:17,610 --> 00:45:21,720
homunculus and then the surrounding

1107
00:45:18,929 --> 00:45:23,099
nebula in the red we always thought

1108
00:45:21,719 --> 00:45:24,869
there was sort of this gap between the

1109
00:45:23,099 --> 00:45:29,400
two but now it's actually filled in with

1110
00:45:24,869 --> 00:45:30,989
magnesium magnesium light and it was

1111
00:45:29,400 --> 00:45:34,110
made possible by taking a really deep

1112

00:45:30,989 --> 00:45:35,729
look at this object in that filter which

1113
00:45:34,110 --> 00:45:38,280
is an ultraviolet so it's a pretty

1114
00:45:35,730 --> 00:45:40,289
high-energy filter and Hubble terms and

1115
00:45:38,280 --> 00:45:42,420
it has implications for our

1116
00:45:40,289 --> 00:45:44,130
understanding of these kinds of objects

1117
00:45:42,420 --> 00:45:45,990
elsewhere in the universe you know I've

1118
00:45:44,130 --> 00:45:47,789
been talking about these h2 regions and

1119
00:45:45,989 --> 00:45:49,709
galaxies these red dots that sort of

1120
00:45:47,789 --> 00:45:51,480
highlight star formation well it's

1121
00:45:49,710 --> 00:45:53,789
possible that there are these magnitude

1122
00:45:51,480 --> 00:45:56,610
regions elsewhere as well to kind of

1123
00:45:53,789 --> 00:45:59,820
highlight another another aspect of this

1124
00:45:56,610 --> 00:46:00,990
kind of formation and one thing I've

1125
00:45:59,820 --> 00:46:02,460
wanted to do with this which is really

1126
00:46:00,989 --> 00:46:04,619

fun and I could do this for any image

1127
00:46:02,460 --> 00:46:07,139
but I thought this would be cool let's

1128
00:46:04,619 --> 00:46:09,210
take a step back and see where this is

1129
00:46:07,139 --> 00:46:09,719
in the sky right there's the Milky Way

1130
00:46:09,210 --> 00:46:11,880
galaxy

1131
00:46:09,719 --> 00:46:13,709
this is a beautiful image made by a Nick

1132
00:46:11,880 --> 00:46:16,289
Reisinger he actually travelled the

1133
00:46:13,710 --> 00:46:18,389
world to take this image over the period

1134
00:46:16,289 --> 00:46:20,039
of about a year took images all around

1135
00:46:18,389 --> 00:46:21,779
the world and put together this stitch

1136
00:46:20,039 --> 00:46:23,340
together this huge panoramic image of

1137
00:46:21,780 --> 00:46:24,930
the Milky Way galaxy and this isn't even

1138
00:46:23,340 --> 00:46:27,780
the whole thing it's just a piece of it

1139
00:46:24,929 --> 00:46:29,909
but that region we were just looking at

1140
00:46:27,780 --> 00:46:33,060
is contained within that little box so

1141
00:46:29,909 --> 00:46:35,170
now let's zoom in on that box this is a

1142
00:46:33,059 --> 00:46:37,389
digitized Sky Survey

1143
00:46:35,170 --> 00:46:39,750
of that region so this is the Carina

1144
00:46:37,389 --> 00:46:42,129
Nebula here this sort of whole structure

1145
00:46:39,750 --> 00:46:45,190
now we can zoom it even further this

1146
00:46:42,130 --> 00:46:47,410
becomes like fractal this box here

1147
00:46:45,190 --> 00:46:50,019
corresponds to a famous Hubble press

1148
00:46:47,409 --> 00:46:52,750
release image from a few years ago the

1149
00:46:50,019 --> 00:46:55,869
Carina complex and now contained within

1150
00:46:52,750 --> 00:46:57,608
this image is at a Carina the image we

1151
00:46:55,869 --> 00:47:03,849
were just looking at in this little box

1152
00:46:57,608 --> 00:47:04,838
right here now we're back and since

1153
00:47:03,849 --> 00:47:06,130
we've been talking about multiple

1154
00:47:04,838 --> 00:47:09,159
wavelengths and multi-wavelength

1155
00:47:06,130 --> 00:47:11,349
astronomy let's back out and take a look

1156
00:47:09,159 --> 00:47:14,588
at it in this context when surrounded in

1157
00:47:11,349 --> 00:47:18,599
x-ray light so this is that same region

1158
00:47:14,588 --> 00:47:21,369
this is at a Carina now same color Khan

1159
00:47:18,599 --> 00:47:23,559
composite but now we've also overlaid it

1160
00:47:21,369 --> 00:47:25,869
with x-ray light and so the x-rays are

1161
00:47:23,559 --> 00:47:27,819
actually emitting sort of outside of

1162
00:47:25,869 --> 00:47:32,019
what we were looking at before this is

1163
00:47:27,818 --> 00:47:35,170
again it's hot gas and edit Carina the

1164
00:47:32,019 --> 00:47:37,750
Hubble image sits inside of that then we

1165
00:47:35,170 --> 00:47:41,139
can take that away you can see in three

1166
00:47:37,750 --> 00:47:43,059
color now that core there is really

1167
00:47:41,139 --> 00:47:45,909
high-energy x-ray it's blue light this

1168
00:47:43,059 --> 00:47:47,680
is a same kind of three color red green

1169

00:47:45,909 --> 00:47:50,348
and blue combination as I've been

1170
00:47:47,679 --> 00:47:51,759
talking about before so that core is

1171
00:47:50,349 --> 00:47:53,260
very highly energetic it's emitting a

1172
00:47:51,760 --> 00:47:55,089
lot of x-ray light and it's radiating

1173
00:47:53,260 --> 00:47:58,390
the surrounding material around it and

1174
00:47:55,088 --> 00:48:04,058
that's that's hot gas emitting x-rays

1175
00:47:58,389 --> 00:48:06,159
and at lower energies now let's shift

1176
00:48:04,059 --> 00:48:07,750
back down now we're looking in optical

1177
00:48:06,159 --> 00:48:09,909
light again this was a Hubble's

1178
00:48:07,750 --> 00:48:12,010
Anniversary image from last year 20th

1179
00:48:09,909 --> 00:48:15,608
anniversary image this is the Lagoon

1180
00:48:12,010 --> 00:48:18,640
Nebula or a Messier 8 and this is a

1181
00:48:15,608 --> 00:48:19,989
great example of Hubble's capabilities

1182
00:48:18,639 --> 00:48:21,670
as a multi wavelength observatory

1183
00:48:19,989 --> 00:48:26,078

because we also looked at it in infrared

1184
00:48:21,670 --> 00:48:28,269
light so that's the infrared view of

1185
00:48:26,079 --> 00:48:29,950
this same region of space when we look

1186
00:48:28,269 --> 00:48:32,139
at it in infrared we actually peer

1187
00:48:29,949 --> 00:48:34,750
through the dust and see the background

1188
00:48:32,139 --> 00:48:36,670
stars behind this nebula and only the

1189
00:48:34,750 --> 00:48:40,150
densest regions the densest clumps of

1190
00:48:36,670 --> 00:48:45,519
materials remain in infrared sort of

1191
