



Space Telescope
Science Institute



1
00:00:04,039 --> 00:00:02,000
ladies and gentlemen and welcome to the

2
00:00:06,800 --> 00:00:04,049
Space Telescope public lecture series

3
00:00:08,390 --> 00:00:06,810
I'm your host dr. Frank summers and I'm

4
00:00:12,110 --> 00:00:08,400
gonna show you something new with our

5
00:00:12,830 --> 00:00:12,120
new remote alright let's see I got this

6
00:00:15,799 --> 00:00:12,840
oh there we go

7
00:00:18,080 --> 00:00:15,809
that's me dr. Frank summers this is a

8
00:00:20,570 --> 00:00:18,090
special remote that I can use to

9
00:00:23,810 --> 00:00:20,580
highlight sections on screen our

10
00:00:26,900 --> 00:00:23,820
webcasting audience does not get to see

11
00:00:28,730 --> 00:00:26,910
the laser pointer when we use the laser

12
00:00:30,890 --> 00:00:28,740
pointer so I'm trying out this for the

13
00:00:32,299 --> 00:00:30,900

first time tonight and if it works

14

00:00:34,220 --> 00:00:32,309

successfully maybe we'll be able to get

15

00:00:36,049 --> 00:00:34,230

our speakers to use it in the future and

16

00:00:39,139 --> 00:00:36,059

the webcasting audience will see all of

17

00:00:41,510 --> 00:00:39,149

our highlights let's see when you came

18

00:00:44,569 --> 00:00:41,520

in there are images on the table

19

00:00:50,090 --> 00:00:44,579

tonight's image is of the ring nebula

20

00:00:52,580 --> 00:00:50,100

NGC 67 20 and the ring nebula is one of

21

00:00:55,130 --> 00:00:52,590

the most beautiful planetary nebula has

22

00:00:58,639 --> 00:00:55,140

nothing to do with planets that's just a

23

00:01:01,580 --> 00:00:58,649

name that unfortunately stuck it is a

24

00:01:03,619 --> 00:01:01,590

dying star if you want to understand it

25

00:01:06,380 --> 00:01:03,629

well you could turn over on the back and

26
00:01:08,510 --> 00:01:06,390
you can see that we have a collection a

27
00:01:11,719 --> 00:01:08,520
few paragraphs that can tell you about

28
00:01:13,880 --> 00:01:11,729
it as well as up here in the upper right

29
00:01:15,560 --> 00:01:13,890
hand corner there are comparisons to

30
00:01:18,710 --> 00:01:15,570
other planetary nebulae

31
00:01:20,929 --> 00:01:18,720
planetary nebulae have some really

32
00:01:25,219 --> 00:01:20,939
really cool shapes it's well worth

33
00:01:28,340 --> 00:01:25,229
investigating we have to do our reminder

34
00:01:30,380 --> 00:01:28,350
please silence your phones we don't want

35
00:01:32,780 --> 00:01:30,390
them going off during the lecture thank

36
00:01:35,210 --> 00:01:32,790
you very much because tonight's lecture

37
00:01:37,160 --> 00:01:35,220
is one you are definitely want going to

38
00:01:40,310 --> 00:01:37,170

want to listen closely to it's called

39

00:01:43,520 --> 00:01:40,320

our colorful universe translating cosmic

40

00:01:47,899 --> 00:01:43,530

light by our very own master image

41

00:01:52,039 --> 00:01:47,909

processor Joseph de Pascua upcoming we

42

00:01:55,160 --> 00:01:52,049

have an August tiny stellar Islands in a

43

00:01:57,709 --> 00:01:55,170

big old universe this will be a talk

44

00:01:59,480 --> 00:01:57,719

about dwarf galaxies okay and dwarf

45

00:02:01,340 --> 00:01:59,490

galaxies you might think ah who cares

46

00:02:03,469 --> 00:02:01,350

about them you know if snow white wake

47

00:02:06,109 --> 00:02:03,479

may care about the Seven Dwarfs but why

48

00:02:08,540 --> 00:02:06,119

would we care about dwarf galaxies well

49

00:02:09,830 --> 00:02:08,550

they are the most numerous type of

50

00:02:11,990 --> 00:02:09,840

galaxies in the universe they're

51
00:02:13,730 --> 00:02:12,000
actually extremely important to

52
00:02:16,940 --> 00:02:13,740
understand to understand how

53
00:02:18,260 --> 00:02:16,950
universe developed and September Brandon

54
00:02:20,960 --> 00:02:18,270
Lawton is going to talk about the

55
00:02:22,820 --> 00:02:20,970
astronomers toolkit he's decided he

56
00:02:25,120 --> 00:02:22,830
wants to talk to you about all the

57
00:02:28,400 --> 00:02:25,130
various tools astronomers use to

58
00:02:29,780 --> 00:02:28,410
investigate the universe and that should

59
00:02:35,000 --> 00:02:29,790
be fun in September right after Labor

60
00:02:38,660 --> 00:02:35,010
Day and in October a perennial fun topic

61
00:02:40,760 --> 00:02:38,670
black holes and gravitational waves we

62
00:02:43,450 --> 00:02:40,770
have learned so much about this

63
00:02:46,760 --> 00:02:43,460

brand-new gravitational wave astronomy

64

00:02:47,930 --> 00:02:46,770

and Emanuel barity from across the

65

00:02:50,990 --> 00:02:47,940

street at Johns Hopkins will be

66

00:02:53,180 --> 00:02:51,000

discussing that if you want to find out

67

00:02:55,430 --> 00:02:53,190

about things you go to our website and

68

00:02:58,790 --> 00:02:55,440

you will find that our website has a

69

00:03:02,870 --> 00:02:58,800

brand new look it doesn't have

70

00:03:05,750 --> 00:03:02,880

unfortunately a short URL so if you want

71

00:03:07,880 --> 00:03:05,760

to go to the website it's HTTP hollow

72

00:03:11,750 --> 00:03:07,890

site org resources - gallery learning -

73

00:03:13,370 --> 00:03:11,760

resources public - lecture - series easy

74

00:03:16,370 --> 00:03:13,380

to remember right take a picture of the

75

00:03:17,330 --> 00:03:16,380

screen oh if you put into your favorite

76

00:03:20,600 --> 00:03:17,340

search engine

77

00:03:25,130 --> 00:03:20,610

Hubble public lectures you should end up

78

00:03:28,730 --> 00:03:25,140

at this webpage okay we have on it our

79

00:03:32,210 --> 00:03:28,740

list of our upcoming lectures we have

80

00:03:34,760 --> 00:03:32,220

the link to our past lectures all right

81

00:03:36,860 --> 00:03:34,770

so if you want to go to our past public

82

00:03:39,410 --> 00:03:36,870

lectures as well as our YouTube playlist

83

00:03:41,750 --> 00:03:39,420

and our webcasting archive where you can

84

00:03:43,790 --> 00:03:41,760

watch them we also have the lecture

85

00:03:46,280 --> 00:03:43,800

announcements email list where you can

86

00:03:48,200 --> 00:03:46,290

enter your email address and subscribe

87

00:03:50,510 --> 00:03:48,210

to the lecture announcements it's

88

00:03:52,730 --> 00:03:50,520

basically two emails a month reminding

89

00:03:54,580 --> 00:03:52,740

you of the upcoming lectures and telling

90

00:03:58,940 --> 00:03:54,590

you where the webcasts are posted

91

00:04:01,040 --> 00:03:58,950

finally they have a new setup for

92

00:04:04,880 --> 00:04:01,050

presenting the lectures this for example

93

00:04:07,970 --> 00:04:04,890

was last month's lecture by Christopher

94

00:04:09,920 --> 00:04:07,980

Britt and it includes the you know the

95

00:04:12,830 --> 00:04:09,930

basic information he now includes the

96

00:04:15,470 --> 00:04:12,840

description okay as well as link to the

97

00:04:19,220 --> 00:04:15,480

webcast on the SDSU IO site and they'll

98

00:04:22,310 --> 00:04:19,230

link to the webcast on YouTube okay

99

00:04:26,420 --> 00:04:22,320

so they have new stuff on our website

100

00:04:27,530 --> 00:04:26,430

for you to look at and get all the

101
00:04:31,370 --> 00:04:27,540
information about our

102
00:04:33,980 --> 00:04:31,380
what series okay the email I showed you

103
00:04:35,480 --> 00:04:33,990
how to sign up the website if you find

104
00:04:37,310 --> 00:04:35,490
yourself that you do not want to do that

105
00:04:39,500 --> 00:04:37,320
and you want to just write it down on a

106
00:04:42,320 --> 00:04:39,510
piece of paper and hand it to me that'll

107
00:04:44,060 --> 00:04:42,330
work as well those who have comments and

108
00:04:48,440 --> 00:04:44,070
questions can send them to public

109
00:04:51,260 --> 00:04:48,450
lecture at STScl dot edu if you like

110
00:04:52,760 --> 00:04:51,270
social media we have social media for

111
00:04:54,770 --> 00:04:52,770
the Hubble Space Telescope for the

112
00:04:56,450 --> 00:04:54,780
upcoming James Webb Space Telescope and

113
00:04:59,360 --> 00:04:56,460

for our Institute the Space Telescope

114

00:05:03,020 --> 00:04:59,370

Science Institute on Facebook Twitter

115

00:05:05,210 --> 00:05:03,030

YouTube and Instagram and if you care

116

00:05:07,700 --> 00:05:05,220

about what I might want to tweet it out

117

00:05:09,590 --> 00:05:07,710

I'm on Facebook and Twitter but I will

118

00:05:12,350 --> 00:05:09,600

warn you I only do that occasionally

119

00:05:15,530 --> 00:05:12,360

because I get very busy my job and I

120

00:05:18,560 --> 00:05:15,540

enjoy my job and I don't do as much

121

00:05:20,330 --> 00:05:18,570

social media as perhaps I should the

122

00:05:23,600 --> 00:05:20,340

Observatory across the street at Johns

123

00:05:25,100 --> 00:05:23,610

Hopkins will not be open tonight they

124

00:05:28,670 --> 00:05:25,110

said it was looking like there could be

125

00:05:30,290 --> 00:05:28,680

showers and thundershowers and things

126

00:05:32,750 --> 00:05:30,300

were not set up properly for it to

127

00:05:35,450 --> 00:05:32,760

handle this and so there will be no

128

00:05:38,270 --> 00:05:35,460

observatory tonight however I always

129

00:05:40,130 --> 00:05:38,280

note that they do have open houses on

130

00:05:42,170 --> 00:05:40,140

Friday evenings if you go to the

131

00:05:44,600 --> 00:05:42,180

Maryland Space Grant Observatory website

132

00:05:47,450 --> 00:05:44,610

you can see the observatory status right

133

00:05:50,510 --> 00:05:47,460

there okay that Observatory status will

134

00:05:52,460 --> 00:05:50,520

be updated on Friday evenings about 6:00

135

00:05:54,470 --> 00:05:52,470

p.m. they tell me if they're going to be

136

00:05:58,460 --> 00:05:54,480

open so you can come down and see it

137

00:06:00,770 --> 00:05:58,470

then alright well we took all a long

138

00:06:03,650 --> 00:06:00,780

time here doing some some extra stuff

139

00:06:06,620 --> 00:06:03,660

here tonight so I have my news from the

140

00:06:08,300 --> 00:06:06,630

universe for july 2019 but i'm only

141

00:06:08,990 --> 00:06:08,310

going to give you a one-story here

142

00:06:12,860 --> 00:06:09,000

tonight okay

143

00:06:15,790 --> 00:06:12,870

and our only story for tonight is the

144

00:06:19,970 --> 00:06:15,800

intriguing atmosphere of a mini Neptune

145

00:06:22,340 --> 00:06:19,980

alright so in our solar system we have

146

00:06:24,890 --> 00:06:22,350

our earth here on the left and we have

147

00:06:27,380 --> 00:06:24,900

Neptune on the right and these are kind

148

00:06:29,720 --> 00:06:27,390

of roughly to scale or as as simple as

149

00:06:32,980 --> 00:06:29,730

two scales I can make it very quickly in

150

00:06:35,390 --> 00:06:32,990

PowerPoint and so Neptune's diameter is

151

00:06:38,870 --> 00:06:35,400

3.9 x earth it's about four times the

152

00:06:41,180 --> 00:06:38,880

size of Earth and it's math is 17 and a

153

00:06:45,410 --> 00:06:41,190

half 17.15 times

154

00:06:47,570 --> 00:06:45,420

earth okay so Neptune is a giant planet

155

00:06:50,120 --> 00:06:47,580

and some people have tied up call it a

156

00:06:52,820 --> 00:06:50,130

gas giant but actually if you're a real

157

00:06:56,270 --> 00:06:52,830

astronomer you call it an ice giant

158

00:06:58,970 --> 00:06:56,280

because Neptune is 30 times further away

159

00:07:01,640 --> 00:06:58,980

from the Sun than Earth it formed out

160

00:07:05,060 --> 00:07:01,650

beyond what we call the frost line and

161

00:07:08,030 --> 00:07:05,070

it formed with a lot of ices falling

162

00:07:11,090 --> 00:07:08,040

onto it okay so the atma the composition

163

00:07:12,290 --> 00:07:11,100

of Neptune's atmosphere contains a lot

164

00:07:15,170 --> 00:07:12,300

more heavy elements than it otherwise

165

00:07:17,150 --> 00:07:15,180

would if it had formed closer in where

166

00:07:20,210 --> 00:07:17,160

Jupiter and Saturn form and those are

167

00:07:24,020 --> 00:07:20,220

commonly called gas giants okay that's

168

00:07:29,960 --> 00:07:24,030

important because this discovery is

169

00:07:33,320 --> 00:07:29,970

about a planet called GJ 3470 B okay

170

00:07:36,560 --> 00:07:33,330

and this is a what we call a mini

171

00:07:39,230 --> 00:07:36,570

Neptune it's mass is twelve point six

172

00:07:41,420 --> 00:07:39,240

times earth so it's not quite as big as

173

00:07:44,000 --> 00:07:41,430

in up tune but it's much bigger than an

174

00:07:47,300 --> 00:07:44,010

earth alright we often have has anybody

175

00:07:49,940 --> 00:07:47,310

heard the phrase super earth okay yeah

176

00:07:52,340 --> 00:07:49,950

okay that is super earth generally we

177

00:07:54,740 --> 00:07:52,350

think of those up to five six seven

178

00:07:56,240 --> 00:07:54,750

maybe eight times the mass of Earth so

179

00:07:58,130 --> 00:07:56,250

this is sort of larger than a super

180

00:07:58,970 --> 00:07:58,140

earth but it's smaller than a full-size

181

00:08:00,950 --> 00:07:58,980

Neptune

182

00:08:03,260 --> 00:08:00,960

so it's it's starting into that

183

00:08:05,150 --> 00:08:03,270

in-between phase okay is it an

184

00:08:08,420 --> 00:08:05,160

earth-like object is a Neptune sized

185

00:08:10,220 --> 00:08:08,430

object at 13 times earth I considered

186

00:08:11,659 --> 00:08:10,230

more of a Neptune Neptune objects what I

187

00:08:14,900 --> 00:08:11,669

call it a mini I would call it a mini

188

00:08:18,230 --> 00:08:14,910

Neptune all right and they have measured

189

00:08:20,870 --> 00:08:18,240

the atmosphere of this object to have a

190

00:08:23,210 --> 00:08:20,880

hydrogen helium atmosphere with a rock

191

00:08:26,570 --> 00:08:23,220

and ice core and at first that's not

192

00:08:29,690 --> 00:08:26,580

really surprising but let's go a little

193

00:08:34,870 --> 00:08:29,700

further this planet has been discovered

194

00:08:38,120 --> 00:08:34,880

around a red dwarf star GJ 3470 okay and

195

00:08:42,020 --> 00:08:38,130

where as I told you that our Neptune is

196

00:08:44,960 --> 00:08:42,030

out beyond this frost line out at 38 30

197

00:08:47,540 --> 00:08:44,970

astronomical units this one in is in so

198

00:08:53,090 --> 00:08:47,550

close that it orbits around its star

199

00:08:54,740 --> 00:08:53,100

every 3.3 days okay it orbits this red

200

00:08:58,550 --> 00:08:54,750

dwarf star in three

201
00:09:00,020 --> 00:08:58,560
days furthermore it's not situated like

202
00:09:01,550 --> 00:09:00,030
this from our point of view it's

203
00:09:04,220 --> 00:09:01,560
actually situated from our point of view

204
00:09:06,890 --> 00:09:04,230
where it passes in front of its star and

205
00:09:09,650 --> 00:09:06,900
behind its star and in front of its star

206
00:09:11,480 --> 00:09:09,660
and behind a star when it passes in

207
00:09:13,730 --> 00:09:11,490
front of its star it's called a transit

208
00:09:16,910 --> 00:09:13,740
when it passes behind the star is called

209
00:09:18,800 --> 00:09:16,920
an eclipse all right and the Hubble

210
00:09:21,470 --> 00:09:18,810
Space Telescope and the Spitzer Space

211
00:09:26,000 --> 00:09:21,480
Telescope have been observing this

212
00:09:28,520 --> 00:09:26,010
planet star combination during let's see

213
00:09:32,060 --> 00:09:28,530

what's the notes they see like 20 a

214

00:09:32,750 --> 00:09:32,070