00:48:40,150 --> 00:48:47,829
this ghostly glow of dust here and this

1192
00:48:45,519 --> 00:48:49,210
highlights the importance of the James

1193
00:48:47,829 --> 00:48:51,210
Webb Space Telescope

1194
00:48:49,210 --> 00:48:54,699
which will be launched in March of 2021

1195
00:48:51,210 --> 00:48:55,838
that is going to be an infrared

1196
00:48:54,699 --> 00:48:56,858
telescope looking at the universe and

1197
00:48:55,838 --> 00:48:59,380
infrared wavelengths

1198
00:48:56,858 --> 00:49:02,799
one of the main science drivers for the

1199
00:48:59,380 --> 00:49:04,750
Webb telescope is peering as far back as

1200
00:49:02,800 --> 00:49:06,910
possible to the farthest reaches of the

1201
00:49:04,750 --> 00:49:09,190
universe looking at the first galaxies

1202
00:49:06,909 --> 00:49:11,318
and the reason we need infrared to do

1203
00:49:09,190 --> 00:49:12,909
that is because those galaxies although

1204
00:49:11,318 --> 00:49:15,818
we look at them we look for certain

1205
00:49:12,909 --> 00:49:18,429
markers in optical wavelengths the

1206
00:49:15,818 --> 00:49:20,858
universe is expanding and its expansion

1207
00:49:18,429 --> 00:49:23,259
is accelerating and so the most distant

1208
00:49:20,858 --> 00:49:24,639
galaxies are emitting that light in

1209
00:49:23,260 --> 00:49:26,829
infrared wavelengths because they're

1210
00:49:24,639 --> 00:49:28,539
actually red shifted sort of like

1211
00:49:26,829 --> 00:49:30,339
Doppler shifting the light that's coming

1212
00:49:28,539 --> 00:49:31,659
out of them is being shifted into longer

1213
00:49:30,338 --> 00:49:33,068
and longer wavelengths and so the light

1214
00:49:31,659 --> 00:49:34,929
that we would typically look for to

1215
00:49:33,068 --> 00:49:37,358
study those galaxies has moved from

1216
00:49:34,929 --> 00:49:39,489
optical to infrared so now we need

1217
00:49:37,358 --> 00:49:41,710
something with Hubble's supervision that

1218
00:49:39,489 --> 00:49:47,558
can see an infrared and that's what the

1219
00:49:41,710 --> 00:49:49,960
James Webb Space Telescope will do so

1220
00:49:47,559 --> 00:49:53,650
what's it take home other than your

1221
00:49:49,960 --> 00:49:56,889
personal belongings light is more than

1222
00:49:53,650 --> 00:50:00,010
meets the eye it's information and it

1223
00:49:56,889 --> 00:50:02,199
surrounds us right now we are in a

1224
00:50:00,010 --> 00:50:04,270
golden age of astronomy we were looking

1225
00:50:02,199 --> 00:50:06,489
in every possible wavelength even beyond

1226

00:50:04,269 --> 00:50:08,019
the electromagnetic spectrum we now have

1227
00:50:06,489 --> 00:50:09,818
what's called multi messenger astronomy

1228
00:50:08,019 --> 00:50:11,949
we're understanding the universe in ways

1229
00:50:09,818 --> 00:50:13,389
we never thought possible gravitational

1230
00:50:11,949 --> 00:50:17,289
waves are giving us a new insight into

1231
00:50:13,389 --> 00:50:19,719
the universe light is the key to

1232
00:50:17,289 --> 00:50:21,730
understanding our universe and now I've

1233
00:50:19,719 --> 00:50:23,399
been talking about all these images the

1234
00:50:21,730 --> 00:50:25,510
way I've been applying color to them

1235
00:50:23,400 --> 00:50:27,519
specifically like the x-ray images you

1236
00:50:25,510 --> 00:50:29,819
may have heard the term false-color when

1237
00:50:27,519 --> 00:50:34,469
they're describing x-ray images right

1238
00:50:29,818 --> 00:50:38,500
don't listen to that false-color is bad

1239
00:50:34,469 --> 00:50:40,838
and that's the essence of the title

1240
00:50:38,500 --> 00:50:43,619

translating cosmic light is really about

1241
00:50:40,838 --> 00:50:46,058
the images and how they're created

1242
00:50:43,619 --> 00:50:48,460
translated or representational color is

1243
00:50:46,059 --> 00:50:51,280
the preferred nomenclature when

1244
00:50:48,460 --> 00:50:52,929
discussing these kinds of images the the

1245
00:50:51,280 --> 00:50:54,548
term false-color just perpetuates this

1246
00:50:52,929 --> 00:50:56,139
idea that the images are somehow fake

1247
00:50:54,548 --> 00:50:59,619
and we're making it up that it's not

1248
00:50:56,139 --> 00:51:01,690
real translated color is really what

1249
00:50:59,619 --> 00:51:03,140
we're doing we're taking stuff that like

1250
00:51:01,690 --> 00:51:04,789
that we can't see with our eyes and

1251
00:51:03,139 --> 00:51:07,819
leading it into something that we can

1252
00:51:04,789 --> 00:51:08,869
see and understand with our eyes and so

1253
00:51:07,820 --> 00:51:13,309
for more information

1254
00:51:08,869 --> 00:51:14,989
oh I need that leave this line Hubble

1255
00:51:13,309 --> 00:51:17,539
say doesn't look like this anymore but

1256
00:51:14,989 --> 00:51:20,959
this is where you can go for all latest

1257
00:51:17,539 --> 00:51:23,029
Hubble news and I also run a blog and

1258
00:51:20,960 --> 00:51:25,610
Frank also contributes to the blog

1259
00:51:23,030 --> 00:51:28,519
called illuminated universe where we

1260
00:51:25,610 --> 00:51:29,539
take a behind-the-scenes look at a lot

1261
00:51:28,519 --> 00:51:31,190
of like what I've been talking about

1262
00:51:29,539 --> 00:51:33,440
tonight sort of how the images come

1263
00:51:31,190 --> 00:51:35,090
about how they're created a lot of times

1264
00:51:33,440 --> 00:51:37,970
we make editorial decisions in our news

1265
00:51:35,090 --> 00:51:39,470
meetings where we've created certain

1266
00:51:37,969 --> 00:51:41,269
products that just don't fit the story

1267
00:51:39,469 --> 00:51:43,819
that we're trying to tell for that

1268
00:51:41,269 --> 00:51:45,320
particular press release but this gives

1269
00:51:43,820 --> 00:51:47,480
us an opportunity to put that

1270
00:51:45,320 --> 00:51:49,400
information out there as well there are

1271
00:51:47,480 --> 00:51:51,469
images that I've created that don't have

1272
00:51:49,400 --> 00:51:55,309
a home so eliminate universes where they

1273
00:51:51,469 --> 00:51:58,339
go and I hope you've enjoyed taking a

1274
00:51:55,309 --> 00:52:00,699
look at illuminate yours thanks I'll be

1275
00:51:58,340 --> 00:52:00,700
happy to

1276
00:52:00,889 --> 00:52:20,349
[Applause]

1277
00:52:09,239 --> 00:52:21,489
thank you hold up you gotta say it into

1278
00:52:20,349 --> 00:52:23,069
the Mike we have an online audience

1279
00:52:21,489 --> 00:52:26,079
ready

1280
00:52:23,070 --> 00:52:29,500
there's no web telescope is it only

1281
00:52:26,079 --> 00:52:33,219
infrared yes only infrared infrared

1282
00:52:29,500 --> 00:52:34,780
there okay yeah it overlaps a little bit

1283

00:52:33,219 --> 00:52:36,969
with what Hubble does because Hubble

1284
00:52:34,780 --> 00:52:57,250
goes out to infrared as well but it's a

1285
00:52:36,969 --> 00:52:59,409
it's an infrared telescope yeah so in

1286
00:52:57,250 --> 00:53:01,659
some images like would you prioritize

1287
00:52:59,409 --> 00:53:04,719
like a certain group of data more than

1288
00:53:01,659 --> 00:53:05,949
the others like if x-ray showed more of

1289
00:53:04,719 --> 00:53:13,449
what you were trying to get it and that

1290
00:53:05,949 --> 00:53:15,369
image would be like yes

1291
00:53:13,449 --> 00:53:18,699
so that eyes that has come up in the

1292
00:53:15,369 --> 00:53:20,230
past where the x-rays are telling a

1293
00:53:18,699 --> 00:53:21,909
certain story and actually what really

1294
00:53:20,230 --> 00:53:22,690
happens is sometimes when we're

1295
00:53:21,909 --> 00:53:23,980
combining all these different

1296
00:53:22,690 --> 00:53:25,720
wavelengths together we run into a

1297
00:53:23,980 --> 00:53:27,579

situation where we're over saturating

1298
00:53:25,719 --> 00:53:30,549
certain areas of the image and in those

1299
00:53:27,579 --> 00:53:33,039
cases I do I will take some some

1300
00:53:30,550 --> 00:53:34,870
liberties with adjusting the levels of

1301
00:53:33,039 --> 00:53:36,900
different components of the image so

1302
00:53:34,869 --> 00:53:39,759
that you can see everything that's there

1303
00:53:36,900 --> 00:53:43,000
yeah and you know I like what you should

1304
00:53:39,760 --> 00:53:45,640
cafe here where you know Hubble is good

1305
00:53:43,000 --> 00:53:51,099
in cafe but the x-rays are amazing in

1306
00:53:45,639 --> 00:53:52,779
gas a right that's so the it sometimes

1307
00:53:51,099 --> 00:53:54,429
when you give talks to public audiences

1308
00:53:52,780 --> 00:53:56,019
they're kind of surprised that you know

1309
00:53:54,429 --> 00:53:58,539
Hubble doesn't always have the most

1310
00:53:56,019 --> 00:54:00,070
beautiful image of an object right if

1311
00:53:58,539 --> 00:54:01,989
you go to other wavelengths you actually

1312
00:54:00,070 --> 00:54:07,900
see a lot more interest interesting

1313
00:54:01,989 --> 00:54:10,779
structure yeah in your experience what

1314
00:54:07,900 --> 00:54:13,660
has been the most remarkable discovery

1315
00:54:10,780 --> 00:54:16,090
in contrast to a hypothesis that you

1316
00:54:13,659 --> 00:54:20,118
have made when you have actually looked

1317
00:54:16,090 --> 00:54:23,869
at it in terms of different

1318
00:54:20,119 --> 00:54:26,660
I'm sure there but what's the most what

1319
00:54:23,869 --> 00:54:28,009
has blown you away the most I would say

1320
00:54:26,659 --> 00:54:30,588
that that Crab Nebula image that I

1321
00:54:28,009 --> 00:54:34,719
showed that really blew me away when I

1322
00:54:30,588 --> 00:54:34,719
pulled all the data together and saw

1323
00:54:35,768 --> 00:54:41,718
that yeah when I put it all together and

1324
00:54:39,650 --> 00:54:44,599
that showed up on the screen I just was

1325
00:54:41,719 --> 00:54:46,068
like in shock because I you know working

1326
00:54:44,599 --> 00:54:48,380
with the Chandra x-ray Observatory for

1327
00:54:46,068 --> 00:54:53,329
15 years I had seen the Crab Nebula many

1328
00:54:48,380 --> 00:54:55,068
many times and I always saw that that

1329
00:54:53,329 --> 00:54:56,660
was my view of the Crab Nebula and then

1330
00:54:55,068 --> 00:54:58,849
of course there was this amazing Hubble

1331
00:54:56,659 --> 00:55:01,159
image of the crab but seeing everything

1332
00:54:58,849 --> 00:55:02,390
from radio to x-ray all together in one

1333
00:55:01,159 --> 00:55:05,568
image just blew my mind

1334
00:55:02,389 --> 00:55:07,400
and as a scientist how much of a rush is

1335
00:55:05,568 --> 00:55:11,199
that I mean how many nights did you say

1336
00:55:07,400 --> 00:55:11,199
it going man that's so cool

1337
00:55:12,039 --> 00:55:17,420
we sometimes you know will admit that

1338
00:55:15,018 --> 00:55:20,508
yeah we do have a fun job yeah thank

1339
00:55:17,420 --> 00:55:23,509
Frank and I geeked out a lot I said we

1340

00:55:20,509 --> 00:55:26,748
have a question online which is sort of

1341
00:55:23,509 --> 00:55:29,659
the same it says which is his favourite

1342
00:55:26,748 --> 00:55:31,278
Hubble photo and I guess you could also

1343
00:55:29,659 --> 00:55:33,170
include Chandra in there to send you

1344
00:55:31,278 --> 00:55:35,449
you've worked Chandra more years and

1345
00:55:33,170 --> 00:55:39,438
you've worked robble I have but you know

1346
00:55:35,449 --> 00:55:40,938
since I've been with Hubble the Lagoon

1347
00:55:39,438 --> 00:55:42,768
Nebula is definitely my favorite image

1348
00:55:40,938 --> 00:55:46,548
so far and I've been here for two years

1349
00:55:42,768 --> 00:55:48,438
now and again seeing this materialize on

1350
00:55:46,548 --> 00:55:51,079
my desktop as I was working on it was

1351
00:55:48,438 --> 00:55:59,298
just a rush like like the Crab Nebula

1352
00:55:51,079 --> 00:56:01,880
yeah it was just amazing experience what

1353
00:55:59,298 --> 00:56:05,358
is the best way to make take a picture

1354
00:56:01,880 --> 00:56:10,479

of the Milky Way the best way to take a

1355
00:56:05,358 --> 00:56:12,768
picture of the Milky Way all sky yeah

1356
00:56:10,478 --> 00:56:14,239
probably what that that guy that I was

1357
00:56:12,768 --> 00:56:15,649
talking about Nick Risinger who

1358
00:56:14,239 --> 00:56:17,298
travelled the world to take a picture of

1359
00:56:15,650 --> 00:56:18,709
the Milky Way because that's the only

1360
00:56:17,298 --> 00:56:20,778
way you can take a picture of the entire

1361
00:56:18,708 --> 00:56:21,588
Milky Way because if you're you know if

1362
00:56:20,778 --> 00:56:23,059
you're only in the Northern Hemisphere

1363
00:56:21,588 --> 00:56:25,548
you're only gonna see a certain portion

1364
00:56:23,059 --> 00:56:27,798
of it so being able to travel the world

1365
00:56:25,548 --> 00:56:31,340
and get the whole view that's that's the

1366
00:56:27,798 --> 00:56:41,239
best way to do it it's very expensive

1367
00:56:31,340 --> 00:56:43,670
Oh what's the farthest object that the

1368
00:56:41,239 --> 00:56:45,919
Hubble Space Telescope has ever like

1369
00:56:43,670 --> 00:56:50,090
seen and would the James Webb telescope

1370
00:56:45,920 --> 00:56:51,500
be able to see farther yes the farthest

1371
00:56:50,090 --> 00:56:53,750
object Hubble has seen was thirteen

1372
00:56:51,500 --> 00:56:56,659