transits and 12 eclipses or is it the

215

00:09:34,430 --> 00:09:32,760

vice-versa

216

00:09:38,000 --> 00:09:34,440

all right so you put the two together

217

00:09:41,470 --> 00:09:38,010

you've got this net 2 mini Neptune sized

218

00:09:46,340 --> 00:09:41,480

planet passing in front of the red dwarf

219

00:09:49,490 --> 00:09:46,350

and in these transits and eclipses you

220

00:09:51,980 --> 00:09:49,500

can take it when it's in front and when

221

00:09:55,220 --> 00:09:51,990

it's not in front subtract off the

222

00:09:57,560 --> 00:09:55,230

spectra and get the atmosphere of the

223

00:09:59,690 --> 00:09:57,570

mini Neptune now we've done this for a

224

00:10:05,480 --> 00:09:59,700

lot of hot Jupiters we may have done it

225

00:10:06,829 --> 00:10:05,490

for a few seconds this is they claim one

226

00:10:09,050 --> 00:10:06,839

of the first time that's been done for a

227

00:10:10,579 --> 00:10:09,060

mini Neptune this is one of the smallest

228

00:10:14,090 --> 00:10:10,589

objects from which we're measuring the

229

00:10:15,320 --> 00:10:14,100

atmosphere now I said hydrogen helium

230

00:10:17,150 --> 00:10:15,330

atmosphere doesn't shouldn't surprise

231

00:10:18,770 --> 00:10:17,160

you much right because hydrogen and

232

00:10:22,610 --> 00:10:18,780

helium are the dominant elements in the

233

00:10:26,120 --> 00:10:22,620

universe however this atmosphere is

234

00:10:29,660 --> 00:10:26,130

really just hydrogen helium it doesn't

235

00:10:32,720 --> 00:10:29,670

contain the water vapor and the methane

236

00:10:35,360 --> 00:10:32,730

that you would expect for a Neptune if

237

00:10:37,579 --> 00:10:35,370

it was normal Neptune it formed out

238

00:10:40,640 --> 00:10:37,589

beyond the frost line and then it you

239

00:10:42,770 --> 00:10:40,650

know migrates inward due to

240

00:10:45,200 --> 00:10:42,780

gravitational interactions ok

241

00:10:47,270 --> 00:10:45,210

planets we don't expect Jupiter's and

242

00:10:49,790 --> 00:10:47,280

Neptune's to form close to their star

243

00:10:52,100 --> 00:10:49,800

they only form way out here and so if it

244

00:10:53,540 --> 00:10:52,110

migrates inward it should still at least

245

00:10:55,160 --> 00:10:53,550

keep its chemical composition in its

246

00:10:57,620 --> 00:10:55,170

atmosphere and there should be water

247

00:11:00,110 --> 00:10:57,630

vapor there should be methane they found

248

00:11:04,070 --> 00:11:00,120

no evidence of such and as such it's a

249

00:11:07,730 --> 00:11:04,080

weird an odd object how does it form a

250

00:11:08,420 --> 00:11:07,740

13 earth mass object without having a

251
00:11:10,850 --> 00:11:08,430
good

252
00:11:13,750 --> 00:11:10,860
of heavier elements in its atmosphere

253
00:11:16,700 --> 00:11:13,760
and that's the conundrum now they make a

254
00:11:20,030 --> 00:11:16,710
speculation that saying well perhaps it

255
00:11:24,050 --> 00:11:20,040
actually formed in situ okay that it

256
00:11:26,270 --> 00:11:24,060
formed in close to its star which I as

257
00:11:27,620 --> 00:11:26,280
an astronomer start to actually laughed

258
00:11:29,780 --> 00:11:27,630
at when it was brought up in the news

259
00:11:33,230 --> 00:11:29,790
meeting it's like come on

260
00:11:35,630 --> 00:11:33,240
you cannot form a giant planet in next

261
00:11:39,110 --> 00:11:35,640
to the star okay that's just not

262
00:11:41,480 --> 00:11:39,120
possible as far as I know maybe they

263
00:11:44,450 --> 00:11:41,490

know something I don't know but what

264

00:11:47,510 --> 00:11:44,460

they've speculated is that the rock and

265

00:11:50,360 --> 00:11:47,520

ice core formed first like a earth size

266

00:11:53,330 --> 00:11:50,370

a very large earth type rocky planet and

267

00:11:55,130 --> 00:11:53,340

that the hydrogen helium atmosphere then

268

00:11:58,460 --> 00:11:55,140

accreted onto it and that would have

269

00:12:00,020 --> 00:11:58,470

gone much larger except that this was

270

00:12:02,120 --> 00:12:00,030

late in the late in the stage and it

271

00:12:04,580 --> 00:12:02,130

only was able to pull in the hydrogen

272

00:12:06,320 --> 00:12:04,590

helium it wasn't out far enough for the

273

00:12:07,880 --> 00:12:06,330

ices to accrete that would have given

274

00:12:11,750 --> 00:12:07,890

the heavy elements in the atmosphere

275

00:12:14,690 --> 00:12:11,760

I consider that a bit speculative but it

276

00:12:17,690 --> 00:12:14,700

does make for an intriguing object that

277

00:12:20,570 --> 00:12:17,700

one of the first small small Neptune

278

00:12:23,540 --> 00:12:20,580

type objects that we measure doesn't

279

00:12:27,020 --> 00:12:23,550

have the characteristic atmosphere we

280

00:12:30,560 --> 00:12:27,030

expect for a Neptune sized object okay

281

00:12:32,420 --> 00:12:30,570

so to be continued as we study this more

282

00:12:36,500 --> 00:12:32,430

with both Hubble and Spitzer and

283

00:12:39,590 --> 00:12:36,510

upcoming space telescopes all right okay

284

00:12:42,590 --> 00:12:39,600

now we move on to our speaker for

285

00:12:45,560 --> 00:12:42,600

tonight and our speaker for tonight is

286

00:12:47,270 --> 00:12:45,570

Joseph de Pascua he got his degree in

287

00:12:50,930 --> 00:12:47,280

astronomy and astrophysics from

288

00:12:53,480 --> 00:12:50,940

Villanova University and then spent 15

289

00:12:56,960 --> 00:12:53,490

years up in Boston at the Chandra x-ray

290

00:12:59,930 --> 00:12:56,970

Center where he became an absolute

291

00:13:02,920 --> 00:12:59,940

expert in astronomical image processing

292

00:13:05,690 --> 00:13:02,930

in data processing in visualization

293

00:13:08,050 --> 00:13:05,700

anything uh taking the universe and

294

00:13:10,820 --> 00:13:08,060

making it understandable and

295

00:13:12,530 --> 00:13:10,830

contributing to press releases I think

296

00:13:15,830 --> 00:13:12,540

Joe can do it okay because when he got

297

00:13:18,110 --> 00:13:15,840

here the first project I worked with him

298

00:13:20,090 --> 00:13:18,120

on I said here try something like this

299

00:13:22,070 --> 00:13:20,100

and I've never gotten anybody in this

300

00:13:24,320 --> 00:13:22,080

building to be able to

301
00:13:26,090 --> 00:13:24,330
to really jump in when you were working

302
00:13:27,590 --> 00:13:26,100
on the candle stuff together and he just

303
00:13:31,160 --> 00:13:27,600
jumped in as a tall figure it out

304
00:13:33,290 --> 00:13:31,170
mayhem he figured it out so he's been

305
00:13:36,560 --> 00:13:33,300
very impressive in his few years here

306
00:13:38,360 --> 00:13:36,570
and he is now our lead image processor

307
00:13:40,700 --> 00:13:38,370
and he's here to talk to you about our

308
00:13:50,050 --> 00:13:40,710
colorful universe translating cosmic

309
00:14:08,960 --> 00:13:50,060
light everyone Joseph de Pascua whoops

310
00:14:10,040 --> 00:14:08,970
what number you want oh well thank you

311
00:14:12,050 --> 00:14:10,050
Frank for that introduction

312
00:14:13,610 --> 00:14:12,060
it was nice and thank you everyone for

313
00:14:16,820 --> 00:14:13,620

being here tonight it's really it's

314

00:14:18,470 --> 00:14:16,830

great to see such a full audience and hi

315

00:14:24,200 --> 00:14:18,480

to everyone out on the Internet as well

316

00:14:26,530 --> 00:14:24,210

I think my family's on - so our cult for

317

00:14:29,060 --> 00:14:26,540

universe translating cosmic light is

318

00:14:31,730 --> 00:14:29,070

intentionally vague enough title that I

319

00:14:34,610 --> 00:14:31,740

can sort of cover whatever I want which

320

00:14:36,680 --> 00:14:34,620

I like what I would like to do though is

321

00:14:38,000 --> 00:14:36,690

to talk a little bit about the the

322

00:14:40,280 --> 00:14:38,010

methods that I use for processing

323

00:14:42,200 --> 00:14:40,290

astronomical data but I want to frame it

324

00:14:44,180 --> 00:14:42,210

in the context of the history of our

325

00:14:46,040 --> 00:14:44,190

understanding of light and so we're

326

00:14:48,520 --> 00:14:46,050

gonna spend the first maybe third of the

327

00:14:50,570 --> 00:14:48,530

talk talking about the history of light

328

00:14:52,670 --> 00:14:50,580

and before I get into that I want to

329

00:14:54,500 --> 00:14:52,680

talk a little bit about just light in

330

00:14:56,480 --> 00:14:54,510

general I mean it's the dominant way

331

00:14:59,240 --> 00:14:56,490

that we experience our world our eyes

332

00:15:02,450 --> 00:14:59,250

are constantly flooded with light but

333

00:15:04,190 --> 00:15:02,460

imagine oh so light carries information

334

00:15:05,810 --> 00:15:04,200

we're surrounded by information imagine

335

00:15:07,570 --> 00:15:05,820

if our eyes were actually sensitive to

336

00:15:10,400 --> 00:15:07,580

light beyond the visible wavelengths

337

00:15:13,040 --> 00:15:10,410

this is a conceptual visualization

338

00:15:15,950 --> 00:15:13,050

showing what it might look like to be

339

00:15:17,990 --> 00:15:15,960

able to see cellphone tower signals in a

340

00:15:19,700 --> 00:15:18,000

city so if our eyes were sensitive to

341

00:15:22,430 --> 00:15:19,710

this kind of light we would just see the

342

00:15:23,750 --> 00:15:22,440

city blanketed in light every one of

343

00:15:24,980 --> 00:15:23,760

these buildings basically has a cell

344

00:15:29,660 --> 00:15:24,990

tower above and it's emitting signals

345

00:15:31,280 --> 00:15:29,670

all the time we're imagine being able to

346

00:15:33,890 --> 00:15:31,290

see Wi-Fi signals this is a

347

00:15:35,840 --> 00:15:33,900

visualization of why free Wi-Fi signals

348

00:15:37,100 --> 00:15:35,850

on the National Mall and that

349

00:15:38,930 --> 00:15:37,110

being on the National Mall sitting on a

350

00:15:42,590 --> 00:15:38,940

park bench and just seeing this swirling

351
00:15:44,809 --> 00:15:42,600
around you it would be overwhelming for

352
00:15:48,800 --> 00:15:44,819
sure very glad that our eyes are

353
00:15:50,269 --> 00:15:48,810
sensitive just a visible light of course

354
00:15:54,079 --> 00:15:50,279
we all know we've heard about the speed

355
00:15:56,600 --> 00:15:54,089
of light 186,000 miles per second or 3

356
00:15:59,180 --> 00:15:56,610
times 10 to the 8 meters per second in

357
00:16:01,879 --> 00:15:59,190
our light bubble of Earth that seems

358
00:16:04,040 --> 00:16:01,889
instantaneous right that's the speed of

359
00:16:06,050 --> 00:16:04,050
light travels around the earth seven and

360
00:16:08,509 --> 00:16:06,060
a half times in one second and so in our

361
00:16:10,819 --> 00:16:08,519
experiential life on this planet light

362
00:16:13,370 --> 00:16:10,829
is instant but as soon as we leave that

363
00:16:16,999 --> 00:16:13,380

light bubble that speed limit becomes

364

00:16:18,769 --> 00:16:17,009

important for example Jupiter which is

365

00:16:20,689 --> 00:16:18,779

up if the clouds clear tonight when we

366

00:16:22,100 --> 00:16:20,699

leave the light that isn't currently

367

00:16:24,470 --> 00:16:22,110

reflecting off of Jupiter as I'm

368

00:16:27,410 --> 00:16:24,480

speaking right now we'll be hitting

369

00:16:29,689 --> 00:16:27,420

earth when you leave here tonight so

370

00:16:31,040 --> 00:16:29,699

keep an eye out when you go outside

371

00:16:35,300 --> 00:16:31,050

for Jupiter it'll be the big bright

372

00:16:36,949 --> 00:16:35,310

thing in the southeast sky and this of

373

00:16:38,480 --> 00:16:36,959

course this speed limit to light gets

374

00:16:41,809 --> 00:16:38,490

even more significant as we move away

375

00:16:44,329 --> 00:16:41,819

from our solar system as a species our

376

00:16:45,740 --> 00:16:44,339

humanity has been generating radio

377

00:16:48,590 --> 00:16:45,750

signals for about a hundred years and

378

00:16:51,490 --> 00:16:48,600

that basically creates a light bubble

379

00:16:53,960 --> 00:16:51,500

around our solar system that's been

380

00:16:56,269 --> 00:16:53,970

expanding into our galaxy for a hundred

381

00:16:58,370 --> 00:16:56,279

years but on a galactic scale it's

382

00:17:00,679 --> 00:16:58,380

pretty insignificant if I were to ask

383

00:17:02,090 --> 00:17:00,689

you to draw a circle on this this is a

384

00:17:05,990 --> 00:17:02,100

visualization of the Milky Way galaxy

385

00:17:09,620 --> 00:17:06,000

and somewhere in here is a circle that

386

00:17:12,020 --> 00:17:09,630

shows how much light has moved through

387

00:17:13,520 --> 00:17:12,030

our galaxy in a hundred years you might

388

00:17:17,169 --> 00:17:13,530

think it would be something like this

389

00:17:22,939 --> 00:17:17,179

but no it's that little dot right there

390

00:17:24,500 --> 00:17:22,949

zoom in on that so when people say why

391

00:17:25,490 --> 00:17:24,510

can't we send a probe up into space to

392

00:17:29,870 --> 00:17:25,500

be able to take a picture of the Milky

393

00:17:30,980 --> 00:17:29,880

Way from above that's why and that's to

394

00:17:33,409 --> 00:17:30,990

me I can travel at the speed of light

395

00:17:35,360 --> 00:17:33,419

which is not possible of course it would

396

00:17:38,960 --> 00:17:35,370

take millions of years generations to be

397

00:17:41,600 --> 00:17:38,970

able to do something like that but now

398

00:17:43,450 --> 00:17:41,610

moving on into the history of light this

399

00:17:46,100 --> 00:17:43,460

is what I call a crash course in light

400

00:17:47,750 --> 00:17:46,110

and I'm by no means an expert in this

401
00:17:49,740 --> 00:17:47,760
but there are a few key concepts that I

402
00:17:52,560 --> 00:17:49,750
want to touch on before we dive into the

403
00:17:54,120 --> 00:17:52,570
processing part of this so we've known

404
00:17:55,410 --> 00:17:54,130
about and have been studying light for

405
00:17:57,270 --> 00:17:55,420
thousands of years going all the way

406
00:17:58,740 --> 00:17:57,280
back to Chinese and ancient Greek

407
00:18:02,250 --> 00:17:58,750
philosophers of course the ancient

408
00:18:04,830 --> 00:18:02,260
Greeks had this idea called EXO was an

409
00:18:06,540 --> 00:18:04,840
EXO mission or extra mission the extra

410
00:18:08,370 --> 00:18:06,550
mission theory of light which was that

411
00:18:10,650 --> 00:18:08,380
our eyes were actually emitting light

412
00:18:12,450 --> 00:18:10,660
rays and so the light that we saw was

413
00:18:15,110 --> 00:18:12,460

actually bounced off of objects from our

414

00:18:17,130 --> 00:18:15,120

eyes of course we know that's not true

415

00:18:19,590 --> 00:18:17,140

what the Greek philosophers gave us

416

00:18:21,570 --> 00:18:19,600

though was really a scientific method a

417

00:18:24,450 --> 00:18:21,580

way of analytically thinking about

418

00:18:26,640 --> 00:18:24,460

things moving on through the Islamic

419

00:18:28,440 --> 00:18:26,650

civilization European enlightenment up

420

00:18:31,110 --> 00:18:28,450

to the discovery of the visible spectrum

421

00:18:33,750 --> 00:18:31,120

with Isaac Newton in 1666 this is where

422

00:18:39,270 --> 00:18:33,760

we finally started to realize that light

423

00:18:41,670 --> 00:18:39,280

is made up of component colors and then

424

00:18:43,440 --> 00:18:41,680

moving beyond visible light William

425

00:18:46,980 --> 00:18:43,450

Herschel discovered infrared light in

426

00:18:48,090 --> 00:18:46,990

1800 he was doing an experiment where he

427

00:18:50,730 --> 00:18:48,100

was actually measuring the temperature

428

00:18:54,630 --> 00:18:50,740

of colors of light so building on the

429

00:18:56,520 --> 00:18:54,640

work of Newton he was able to use a

430

00:18:57,930 --> 00:18:56,530

prism to it break down light into its

431

00:18:59,190 --> 00:18:57,940

component colors and then he was

432

00:19:01,020 --> 00:18:59,200

actually just using the thermometer to

433

00:19:03,660 --> 00:19:01,030

measure the temperature of the light and

434

00:19:05,820 --> 00:19:03,670

what he noticed was blue light was

435

00:19:07,740 --> 00:19:05,830

cooler than redder light and so as he

436

00:19:09,780 --> 00:19:07,750

went from blue to red the temperature

437

00:19:12,290 --> 00:19:09,790

was going up but then as he went just

438

00:19:14,190 --> 00:19:12,300

beyond read the thermometer kept rising

439

00:19:16,560 --> 00:19:14,200

so what's going on here there's nothing

440

00:19:17,700 --> 00:19:16,570

there that you can see but the

441

00:19:18,930 --> 00:19:17,710

thermometer is rising there must be

442

00:19:20,970 --> 00:19:18,940

something there that's causing it to

443

00:19:22,260 --> 00:19:20,980

rise that's actually infrared light

444

00:19:25,130 --> 00:19:22,270

there's light there that our eyes are

445

00:19:26,910 --> 00:19:25,140

not sensitive to and now we can thank

446

00:19:28,890 --> 00:19:26,920

William Herschel for discovering

447

00:19:31,740 --> 00:19:28,900

infrared light if you have a cell phone

448

00:19:33,930 --> 00:19:31,750

with face ID that's how it works it uses

449

00:19:35,760 --> 00:19:33,940

infrared light to project something onto

450

00:19:37,680 --> 00:19:35,770

your face that basically creates a grid

451
00:19:40,440 --> 00:19:37,690
the phone recognizes your face in that

452
00:19:45,270 --> 00:19:40,450
grid and then unlocks your phone so you

453
00:19:47,790 --> 00:19:45,280
can check Facebook moving on into

454
00:19:51,840 --> 00:19:47,800
spectroscopy Joseph von Fraunhofer in

455
00:19:54,330 --> 00:19:51,850
1814 he develops a method for

456
00:19:57,720 --> 00:19:54,340
analytically looking at the spectrum

457
00:19:59,760 --> 00:19:57,730
that's generated from a prism and also

458
00:20:01,080 --> 00:19:59,770
discovers the the dark absorption lines

459
00:20:02,580 --> 00:20:01,090
that we see you if you look at a solar

460
00:20:03,930 --> 00:20:02,590
spectrum you see all these dark lines in

461
00:20:06,119 --> 00:20:03,940
there and that's caused by

462
00:20:08,430 --> 00:20:06,129
atoms and molecules in the solar

463
00:20:10,559 --> 00:20:08,440

atmosphere absorbing light at specific

464

00:20:13,529 --> 00:20:10,569

frequencies and so this is where we

465

00:20:19,469 --> 00:20:13,539

start to move from qualitative to

466

00:20:22,739 --> 00:20:19,479

quantitative analysis of light building

467

00:20:24,539 --> 00:20:22,749

on even further James Clerk Maxwell and

468

00:20:26,699 --> 00:20:24,549

this is a really pivotal moment in our

469

00:20:28,259 --> 00:20:26,709

understanding of light he discovers this

470

00:20:29,399 --> 00:20:28,269

connection studying electricity and

471

00:20:32,759 --> 00:20:29,409

magnetism and he discovers this

472

00:20:34,319 --> 00:20:32,769

connection with with light where these

473

00:20:36,119 --> 00:20:34,329

fields these oscillating fields of

474

00:20:38,569 --> 00:20:36,129

electricity and magnetism are moving at

475

00:20:40,589 --> 00:20:38,579

what is known as the speed of light see

476

00:20:42,149 --> 00:20:40,599

and so this is the first time that we

477

00:20:43,589 --> 00:20:42,159

draw this connection that light that we

478

00:20:47,449 --> 00:20:43,599

see with our eyes is actually the same

479

00:20:53,519 --> 00:20:47,459

thing as electromagnetic spectrum and

480

00:20:56,849 --> 00:20:53,529

that was in 1860 in 1895 Wilhelm

481

00:21:01,409 --> 00:20:56,859

roentgen discovers x-rays because he's

482

00:21:06,749 --> 00:21:03,959

he was experimenting with vacuum tubes

483

00:21:08,849 --> 00:21:06,759

in the lab and and discovered this there

484

00:21:11,159 --> 00:21:08,859

was a he had a tube shining and across

485

00:21:15,239 --> 00:21:11,169

the room there was this material that

486

00:21:16,649 --> 00:21:15,249

was tough blow to fluorescing and it was

487

00:21:18,959 --> 00:21:16,659

basically x-rays were being shot across

488

00:21:22,349 --> 00:21:18,969

the room hitting this this piece of film

489

00:21:23,459 --> 00:21:22,359

and lighting it up and then from that he

490

00:21:26,099 --> 00:21:23,469

goes on to become the father at

491

00:21:29,069 --> 00:21:26,109

diagnostic radiology and he also wins

492

00:21:36,329 --> 00:21:29,079

the first Nobel Prize in 1901 which is

493

00:21:39,239 --> 00:21:36,339

really cool and you may notice that

494

00:21:41,699 --> 00:21:39,249

the name Rankin may sound familiar his

495

00:21:43,499 --> 00:21:41,709

name became synonymous with x-rays so he

496

00:21:45,449 --> 00:21:43,509

called it x-rays but then people

497

00:21:46,799 --> 00:21:45,459

especially in Germany called them wrong

498

00:21:51,379 --> 00:21:46,809

can raise and if you've watched

499

00:21:57,269 --> 00:21:53,909

building on the work of Maxwell in the

500

00:21:59,339 --> 00:21:57,279

Einstein era Einstein discovers in 1905

501
00:22:00,749 --> 00:21:59,349
the photoelectric effect and this is

502
00:22:02,459 --> 00:22:00,759
where we start to have an understanding

503
00:22:05,459 --> 00:22:02,469
of light as both a wave and a particle

504
00:22:08,219 --> 00:22:05,469
the wave particle duality of light

505
00:22:14,759 --> 00:22:08,229
Einstein also wins a Nobel Prize very

506
00:22:15,930 --> 00:22:14,769
cool for this work in 1921 so now with

507
00:22:18,149 --> 00:22:15,940
this sort of rudimentary understanding

508
00:22:19,820 --> 00:22:18,159
of our history of understanding

509
00:22:21,570 --> 00:22:19,830
we now have a framework for

510
00:22:23,100 --> 00:22:21,580
understanding how light is paved the

511
00:22:26,009 --> 00:22:23,110
wave this understanding is paved the way

512
00:22:27,930 --> 00:22:26,019
for astronomical spectroscopy which is

513
00:22:31,580 --> 00:22:27,940

now taking astronomy into a quantitative

514

00:22:34,109 --> 00:22:31,590

realm and allows astronomers to start to

515

00:22:37,200 --> 00:22:34,119

qualify stars by the nature of their

516

00:22:39,389 --> 00:22:37,210

light we can we can classify them that

517

00:22:41,159 --> 00:22:39,399

way and so as I mentioned before this is

518

00:22:42,960 --> 00:22:41,169

a this is a really detailed solar

519

00:22:44,729 --> 00:22:42,970

spectrum here and all of these dark

520

00:22:46,680 --> 00:22:44,739

lines here are caused by atoms and

521

00:22:48,479 --> 00:22:46,690

molecules in the solar atmosphere and

522

00:22:52,470 --> 00:22:48,489

using this information this is how we

523

00:22:54,899 --> 00:22:52,480

can classify stars but there are other

524

00:22:58,379 --> 00:22:54,909

ways that we get information from stars

525

00:23:00,509 --> 00:22:58,389

notably just by their light and there's

526

00:23:02,190 --> 00:23:00,519

a really great example of how just just

527

00:23:05,159 --> 00:23:02,200

measuring light and its intensity is

528

00:23:07,590 --> 00:23:05,169

really important not even 100 years ago

529

00:23:10,409 --> 00:23:07,600

we had this concept of the size of our

530

00:23:12,359 --> 00:23:10,419

universe that was was completely

531

00:23:13,379 --> 00:23:12,369

different than what we think today there

532

00:23:15,029 --> 00:23:13,389

was something called the great debate

533

00:23:18,899 --> 00:23:15,039

between Harlow Shapley and Herbert

534

00:23:21,330 --> 00:23:18,909

Curtis in 1920 where Shapley was on the

535

00:23:22,340 --> 00:23:21,340

side of saying that our universe was the

536

00:23:24,389 --> 00:23:22,350

Milky Way galaxy

537

00:23:26,249 --> 00:23:24,399

everything the entirety of the universe

538

00:23:27,570 --> 00:23:26,259

when we look up in the sky was contained

539

00:23:30,239 --> 00:23:27,580

within the hundred thousand light years

540

00:23:33,389 --> 00:23:30,249

or so of the Milky Way and Herbert

541

00:23:34,619 --> 00:23:33,399

Curtis was arguing that observational

542

00:23:37,320 --> 00:23:34,629

astronomers were looking up in the night

543

00:23:40,049 --> 00:23:37,330

sky and seeing what they called spiral

544

00:23:41,820 --> 00:23:40,059

nebulae now Herbert Curtis theorized

545

00:23:44,460 --> 00:23:41,830

that these spiral nebulae were actually

546

00:23:46,680 --> 00:23:44,470

island universes or other galaxies in

547

00:23:50,669 --> 00:23:46,690

their own right much further distant

548

00:23:52,259 --> 00:23:50,679

from the Milky Way and so this was this

549

00:23:55,470 --> 00:23:52,269

is kind of what the state of the art was

550

00:24:00,440 --> 00:23:55,480

not in 1920 but one of the first hand

551
00:24:06,389 --> 00:24:02,700
of course light was the answer to

552
00:24:09,499 --> 00:24:06,399
figuring out the distance and and the

553
00:24:11,669 --> 00:24:09,509
true size of the universe and this was

554
00:24:13,200 --> 00:24:11,679
through the importance of Cepheid

555
00:24:15,989 --> 00:24:13,210
variable stars these are a type of star

556
00:24:18,090 --> 00:24:15,999
that pulsate with a known frequency that

557
00:24:20,269 --> 00:24:18,100
is directly related to their luminosity

558
00:24:22,169 --> 00:24:20,279
the amount of light they give off

559
00:24:24,180 --> 00:24:22,179
Henrietta Leavitt at the Harvard

560
00:24:25,200 --> 00:24:24,190
Observatory discovered this they call it

561
00:24:28,649 --> 00:24:25,210
appears she call it a period-luminosity

562
00:24:30,389 --> 00:24:28,659
relationship and so if you are able to

563
00:24:31,529 --> 00:24:30,399

accurately measure the period of

564

00:24:33,149 --> 00:24:31,539

pulsations of a Steffie

565

00:24:35,190 --> 00:24:33,159

variable star and you're able to

566

00:24:38,729 --> 00:24:35,200

determine the distance to the star very

567

00:24:40,259 --> 00:24:38,739

accurately and just to give you a sort

568

00:24:42,570 --> 00:24:40,269

of a down-to-earth example of how this

569

00:24:45,210 --> 00:24:42,580

works let's consider the 100 watt light

570

00:24:47,369 --> 00:24:45,220

bulb its absolute magnitude or its

571

00:24:49,590 --> 00:24:47,379

intrinsic brightness is 100 watts it's

572

00:24:51,899 --> 00:24:49,600

printed right on it its apparent

573

00:24:54,060 --> 00:24:51,909

magnitude is the brightness that you

574

00:24:56,999 --> 00:24:54,070

would measure from a distance to that

575

00:24:59,580 --> 00:24:57,009

light bulb okay and that has a very

576

00:25:01,580 --> 00:24:59,590

well-known relationship where the light

577

00:25:03,629 --> 00:25:01,590

falls off as a 1 over R squared

578

00:25:05,849 --> 00:25:03,639

relationship so as you go away from the

579

00:25:08,669 --> 00:25:05,859

light bulb that the brightness is

580

00:25:11,849 --> 00:25:08,679

dropping significantly and this way in

581

00:25:14,629 --> 00:25:11,859

this way and the true equation here this

582

00:25:16,649 --> 00:25:14,639

is how you can just derive the distance

583

00:25:19,950 --> 00:25:16,659

once you've measured that apparent

584

00:25:21,989 --> 00:25:19,960

magnitude and if you know the absolute

585

00:25:27,960 --> 00:25:21,999

magnitude then you can determine the

586

00:25:29,609 --> 00:25:27,970

distance to that bulb so this period

587

00:25:31,680 --> 00:25:29,619

luminosity function is essential in

588

00:25:36,299 --> 00:25:31,690

understanding the distances to the

589

00:25:38,519 --> 00:25:36,309

Cepheid variable stars so combined with

590

00:25:39,690 --> 00:25:38,529

their apparent magnitude we can now get

591

00:25:41,249 --> 00:25:39,700

an accurate distance measurement and

592

00:25:44,879 --> 00:25:41,259

that's exactly how this debate was

593

00:25:46,859 --> 00:25:44,889

finally settled in 1923 Edwin Hubble was

594

00:25:50,789 --> 00:25:46,869

observing Cepheid variable stars in the

595

00:25:55,499 --> 00:25:50,799

Andromeda nebula when he discovered this

596

00:25:57,239 --> 00:25:55,509

variable clearly denoted as var and

597

00:25:59,310 --> 00:25:57,249

using the the period-luminosity

598

00:26:01,049 --> 00:25:59,320

relationship he was able to determine an

599

00:26:03,450 --> 00:26:01,059

accurate distance to the Andromeda

600

00:26:06,089 --> 00:26:03,460

galaxy which was two and a half million

601
00:26:08,849 --> 00:26:06,099
light-years which was way further than

602
00:26:10,080 --> 00:26:08,859
the understanding of the size of the

603
00:26:11,940 --> 00:26:10,090
Milky Way galaxy at that time which was

604
00:26:13,859 --> 00:26:11,950
about a hundred thousand light years so

605
00:26:15,810 --> 00:26:13,869
a completely blew open our concept of

606
00:26:20,310 --> 00:26:15,820
the size of the universe just through

607
00:26:22,169 --> 00:26:20,320
measuring the brightness of light back

608
00:26:24,180 --> 00:26:22,179
in 2011 the Hubble Space Telescope

609
00:26:26,039 --> 00:26:24,190
actually went and looked at that same

610
00:26:27,659 --> 00:26:26,049
exact variable star and we measured a

611
00:26:32,639 --> 00:26:27,669
very accurate light curve and working

612
00:26:34,560 --> 00:26:32,649
with ground-based astronomers we have we

613
00:26:36,149 --> 00:26:34,570

determined a period of 31.4 days for

614

00:26:40,139 --> 00:26:36,159

that particular Cepheid variable star

615

00:26:42,210 --> 00:26:40,149

and so forth at work and for his many

616

00:26:44,339 --> 00:26:42,220

other contributions to our understanding

617

00:26:45,390 --> 00:26:44,349

of the event universe we named our

618

00:26:49,110 --> 00:26:45,400

favorite Space Telescope

619

00:26:50,520 --> 00:26:49,120

after Edwin Hubble the Hubble Space

620

00:26:53,070 --> 00:26:50,530

Telescope is arguably the greatest

621

00:26:55,680 --> 00:26:53,080

scientific endeavor of in the history of

622

00:26:57,510 --> 00:26:55,690

humanity for the last 29 years it has

623

00:26:59,970 --> 00:26:57,520

been providing us with breathtaking

624

00:27:03,860 --> 00:26:59,980

views of the cosmos and groundbreaking

625

00:27:05,940 --> 00:27:03,870

science thanks in no small part to the

626

00:27:08,580 --> 00:27:05,950

courageous men and women of the

627

00:27:10,740 --> 00:27:08,590

astronaut program who went up in four

628

00:27:11,970 --> 00:27:10,750

Shuttle missions servicing missions to

629

00:27:15,000 --> 00:27:11,980

make sure that Hubble was working in

630

00:27:16,800 --> 00:27:15,010

tip-top shape Hubble has become

631

00:27:17,820 --> 00:27:16,810

synonymous with astronomy and has

632

00:27:19,560 --> 00:27:17,830

literally transformed our understanding

633

00:27:21,000 --> 00:27:19,570

of the universe but also our

634

00:27:23,700 --> 00:27:21,010

understanding of what the universe looks

635

00:27:26,010 --> 00:27:23,710

like I think of these images as cosmic

636

00:27:27,380 --> 00:27:26,020

landscapes and as an image processor I

637

00:27:29,490 --> 00:27:27,390

approach them as a photographer would