point four billion light years away

1373
00:56:53,750 --> 00:56:59,929
I believe thirteen point two round 13

1374
00:56:56,659 --> 00:57:01,759
billion thirteen it's kind of you know

1375
00:56:59,929 --> 00:57:05,059
our uncertainty grows when we get to

1376
00:57:01,760 --> 00:57:06,770
that level but yes yeah but that so for

1377
00:57:05,059 --> 00:57:10,130
Hubble that is just like a faint red

1378
00:57:06,769 --> 00:57:13,400
smudge in an image Webb will be able to

1379
00:57:10,130 --> 00:57:16,550
resolve more detail out of that not a

1380
00:57:13,400 --> 00:57:18,980
lot of details but yeah I mean we talked

1381
00:57:16,550 --> 00:57:21,080
about generosity we often talk about

1382
00:57:18,980 --> 00:57:24,110
probing the first billion years of

1383
00:57:21,079 --> 00:57:26,750
cosmic history and that by looking into

1384
00:57:24,110 --> 00:57:30,110
the infrared we will see things at just

1385
00:57:26,750 --> 00:57:33,320
slightly larger red shifts so we will be

1386
00:57:30,110 --> 00:57:36,079
able to see things into you know almost

1387
00:57:33,320 --> 00:57:38,330
- the first galaxies that form right

1388
00:57:36,079 --> 00:57:40,759
we're trying we're seeing you know

1389
00:57:38,329 --> 00:57:44,150
toddler galaxies we want to see the baby

1390
00:57:40,760 --> 00:57:46,670
galaxies okay and that's really the

1391
00:57:44,150 --> 00:57:49,070
promise of looking into the infrared is

1392
00:57:46,670 --> 00:57:51,170
we will be able to see that light which

1393
00:57:49,070 --> 00:57:53,960
gets red shifted all the way into the

1394
00:57:51,170 --> 00:58:02,150
mid infrared yeah so Webb will be able

1395
00:57:53,960 --> 00:58:05,780
to see further billion billion yes are

1396
00:58:02,150 --> 00:58:09,079
you able to pull up really quick the

1397

00:58:05,780 --> 00:58:11,980
pink of the deep field the Hubble Deep

1398
00:58:09,079 --> 00:58:14,840
Field yes because this my question goes

1399
00:58:11,980 --> 00:58:20,869
right along with what the last question

1400
00:58:14,840 --> 00:58:24,289
was yes so somewhere in there is the red

1401
00:58:20,869 --> 00:58:26,900
dot that science has told us that's the

1402
00:58:24,289 --> 00:58:29,750
farthest galaxy that we can see out of

1403
00:58:26,900 --> 00:58:32,420
that picture if you can go back to it

1404
00:58:29,750 --> 00:58:35,030
again out of that picture how does

1405
00:58:32,420 --> 00:58:37,430
science determine that's it that's the

1406
00:58:35,030 --> 00:58:40,190
oldest thing that we've seen how are you

1407
00:58:37,429 --> 00:58:43,129
able to determine that so when we take

1408
00:58:40,190 --> 00:58:44,760
these datasets it does make a beautiful

1409
00:58:43,130 --> 00:58:46,680
image but there's also

1410
00:58:44,760 --> 00:58:48,540
more data there than just the image

1411
00:58:46,679 --> 00:58:51,239

there's spectroscopy and we're able to

1412
00:58:48,539 --> 00:58:53,279
do spectroscopic redshift studies of the

1413
00:58:51,239 --> 00:58:54,809
galaxies from the image so we can

1414
00:58:53,280 --> 00:58:56,610
actually pull out

1415
00:58:54,809 --> 00:58:58,320
we call them postage stamp images we

1416
00:58:56,610 --> 00:58:59,610
actually have software that we'll go

1417
00:58:58,320 --> 00:59:01,620
through with the image and analyze it

1418
00:58:59,610 --> 00:59:04,740
and pull out each individual galaxy and

1419
00:59:01,619 --> 00:59:06,869
create a little image of that and from

1420
00:59:04,739 --> 00:59:09,179
that image be able to determine the

1421
00:59:06,869 --> 00:59:11,250
redshift of that galaxy basically that

1422
00:59:09,179 --> 00:59:12,899
gives you a distance estimate for it and

1423
00:59:11,250 --> 00:59:16,050
so when you look through this image that

1424
00:59:12,900 --> 00:59:20,280
way in that method that red dot becomes

1425
00:59:16,050 --> 00:59:21,990
the farthest object I think so but I'm

1426
00:59:20,280 --> 00:59:23,910
probably not gonna be able to see it

1427
00:59:21,989 --> 00:59:26,009
yeah and this is the one with the

1428
00:59:23,909 --> 00:59:27,719
ultraviolet added to it so it's hard to

1429
00:59:26,010 --> 00:59:32,370
pick out the the red dots in this

1430
00:59:27,719 --> 00:59:35,219
version of it right okay we get a

1431
00:59:32,369 --> 00:59:37,259
question from online that says how long

1432
00:59:35,219 --> 00:59:39,119
does it take for you to prepare one of

1433
00:59:37,260 --> 00:59:41,910
these images I believe that's right

1434
00:59:39,119 --> 00:59:44,029
there that's one of them yeah how long

1435
00:59:41,909 --> 00:59:46,799
does it take yeah that's a good question

1436
00:59:44,030 --> 00:59:47,490
some of these images can take I can do

1437
00:59:46,800 --> 00:59:49,830
it in an afternoon

1438
00:59:47,489 --> 00:59:51,449
some can take a week to a few weeks

1439
00:59:49,829 --> 00:59:52,559
depends on the complexity of the data

1440
00:59:51,449 --> 00:59:54,539
set

1441
00:59:52,559 --> 00:59:56,340
a lot of Hubble's like really famous

1442
00:59:54,539 --> 00:59:58,550
images are actually mosaics which means

1443
00:59:56,340 --> 01:00:00,780
Hubble goes and takes multiple images

1444
00:59:58,550 --> 01:00:03,840
and stitches them together

1445
01:00:00,780 --> 01:00:05,970
well I stitch them together and those

1446
01:00:03,840 --> 01:00:08,340
ones take a lot more work there's a lot

1447
01:00:05,969 --> 01:00:11,399
more pre-processing to get the mosaic

1448
01:00:08,340 --> 01:00:12,690
image looking nice and then putting it

1449
01:00:11,400 --> 01:00:14,389
all together it becomes a very

1450
01:00:12,690 --> 01:00:18,000
computationally intensive thing as well

1451
01:00:14,389 --> 01:00:19,379
because these images are like billions

1452
01:00:18,000 --> 01:00:21,449
well not billions but millions of pixels

1453
01:00:19,380 --> 01:00:23,130
across and you end up getting Photoshop

1454

01:00:21,449 --> 01:00:24,480
files that are like 10 gigabytes in size

1455
01:00:23,130 --> 01:00:27,390
and it just takes a long time to deal

1456
01:00:24,480 --> 01:00:32,340
with them so yeah there's a big range

1457
01:00:27,389 --> 01:00:35,190
and the time it takes you mentioned

1458
01:00:32,340 --> 01:00:36,780
images being north up and I was I mean I

1459
01:00:35,190 --> 01:00:41,849
think of North in reference to our polls

1460
01:00:36,780 --> 01:00:43,320
how is North oriented in space imagine

1461
01:00:41,849 --> 01:00:45,449
taking latitude and longitude of Earth

1462
01:00:43,320 --> 01:00:47,190
and just extending it out into space and

1463
01:00:45,449 --> 01:00:50,009
it becomes right Ascension and

1464
01:00:47,190 --> 01:00:52,230
declination and there is a north and

1465
01:00:50,010 --> 01:00:54,540
south to that and so in yeah if the

1466
01:00:52,230 --> 01:00:56,510
images that are north upper yeah it's

1467
01:00:54,539 --> 01:00:58,710
but if you're in the southern hemisphere

1468
01:00:56,510 --> 01:01:00,869

your natural orientation

1469