638

00:27:31,650 --> 00:27:29,500

trying to pull out as much detail as

639

00:27:34,650 --> 00:27:31,660

possible while respecting the inherent

640

00:27:36,120 --> 00:27:34,660

data indeed the further we look the

641

00:27:40,860 --> 00:27:36,130

deeper we look with Hubble the deeper it

642

00:27:42,240 --> 00:27:40,870

gets and now I'd like to actually

643

00:27:45,120 --> 00:27:42,250

explore a little further some of the

644

00:27:47,340 --> 00:27:45,130

sorry some of the photographic concepts

645

00:27:48,780 --> 00:27:47,350

that I was talking about here the visual

646

00:27:50,820 --> 00:27:48,790

principles that that are sort of a

647

00:27:52,290 --> 00:27:50,830

guiding force in the work that I do when

648

00:27:54,120 --> 00:27:52,300

I'm taking the data from the telescope

649

00:27:56,490 --> 00:27:54,130

and turning it into press release

650

00:27:57,870 --> 00:27:56,500

imagery and so the three three key

651
00:28:00,360 --> 00:27:57,880
concepts that I always try to keep in

652
00:28:05,100 --> 00:28:00,370
mind are tonality color and Composition

653
00:28:07,860 --> 00:28:05,110
in these images so starting with

654
00:28:10,740 --> 00:28:07,870
tonality when we get the data from the

655
00:28:12,480 --> 00:28:10,750
telescope it comes down it looks

656
00:28:14,190 --> 00:28:12,490
basically just black and that's because

657
00:28:17,130 --> 00:28:14,200
the sensors the detectors on the

658
00:28:19,200 --> 00:28:17,140
telescope are very sensitive to light in

659
00:28:22,710 --> 00:28:19,210
a way that our eyes are not there's a

660
00:28:24,390 --> 00:28:22,720
huge dynamic range meaning that the the

661
00:28:27,690 --> 00:28:24,400
darkest darks and the brightest brights

662
00:28:30,150 --> 00:28:27,700
there's just a huge range of intensity

663
00:28:31,680 --> 00:28:30,160

values between the two much more than

664

00:28:33,390 --> 00:28:31,690

our eyes could see or much more that can

665

00:28:35,850 --> 00:28:33,400

even be displayed on an on a computer

666

00:28:37,650 --> 00:28:35,860

screen and so we have to scale that data

667

00:28:39,840 --> 00:28:37,660

so the first step is to be able to pull

668

00:28:41,760 --> 00:28:39,850

out the details of the data and so in

669

00:28:44,400 --> 00:28:41,770

this this is a linear scaling of an

670

00:28:46,140 --> 00:28:44,410

image we're using a linear scale you

671

00:28:48,420 --> 00:28:46,150

basically just see the brightest points

672

00:28:49,680 --> 00:28:48,430

so the Stars the Centers of the galaxies

673

00:28:52,380 --> 00:28:49,690

those are the things that are showing up

674

00:28:53,730 --> 00:28:52,390

when you do a linear scale now if you

675

00:28:56,070 --> 00:28:53,740

want to pull out more detail and see

676

00:28:58,320 --> 00:28:56,080

stuff that's that's darker than those

677

00:28:59,120 --> 00:28:58,330

bright point sources you need to ramp it

678

00:29:01,610 --> 00:28:59,130

up you need to

679

00:29:04,460 --> 00:29:01,620

that black level and just squish it up

680

00:29:05,960 --> 00:29:04,470

there and so now you can actually see

681

00:29:07,669 --> 00:29:05,970

some of that faint detail in that faint

682

00:29:09,680 --> 00:29:07,679

structure and the galaxies the the dust

683

00:29:11,900 --> 00:29:09,690

structure but because we stayed with a

684

00:29:13,400 --> 00:29:11,910

linear scaling we've sacrificed the

685

00:29:14,960 --> 00:29:13,410

cores of the galaxies and the cores of

686

00:29:17,450 --> 00:29:14,970

these bright stars now they're all blown

687

00:29:20,180 --> 00:29:17,460

out and we've we've lost we've lost data

688

00:29:22,310 --> 00:29:20,190

by doing this this is a completely

689

00:29:25,340 --> 00:29:22,320

saturated to white so you've lost that

690

00:29:27,350 --> 00:29:25,350

data so we need to do a nonlinear

691

00:29:30,200 --> 00:29:27,360

transformation to the image to be able

692

00:29:32,240 --> 00:29:30,210

to recover the details in those cores

693

00:29:34,700 --> 00:29:32,250

but also be able to see the structure

694

00:29:36,080 --> 00:29:34,710

the faint structure in those galaxies so

695

00:29:37,789 --> 00:29:36,090

a nonlinear transformation like a

696

00:29:40,279 --> 00:29:37,799

logarithmic transformation onto the

697

00:29:41,810 --> 00:29:40,289

image will allow you to see the full

698

00:29:44,960 --> 00:29:41,820

range of brightness from darkest to

699

00:29:47,210 --> 00:29:44,970

bright without sacrificing anything so

700

00:29:50,930 --> 00:29:47,220

this is a key first step in in working

701
00:29:52,520 --> 00:29:50,940
on these these data and an example of a

702
00:29:53,630 --> 00:29:52,530
tool that you could use to do this kind

703
00:29:55,640 --> 00:29:53,640
of thing is this is called fits

704
00:29:58,520 --> 00:29:55,650
Liberator it's available for free from

705
00:30:00,110 --> 00:29:58,530
the Space Telescope org I don't actually

706
00:30:01,880 --> 00:30:00,120
use this tool I use something called pix

707
00:30:05,060 --> 00:30:01,890
insight if you're an astronaut odd refer

708
00:30:06,409 --> 00:30:05,070
you may be familiar with that basically

709
00:30:08,360 --> 00:30:06,419
all this does is it allows you to do

710
00:30:10,120 --> 00:30:08,370
that kind of transformation that kind of

711
00:30:12,440 --> 00:30:10,130
nonlinear transformation to your data

712
00:30:14,060 --> 00:30:12,450
you basically select the stretch

713
00:30:16,010 --> 00:30:14,070

function here so in this case it's an

714

00:30:18,440 --> 00:30:16,020

arc sine function which is a nonlinear

715

00:30:19,960 --> 00:30:18,450

transformation and then in here you see

716

00:30:23,000 --> 00:30:19,970

the histogram which is basically just

717

00:30:25,330 --> 00:30:23,010

showing you the intensity values from

718

00:30:28,640 --> 00:30:25,340

dark to bright across the whole image

719

00:30:30,680 --> 00:30:28,650

okay so there's a lot of really dark

720

00:30:31,970 --> 00:30:30,690

stuff and then a tip there's a long tail

721

00:30:33,230 --> 00:30:31,980

to the bright stuff so the brightest

722

00:30:34,850 --> 00:30:33,240

things are these stars and then

723

00:30:37,490 --> 00:30:34,860

everything else sort of shows up in the

724

00:30:39,080 --> 00:30:37,500

in the darkest range and so you can now

725

00:30:40,850 --> 00:30:39,090

stretch that out and then you can change

726
00:30:42,970 --> 00:30:40,860
your white and black points to suit your

727
00:30:45,140 --> 00:30:42,980
needs

728
00:30:47,960 --> 00:30:45,150
so now thinking about color and

729
00:30:51,440 --> 00:30:47,970
composite color this is how we get color

730
00:30:52,940 --> 00:30:51,450
from these images Hubble takes images in

731
00:30:55,010 --> 00:30:52,950
different filters and those filters

732
00:30:57,830 --> 00:30:55,020
allow certain wavelengths of light to

733
00:31:00,020 --> 00:30:57,840
pass through to create images specific

734
00:31:01,970 --> 00:31:00,030
to those wavelengths so when we look

735
00:31:03,380 --> 00:31:01,980
through color filters we see color but

736
00:31:05,539 --> 00:31:03,390
Hubble's detectors see in black and

737
00:31:06,770 --> 00:31:05,549
white and so the images that we get from

738
00:31:09,409 --> 00:31:06,780

the telescope are black and white

739

00:31:12,530 --> 00:31:09,419

we need to apply color after the fact to

740

00:31:14,060 --> 00:31:12,540

make a color image and so for the exam

741

00:31:16,720 --> 00:31:14,070

that we were looking at this is Stefan's

742

00:31:19,730 --> 00:31:16,730

quintet this is what we call a natural

743

00:31:23,090 --> 00:31:19,740

broadband color the three filters that

744

00:31:24,770 --> 00:31:23,100

are here are basically red green and

745

00:31:26,480 --> 00:31:24,780

blue essentially since the sensitivity

746

00:31:29,570 --> 00:31:26,490

of our eyes that's why we call it

747

00:31:30,980 --> 00:31:29,580

natural color each filter covers a sort

748

00:31:32,960 --> 00:31:30,990

of a broad wavelength range

749

00:31:36,590 --> 00:31:32,970

corresponding to blue light green light

750

00:31:38,210 --> 00:31:36,600

and red light so we take these data

751
00:31:40,280 --> 00:31:38,220
we've scaled them now appropriately with

752
00:31:42,620 --> 00:31:40,290
a nonlinear transformation now we apply

753
00:31:45,710 --> 00:31:42,630
color to them according to their

754
00:31:47,960 --> 00:31:45,720
wavelengths in the filters and then we

755
00:31:48,620 --> 00:31:47,970
combine them together in image editing

756
00:31:52,760 --> 00:31:48,630
software

757
00:31:55,190 --> 00:31:52,770
maybe Photoshop and you get this now

758
00:31:58,820 --> 00:31:55,200
this isn't the end of the story this is

759
00:32:00,680 --> 00:31:58,830
where the the more subjective aesthetics

760
00:32:03,140 --> 00:32:00,690
come into play so the photographer's eye

761
00:32:06,020 --> 00:32:03,150
becomes important here to be able to

762
00:32:08,690 --> 00:32:06,030
notice if there's a color cast in this

763
00:32:10,160 --> 00:32:08,700

image if there are things that are that

764

00:32:11,420 --> 00:32:10,170

need to be cleaned up a lot of times

765

00:32:14,900 --> 00:32:11,430

there are artifacts in these images

766

00:32:16,790 --> 00:32:14,910

there are cosmic rays there are ghosts

767

00:32:17,900 --> 00:32:16,800

from reflect internal reflections of the

768

00:32:19,430 --> 00:32:17,910

telescope and all these things have to

769

00:32:22,910 --> 00:32:19,440

be taken out of the image for for a

770

00:32:25,130 --> 00:32:22,920

press release and so after cleaning all

771

00:32:27,650 --> 00:32:25,140

that up and adjusting contrast and

772

00:32:31,100 --> 00:32:27,660

tonality we get we arrive at the the

773

00:32:32,690 --> 00:32:31,110

clean press release image using the the

774

00:32:35,180 --> 00:32:32,700

full tonal range and preserving as much

775

00:32:37,880 --> 00:32:35,190

of the color to show off all of the

776

00:32:39,590 --> 00:32:37,890

important structures in the image so for

777

00:32:42,140 --> 00:32:39,600

example that the galaxy the foreground

778

00:32:44,570 --> 00:32:42,150

galaxy here these bright red regions are

779

00:32:46,490 --> 00:32:44,580

they're called h2 regions their pockets

780

00:32:48,290 --> 00:32:46,500

of hydrogen gas where stars are forming

781

00:32:50,000 --> 00:32:48,300

and we want to be able to see that

782

00:32:53,390 --> 00:32:50,010

clearly in the image and so it's

783

00:32:55,730 --> 00:32:53,400

processed to show that now looking at

784

00:32:59,180 --> 00:32:55,740

another type of image that Hubble will

785

00:33:02,690 --> 00:32:59,190

typically take data on is a narrowband

786

00:33:04,010 --> 00:33:02,700

image and now this is similar to what we

787

00:33:06,440 --> 00:33:04,020

were just talking about within the

788

00:33:08,960 --> 00:33:06,450

natural color only with narrow bands the

789

00:33:11,240 --> 00:33:08,970

filters that we use are looking at very

790

00:33:14,110 --> 00:33:11,250

specific wavelengths very small regions

791

00:33:16,250 --> 00:33:14,120

of the electromagnetic spectrum and

792

00:33:17,780 --> 00:33:16,260

we're taking an image and each one of

793

00:33:20,090 --> 00:33:17,790

those filters and now combining them

794

00:33:22,310 --> 00:33:20,100

together to make a color image but

795

00:33:26,180 --> 00:33:22,320

unlike before where we had the sort of

796

00:33:28,280 --> 00:33:26,190

natural transmen translation from

797

00:33:30,290 --> 00:33:28,290

red green and blue based on the filters

798

00:33:32,600 --> 00:33:30,300

in this case these filters that

799

00:33:34,790 --> 00:33:32,610

correspond to oxygen hydrogen and sulfur

800

00:33:37,010 --> 00:33:34,800

if I were to color them according to

801
00:33:39,500 --> 00:33:37,020
where they actually exist on the visible

802
00:33:42,350 --> 00:33:39,510
spectrum you would basically get cyan

803
00:33:45,250 --> 00:33:42,360
red and slightly more red which creates

804
00:33:48,560 --> 00:33:45,260
this image which is kind of ugly and

805
00:33:50,090 --> 00:33:48,570
doesn't actually tell you a lot it's

806
00:33:51,950 --> 00:33:50,100
it's aesthetically it's not very nice

807
00:33:54,740 --> 00:33:51,960
but it also doesn't really reveal the

808
00:33:59,840 --> 00:33:54,750
true beauty and the true depth of the

809
00:34:02,330 --> 00:33:59,850
data so instead of using the the colors

810
00:34:04,810 --> 00:34:02,340
as they're assigned in the spectrum we

811
00:34:08,870 --> 00:34:04,820
can apply this sort of RGB mentality to

812
00:34:11,210 --> 00:34:08,880
shift wavelengths shift the filters and

813
00:34:12,470 --> 00:34:11,220

apply blue green and red to these as

814

00:34:14,030 --> 00:34:12,480

well as long as it's chromatically

815

00:34:15,950 --> 00:34:14,040

ordered so that the shortest wavelengths

816

00:34:18,880 --> 00:34:15,960

get blue and the longest wavelengths get

817

00:34:22,970 --> 00:34:18,890

red and then green comes in the middle

818

00:34:25,970 --> 00:34:22,980

so now oxygen becomes pure blue hydrogen

819

00:34:27,169 --> 00:34:25,980

becomes green and sulfur stays red but

820

00:34:29,080 --> 00:34:27,179

when you combine them together this way

821

00:34:31,400 --> 00:34:29,090

you get this much more pleasing

822

00:34:32,780 --> 00:34:31,410

composite image that actually reveals

823

00:34:34,610 --> 00:34:32,790

more detail because you've now created

824

00:34:36,560 --> 00:34:34,620

an image that has a fuller color range

825

00:34:39,290 --> 00:34:36,570

in it it allows more of the data to show

826

00:34:41,600 --> 00:34:39,300

off I mean I would argue that the the

827

00:34:44,600 --> 00:34:41,610

wispy details surrounding the nebula

828

00:34:48,380 --> 00:34:44,610

here are much more apparent in the image

829

00:34:49,610 --> 00:34:48,390

that's RGB and of course this is the

830

00:34:50,169 --> 00:34:49,620

Eagle Nebula I probably should have led

831

00:34:55,090 --> 00:34:50,179

with that

832

00:34:57,110 --> 00:34:55,100

the famous pillars of creation image and

833

00:35:00,590 --> 00:34:57,120

then there's the post-processing steps

834

00:35:03,050 --> 00:35:00,600

so here is the that the basic color

835

00:35:06,080 --> 00:35:03,060

combination RG and B from those narrow

836

00:35:06,650 --> 00:35:06,090

band filters but that's not the end of

837

00:35:09,380 --> 00:35:06,660

the story

838

00:35:10,700 --> 00:35:09,390

we will now want to take away the color

839

00:35:12,410 --> 00:35:10,710

casts we want to do additional

840

00:35:14,900 --> 00:35:12,420

processing we want to brighten it we

841

00:35:16,400 --> 00:35:14,910

want to highlight different features the

842

00:35:18,860 --> 00:35:16,410

stars look a little strange let's take

843

00:35:20,780 --> 00:35:18,870

some of that red out of the stars let's

844

00:35:23,450 --> 00:35:20,790

emphasize the structure of the the

845

00:35:25,640 --> 00:35:23,460

pillars of creation themselves balance

846

00:35:28,010 --> 00:35:25,650

the color better pull out the shadow

847

00:35:30,860 --> 00:35:28,020

details as much as we can and then crop

848

00:35:33,620 --> 00:35:30,870

it and that's just work the composition

849

00:35:35,630 --> 00:35:33,630

comes into play these images are these

850