01:00:58,710 --> 01:01:02,699
be south up because everything abroad

1470
01:01:00,869 --> 01:01:04,650
rotates around the southern celestial

1471
01:01:02,699 --> 01:01:06,419
Pole versus here everything rotates

1472
01:01:04,650 --> 01:01:08,519
around the northern celestial Pole right

1473
01:01:06,420 --> 01:01:22,858
see there's no up or down yeah there is

1474
01:01:08,519 --> 01:01:24,599
no up or down based on your formation of

1475
01:01:22,858 --> 01:01:28,380
these images where you consider yourself

1476
01:01:24,599 --> 01:01:34,830
an artist or a scientist that's a great

1477
01:01:28,380 --> 01:01:36,480
answer is yes right both I feel like I

1478
01:01:34,829 --> 01:01:38,579
get to exercise both halves of my brain

1479
01:01:36,480 --> 01:01:40,409
when I work on an image because there is

1480
01:01:38,579 --> 01:01:42,539
a scientific aspect to it there's the

1481
01:01:40,409 --> 01:01:45,210
data preparation the pre-processing and

1482
01:01:42,539 --> 01:01:47,159
and then also as I'm processing and

1483
01:01:45,210 --> 01:01:49,199
moving into the realm of art I'm also

1484
01:01:47,159 --> 01:01:50,879
keeping in mind this story that's gonna

1485
01:01:49,199 --> 01:01:52,439
be associated with this image because

1486
01:01:50,880 --> 01:01:53,608
every image has to tell a story it has

1487
01:01:52,440 --> 01:01:55,559
to be a part of a press release that's

1488
01:01:53,608 --> 01:01:57,239
telling a story like that edit kareena

1489
01:01:55,559 --> 01:01:59,549
image the blue data there that's that's

1490
01:01:57,239 --> 01:02:00,719
the key to that image and so when I was

1491
01:01:59,550 --> 01:02:08,640
processing and I was keeping that in

1492
01:02:00,719 --> 01:02:10,858
mind as anyway grant we have question in

1493
01:02:08,639 --> 01:02:12,389
the center as well so so you mentioned

1494
01:02:10,858 --> 01:02:14,670
there's a wide dynamic range on the

1495
01:02:12,389 --> 01:02:20,400
sensors themselves actually how wide is

1496
01:02:14,670 --> 01:02:24,900
it like zero - there are 32-bit images

1497
01:02:20,400 --> 01:02:28,769
yeah so yeah but the the detectors the

1498
01:02:24,900 --> 01:02:32,099
original detectors were only like 65,000

1499
01:02:28,769 --> 01:02:35,820
six-letter over that yeah yeah for some

1500
01:02:32,099 --> 01:02:40,349
of them but I've been on the web it's

1501
01:02:35,820 --> 01:02:43,800
it's it's yeah it's the CCD charge count

1502
01:02:40,349 --> 01:02:45,720
of this of the detectors which I was in

1503
01:02:43,800 --> 01:02:47,130
the tens of thousands for the original

1504
01:02:45,719 --> 01:02:51,750
Hubble images I don't know what the

1505
01:02:47,130 --> 01:02:53,460
current stuff is I know that fits files

1506
01:02:51,750 --> 01:02:56,750
that you download from master usually

1507
01:02:53,460 --> 01:02:56,750
32-bit yeah

1508
01:03:01,320 --> 01:03:05,309
I was wondering if you could explain

1509
01:03:03,960 --> 01:03:09,000
more

1510
01:03:05,309 --> 01:03:11,489
when we get around to creating the W

1511

01:03:09,000 --> 01:03:13,800
first telescope after James who have I

1512
01:03:11,489 --> 01:03:16,019
know I'm jumping the gun well w first

1513
01:03:13,800 --> 01:03:19,320
which has a huge field if you will that

1514
01:03:16,019 --> 01:03:22,409
make your job easier and how will we

1515
01:03:19,320 --> 01:03:25,230
ever process I mean must be huge banks

1516
01:03:22,409 --> 01:03:28,440
of data and that's I guess that's a

1517
01:03:25,230 --> 01:03:30,240
problem they'll be resolving as time

1518
01:03:28,440 --> 01:03:34,110
goes on but how will that affect your

1519
01:03:30,239 --> 01:03:39,209
job pull up that that's future Joe's

1520
01:03:34,110 --> 01:03:42,360
problem but you're right the W first

1521
01:03:39,210 --> 01:03:44,039
telescope is it's an infrared telescope

1522
01:03:42,360 --> 01:03:46,079
that has a field of view that's a

1523
01:03:44,039 --> 01:03:47,309
hundred times that of Hubble's so every

1524
01:03:46,079 --> 01:03:50,579
image that it takes will be a hundred

1525
01:03:47,309 --> 01:03:52,259

Hubble's essentially so every time I

1526
01:03:50,579 --> 01:03:55,889
deal with one of those images it's gonna

1527
01:03:52,260 --> 01:03:58,170
be a huge mosaic multi-gigabyte image

1528
01:03:55,889 --> 01:04:00,289
file so it's gonna be a real challenge

1529
01:03:58,170 --> 01:04:02,700
and we're kind of working with the

1530
01:04:00,289 --> 01:04:03,989
instrument teams to figure out how we'll

1531
01:04:02,699 --> 01:04:06,750
actually deal with the volume of data

1532
01:04:03,989 --> 01:04:08,609
like that it may actually end up being a

1533
01:04:06,750 --> 01:04:11,250
cloud computing that we do for that

1534
01:04:08,610 --> 01:04:13,380
right I mean this is a thing in a lot of

1535
01:04:11,250 --> 01:04:15,840
astronomy we're getting these very large

1536
01:04:13,380 --> 01:04:20,309
surveys the dark energy camera that is

1537
01:04:15,840 --> 01:04:22,440
like 520 million pixels per image 520

1538
01:04:20,309 --> 01:04:24,690
million pixels per image okay

1539
01:04:22,440 --> 01:04:27,630
these are getting to be more and more

1540
01:04:24,690 --> 01:04:29,400
common in astronomy we're gonna the LSST

1541
01:04:27,630 --> 01:04:31,079
which is going to take you know

1542
01:04:29,400 --> 01:04:33,269
petabytes a night or something like that

1543
01:04:31,079 --> 01:04:38,880
I don't know it just all sky's images

1544
01:04:33,269 --> 01:04:40,949
okay data processing is a huge thing so

1545
01:04:38,880 --> 01:04:44,519
all of you young kids that that are out

1546
01:04:40,949 --> 01:04:46,619
here thinking you know data processing

1547
01:04:44,519 --> 01:04:49,530
and data analytics it's a huge

1548
01:04:46,619 --> 01:04:51,239
burgeoning field because it's not just

1549
01:04:49,530 --> 01:04:54,210
an astronomer where we have way too much

1550
01:04:51,239 --> 01:05:07,849
data to deal with we're developing it

1551
01:04:54,210 --> 01:05:10,440
all over and yeah it's gonna be fun hi

1552
01:05:07,849 --> 01:05:12,360
so it's my understanding like with the

1553
01:05:10,440 --> 01:05:15,929
Hubble it's like looking at a really

1554
01:05:12,360 --> 01:05:17,750
small portion of the sky but just

1555
01:05:15,929 --> 01:05:22,190
looking very deep

1556
01:05:17,750 --> 01:05:24,949
yes that is that correct so are there I

1557
01:05:22,190 --> 01:05:26,510
guess do you does it ever get used to

1558
01:05:24,949 --> 01:05:29,480
look at things that are closer or are

1559
01:05:26,510 --> 01:05:33,260
there just other telescopes that look

1560
01:05:29,480 --> 01:05:35,449
like can we look at Pluto very you know

1561
01:05:33,260 --> 01:05:37,609
get a very good view of Pluto which is

1562
01:05:35,449 --> 01:05:40,759
much closer than like this stuff you're

1563
01:05:37,608 --> 01:05:43,608
showing right like in order to and like

1564
01:05:40,760 --> 01:05:46,970
can we are there telescopes like that

1565
01:05:43,608 --> 01:05:50,059
and do we ever look at like other solar

1566
01:05:46,969 --> 01:05:52,069
systems to compare to ours and kind of

1567
01:05:50,059 --> 01:05:55,579
see planetary movement and that kind of

1568

01:05:52,070 --> 01:05:57,470
thing I guess that's my general question

1569
01:05:55,579 --> 01:05:59,929
okay so this is actually a Hubble image

1570
01:05:57,469 --> 01:06:02,239
of Jupiter here taken two years ago so

1571
01:05:59,929 --> 01:06:04,519
Hubble does look at nearby objects as

1572
01:06:02,239 --> 01:06:06,169
well and you're right about the the the

1573
01:06:04,519 --> 01:06:09,079
size it's equivalent to looking through

1574
01:06:06,170 --> 01:06:11,210
the eye of Eisenhower on a dime held at

1575
01:06:09,079 --> 01:06:13,759
arm's length that's roughly the field of

1576
01:06:11,210 --> 01:06:17,480
view Hubble yeah it's like 112 millionth

1577
01:06:13,760 --> 01:06:19,910
of the entire night sky okay one part in

1578
01:06:17,480 --> 01:06:24,079
12 million Frank has a really great blog

1579
01:06:19,909 --> 01:06:26,598
post on the universe about angular

1580
01:06:24,079 --> 01:06:28,549
resolution and why Hubble can take an

1581
01:06:26,599 --> 01:06:30,859
image of Pluto but it doesn't look very

1582
01:06:28,550 --> 01:06:33,530

good because Pluto is a very small

1583
01:06:30,858 --> 01:06:36,259
object and it's relatively distant in

1584
01:06:33,530 --> 01:06:37,580
terms of or Hubble's looking a galaxy

1585
01:06:36,260 --> 01:06:39,680
like the Whirlpool Galaxy is just

1586
01:06:37,579 --> 01:06:41,630
enormous hundreds of thousands of light

1587
01:06:39,679 --> 01:06:43,190
years all right not quite that big but

1588
01:06:41,630 --> 01:06:44,390
like sixty-five thousand light years

1589
01:06:43,190 --> 01:06:46,608
five thousand light years across

1590
01:06:44,389 --> 01:06:48,289
so it's something enormous you can see a

1591
01:06:46,608 --> 01:06:52,358
lot of detail with that with Hubble

1592
01:06:48,289 --> 01:06:52,358
but yeah check out the blog post Oh

1593
01:06:53,019 --> 01:06:59,500
which part of the electric medics read

1594
01:06:56,119 --> 01:07:04,700
from do you think takes the best images

1595
01:06:59,500 --> 01:07:08,179
of course now that's a very subjective

1596
01:07:04,699 --> 01:07:10,549
question I mean I think as humans we're

1597
01:07:08,179 --> 01:07:15,529
used to the visible light so we're gonna

1598
01:07:10,550 --> 01:07:18,700
favor that but I gotta say that I would

1599
01:07:15,530 --> 01:07:21,920
love to see more work on radio images

1600
01:07:18,699 --> 01:07:24,199
because radio images you need to take

1601
01:07:21,920 --> 01:07:26,690
like the VLA in several different

1602
01:07:24,199 --> 01:07:28,659
configurations to get the detail but

1603
01:07:26,690 --> 01:07:31,250
radio images and have incredibly

1604
01:07:28,659 --> 01:07:34,848
incredible micro arc second

1605
01:07:31,250 --> 01:07:36,739
detail that Hubble can't have and so

1606
01:07:34,849 --> 01:07:39,140
some of the radio images when they take

1607
01:07:36,739 --> 01:07:42,259
the time to actually process them are

1608
01:07:39,139 --> 01:07:44,449
really cool like the black hole in EM 87

1609
01:07:42,260 --> 01:07:48,440
yeah yeah

1610
01:07:44,449 --> 01:07:49,909
so radio has a lot of potential I don't

1611
01:07:48,440 --> 01:07:54,380
think has been exploited enough by the

1612
01:07:49,909 --> 01:07:56,899
radio community I have a question

1613
01:07:54,380 --> 01:08:00,769
actually about the lithograph for both

1614
01:07:56,900 --> 01:08:03,530
of these is the ring nebula sort of what

1615
01:08:00,769 --> 01:08:07,070
may be happening with our Sun and about

1616
01:08:03,530 --> 01:08:10,970
eight billion years or is this a sort of

1617
01:08:07,070 --> 01:08:13,039
thing will be going on with our son yeah

1618
01:08:10,969 --> 01:08:15,858
let's see it's gonna puff up and cast

1619
01:08:13,039 --> 01:08:17,359
off material into space it's not quite

1620
01:08:15,858 --> 01:08:21,170
massive enough to do much more than that

1621
01:08:17,359 --> 01:08:24,259
it'll just sort of peter out I don't

1622
01:08:21,170 --> 01:08:25,579
know what do you think yeah the or the

1623
01:08:24,259 --> 01:08:27,798
textbook answer that you will get

1624
01:08:25,579 --> 01:08:29,988
normally from an astronomy 101 class is

1625

01:08:27,798 --> 01:08:32,689
yes our Sun will go off and die by being

1626
01:08:29,988 --> 01:08:36,798
a planetary nebula the research level

1627
01:08:32,689 --> 01:08:39,679
answer is probably not quite as pretty

1628
01:08:36,798 --> 01:08:41,960
as the ring nebula because it looks like

1629
01:08:39,680 --> 01:08:43,819
you need about one and a half to two

1630
01:08:41,960 --> 01:08:46,789
solar masses to really blow off a

1631
01:08:43,819 --> 01:08:48,500
planetary nebula that's you know still

1632
01:08:46,789 --> 01:08:51,259
uncertain right now it's still subject

1633
01:08:48,500 --> 01:08:52,850
to research but the folks I've talked to

1634
01:08:51,259 --> 01:08:55,789
say yeah the sun's not going to go

1635
01:08:52,850 --> 01:08:58,940
planetary like that it'll it'll still

1636
01:08:55,789 --> 01:09:06,560
have mass loss but it won't be a nice

1637
01:08:58,939 --> 01:09:09,798
beautiful nebula so about how many

1638
01:09:06,560 --> 01:09:15,289
galaxies was Hubble able to identify

1639
01:09:09,798 --> 01:09:17,689

since its launch since launch well let's

1640
01:09:15,289 --> 01:09:19,699
see let's just take yeah the candles

1641
01:09:17,689 --> 01:09:21,588
alright yeah take the candles field so

1642
01:09:19,699 --> 01:09:24,380
this one Deep Field image that we've

1643
01:09:21,588 --> 01:09:26,420
done with Hubble had what's 65 thousand

1644
01:09:24,380 --> 01:09:28,630
galaxies in it I think yeah and that's

1645
01:09:26,420 --> 01:09:30,980
just one image it's one very deep image

1646
01:09:28,630 --> 01:09:36,980
no I'm talking about like naming them

1647
01:09:30,979 --> 01:09:40,818
actually we don't name them yeah big if

1648
01:09:36,979 --> 01:09:43,579
they get catalog numbers yeah okay yeah

1649
01:09:40,819 --> 01:09:44,900
so if you're in the Hubble Deep Field

1650
01:09:43,579 --> 01:09:47,119
you'd be HD

1651
01:09:44,899 --> 01:09:49,579
and then it'd be your RA in your deck as

1652
01:09:47,119 --> 01:09:52,760
your as your catalog name unless there's

1653
01:09:49,579 --> 01:09:54,470
a specific reason I mean what the Sloan

1654
01:09:52,760 --> 01:09:57,619
Digital Sky Survey has how many millions

1655
01:09:54,470 --> 01:09:59,329
of galaxies in it yeah I mean when you

1656
01:09:57,619 --> 01:10:00,050
get up to millions and such you can't

1657
01:09:59,329 --> 01:10:03,710
name them

1658
01:10:00,050 --> 01:10:15,110
Jeff and Fred no justice gets a little

1659
01:10:03,710 --> 01:10:16,550
full tiresome to try and do that how did

1660
01:10:15,109 --> 01:10:19,549
you say that this is what you want do