00:35:37,130 --> 00:35:35,640

are objects in space there's no up or

851
00:35:39,600 --> 00:35:37,140
down although astronomers will argue

852
00:35:45,070 --> 00:35:42,910
it must be Northup it doesn't have to be

853
00:35:47,340 --> 00:35:45,080
Northup it can be any orientation that

854
00:35:49,840 --> 00:35:47,350
works aesthetically if we want it to be

855
00:35:53,050 --> 00:35:49,850
so that's where the photographer's eye

856
00:35:54,430 --> 00:35:53,060
again comes into play so now I'd like to

857
00:35:55,630 --> 00:35:54,440
shift a little bit from what we've been

858
00:35:58,150 --> 00:35:55,640
talking about with Hubble into more

859
00:35:59,770 --> 00:35:58,160
multi-wavelength astronomy and before I

860
00:36:01,240 --> 00:35:59,780
do that I just want to give you a quick

861
00:36:02,710 --> 00:36:01,250
refresher on the electromagnetic

862
00:36:04,030 --> 00:36:02,720
spectrum I've been talking about it a

863
00:36:06,730 --> 00:36:04,040

lot but I never actually showed this

864

00:36:07,780 --> 00:36:06,740

this graph I'm sure most of you are

865

00:36:10,030 --> 00:36:07,790

familiar with the electromagnetic

866

00:36:13,930 --> 00:36:10,040

spectrum this is light in all its forms

867

00:36:15,640 --> 00:36:13,940

from the the lowest energy longest

868

00:36:17,350 --> 00:36:15,650

wavelengths up to the highest energy

869

00:36:19,540 --> 00:36:17,360

shortest wavelengths so radio microwave

870

00:36:21,700 --> 00:36:19,550

infrared visible light UV x-ray gamma

871

00:36:23,710 --> 00:36:21,710

ray it's all there this is everything

872

00:36:24,970 --> 00:36:23,720

all that we well not that all that we

873

00:36:27,280 --> 00:36:24,980

see all that we see is just that little

874

00:36:28,690 --> 00:36:27,290

bit in the middle and that's because our

875

00:36:30,070 --> 00:36:28,700

eyes have evolved on a planet that

876

00:36:33,790 --> 00:36:30,080

orbits a star that emits most of its

877

00:36:35,530 --> 00:36:33,800

light in the visible wavelengths so as

878

00:36:36,580 --> 00:36:35,540

I'm showing these images in the

879

00:36:38,290 --> 00:36:36,590

following slides I'm gonna have this

880

00:36:40,960 --> 00:36:38,300

handy little guide here to tell you

881

00:36:42,820 --> 00:36:40,970

which wavelengths of light are actually

882

00:36:44,520 --> 00:36:42,830

shown in that image and how they're

883

00:36:46,600 --> 00:36:44,530

colored so keep an eye out for that

884

00:36:49,090 --> 00:36:46,610

before I show the images that I want to

885

00:36:53,050 --> 00:36:49,100

just review quickly the NASA's Great

886

00:36:55,210 --> 00:36:53,060

observatories program this was NASA's

887

00:36:58,420 --> 00:36:55,220

attempt to to really broaden our

888

00:36:59,800 --> 00:36:58,430

horizons visually speaking to take in as

889

00:37:02,890 --> 00:36:59,810

much light as possible in all the

890

00:37:04,360 --> 00:37:02,900

different wavelength ranges and they

891

00:37:05,890 --> 00:37:04,370

have to be for most part they have to be

892

00:37:09,640 --> 00:37:05,900

space-based observatories because

893

00:37:12,850 --> 00:37:09,650

Earth's atmosphere is opaque to most of

894

00:37:14,050 --> 00:37:12,860

these high-energy most of the

895

00:37:15,880 --> 00:37:14,060

high-energy part of the electromagnetic

896

00:37:18,040 --> 00:37:15,890

spectrum gamma rays x-rays they're all

897

00:37:21,940 --> 00:37:18,050

and UV are mostly absorbed by our

898

00:37:23,470 --> 00:37:21,950

atmosphere which is good for us in the

899

00:37:25,180 --> 00:37:23,480

infrared is also mostly absorbed by the

900

00:37:26,590 --> 00:37:25,190

atmosphere and so we have to put these

901
00:37:29,050 --> 00:37:26,600
observatories up in space above our

902
00:37:31,030 --> 00:37:29,060
atmosphere of course with Hubble it's it

903
00:37:32,830 --> 00:37:31,040
really helps to have the telescope up in

904
00:37:34,240 --> 00:37:32,840
space because even though the atmosphere

905
00:37:38,880 --> 00:37:34,250
it lets visible light through it does

906
00:37:41,080 --> 00:37:38,890
distort it so NASA's Great observatories

907
00:37:44,260 --> 00:37:41,090
include the Compton gamma ray

908
00:37:47,590 --> 00:37:44,270
Observatory which was launched in 1991

909
00:37:49,300 --> 00:37:47,600
and operated until 2000 the Chandra

910
00:37:51,850 --> 00:37:49,310
x-ray Observatory which is this year

911
00:37:52,960 --> 00:37:51,860
celebrating 20 years in orbit Hubble

912
00:37:55,900 --> 00:37:52,970
Space Telescope which is

913
00:37:58,420 --> 00:37:55,910

29 years in orbit and the Spitzer Space

914

00:38:00,760 --> 00:37:58,430

Telescope which was launched in 2003 and

915

00:38:05,770 --> 00:38:00,770

is supposed to be shut down in January

916

00:38:06,790 --> 00:38:05,780

so why would why don't we want to look

917

00:38:11,109 --> 00:38:06,800

at the universe in multiple wavelengths

918

00:38:13,630 --> 00:38:11,119

I like to make this analogy to listening

919

00:38:14,770 --> 00:38:13,640

to an orchestra and imagine that you're

920

00:38:17,650 --> 00:38:14,780

listening to the orchestra but you can

921

00:38:18,960 --> 00:38:17,660

only hear a brass section it's gonna be

922

00:38:21,190 --> 00:38:18,970

a very different experience

923

00:38:22,570 --> 00:38:21,200

similarly when we're looking in space

924

00:38:24,760 --> 00:38:22,580

and we're trying to observe the universe

925

00:38:26,980 --> 00:38:24,770

and understand it it really helps to

926

00:38:28,000 --> 00:38:26,990

look and as many wavelengths as possible

927

00:38:31,180 --> 00:38:28,010

because there's a lot more information

928

00:38:34,060 --> 00:38:31,190

there so let's look at something in

929

00:38:36,130 --> 00:38:34,070

x-ray light now we're in high energies

930

00:38:39,130 --> 00:38:36,140

we shift it into high gear this is

931

00:38:41,050 --> 00:38:39,140

Cassiopeia A and it's an x-ray image in

932

00:38:42,940 --> 00:38:41,060

red green and blue so following a

933

00:38:44,520 --> 00:38:42,950

similar coloring pattern to what I

934

00:38:47,290 --> 00:38:44,530

showed you with the narrowband imaging

935

00:38:49,690 --> 00:38:47,300

now we're applying that concept to x-ray

936

00:38:51,310 --> 00:38:49,700

light we're breaking it down into low

937

00:38:53,920 --> 00:38:51,320

medium and high energy x-rays and

938

00:38:55,570 --> 00:38:53,930

applying red green and blue colors to

939

00:38:57,790 --> 00:38:55,580

those images and when you put that all

940

00:39:01,120 --> 00:38:57,800

together you get this amazing image of a

941

00:39:02,890 --> 00:39:01,130

supernova remnant where this bright spot

942

00:39:05,170 --> 00:39:02,900

here is a neutron star that's left over

943

00:39:07,930 --> 00:39:05,180

after the explosion a supernova of a

944

00:39:10,720 --> 00:39:07,940

star all of that material was blasted

945

00:39:13,390 --> 00:39:10,730

off into space and is emitting x-rays

946

00:39:15,370 --> 00:39:13,400

it's very hot and there are blast waves

947

00:39:17,650 --> 00:39:15,380

moving outward and there's one moving

948

00:39:19,440 --> 00:39:17,660

inwards called a reverse shock the

949

00:39:21,730 --> 00:39:19,450

highest-energy x-rays which are blue

950

00:39:23,560 --> 00:39:21,740

surrounds all of the material inside

951
00:39:25,630 --> 00:39:23,570
that's the shockwave moving out into

952
00:39:27,940 --> 00:39:25,640
space there's even this cool jet

953
00:39:29,500 --> 00:39:27,950
shooting out to the side here that's

954
00:39:31,450 --> 00:39:29,510
mostly green light that actually

955
00:39:34,120 --> 00:39:31,460
corresponds to iron that's emitting

956
00:39:36,430 --> 00:39:34,130
x-rays and that's a really interesting

957
00:39:38,650 --> 00:39:36,440
feature some somehow the star when it

958
00:39:40,210 --> 00:39:38,660
exploded preferentially shot material

959
00:39:43,480 --> 00:39:40,220
out in one direction and that became the

960
00:39:45,730 --> 00:39:43,490
jet moving in that direction but now we

961
00:39:47,170 --> 00:39:45,740
can apply this multi-wavelength concept

962
00:39:50,109 --> 00:39:47,180
to it and bring in Hubble Space

963
00:39:52,480 --> 00:39:50,119

Telescope data and if I take away the

964

00:39:54,930 --> 00:39:52,490

x-ray data we get a very different

965

00:39:58,060 --> 00:39:54,940

understanding of the supernova remnant

966

00:39:59,530 --> 00:39:58,070

most of what we're seeing here traces a

967

00:40:02,170 --> 00:39:59,540

lot of what we saw in the x-rays but

968

00:40:04,690 --> 00:40:02,180

leaves a lot out too this is oxygen

969

00:40:06,250 --> 00:40:04,700

mostly oxygen that's emitting it's

970

00:40:11,260 --> 00:40:06,260

radiating and visit

971

00:40:14,890 --> 00:40:11,270

wavelengths but also an x-ray we were

972

00:40:16,360 --> 00:40:14,900

back to the x-ray here's another one of

973

00:40:21,070 --> 00:40:16,370

my favorites this the Whirlpool Galaxy

974

00:40:25,270 --> 00:40:21,080

and what we're looking at here is the

975

00:40:28,060 --> 00:40:25,280

full color natural color broadband red

976
00:40:31,720 --> 00:40:28,070
green and blue optical image and x-rays

977
00:40:33,220 --> 00:40:31,730
overlaid in purple and now this is a

978
00:40:34,870 --> 00:40:33,230
this is of just a beautiful spiral

979
00:40:36,520 --> 00:40:34,880
galaxy that we many people are familiar

980
00:40:38,920 --> 00:40:36,530
with with that's been a very famous

981
00:40:41,290 --> 00:40:38,930
Hubble image full of these h2 regions

982
00:40:43,780 --> 00:40:41,300
these regions of star formation full of

983
00:40:46,300 --> 00:40:43,790
blue stars lots of intricate dust lanes

984
00:40:48,670 --> 00:40:46,310
moving out and it's spiral but when we

985
00:40:51,610 --> 00:40:48,680
look at it in the solely in x-rays we

986
00:40:53,530 --> 00:40:51,620
see a very different view mainly what

987
00:40:56,080 --> 00:40:53,540
we're looking at here is hot gas the hot

988
00:40:58,050 --> 00:40:56,090

gas between stars and all the points

989

00:41:01,480 --> 00:40:58,060

sources here most of those are actually

990

00:41:04,690 --> 00:41:01,490

black holes or x-ray binaries neutron

991

00:41:06,550 --> 00:41:04,700

saw our black hole binaries and of

992

00:41:10,090 --> 00:41:06,560

course there's the supermassive black

993

00:41:11,350 --> 00:41:10,100

hole at the center of the the Whirlpool

994

00:41:12,970 --> 00:41:11,360

Galaxy as well that we're seeing in

995

00:41:14,290 --> 00:41:12,980

x-ray light so all of this is this is

996

00:41:15,580 --> 00:41:14,300

very high-energy phenomena that's

997

00:41:18,400 --> 00:41:15,590

emitting x-rays and we're seeing that

998

00:41:20,020 --> 00:41:18,410

here and now we can also apply the three

999

00:41:22,840 --> 00:41:20,030

color method to this and get even more

1000

00:41:24,550 --> 00:41:22,850

information from the x-ray data and so

1001
00:41:25,870 --> 00:41:24,560
now we're seeing that most of that hot

1002
00:41:28,060 --> 00:41:25,880
gas that we're looking at is actually

1003
00:41:29,710 --> 00:41:28,070
emitting low-energy x-rays and it's

1004
00:41:32,470 --> 00:41:29,720
those point sources that are really the

1005
00:41:38,080 --> 00:41:32,480
really super energetic bright white

1006
00:41:39,850 --> 00:41:38,090
lights of this in this galaxy now moving

1007
00:41:41,920 --> 00:41:39,860
on so one of my favorite images that I

1008
00:41:45,910 --> 00:41:41,930
one of the first images I worked on when

1009
00:41:48,280 --> 00:41:45,920
I came over to space telescope the Crab

1010
00:41:49,630 --> 00:41:48,290
Nebula so this is a supernova remnant

1011
00:41:52,480 --> 00:41:49,640
another supernova remnant they're my

1012
00:41:54,720 --> 00:41:52,490
favorite in the constellation of Taurus

1013
00:41:57,310 --> 00:41:54,730

it's about 6,500 light years away and

1014

00:41:58,540 --> 00:41:57,320

this image is actually made up of five

1015

00:42:00,250 --> 00:41:58,550

different wavelengths of light

1016

00:42:03,550 --> 00:42:00,260

all combined together so now we're kind

1017

00:42:05,830 --> 00:42:03,560

of taking our concept of three color and

1018

00:42:07,420 --> 00:42:05,840

playing around with it and when I made

1019

00:42:10,390 --> 00:42:07,430

this image I really was thinking that

1020

00:42:12,070 --> 00:42:10,400

way I was like I have this concept for

1021

00:42:14,800 --> 00:42:12,080

how to put together images with three

1022

00:42:16,660 --> 00:42:14,810

with 3m and three component images red

1023

00:42:18,610 --> 00:42:16,670

green and blue how can we apply that to

1024

00:42:20,050 --> 00:42:18,620

something that has more more than three

1025

00:42:23,080 --> 00:42:20,060

channels to it

1026

00:42:24,970 --> 00:42:23,090

well basically I just took the color

1027

00:42:27,330 --> 00:42:24,980

wheel and broke it down I just divided

1028

00:42:31,600 --> 00:42:27,340

it by five and so then you get steps of

1029

00:42:34,330 --> 00:42:31,610

72 per color so the lowest wavelength

1030

00:42:39,370 --> 00:42:34,340

radio data gets read and then you move

1031

00:42:41,790 --> 00:42:39,380

up 72 color units into the green sort of

1032

00:42:44,860 --> 00:42:41,800

orangish green to get to infra red and

1033

00:42:48,190 --> 00:42:44,870

then optical and an ultraviolet and

1034

00:42:50,290 --> 00:42:48,200

x-ray so it's really basically a simple

1035

00:42:53,200 --> 00:42:50,300

application of this this idea of how to

1036

00:42:55,330 --> 00:42:53,210

apply color to the data and now we can

1037

00:42:57,760 --> 00:42:55,340

step through each one and see in the

1038

00:42:59,620 --> 00:42:57,770

Crab Nebula this is a neutron star

1039

00:43:01,870 --> 00:42:59,630

pulsar at the centre here again it's

1040

00:43:03,550 --> 00:43:01,880

another supernova remnant there's a disk

1041

00:43:04,870 --> 00:43:03,560

of material swirling around this and

1042

00:43:07,480 --> 00:43:04,880

this is again all x-rays are very

1043

00:43:08,710 --> 00:43:07,490

high-energy this material swirling

1044

00:43:10,510 --> 00:43:08,720

around the star there are jets coming

1045

00:43:12,610 --> 00:43:10,520

out of it and it's basically the heart

1046

00:43:14,050 --> 00:43:12,620

the engine of this whole supernova

1047

00:43:17,080 --> 00:43:14,060

remnant it's just a radiating everything

1048

00:43:19,660 --> 00:43:17,090

around it so as we step down an energy

1049

00:43:22,090 --> 00:43:19,670

shift in wavelengths now we're looking

1050

00:43:24,970 --> 00:43:22,100

at ultraviolet light and that starts to

1051
00:43:28,270 --> 00:43:24,980
show more of the interior of the nebulas

1052
00:43:29,860 --> 00:43:28,280
structure surrounding the Pulsar now

1053
00:43:31,690 --> 00:43:29,870
with Hubble and it's superb resolution

1054
00:43:33,070 --> 00:43:31,700
we're seeing filaments of material that

1055
00:43:36,070 --> 00:43:33,080
were ejected from that star and are

1056
00:43:37,540 --> 00:43:36,080
being irradiated by that core and you

1057
00:43:40,420 --> 00:43:37,550
can kind of see a ghost of that core

1058
00:43:42,160 --> 00:43:40,430
here this sort of ghostly glow in the

1059
00:43:44,380 --> 00:43:42,170
middle here that's again coming from

1060
00:43:48,580 --> 00:43:44,390
that neutron star and it's and it's

1061
00:43:49,900 --> 00:43:48,590