1661
01:10:16,550 --> 01:10:21,619
for your for a living like editing and

1662
01:10:19,550 --> 01:10:24,860
taking these pictures and processing

1663
01:10:21,619 --> 01:10:25,670
them oh yeah good question I always

1664
01:10:24,859 --> 01:10:27,949
loved astronomy

1665
01:10:25,670 --> 01:10:31,730
as a kid growing up I just like was

1666
01:10:27,949 --> 01:10:33,229
fascinated with the Stars and then when

1667
01:10:31,729 --> 01:10:34,369
I went to college I studied astronomy

1668
01:10:33,229 --> 01:10:36,439
and astrophysics and I thought I was

1669
01:10:34,369 --> 01:10:38,199
gonna go the PhD were out and sort of

1670
01:10:36,439 --> 01:10:40,639
you know become a professor or something

1671
01:10:38,199 --> 01:10:43,130
but after I graduate from undergrad I

1672
01:10:40,640 --> 01:10:46,880
was doing research work when I was at

1673
01:10:43,130 --> 01:10:48,529
Chandra I was doing calibration and

1674
01:10:46,880 --> 01:10:51,170
instrument operations for the Chandra

1675
01:10:48,529 --> 01:10:53,809
telescope and I loved that work but it

1676
01:10:51,170 --> 01:10:55,730
wasn't it just didn't it wasn't my

1677
01:10:53,810 --> 01:10:57,920
calling I think and I always had this

1678
01:10:55,729 --> 01:11:00,319
sort of artistic side I did painting I'm

1679
01:10:57,920 --> 01:11:03,710
a musician I wanted to engage that as

1680
01:11:00,319 --> 01:11:05,179
well as as a part of my career and so an

1681
01:11:03,710 --> 01:11:08,180
opportunity arose when I was at Chandra

1682

01:11:05,180 --> 01:11:10,430
to do image processing for public

1683
01:11:08,180 --> 01:11:12,680
outreach and I jumped on it and then

1684
01:11:10,430 --> 01:11:15,170
through that my experience there with

1685
01:11:12,680 --> 01:11:16,730
eight years sort of made connections

1686
01:11:15,170 --> 01:11:20,690
with people at Space Telescope and then

1687
01:11:16,729 --> 01:11:22,189
was able to come down here so is it was

1688
01:11:20,689 --> 01:11:23,809
always there and it was just being able

1689
01:11:22,189 --> 01:11:30,259
to figure out the path to get everything

1690
01:11:23,810 --> 01:11:32,150
together in the same job yeah and since

1691
01:11:30,260 --> 01:11:35,570
we have a bunch of the cty students here

1692
01:11:32,149 --> 01:11:39,559
today sometimes they call CT why geek

1693
01:11:35,569 --> 01:11:42,409
camp right okay you think your geeks you

1694
01:11:39,560 --> 01:11:44,210
can also be artistic okay Joe and I are

1695
01:11:42,409 --> 01:11:45,619
two people who get to do some really

1696
01:11:44,210 --> 01:11:48,529

geeky stuff with the Hubble Space

1697
01:11:45,619 --> 01:11:51,170
Telescope but we've worked on IMAX films

1698
01:11:48,529 --> 01:11:53,269
together okay we get to work on movies

1699
01:11:51,170 --> 01:11:55,039
and visualizations and artistic things

1700
01:11:53,270 --> 01:11:57,350
we get to work with and field who's a

1701
01:11:55,039 --> 01:11:58,670
wonderful artist we get to work with you

1702
01:11:57,350 --> 01:12:00,950
know writers and

1703
01:11:58,670 --> 01:12:03,739
and everything you can bow you can

1704
01:12:00,949 --> 01:12:06,470
satisfy both your artistic side as well

1705
01:12:03,739 --> 01:12:08,840
as your scientific side in your career

1706
01:12:06,470 --> 01:12:10,820
so don't do not limit yourself okay I

1707
01:12:08,840 --> 01:12:12,860
always like to tell the kids that

1708
01:12:10,819 --> 01:12:14,659
because you know don't think you have to

1709
01:12:12,859 --> 01:12:17,869
be one or the other you really can do

1710
01:12:14,659 --> 01:12:19,789
both do you think if there is a

1711
01:12:17,869 --> 01:12:22,039
possibility in the future that we will

1712
01:12:19,789 --> 01:12:24,289
launch another gamma-ray Observatory or

1713
01:12:22,039 --> 01:12:26,329
ray Observatory after your Compton shut

1714
01:12:24,289 --> 01:12:28,850
down mm there's possible that might

1715
01:12:26,329 --> 01:12:31,309
happen again in the future

1716
01:12:28,850 --> 01:12:32,900
I believe the Fermi telescope is

1717
01:12:31,310 --> 01:12:34,250
actually also a gamma ray telescope so

1718
01:12:32,899 --> 01:12:36,319
there is a telescope currently operating

1719
01:12:34,250 --> 01:12:38,569
that's looking at gamma rays it's just

1720
01:12:36,319 --> 01:12:40,130
not one of the great observatories it's

1721
01:12:38,569 --> 01:12:45,889
just a pretty good observatory pretty

1722
01:12:40,130 --> 01:12:48,699
good now Fermi is wonderful okay but

1723
01:12:45,890 --> 01:13:05,270
it's just not in that I don't know

1724
01:12:48,699 --> 01:13:07,010
branding so you receive images that are

1725
01:13:05,270 --> 01:13:08,600
black and white you spend a lot of time

1726
01:13:07,010 --> 01:13:10,190
processing and working with the black

1727
01:13:08,600 --> 01:13:12,110
and white and all of a sudden you start

1728
01:13:10,189 --> 01:13:13,909
to add color to it so you spent hours

1729
01:13:12,109 --> 01:13:17,869
maybe in black and white before you see

1730
01:13:13,909 --> 01:13:19,430
the color sometimes yes I'm actually

1731
01:13:17,869 --> 01:13:21,140
working on an image of Jupiter that was

1732
01:13:19,430 --> 01:13:23,690
just taken a few weeks ago right now and

1733
01:13:21,140 --> 01:13:24,230
in that case yes I've been working on it

1734
01:13:23,689 --> 01:13:26,869
in black and white

1735
01:13:24,229 --> 01:13:28,729
the challenge with making an image of

1736
01:13:26,869 --> 01:13:30,579
Jupiter is that when Hubble takes the

1737
01:13:28,729 --> 01:13:33,289
three images to make a color image

1738
01:13:30,579 --> 01:13:35,600
Jupiter is moving so fast that it

1739

01:13:33,289 --> 01:13:37,100
changes while it's taking the data right

1740
01:13:35,600 --> 01:13:38,870
so to make a color image you have to

1741
01:13:37,100 --> 01:13:41,180
sort of account for this slight rotation

1742
01:13:38,869 --> 01:13:44,029
and the movement of Jupiter as it's

1743
01:13:41,180 --> 01:13:45,470
being photographed so that takes a lot

1744
01:13:44,029 --> 01:13:46,550
of work in black and white to get

1745
01:13:45,470 --> 01:13:49,460
everything lined up I mean I'm

1746
01:13:46,550 --> 01:13:51,829
essentially like warping clouds in

1747
01:13:49,460 --> 01:13:54,770
Jupiter and lining them up in black and

1748
01:13:51,829 --> 01:13:56,840
white and then applying color a question

1749
01:13:54,770 --> 01:13:59,720
from online what instrument do you play

1750
01:13:56,840 --> 01:14:00,840
and go ahead and plug your band if you'd

1751
01:13:59,720 --> 01:14:03,480
like

1752
01:14:00,840 --> 01:14:03,989
I play guitar my band is called riding

1753
01:14:03,479 --> 01:14:09,869

shotgun

1754
01:14:03,989 --> 01:14:16,229
check out riding shotgun calm shameless

1755
01:14:09,869 --> 01:14:21,140
plug are you related to the violist

1756
01:14:16,229 --> 01:14:22,429
Joseph de Pascua way no I get that a lot

1757
01:14:21,140 --> 01:14:25,050
[Applause]