swirling disc of material as we shift

1062
00:43:52,120 --> 00:43:49,910
down to longer wavelengths lower

1063
00:43:54,070 --> 00:43:52,130

energies now we're looking at warm dust

1064

00:43:56,290 --> 00:43:54,080

so this is kind of tracing those

1065

00:43:57,520 --> 00:43:56,300

filaments as well and the only gets a

1066

00:44:00,610 --> 00:43:57,530

radio wavelengths we're actually looking

1067

00:44:02,170 --> 00:44:00,620

at more of we're getting an

1068

00:44:04,270 --> 00:44:02,180

understanding of the magnetic fields

1069

00:44:06,460 --> 00:44:04,280

that are constraining all of the

1070

00:44:08,080 --> 00:44:06,470

material in the supernova remnant and so

1071

00:44:10,570 --> 00:44:08,090

now this is a really great example of

1072

00:44:12,340 --> 00:44:10,580

why it matters to look at the universe

1073

00:44:13,630 --> 00:44:12,350

and multiple wavelengths having all of

1074

00:44:14,770 --> 00:44:13,640

this information and being able to see

1075

00:44:16,600 --> 00:44:14,780

it all at once gives you a much

1076

00:44:21,530 --> 00:44:16,610

different picture of what's happening

1077

00:44:25,460 --> 00:44:23,540

now here's a really good one I just put

1078

00:44:28,220 --> 00:44:25,470

this in here yesterday this is a press

1079

00:44:31,250 --> 00:44:28,230

release from yesterday of Etta karena

1080

00:44:34,550 --> 00:44:31,260

this is 7,500 light-years away in the

1081

00:44:36,500 --> 00:44:34,560

Carina constellation and basically

1082

00:44:38,180 --> 00:44:36,510

there's there was an explosion about 170

1083

00:44:40,130 --> 00:44:38,190

years ago and there's this sort of

1084

00:44:41,720 --> 00:44:40,140

bipolar outflow coming out there was

1085

00:44:44,840 --> 00:44:41,730

there was a triple star system we think

1086

00:44:46,580 --> 00:44:44,850

maybe one of the stars absorbed the

1087

00:44:48,650 --> 00:44:46,590

other star and created this explosion so

1088

00:44:50,390 --> 00:44:48,660

now there's a binary system in here the

1089

00:44:51,890 --> 00:44:50,400

really interesting thing about this new

1090

00:44:55,090 --> 00:44:51,900

image that just came out yesterday and

1091

00:44:59,630 --> 00:44:55,100

it's a celebration of the 4th of July

1092

00:45:02,540 --> 00:44:59,640

the blue data here this is all new this

1093

00:45:05,060 --> 00:45:02,550

was just taken last year and it's it's

1094

00:45:06,650 --> 00:45:05,070

highlighting magnesium and I should say

1095

00:45:07,820 --> 00:45:06,660

this is a just as just Hubble data this

1096

00:45:09,730 --> 00:45:07,830

is just an optical image we're not

1097

00:45:12,440 --> 00:45:09,740

looking at x-rays or anything like that

1098

00:45:15,350 --> 00:45:12,450

but this was the first time that we were

1099

00:45:17,600 --> 00:45:15,360

able to see material sort of between the

1100

00:45:18,920 --> 00:45:17,610

we call this the homunculus between the

1101
00:45:21,710 --> 00:45:18,930
homunculus and then the surrounding

1102
00:45:23,090 --> 00:45:21,720
nebula in the red we always thought

1103
00:45:24,860 --> 00:45:23,100
there was sort of this gap between the

1104
00:45:29,390 --> 00:45:24,870
two but now it's actually filled in with

1105
00:45:30,980 --> 00:45:29,400
magnesium magnesium light and it was

1106
00:45:34,100 --> 00:45:30,990
made possible by taking a really deep

1107
00:45:35,720 --> 00:45:34,110
look at this object in that filter which

1108
00:45:38,270 --> 00:45:35,730
is an ultraviolet so it's a pretty

1109
00:45:40,280 --> 00:45:38,280
high-energy filter and Hubble terms and

1110
00:45:42,410 --> 00:45:40,290
it has implications for our

1111
00:45:44,120 --> 00:45:42,420
understanding of these kinds of objects

1112
00:45:45,980 --> 00:45:44,130
elsewhere in the universe you know I've

1113
00:45:47,780 --> 00:45:45,990

been talking about these h2 regions and

1114

00:45:49,700 --> 00:45:47,790

galaxies these red dots that sort of

1115

00:45:51,470 --> 00:45:49,710

highlight star formation well it's

1116

00:45:53,780 --> 00:45:51,480

possible that there are these magnitude

1117

00:45:56,600 --> 00:45:53,790

regions elsewhere as well to kind of

1118

00:45:59,810 --> 00:45:56,610

highlight another another aspect of this

1119

00:46:00,980 --> 00:45:59,820

kind of formation and one thing I've

1120

00:46:02,450 --> 00:46:00,990

wanted to do with this which is really

1121

00:46:04,610 --> 00:46:02,460

fun and I could do this for any image

1122

00:46:07,130 --> 00:46:04,620

but I thought this would be cool let's

1123

00:46:09,200 --> 00:46:07,140

take a step back and see where this is

1124

00:46:09,710 --> 00:46:09,210

in the sky right there's the Milky Way

1125

00:46:11,870 --> 00:46:09,720

galaxy

1126
00:46:13,700 --> 00:46:11,880
this is a beautiful image made by a Nick

1127
00:46:16,280 --> 00:46:13,710
Reisinger he actually travelled the

1128
00:46:18,380 --> 00:46:16,290
world to take this image over the period

1129
00:46:20,030 --> 00:46:18,390
of about a year took images all around

1130
00:46:21,770 --> 00:46:20,040
the world and put together this stitch

1131
00:46:23,330 --> 00:46:21,780
together this huge panoramic image of

1132
00:46:24,920 --> 00:46:23,340
the Milky Way galaxy and this isn't even

1133
00:46:27,770 --> 00:46:24,930
the whole thing it's just a piece of it

1134
00:46:29,900 --> 00:46:27,780
but that region we were just looking at

1135
00:46:33,050 --> 00:46:29,910
is contained within that little box so

1136
00:46:35,160 --> 00:46:33,060
now let's zoom in on that box this is a

1137
00:46:37,380 --> 00:46:35,170
digitized Sky Survey

1138
00:46:39,740 --> 00:46:37,390

of that region so this is the Carina

1139

00:46:42,120 --> 00:46:39,750

Nebula here this sort of whole structure

1140

00:46:45,180 --> 00:46:42,130

now we can zoom it even further this

1141

00:46:47,400 --> 00:46:45,190

becomes like fractal this box here

1142

00:46:50,010 --> 00:46:47,410

corresponds to a famous Hubble press

1143

00:46:52,740 --> 00:46:50,020

release image from a few years ago the

1144

00:46:55,859 --> 00:46:52,750

Carina complex and now contained within

1145

00:46:57,599 --> 00:46:55,869

this image is at a Carina the image we

1146

00:47:03,839 --> 00:46:57,609

were just looking at in this little box

1147

00:47:04,829 --> 00:47:03,849

right here now we're back and since

1148

00:47:06,120 --> 00:47:04,839

we've been talking about multiple

1149

00:47:09,150 --> 00:47:06,130

wavelengths and multi-wavelength

1150

00:47:11,339 --> 00:47:09,160

astronomy let's back out and take a look

1151
00:47:14,579 --> 00:47:11,349
at it in this context when surrounded in

1152
00:47:18,589 --> 00:47:14,589
x-ray light so this is that same region

1153
00:47:21,359 --> 00:47:18,599
this is at a Carina now same color Khan

1154
00:47:23,549 --> 00:47:21,369
composite but now we've also overlaid it

1155
00:47:25,859 --> 00:47:23,559
with x-ray light and so the x-rays are

1156
00:47:27,809 --> 00:47:25,869
actually emitting sort of outside of

1157
00:47:32,010 --> 00:47:27,819
what we were looking at before this is

1158
00:47:35,160 --> 00:47:32,020
again it's hot gas and edit Carina the

1159
00:47:37,740 --> 00:47:35,170
Hubble image sits inside of that then we

1160
00:47:41,130 --> 00:47:37,750
can take that away you can see in three

1161
00:47:43,049 --> 00:47:41,140
color now that core there is really

1162
00:47:45,900 --> 00:47:43,059
high-energy x-ray it's blue light this

1163
00:47:47,670 --> 00:47:45,910

is a same kind of three color red green

1164

00:47:50,339 --> 00:47:47,680

and blue combination as I've been

1165

00:47:51,750 --> 00:47:50,349

talking about before so that core is

1166

00:47:53,250 --> 00:47:51,760

very highly energetic it's emitting a

1167

00:47:55,079 --> 00:47:53,260

lot of x-ray light and it's radiating

1168

00:47:58,380 --> 00:47:55,089

the surrounding material around it and

1169

00:48:04,049 --> 00:47:58,390

that's that's hot gas emitting x-rays

1170

00:48:06,150 --> 00:48:04,059

and at lower energies now let's shift

1171

00:48:07,740 --> 00:48:06,160

back down now we're looking in optical

1172

00:48:09,900 --> 00:48:07,750

light again this was a Hubble's

1173

00:48:12,000 --> 00:48:09,910

Anniversary image from last year 20th

1174

00:48:15,599 --> 00:48:12,010

anniversary image this is the Lagoon

1175

00:48:18,630 --> 00:48:15,609

Nebula or a Messier 8 and this is a

1176

00:48:19,980 --> 00:48:18,640

great example of Hubble's capabilities

1177

00:48:21,660 --> 00:48:19,990

as a multi wavelength observatory

1178

00:48:26,069 --> 00:48:21,670

because we also looked at it in infrared

1179

00:48:28,260 --> 00:48:26,079

light so that's the infrared view of

1180

00:48:29,940 --> 00:48:28,270

this same region of space when we look

1181

00:48:32,130 --> 00:48:29,950

at it in infrared we actually peer

1182

00:48:34,740 --> 00:48:32,140

through the dust and see the background

1183

00:48:36,660 --> 00:48:34,750

stars behind this nebula and only the

1184

00:48:40,140 --> 00:48:36,670

densest regions the densest clumps of

1185

00:48:45,510 --> 00:48:40,150

materials remain in infrared sort of

1186

00:48:47,819 --> 00:48:45,520

this ghostly glow of dust here and this

1187

00:48:49,200 --> 00:48:47,829

highlights the importance of the James

1188

00:48:51,200 --> 00:48:49,210

Webb Space Telescope

1189

00:48:54,690 --> 00:48:51,210
which will be launched in March of 2021

1190

00:48:55,829 --> 00:48:54,700
that is going to be an infrared

1191

00:48:56,849 --> 00:48:55,839
telescope looking at the universe and

1192

00:48:59,370 --> 00:48:56,859
infrared wavelengths

1193

00:49:02,790 --> 00:48:59,380
one of the main science drivers for the

1194

00:49:04,740 --> 00:49:02,800
Webb telescope is peering as far back as

1195

00:49:06,900 --> 00:49:04,750
possible to the farthest reaches of the

1196

00:49:09,180 --> 00:49:06,910
universe looking at the first galaxies

1197

00:49:11,309 --> 00:49:09,190
and the reason we need infrared to do

1198

00:49:12,900 --> 00:49:11,319
that is because those galaxies although

1199

00:49:15,809 --> 00:49:12,910
we look at them we look for certain

1200

00:49:18,420 --> 00:49:15,819
markers in optical wavelengths the

1201
00:49:20,849 --> 00:49:18,430
universe is expanding and its expansion

1202
00:49:23,250 --> 00:49:20,859
is accelerating and so the most distant

1203
00:49:24,630 --> 00:49:23,260
galaxies are emitting that light in

1204
00:49:26,819 --> 00:49:24,640
infrared wavelengths because they're

1205
00:49:28,530 --> 00:49:26,829
actually red shifted sort of like

1206
00:49:30,329 --> 00:49:28,540
Doppler shifting the light that's coming

1207
00:49:31,650 --> 00:49:30,339
out of them is being shifted into longer

1208
00:49:33,059 --> 00:49:31,660
and longer wavelengths and so the light

1209
00:49:34,920 --> 00:49:33,069
that we would typically look for to

1210
00:49:37,349 --> 00:49:34,930
study those galaxies has moved from

1211
00:49:39,480 --> 00:49:37,359
optical to infrared so now we need

1212
00:49:41,700 --> 00:49:39,490
something with Hubble's supervision that

1213
00:49:47,549 --> 00:49:41,710

can see an infrared and that's what the

1214

00:49:49,950 --> 00:49:47,559

James Webb Space Telescope will do so

1215

00:49:53,640 --> 00:49:49,960

what's it take home other than your

1216

00:49:56,880 --> 00:49:53,650

personal belongings light is more than

1217

00:50:00,000 --> 00:49:56,890

meets the eye it's information and it

1218

00:50:02,190 --> 00:50:00,010

surrounds us right now we are in a

1219

00:50:04,260 --> 00:50:02,200

golden age of astronomy we were looking

1220

00:50:06,480 --> 00:50:04,270

in every possible wavelength even beyond

1221

00:50:08,010 --> 00:50:06,490

the electromagnetic spectrum we now have

1222

00:50:09,809 --> 00:50:08,020

what's called multi messenger astronomy

1223

00:50:11,940 --> 00:50:09,819

we're understanding the universe in ways

1224

00:50:13,380 --> 00:50:11,950

we never thought possible gravitational

1225

00:50:17,280 --> 00:50:13,390

waves are giving us a new insight into

1226

00:50:19,710 --> 00:50:17,290

the universe light is the key to

1227

00:50:21,720 --> 00:50:19,720

understanding our universe and now I've

1228

00:50:23,390 --> 00:50:21,730

been talking about all these images the

1229

00:50:25,500 --> 00:50:23,400

way I've been applying color to them

1230

00:50:27,510 --> 00:50:25,510

specifically like the x-ray images you

1231

00:50:29,809 --> 00:50:27,520

may have heard the term false-color when

1232

00:50:34,460 --> 00:50:29,819

they're describing x-ray images right

1233

00:50:38,490 --> 00:50:34,470

don't listen to that false-color is bad

1234

00:50:40,829 --> 00:50:38,500

and that's the essence of the title

1235

00:50:43,609 --> 00:50:40,839

translating cosmic light is really about

1236

00:50:46,049 --> 00:50:43,619

the images and how they're created

1237

00:50:48,450 --> 00:50:46,059

translated or representational color is

1238

00:50:51,270 --> 00:50:48,460

the preferred nomenclature when

1239

00:50:52,920 --> 00:50:51,280

discussing these kinds of images the the

1240

00:50:54,539 --> 00:50:52,930

term false-color just perpetuates this

1241

00:50:56,130 --> 00:50:54,549

idea that the images are somehow fake

1242

00:50:59,609 --> 00:50:56,140

and we're making it up that it's not

1243

00:51:01,680 --> 00:50:59,619

real translated color is really what

1244

00:51:03,130 --> 00:51:01,690

we're doing we're taking stuff that like

1245

00:51:04,780 --> 00:51:03,140

that we can't see with our eyes and

1246

00:51:07,810 --> 00:51:04,790

leading it into something that we can

1247

00:51:08,860 --> 00:51:07,820

see and understand with our eyes and so

1248

00:51:13,300 --> 00:51:08,870

for more information

1249

00:51:14,980 --> 00:51:13,310

oh I need that leave this line Hubble

1250

00:51:17,530 --> 00:51:14,990

say doesn't look like this anymore but

1251
00:51:20,950 --> 00:51:17,540
this is where you can go for all latest

1252
00:51:23,020 --> 00:51:20,960
Hubble news and I also run a blog and

1253
00:51:25,600 --> 00:51:23,030
Frank also contributes to the blog

1254
00:51:28,510 --> 00:51:25,610
called illuminated universe where we

1255
00:51:29,530 --> 00:51:28,520
take a behind-the-scenes look at a lot

1256
00:51:31,180 --> 00:51:29,540
of like what I've been talking about

1257
00:51:33,430 --> 00:51:31,190
tonight sort of how the images come

1258
00:51:35,080 --> 00:51:33,440
about how they're created a lot of times

1259
00:51:37,960 --> 00:51:35,090
we make editorial decisions in our news

1260
00:51:39,460 --> 00:51:37,970
meetings where we've created certain

1261
00:51:41,260 --> 00:51:39,470
products that just don't fit the story

1262
00:51:43,810 --> 00:51:41,270
that we're trying to tell for that

1263
00:51:45,310 --> 00:51:43,820

particular press release but this gives

1264

00:51:47,470 --> 00:51:45,320

us an opportunity to put that

1265

00:51:49,390 --> 00:51:47,480

information out there as well there are

1266

00:51:51,460 --> 00:51:49,400

images that I've created that don't have

1267

00:51:55,300 --> 00:51:51,470

a home so eliminate universes where they

1268

00:51:58,330 --> 00:51:55,310

go and I hope you've enjoyed taking a

1269

00:52:00,880 --> 00:51:58,340

look at illuminate yours thanks I'll be

1270

00:52:20,340 --> 00:52:09,230

[Applause]