1758
01:14:22,430 --> 01:14:26,460
my dad is also Joseph D Pasquale and we

1759
01:14:25,050 --> 01:14:30,989
used to get phone calls when I was a kid

1760
01:14:26,460 --> 01:14:32,850
asking for the violinist all right just

1761
01:14:30,989 --> 01:14:34,979
a couple more questions here alright

1762
01:14:32,850 --> 01:14:39,300
well I guess I have a second one here so

1763
01:14:34,979 --> 01:14:42,899
I'm wondering if you have seen images

1764
01:14:39,300 --> 01:14:44,670
that then make you go hey wait this

1765
01:14:42,899 --> 01:14:46,469
doesn't agree with you know our current

1766
01:14:44,670 --> 01:14:48,239
understanding of physics and you know

1767
01:14:46,470 --> 01:14:49,650
how do you guys go about do you have to

1768
01:14:48,239 --> 01:14:51,179
like contact someone else

1769
01:14:49,649 --> 01:14:54,509
and say hey what do you guys think about

1770
01:14:51,180 --> 01:14:58,740
this and kind of like have you run into

1771
01:14:54,510 --> 01:15:01,230
anything like that in I know all the

1772
01:14:58,739 --> 01:15:03,059
stuff you've seen yes so I have a good

1773
01:15:01,229 --> 01:15:04,939
example with that I don't know how great

1774
01:15:03,060 --> 01:15:09,450
I can explain it without my head but

1775
01:15:04,939 --> 01:15:11,879
when there was a gravitational wave

1776
01:15:09,449 --> 01:15:14,189
event in August 2017

1777
01:15:11,880 --> 01:15:15,510
I will took some data of the object it

1778
01:15:14,189 --> 01:15:18,000
was a it's called a Killa Nova just

1779
01:15:15,510 --> 01:15:20,570
enormous explosion and it was looking at

1780
01:15:18,000 --> 01:15:23,460
infrared and two different filters and

1781
01:15:20,569 --> 01:15:26,460
we were making color images of that

1782
01:15:23,460 --> 01:15:29,939
object spaced out by a few days at a

1783
01:15:26,460 --> 01:15:32,039
time and what I noticed was the first

1784
01:15:29,939 --> 01:15:32,489
image the object appeared to be sort of

1785
01:15:32,039 --> 01:15:34,260
yellowish

1786
01:15:32,489 --> 01:15:35,489
and the second one it turned blue which

1787
01:15:34,260 --> 01:15:36,690
was kind of surprising and then the

1788
01:15:35,489 --> 01:15:38,789
third one it was back to being yellow

1789
01:15:36,689 --> 01:15:40,799
but dimmer and it turned out that in

1790
01:15:38,789 --> 01:15:43,199
that middle observation there was a

1791
01:15:40,800 --> 01:15:44,699
slight gap in between when the two

1792
01:15:43,199 --> 01:15:45,899
different filters were taken and it was

1793
01:15:44,699 --> 01:15:47,579
just long enough that the object had

1794
01:15:45,899 --> 01:15:49,139
actually dimmed enough to allow the

1795
01:15:47,579 --> 01:15:51,420
shorter wavelengths to be brighter than

1796

01:15:49,140 --> 01:15:54,450
the longer wavelength and so the color

1797
01:15:51,420 --> 01:15:56,789
changed and that was a surprise and so

1798
01:15:54,449 --> 01:15:58,439
we usually are working with the we call

1799
01:15:56,789 --> 01:15:59,819
the principal investigator the scientist

1800
01:15:58,439 --> 01:16:03,059
who took the data when we make these

1801
01:15:59,819 --> 01:16:05,039
press release out images so we went back

1802
01:16:03,060 --> 01:16:06,600
and forth with the investigators and

1803
01:16:05,039 --> 01:16:08,880
determined that yeah there was this

1804
01:16:06,600 --> 01:16:10,079
issue where there was a separation that

1805
01:16:08,880 --> 01:16:11,789
shouldn't have been there but

1806
01:16:10,079 --> 01:16:14,100
unfortunately was that caused this

1807
01:16:11,789 --> 01:16:14,729
change in the color that's not intrinsic

1808
01:16:14,100 --> 01:16:18,390
to the object

1809
01:16:14,729 --> 01:16:20,369
it was just because of that break yeah

1810
01:16:18,390 --> 01:16:21,630

and so that was a case where you know

1811
01:16:20,369 --> 01:16:22,800
there was something surprising we talked

1812
01:16:21,630 --> 01:16:24,029
to the scientists about it we figured it

1813
01:16:22,800 --> 01:16:24,989
out and then we ended up just really

1814
01:16:24,029 --> 01:16:26,670
seeing it as a black-and-white because

1815
01:16:24,989 --> 01:16:31,439
the whole goal was to show that it was

1816
01:16:26,670 --> 01:16:42,569
dimming over time quickly I hope that

1817
01:16:31,439 --> 01:16:44,909
made sense okay one comment from online

1818
01:16:42,569 --> 01:16:56,399
says riding shotgun could use a good

1819
01:16:44,909 --> 01:16:59,010
tuba player I love the Internet yeah so

1820
01:16:56,399 --> 01:17:00,719
so we have all these telescope that we

1821
01:16:59,010 --> 01:17:02,970
can take a look at pretty deep and

1822
01:17:00,720 --> 01:17:05,430
faraway object in space what do you

1823
01:17:02,970 --> 01:17:07,140
think personally is the most important

1824
01:17:05,430 --> 01:17:10,050
takeaway work most important thing we

1825
01:17:07,140 --> 01:17:11,940
can learn from these from these images

1826
01:17:10,050 --> 01:17:14,220
because they're pretty far away and we

1827
01:17:11,939 --> 01:17:16,369
probably won't get to them that easily

1828
01:17:14,220 --> 01:17:19,079
so what do you think it's the most

1829
01:17:16,369 --> 01:17:21,479
valuable thing that we can study from it

1830
01:17:19,079 --> 01:17:23,479
well I think every time we look at

1831
01:17:21,479 --> 01:17:25,379
something where we're just trying to

1832
01:17:23,479 --> 01:17:28,439
deepen our understanding of the universe

1833
01:17:25,380 --> 01:17:30,359
in general I mean you're familiar with

1834
01:17:28,439 --> 01:17:33,210
this Carl Sagan quote that we are star

1835
01:17:30,359 --> 01:17:34,799
stuff we're made of the materials that

1836
01:17:33,210 --> 01:17:36,420
were generated forged in the hearts of

1837
01:17:34,800 --> 01:17:40,079
the stars that exploded billions of

1838
01:17:36,420 --> 01:17:42,119
years ago and also taking that a step

1839
01:17:40,079 --> 01:17:44,039
further we are the universe trying to

1840
01:17:42,119 --> 01:17:46,170
understand itself and I really love that

1841
01:17:44,039 --> 01:17:47,819
concept of the material of the universe

1842
01:17:46,170 --> 01:17:49,649
becoming conscious and tried to

1843
01:17:47,819 --> 01:17:51,989
understand itself and looking out and

1844
01:17:49,649 --> 01:17:53,939
peering into into space so it's sort of

1845
01:17:51,989 --> 01:17:55,260
a way of humanity trying to understand

1846
01:17:53,939 --> 01:17:57,179
itself the universe trying to understand

1847
01:17:55,260 --> 01:17:58,260
itself well sort of wrapped into one so

1848
01:17:57,180 --> 01:18:01,500
it's you know it's like the most

1849
01:17:58,260 --> 01:18:02,909
fundamental questions that we have we're

1850
01:18:01,500 --> 01:18:11,399
trying to find answers to when we look

1851
01:18:02,909 --> 01:18:12,989
in the space okay we got one two three

1852
01:18:11,399 --> 01:18:14,969
and then we're done okay cuz we're get

1853

01:18:12,989 --> 01:18:16,439
where you are going going I know we

1854
01:18:14,970 --> 01:18:18,329
could get these guys asking questions

1855
01:18:16,439 --> 01:18:19,979
forever but go ahead so what were your

1856
01:18:18,329 --> 01:18:21,479
thoughts on the black hole image that we

1857
01:18:19,979 --> 01:18:23,189
recently got earlier in the year I

1858
01:18:21,479 --> 01:18:25,859
thought that was incredible

1859
01:18:23,189 --> 01:18:27,989
that was an amazing image I wish that

1860
01:18:25,859 --> 01:18:28,589
there was a little more providing

1861
01:18:27,989 --> 01:18:31,349
context

1862
01:18:28,590 --> 01:18:33,659
of where in the universe this object

1863
01:18:31,349 --> 01:18:35,099
actually was and what it looks like in

1864
01:18:33,658 --> 01:18:37,319
other wavelengths because I work so much

1865
01:18:35,099 --> 01:18:39,599
in multi-wavelength I wanted to see that

1866
01:18:37,319 --> 01:18:41,368
that image of the doughnut in context

1867
01:18:39,599 --> 01:18:42,810

with everything else around it but

1868
01:18:41,368 --> 01:18:44,130
otherwise yeah I was just an incredible

1869
01:18:42,810 --> 01:18:49,159
achievement to be able to take that

1870
01:18:44,130 --> 01:18:52,349
image all right so I was just wondering

1871
01:18:49,158 --> 01:18:55,710
you said it had like terabytes of data

1872
01:18:52,349 --> 01:18:58,980
and stuff so I was wondering how long it

1873
01:18:55,710 --> 01:19:03,029
takes to transmit all that data from the

1874
01:18:58,979 --> 01:19:07,138
telescope to the computer that you're

1875
01:19:03,029 --> 01:19:09,059
using to process the images right so the

1876
01:19:07,139 --> 01:19:12,449
data actually on the telescope is stored

1877
01:19:09,060 --> 01:19:14,250
on there's hard basically hard drives on

1878
01:19:12,448 --> 01:19:16,019
the telescope and it's not terabytes of

1879
01:19:14,250 --> 01:19:19,020
data that are stored on the telescope

1880
01:19:16,020 --> 01:19:20,909
it's just over 29 years worth of

1881
01:19:19,020 --> 01:19:23,520
observations we now have terabytes of

1882
01:19:20,908 --> 01:19:25,289
data at any given time there's probably

1883
01:19:23,520 --> 01:19:27,090
megabytes to gigabytes of data on the

1884
01:19:25,289 --> 01:19:29,399
telescope itself that are transmitted

1885
01:19:27,090 --> 01:19:31,949
down through NASA's Deep Space Network a

1886
01:19:29,399 --> 01:19:34,379
series of satellite dishes and then they

1887
01:19:31,948 --> 01:19:36,238
make their way here to the multi mission

1888
01:19:34,380 --> 01:19:38,429
the Mikulski archive at Space Telescope

1889
01:19:36,238 --> 01:19:40,289
mast and that data is available to

1890
01:19:38,429 --> 01:19:43,679
anyone who wants to take a look at it

1891
01:19:40,289 --> 01:19:46,800
mass test es e IE d you I think that's

1892
01:19:43,679 --> 01:19:49,770
the URL it is however a very geek

1893
01:19:46,800 --> 01:19:52,320
friendly website it's not a user

1894
01:19:49,770 --> 01:19:57,469
friendly website for scientists by

1895
01:19:52,319 --> 01:19:59,899
scientists all right there was one hmm

1896
01:19:57,469 --> 01:20:03,448
yeah the context of the black hole I put

1897
01:19:59,899 --> 01:20:06,118
it's on our Hubble site YouTube channel

1898
01:20:03,448 --> 01:20:08,879
so on our Hubble Space Telescope YouTube

1899
01:20:06,118 --> 01:20:12,000
channel I made a video zooming in just

1900
01:20:08,880 --> 01:20:13,159
to what this series of stills actually I

1901
01:20:12,000 --> 01:20:16,139
showed it at the public lecture series

1902
01:20:13,158 --> 01:20:18,329
just to give context on that because we

1903
01:20:16,139 --> 01:20:20,909
here were unhappy that it didn't that

1904
01:20:18,329 --> 01:20:24,658
the press release that from the official

1905
01:20:20,908 --> 01:20:26,759
team did not have enough context yeah

1906
01:20:24,658 --> 01:20:30,598
last question so you stitch together

1907
01:20:26,760 --> 01:20:32,400
images in color so how because Hubble

1908
01:20:30,599 --> 01:20:34,050
takes images in black and white would

1909
01:20:32,399 --> 01:20:36,629
you say the color images that you stitch

1910

01:20:34,050 --> 01:20:38,070
together are more or less useful than

1911
01:20:36,630 --> 01:20:42,609
the black and white images that are

1912
01:20:38,069 --> 01:20:44,920
taken by Hubble that's a good question

1913
01:20:42,609 --> 01:20:47,049
so the scientists the black-and-white

1914
01:20:44,920 --> 01:20:49,149
the data the raw data is what they're

1915
01:20:47,050 --> 01:20:51,190
looking for it's the most useful for

1916
01:20:49,149 --> 01:20:53,889
them but there have been cases where

1917
01:20:51,189 --> 01:20:55,389
I've worked directly with scientists to

1918
01:20:53,890 --> 01:20:57,539
make an image that it's then used for

1919
01:20:55,390 --> 01:21:00,130
analysis or it becomes a part of a paper

1920
01:20:57,539 --> 01:21:02,529
so it goes both ways sometimes the color

1921
01:21:00,130 --> 01:21:04,060
image reveals details that are not

1922
01:21:02,529 --> 01:21:06,069
immediately obvious by looking at the

1923
01:21:04,060 --> 01:21:08,770
black and white data because you have

1924
01:21:06,069 --> 01:21:12,369

more than one image together you can

1925
01:21:08,770 --> 01:21:14,950
actually see more at one time so kind of

1926
01:21:12,369 --> 01:21:17,250
goes both ways all right I'm sorry I

1927
01:21:14,949 --> 01:21:20,639
don't have to cut it off there but

1928
01:21:17,250 --> 01:21:20,640
conversations like this

1929
01:21:26,920 --> 01:21:32,529
please join us in August we will see you

1930
01:21:29,720 --> 01:21:32,530
then thank you all