1271

00:52:21,480 --> 00:52:20,350

thank you hold up you gotta say it into

1272

00:52:23,060 --> 00:52:21,490

the Mike we have an online audience

1273

00:52:26,070 --> 00:52:23,070

ready

1274

00:52:29,490 --> 00:52:26,080

there's no web telescope is it only

1275

00:52:33,210 --> 00:52:29,500

infrared yes only infrared infrared

1276

00:52:34,770 --> 00:52:33,220

there okay yeah it overlaps a little bit

1277

00:52:36,960 --> 00:52:34,780

with what Hubble does because Hubble

1278

00:52:57,240 --> 00:52:36,970

goes out to infrared as well but it's a

1279

00:52:59,400 --> 00:52:57,250

it's an infrared telescope yeah so in

1280

00:53:01,650 --> 00:52:59,410

some images like would you prioritize

1281

00:53:04,710 --> 00:53:01,660

like a certain group of data more than

1282

00:53:05,940 --> 00:53:04,720

the others like if x-ray showed more of

1283

00:53:13,440 --> 00:53:05,950

what you were trying to get it and that

1284

00:53:15,360 --> 00:53:13,450

image would be like yes

1285

00:53:18,690 --> 00:53:15,370

so that eyes that has come up in the

1286

00:53:20,220 --> 00:53:18,700

past where the x-rays are telling a

1287

00:53:21,900 --> 00:53:20,230

certain story and actually what really

1288

00:53:22,680 --> 00:53:21,910

happens is sometimes when we're

1289

00:53:23,970 --> 00:53:22,690

combining all these different

1290

00:53:25,710 --> 00:53:23,980

wavelengths together we run into a

1291

00:53:27,570 --> 00:53:25,720

situation where we're over saturating

1292

00:53:30,540 --> 00:53:27,580

certain areas of the image and in those

1293

00:53:33,030 --> 00:53:30,550

cases I do I will take some some

1294

00:53:34,860 --> 00:53:33,040

liberties with adjusting the levels of

1295

00:53:36,890 --> 00:53:34,870

different components of the image so

1296

00:53:39,750 --> 00:53:36,900

that you can see everything that's there

1297

00:53:42,990 --> 00:53:39,760

yeah and you know I like what you should

1298

00:53:45,630 --> 00:53:43,000

cafe here where you know Hubble is good

1299

00:53:51,090 --> 00:53:45,640

in cafe but the x-rays are amazing in

1300

00:53:52,770 --> 00:53:51,100

gas a right that's so the it sometimes

1301
00:53:54,420 --> 00:53:52,780
when you give talks to public audiences

1302
00:53:56,010 --> 00:53:54,430
they're kind of surprised that you know

1303
00:53:58,530 --> 00:53:56,020
Hubble doesn't always have the most

1304
00:54:00,060 --> 00:53:58,540
beautiful image of an object right if

1305
00:54:01,980 --> 00:54:00,070
you go to other wavelengths you actually

1306
00:54:07,890 --> 00:54:01,990
see a lot more interest interesting

1307
00:54:10,770 --> 00:54:07,900
structure yeah in your experience what

1308
00:54:13,650 --> 00:54:10,780
has been the most remarkable discovery

1309
00:54:16,080 --> 00:54:13,660
in contrast to a hypothesis that you

1310
00:54:20,109 --> 00:54:16,090
have made when you have actually looked

1311
00:54:23,859 --> 00:54:20,119
at it in terms of different

1312
00:54:26,650 --> 00:54:23,869
I'm sure there but what's the most what

1313
00:54:27,999 --> 00:54:26,660

has blown you away the most I would say

1314

00:54:30,579 --> 00:54:28,009

that that Crab Nebula image that I

1315

00:54:35,759 --> 00:54:30,589

showed that really blew me away when I

1316

00:54:41,709 --> 00:54:39,640

that yeah when I put it all together and

1317

00:54:44,589 --> 00:54:41,719

that showed up on the screen I just was

1318

00:54:46,059 --> 00:54:44,599

like in shock because I you know working

1319

00:54:48,370 --> 00:54:46,069

with the Chandra x-ray Observatory for

1320

00:54:53,319 --> 00:54:48,380

15 years I had seen the Crab Nebula many

1321

00:54:55,059 --> 00:54:53,329

many times and I always saw that that

1322

00:54:56,650 --> 00:54:55,069

was my view of the Crab Nebula and then

1323

00:54:58,839 --> 00:54:56,660

of course there was this amazing Hubble

1324

00:55:01,150 --> 00:54:58,849

image of the crab but seeing everything

1325

00:55:02,380 --> 00:55:01,160

from radio to x-ray all together in one

1326

00:55:05,559 --> 00:55:02,390

image just blew my mind

1327

00:55:07,390 --> 00:55:05,569

and as a scientist how much of a rush is

1328

00:55:12,029 --> 00:55:07,400

that I mean how many nights did you say

1329

00:55:17,410 --> 00:55:15,009

we sometimes you know will admit that

1330

00:55:20,499 --> 00:55:17,420

yeah we do have a fun job yeah thank

1331

00:55:23,499 --> 00:55:20,509

Frank and I geeked out a lot I said we

1332

00:55:26,739 --> 00:55:23,509

have a question online which is sort of

1333

00:55:29,650 --> 00:55:26,749

the same it says which is his favourite

1334

00:55:31,269 --> 00:55:29,660

Hubble photo and I guess you could also

1335

00:55:33,160 --> 00:55:31,279

include Chandra in there to send you

1336

00:55:35,439 --> 00:55:33,170

you've worked Chandra more years and

1337

00:55:39,429 --> 00:55:35,449

you've worked robble I have but you know

1338

00:55:40,929 --> 00:55:39,439

since I've been with Hubble the Lagoon

1339

00:55:42,759 --> 00:55:40,939

Nebula is definitely my favorite image

1340

00:55:46,539 --> 00:55:42,769

so far and I've been here for two years

1341

00:55:48,429 --> 00:55:46,549

now and again seeing this materialize on

1342

00:55:51,069 --> 00:55:48,439

my desktop as I was working on it was

1343

00:55:59,289 --> 00:55:51,079

just a rush like like the Crab Nebula

1344

00:56:01,870 --> 00:55:59,299

yeah it was just amazing experience what

1345

00:56:05,349 --> 00:56:01,880

is the best way to make take a picture

1346

00:56:10,469 --> 00:56:05,359

of the Milky Way the best way to take a

1347

00:56:12,759 --> 00:56:10,479

picture of the Milky Way all sky yeah

1348

00:56:14,229 --> 00:56:12,769

probably what that that guy that I was

1349

00:56:15,640 --> 00:56:14,239

talking about Nick Risinger who

1350

00:56:17,289 --> 00:56:15,650

travelled the world to take a picture of

1351

00:56:18,699 --> 00:56:17,299

the Milky Way because that's the only

1352

00:56:20,769 --> 00:56:18,709

way you can take a picture of the entire

1353

00:56:21,579 --> 00:56:20,779

Milky Way because if you're you know if

1354

00:56:23,049 --> 00:56:21,589

you're only in the Northern Hemisphere

1355

00:56:25,539 --> 00:56:23,059

you're only gonna see a certain portion

1356

00:56:27,789 --> 00:56:25,549

of it so being able to travel the world

1357

00:56:31,330 --> 00:56:27,799

and get the whole view that's that's the

1358

00:56:41,230 --> 00:56:31,340

best way to do it it's very expensive

1359

00:56:43,660 --> 00:56:41,240

Oh what's the farthest object that the

1360

00:56:45,910 --> 00:56:43,670

Hubble Space Telescope has ever like

1361

00:56:50,080 --> 00:56:45,920

seen and would the James Webb telescope

1362

00:56:51,490 --> 00:56:50,090

be able to see farther yes the farthest

1363

00:56:53,740 --> 00:56:51,500

object Hubble has seen was thirteen

1364

00:56:56,650 --> 00:56:53,750

point four billion light years away

1365

00:56:59,920 --> 00:56:56,660

I believe thirteen point two round 13

1366

00:57:01,750 --> 00:56:59,930

billion thirteen it's kind of you know

1367

00:57:05,050 --> 00:57:01,760

our uncertainty grows when we get to

1368

00:57:06,760 --> 00:57:05,060

that level but yes yeah but that so for

1369

00:57:10,120 --> 00:57:06,770

Hubble that is just like a faint red

1370

00:57:13,390 --> 00:57:10,130

smudge in an image Webb will be able to

1371

00:57:16,540 --> 00:57:13,400

resolve more detail out of that not a

1372

00:57:18,970 --> 00:57:16,550

lot of details but yeah I mean we talked

1373

00:57:21,070 --> 00:57:18,980

about generosity we often talk about

1374

00:57:24,100 --> 00:57:21,080

probing the first billion years of

1375

00:57:26,740 --> 00:57:24,110

cosmic history and that by looking into

1376

00:57:30,100 --> 00:57:26,750

the infrared we will see things at just

1377

00:57:33,310 --> 00:57:30,110

slightly larger red shifts so we will be

1378

00:57:36,070 --> 00:57:33,320

able to see things into you know almost

1379

00:57:38,320 --> 00:57:36,080

- the first galaxies that form right

1380

00:57:40,750 --> 00:57:38,330

we're trying we're seeing you know

1381

00:57:44,140 --> 00:57:40,760

toddler galaxies we want to see the baby

1382

00:57:46,660 --> 00:57:44,150

galaxies okay and that's really the

1383

00:57:49,060 --> 00:57:46,670

promise of looking into the infrared is

1384

00:57:51,160 --> 00:57:49,070

we will be able to see that light which

1385

00:57:53,950 --> 00:57:51,170

gets red shifted all the way into the

1386

00:58:02,140 --> 00:57:53,960

mid infrared yeah so Webb will be able

1387

00:58:05,770 --> 00:58:02,150

to see further billion billion yes are

1388

00:58:09,070 --> 00:58:05,780

you able to pull up really quick the

1389

00:58:11,970 --> 00:58:09,080

pink of the deep field the Hubble Deep

1390

00:58:14,830 --> 00:58:11,980

Field yes because this my question goes

1391

00:58:20,860 --> 00:58:14,840

right along with what the last question

1392

00:58:24,280 --> 00:58:20,870

was yes so somewhere in there is the red

1393

00:58:26,890 --> 00:58:24,290

dot that science has told us that's the

1394

00:58:29,740 --> 00:58:26,900

farthest galaxy that we can see out of

1395

00:58:32,410 --> 00:58:29,750

that picture if you can go back to it

1396

00:58:35,020 --> 00:58:32,420

again out of that picture how does

1397

00:58:37,420 --> 00:58:35,030

science determine that's it that's the

1398

00:58:40,180 --> 00:58:37,430

oldest thing that we've seen how are you

1399

00:58:43,120 --> 00:58:40,190

able to determine that so when we take

1400

00:58:44,750 --> 00:58:43,130

these datasets it does make a beautiful

1401

00:58:46,670 --> 00:58:44,760

image but there's also

1402

00:58:48,530 --> 00:58:46,680

more data there than just the image

1403

00:58:51,230 --> 00:58:48,540

there's spectroscopy and we're able to

1404

00:58:53,270 --> 00:58:51,240

do spectroscopic redshift studies of the

1405

00:58:54,800 --> 00:58:53,280

galaxies from the image so we can

1406

00:58:56,600 --> 00:58:54,810

actually pull out

1407

00:58:58,310 --> 00:58:56,610

we call them postage stamp images we

1408

00:58:59,600 --> 00:58:58,320

actually have software that we'll go

1409

00:59:01,610 --> 00:58:59,610

through with the image and analyze it

1410

00:59:04,730 --> 00:59:01,620

and pull out each individual galaxy and

1411

00:59:06,860 --> 00:59:04,740

create a little image of that and from

1412

00:59:09,170 --> 00:59:06,870

that image be able to determine the

1413

00:59:11,240 --> 00:59:09,180

redshift of that galaxy basically that

1414

00:59:12,890 --> 00:59:11,250

gives you a distance estimate for it and

1415

00:59:16,040 --> 00:59:12,900

so when you look through this image that

1416

00:59:20,270 --> 00:59:16,050

way in that method that red dot becomes

1417

00:59:21,980 --> 00:59:20,280

the farthest object I think so but I'm

1418

00:59:23,900 --> 00:59:21,990

probably not gonna be able to see it

1419

00:59:26,000 --> 00:59:23,910

yeah and this is the one with the

1420

00:59:27,710 --> 00:59:26,010

ultraviolet added to it so it's hard to

1421

00:59:32,360 --> 00:59:27,720

pick out the the red dots in this

1422

00:59:35,210 --> 00:59:32,370

version of it right okay we get a

1423

00:59:37,250 --> 00:59:35,220

question from online that says how long

1424

00:59:39,110 --> 00:59:37,260

does it take for you to prepare one of

1425

00:59:41,900 --> 00:59:39,120

these images I believe that's right

1426

00:59:44,020 --> 00:59:41,910

there that's one of them yeah how long

1427

00:59:46,790 --> 00:59:44,030

does it take yeah that's a good question

1428

00:59:47,480 --> 00:59:46,800

some of these images can take I can do

1429

00:59:49,820 --> 00:59:47,490

it in an afternoon

1430

00:59:51,440 --> 00:59:49,830

some can take a week to a few weeks

1431

00:59:52,550 --> 00:59:51,450

depends on the complexity of the data

1432

00:59:54,530 --> 00:59:52,560

set

1433

00:59:56,330 --> 00:59:54,540

a lot of Hubble's like really famous

1434

00:59:58,540 --> 00:59:56,340

images are actually mosaics which means

1435

01:00:00,770 --> 00:59:58,550

Hubble goes and takes multiple images

1436

01:00:03,830 --> 01:00:00,780

and stitches them together

1437

01:00:05,960 --> 01:00:03,840

well I stitch them together and those

1438

01:00:08,330 --> 01:00:05,970

ones take a lot more work there's a lot

1439

01:00:11,390 --> 01:00:08,340

more pre-processing to get the mosaic

1440

01:00:12,680 --> 01:00:11,400

image looking nice and then putting it

1441

01:00:14,380 --> 01:00:12,690

all together it becomes a very

1442

01:00:17,990 --> 01:00:14,390

computationally intensive thing as well

1443

01:00:19,370 --> 01:00:18,000

because these images are like billions

1444

01:00:21,440 --> 01:00:19,380

well not billions but millions of pixels

1445

01:00:23,120 --> 01:00:21,450

across and you end up getting Photoshop

1446

01:00:24,470 --> 01:00:23,130

files that are like 10 gigabytes in size

1447

01:00:27,380 --> 01:00:24,480

and it just takes a long time to deal

1448

01:00:32,330 --> 01:00:27,390

with them so yeah there's a big range

1449

01:00:35,180 --> 01:00:32,340

and the time it takes you mentioned

1450

01:00:36,770 --> 01:00:35,190

images being north up and I was I mean I

1451

01:00:41,840 --> 01:00:36,780

think of North in reference to our polls

1452

01:00:43,310 --> 01:00:41,850

how is North oriented in space imagine

1453

01:00:45,440 --> 01:00:43,320

taking latitude and longitude of Earth

1454

01:00:47,180 --> 01:00:45,450

and just extending it out into space and

1455

01:00:50,000 --> 01:00:47,190

it becomes right Ascension and

1456

01:00:52,220 --> 01:00:50,010

declination and there is a north and

1457

01:00:54,530 --> 01:00:52,230

south to that and so in yeah if the

1458

01:00:56,500 --> 01:00:54,540

images that are north upper yeah it's

1459

01:00:58,700 --> 01:00:56,510

but if you're in the southern hemisphere

1460

01:01:00,859 --> 01:00:58,710

your natural orientation

1461

01:01:02,690 --> 01:01:00,869

be south up because everything abroad

1462

01:01:04,640 --> 01:01:02,700

rotates around the southern celestial

1463

01:01:06,410 --> 01:01:04,650

Pole versus here everything rotates

1464

01:01:08,510 --> 01:01:06,420

around the northern celestial Pole right

1465

01:01:22,849 --> 01:01:08,520

see there's no up or down yeah there is

1466

01:01:24,589 --> 01:01:22,859

no up or down based on your formation of

1467

01:01:28,370 --> 01:01:24,599

these images where you consider yourself

1468

01:01:34,820 --> 01:01:28,380

an artist or a scientist that's a great

1469

01:01:36,470 --> 01:01:34,830

answer is yes right both I feel like I

1470

01:01:38,570 --> 01:01:36,480

get to exercise both halves of my brain

1471

01:01:40,400 --> 01:01:38,580

when I work on an image because there is

1472

01:01:42,530 --> 01:01:40,410

a scientific aspect to it there's the

1473

01:01:45,200 --> 01:01:42,540

data preparation the pre-processing and

1474

01:01:47,150 --> 01:01:45,210

and then also as I'm processing and

1475

01:01:49,190 --> 01:01:47,160

moving into the realm of art I'm also

1476
01:01:50,870 --> 01:01:49,200
keeping in mind this story that's gonna

1477
01:01:52,430 --> 01:01:50,880
be associated with this image because

1478
01:01:53,599 --> 01:01:52,440
every image has to tell a story it has

1479
01:01:55,550 --> 01:01:53,609
to be a part of a press release that's

1480
01:01:57,230 --> 01:01:55,560
telling a story like that edit kareena

1481
01:01:59,540 --> 01:01:57,240
image the blue data there that's that's

1482
01:02:00,710 --> 01:01:59,550
the key to that image and so when I was

1483
01:02:08,630 --> 01:02:00,720
processing and I was keeping that in

1484
01:02:10,849 --> 01:02:08,640
mind as anyway grant we have question in

1485
01:02:12,380 --> 01:02:10,859
the center as well so so you mentioned

1486
01:02:14,660 --> 01:02:12,390
there's a wide dynamic range on the

1487
01:02:20,390 --> 01:02:14,670
sensors themselves actually how wide is

1488
01:02:24,890 --> 01:02:20,400

it like zero - there are 32-bit images

1489

01:02:28,760 --> 01:02:24,900

yeah so yeah but the the detectors the

1490

01:02:32,089 --> 01:02:28,770

original detectors were only like 65,000

1491

01:02:35,810 --> 01:02:32,099

six-letter over that yeah yeah for some

1492

01:02:40,339 --> 01:02:35,820

of them but I've been on the web it's

1493

01:02:43,790 --> 01:02:40,349

it's it's yeah it's the CCD charge count

1494

01:02:45,710 --> 01:02:43,800

of this of the detectors which I was in

1495

01:02:47,120 --> 01:02:45,720

the tens of thousands for the original

1496

01:02:51,740 --> 01:02:47,130

Hubble images I don't know what the

1497

01:02:53,450 --> 01:02:51,750

current stuff is I know that fits files

1498

01:03:01,310 --> 01:02:53,460

that you download from master usually

1499

01:03:05,300 --> 01:03:03,950

I was wondering if you could explain

1500

01:03:08,990 --> 01:03:05,310

more

1501
01:03:11,480 --> 01:03:09,000
when we get around to creating the W

1502
01:03:13,790 --> 01:03:11,490
first telescope after James who have I

1503
01:03:16,010 --> 01:03:13,800
know I'm jumping the gun well w first

1504
01:03:19,310 --> 01:03:16,020
which has a huge field if you will that

1505
01:03:22,400 --> 01:03:19,320
make your job easier and how will we

1506
01:03:25,220 --> 01:03:22,410
ever process I mean must be huge banks

1507
01:03:28,430 --> 01:03:25,230
of data and that's I guess that's a

1508
01:03:30,230 --> 01:03:28,440
problem they'll be resolving as time

1509
01:03:34,100 --> 01:03:30,240
goes on but how will that affect your

1510
01:03:39,200 --> 01:03:34,110
job pull up that that's future Joe's

1511
01:03:42,350 --> 01:03:39,210
problem but you're right the W first

1512
01:03:44,030 --> 01:03:42,360
telescope is it's an infrared telescope

1513
01:03:46,070 --> 01:03:44,040

that has a field of view that's a

1514

01:03:47,300 --> 01:03:46,080

hundred times that of Hubble's so every

1515

01:03:50,570 --> 01:03:47,310

image that it takes will be a hundred

1516

01:03:52,250 --> 01:03:50,580

Hubble's essentially so every time I

1517

01:03:55,880 --> 01:03:52,260

deal with one of those images it's gonna

1518

01:03:58,160 --> 01:03:55,890

be a huge mosaic multi-gigabyte image

1519

01:04:00,280 --> 01:03:58,170

file so it's gonna be a real challenge

1520

01:04:02,690 --> 01:04:00,290

and we're kind of working with the

1521

01:04:03,980 --> 01:04:02,700

instrument teams to figure out how we'll

1522

01:04:06,740 --> 01:04:03,990

actually deal with the volume of data

1523

01:04:08,600 --> 01:04:06,750

like that it may actually end up being a

1524

01:04:11,240 --> 01:04:08,610

cloud computing that we do for that

1525

01:04:13,370 --> 01:04:11,250

right I mean this is a thing in a lot of

1526

01:04:15,830 --> 01:04:13,380

astronomy we're getting these very large

1527

01:04:20,300 --> 01:04:15,840

surveys the dark energy camera that is

1528

01:04:22,430 --> 01:04:20,310

like 520 million pixels per image 520

1529

01:04:24,680 --> 01:04:22,440

million pixels per image okay

1530

01:04:27,620 --> 01:04:24,690

these are getting to be more and more

1531

01:04:29,390 --> 01:04:27,630

common in astronomy we're gonna the LSST

1532

01:04:31,070 --> 01:04:29,400

which is going to take you know

1533

01:04:33,260 --> 01:04:31,080

petabytes a night or something like that

1534

01:04:38,870 --> 01:04:33,270

I don't know it just all sky's images

1535

01:04:40,940 --> 01:04:38,880

okay data processing is a huge thing so

1536

01:04:44,510 --> 01:04:40,950

all of you young kids that that are out

1537

01:04:46,610 --> 01:04:44,520

here thinking you know data processing

1538

01:04:49,520 --> 01:04:46,620

and data analytics it's a huge

1539

01:04:51,230 --> 01:04:49,530

burgeoning field because it's not just

1540

01:04:54,200 --> 01:04:51,240

an astronomer where we have way too much

1541

01:05:07,840 --> 01:04:54,210

data to deal with we're developing it

1542

01:05:10,430 --> 01:05:07,850

all over and yeah it's gonna be fun hi

1543

01:05:12,350 --> 01:05:10,440

so it's my understanding like with the

1544

01:05:15,920 --> 01:05:12,360

Hubble it's like looking at a really

1545

01:05:17,740 --> 01:05:15,930

small portion of the sky but just

1546

01:05:22,180 --> 01:05:17,750

looking very deep

1547

01:05:24,940 --> 01:05:22,190

yes that is that correct so are there I

1548

01:05:26,500 --> 01:05:24,950

guess do you does it ever get used to

1549

01:05:29,470 --> 01:05:26,510

look at things that are closer or are

1550

01:05:33,250 --> 01:05:29,480

there just other telescopes that look

1551
01:05:35,440 --> 01:05:33,260
like can we look at Pluto very you know

1552
01:05:37,599 --> 01:05:35,450
get a very good view of Pluto which is

1553
01:05:40,750 --> 01:05:37,609
much closer than like this stuff you're

1554
01:05:43,599 --> 01:05:40,760
showing right like in order to and like

1555
01:05:46,960 --> 01:05:43,609
can we are there telescopes like that

1556
01:05:50,050 --> 01:05:46,970
and do we ever look at like other solar

1557
01:05:52,060 --> 01:05:50,060
systems to compare to ours and kind of

1558
01:05:55,570 --> 01:05:52,070
see planetary movement and that kind of

1559
01:05:57,460 --> 01:05:55,580
thing I guess that's my general question

1560
01:05:59,920 --> 01:05:57,470
okay so this is actually a Hubble image

1561
01:06:02,230 --> 01:05:59,930
of Jupiter here taken two years ago so

1562
01:06:04,510 --> 01:06:02,240
Hubble does look at nearby objects as

1563
01:06:06,160 --> 01:06:04,520

well and you're right about the the the

1564

01:06:09,070 --> 01:06:06,170

size it's equivalent to looking through

1565

01:06:11,200 --> 01:06:09,080

the eye of Eisenhower on a dime held at

1566

01:06:13,750 --> 01:06:11,210

arm's length that's roughly the field of

1567

01:06:17,470 --> 01:06:13,760

view Hubble yeah it's like 112 millionth

1568

01:06:19,900 --> 01:06:17,480

of the entire night sky okay one part in

1569

01:06:24,070 --> 01:06:19,910

12 million Frank has a really great blog

1570

01:06:26,589 --> 01:06:24,080

post on the universe about angular

1571

01:06:28,540 --> 01:06:26,599

resolution and why Hubble can take an

1572

01:06:30,849 --> 01:06:28,550

image of Pluto but it doesn't look very

1573

01:06:33,520 --> 01:06:30,859

good because Pluto is a very small

1574

01:06:36,250 --> 01:06:33,530

object and it's relatively distant in

1575

01:06:37,570 --> 01:06:36,260

terms of or Hubble's looking a galaxy

1576

01:06:39,670 --> 01:06:37,580

like the Whirlpool Galaxy is just

1577

01:06:41,620 --> 01:06:39,680

enormous hundreds of thousands of light

1578

01:06:43,180 --> 01:06:41,630

years all right not quite that big but

1579

01:06:44,380 --> 01:06:43,190

like sixty-five thousand light years

1580

01:06:46,599 --> 01:06:44,390

five thousand light years across

1581

01:06:48,280 --> 01:06:46,609

so it's something enormous you can see a

1582

01:06:53,010 --> 01:06:48,290

lot of detail with that with Hubble

1583

01:06:59,490 --> 01:06:56,109

which part of the electric medics read

1584

01:07:04,690 --> 01:06:59,500

from do you think takes the best images

1585

01:07:08,170 --> 01:07:04,700

of course now that's a very subjective

1586

01:07:10,540 --> 01:07:08,180

question I mean I think as humans we're

1587

01:07:15,520 --> 01:07:10,550

used to the visible light so we're gonna

1588

01:07:18,690 --> 01:07:15,530

favor that but I gotta say that I would

1589

01:07:21,910 --> 01:07:18,700

love to see more work on radio images

1590

01:07:24,190 --> 01:07:21,920

because radio images you need to take

1591

01:07:26,680 --> 01:07:24,200

like the VLA in several different

1592

01:07:28,650 --> 01:07:26,690

configurations to get the detail but

1593

01:07:31,240 --> 01:07:28,660

radio images and have incredibly

1594

01:07:34,839 --> 01:07:31,250

incredible micro arc second

1595

01:07:36,730 --> 01:07:34,849

detail that Hubble can't have and so

1596

01:07:39,130 --> 01:07:36,740

some of the radio images when they take

1597

01:07:42,250 --> 01:07:39,140

the time to actually process them are

1598

01:07:44,440 --> 01:07:42,260

really cool like the black hole in EM 87

1599

01:07:48,430 --> 01:07:44,450

yeah yeah

1600

01:07:49,900 --> 01:07:48,440

so radio has a lot of potential I don't

1601
01:07:54,370 --> 01:07:49,910
think has been exploited enough by the

1602
01:07:56,890 --> 01:07:54,380
radio community I have a question

1603
01:08:00,760 --> 01:07:56,900
actually about the lithograph for both

1604
01:08:03,520 --> 01:08:00,770
of these is the ring nebula sort of what

1605
01:08:07,060 --> 01:08:03,530
may be happening with our Sun and about

1606
01:08:10,960 --> 01:08:07,070
eight billion years or is this a sort of

1607
01:08:13,030 --> 01:08:10,970
thing will be going on with our son yeah

1608
01:08:15,849 --> 01:08:13,040
let's see it's gonna puff up and cast

1609
01:08:17,349 --> 01:08:15,859
off material into space it's not quite

1610
01:08:21,160 --> 01:08:17,359
massive enough to do much more than that

1611
01:08:24,249 --> 01:08:21,170
it'll just sort of peter out I don't

1612
01:08:25,570 --> 01:08:24,259
know what do you think yeah the or the

1613
01:08:27,789 --> 01:08:25,580

textbook answer that you will get

1614

01:08:29,979 --> 01:08:27,799

normally from an astronomy 101 class is

1615

01:08:32,680 --> 01:08:29,989

yes our Sun will go off and die by being

1616

01:08:36,789 --> 01:08:32,690

a planetary nebula the research level

1617

01:08:39,670 --> 01:08:36,799

answer is probably not quite as pretty

1618

01:08:41,950 --> 01:08:39,680

as the ring nebula because it looks like

1619

01:08:43,809 --> 01:08:41,960

you need about one and a half to two

1620

01:08:46,780 --> 01:08:43,819

solar masses to really blow off a

1621

01:08:48,490 --> 01:08:46,790

planetary nebula that's you know still

1622

01:08:51,249 --> 01:08:48,500

uncertain right now it's still subject

1623

01:08:52,840 --> 01:08:51,259

to research but the folks I've talked to

1624

01:08:55,780 --> 01:08:52,850

say yeah the sun's not going to go

1625

01:08:58,930 --> 01:08:55,790

planetary like that it'll it'll still

1626
01:09:06,550 --> 01:08:58,940
have mass loss but it won't be a nice

1627
01:09:09,789 --> 01:09:06,560
beautiful nebula so about how many

1628
01:09:15,280 --> 01:09:09,799
galaxies was Hubble able to identify

1629
01:09:17,680 --> 01:09:15,290
since its launch since launch well let's

1630
01:09:19,690 --> 01:09:17,690
see let's just take yeah the candles

1631
01:09:21,579 --> 01:09:19,700
alright yeah take the candles field so

1632
01:09:24,370 --> 01:09:21,589
this one Deep Field image that we've

1633
01:09:26,410 --> 01:09:24,380
done with Hubble had what's 65 thousand

1634
01:09:28,620 --> 01:09:26,420
galaxies in it I think yeah and that's

1635
01:09:30,970 --> 01:09:28,630
just one image it's one very deep image

1636
01:09:36,970 --> 01:09:30,980
no I'm talking about like naming them

1637
01:09:40,809 --> 01:09:36,980
actually we don't name them yeah big if

1638
01:09:43,570 --> 01:09:40,819

they get catalog numbers yeah okay yeah

1639

01:09:44,890 --> 01:09:43,580

so if you're in the Hubble Deep Field

1640

01:09:47,110 --> 01:09:44,900

you'd be HD

1641

01:09:49,570 --> 01:09:47,120

and then it'd be your RA in your deck as

1642

01:09:52,750 --> 01:09:49,580

your as your catalog name unless there's

1643

01:09:54,460 --> 01:09:52,760

a specific reason I mean what the Sloan

1644

01:09:57,610 --> 01:09:54,470

Digital Sky Survey has how many millions

1645

01:09:59,320 --> 01:09:57,620

of galaxies in it yeah I mean when you

1646

01:10:00,040 --> 01:09:59,330

get up to millions and such you can't

1647

01:10:03,700 --> 01:10:00,050

name them

1648

01:10:15,100 --> 01:10:03,710

Jeff and Fred no justice gets a little

1649

01:10:16,540 --> 01:10:15,110

full tiresome to try and do that how did

1650

01:10:19,540 --> 01:10:16,550

you say that this is what you want do

1651
01:10:21,610 --> 01:10:19,550
for your for a living like editing and

1652
01:10:24,850 --> 01:10:21,620
taking these pictures and processing

1653
01:10:25,660 --> 01:10:24,860
them oh yeah good question I always

1654
01:10:27,940 --> 01:10:25,670
loved astronomy

1655
01:10:31,720 --> 01:10:27,950
as a kid growing up I just like was

1656
01:10:33,220 --> 01:10:31,730
fascinated with the Stars and then when

1657
01:10:34,360 --> 01:10:33,230
I went to college I studied astronomy

1658
01:10:36,430 --> 01:10:34,370
and astrophysics and I thought I was

1659
01:10:38,190 --> 01:10:36,440
gonna go the PhD were out and sort of

1660
01:10:40,630 --> 01:10:38,200
you know become a professor or something

1661
01:10:43,120 --> 01:10:40,640
but after I graduate from undergrad I

1662
01:10:46,870 --> 01:10:43,130
was doing research work when I was at

1663
01:10:48,520 --> 01:10:46,880

Chandra I was doing calibration and

1664

01:10:51,160 --> 01:10:48,530

instrument operations for the Chandra

1665

01:10:53,800 --> 01:10:51,170

telescope and I loved that work but it

1666

01:10:55,720 --> 01:10:53,810

wasn't it just didn't it wasn't my

1667

01:10:57,910 --> 01:10:55,730

calling I think and I always had this

1668

01:11:00,310 --> 01:10:57,920

sort of artistic side I did painting I'm

1669

01:11:03,700 --> 01:11:00,320

a musician I wanted to engage that as

1670

01:11:05,170 --> 01:11:03,710

well as as a part of my career and so an

1671

01:11:08,170 --> 01:11:05,180

opportunity arose when I was at Chandra

1672

01:11:10,420 --> 01:11:08,180

to do image processing for public

1673

01:11:12,670 --> 01:11:10,430

outreach and I jumped on it and then

1674

01:11:15,160 --> 01:11:12,680

through that my experience there with

1675

01:11:16,720 --> 01:11:15,170

eight years sort of made connections

1676

01:11:20,680 --> 01:11:16,730

with people at Space Telescope and then

1677

01:11:22,180 --> 01:11:20,690

was able to come down here so is it was

1678

01:11:23,800 --> 01:11:22,190

always there and it was just being able

1679

01:11:30,250 --> 01:11:23,810

to figure out the path to get everything

1680

01:11:32,140 --> 01:11:30,260

together in the same job yeah and since

1681

01:11:35,560 --> 01:11:32,150

we have a bunch of the city students here

1682

01:11:39,550 --> 01:11:35,570

today sometimes they call CT why geek

1683

01:11:42,400 --> 01:11:39,560

camp right okay you think your geeks you

1684

01:11:44,200 --> 01:11:42,410

can also be artistic okay Joe and I are

1685

01:11:45,610 --> 01:11:44,210

two people who get to do some really

1686

01:11:48,520 --> 01:11:45,620

geeky stuff with the Hubble Space

1687

01:11:51,160 --> 01:11:48,530

Telescope but we've worked on IMAX films

1688

01:11:53,260 --> 01:11:51,170

together okay we get to work on movies

1689

01:11:55,030 --> 01:11:53,270

and visualizations and artistic things

1690

01:11:57,340 --> 01:11:55,040

we get to work with and field who's a

1691

01:11:58,660 --> 01:11:57,350

wonderful artist we get to work with you

1692

01:12:00,940 --> 01:11:58,670

know writers and

1693

01:12:03,730 --> 01:12:00,950

and everything you can bow you can

1694

01:12:06,460 --> 01:12:03,740

satisfy both your artistic side as well

1695

01:12:08,830 --> 01:12:06,470

as your scientific side in your career

1696

01:12:10,810 --> 01:12:08,840

so don't do not limit yourself okay I

1697

01:12:12,850 --> 01:12:10,820

always like to tell the kids that

1698

01:12:14,650 --> 01:12:12,860

because you know don't think you have to

1699

01:12:17,860 --> 01:12:14,660

be one or the other you really can do

1700

01:12:19,780 --> 01:12:17,870

both do you think if there is a

1701

01:12:22,030 --> 01:12:19,790

possibility in the future that we will

1702

01:12:24,280 --> 01:12:22,040

launch another gamma-ray Observatory or

1703

01:12:26,320 --> 01:12:24,290

ray Observatory after your Compton shut

1704

01:12:28,840 --> 01:12:26,330

down mm there's possible that might

1705

01:12:31,300 --> 01:12:28,850

happen again in the future

1706

01:12:32,890 --> 01:12:31,310

I believe the Fermi telescope is

1707

01:12:34,240 --> 01:12:32,900

actually also a gamma ray telescope so

1708

01:12:36,310 --> 01:12:34,250

there is a telescope currently operating

1709

01:12:38,560 --> 01:12:36,320

that's looking at gamma rays it's just

1710

01:12:40,120 --> 01:12:38,570

not one of the great observatories it's

1711

01:12:45,880 --> 01:12:40,130

just a pretty good observatory pretty

1712

01:12:48,690 --> 01:12:45,890

good now Fermi is wonderful okay but

1713

01:13:05,260 --> 01:12:48,700

it's just not in that I don't know

1714

01:13:07,000 --> 01:13:05,270

branding so you receive images that are

1715

01:13:08,590 --> 01:13:07,010

black and white you spend a lot of time

1716

01:13:10,180 --> 01:13:08,600

processing and working with the black

1717

01:13:12,100 --> 01:13:10,190

and white and all of a sudden you start

1718

01:13:13,900 --> 01:13:12,110

to add color to it so you spent hours

1719

01:13:17,860 --> 01:13:13,910

maybe in black and white before you see

1720

01:13:19,420 --> 01:13:17,870

the color sometimes yes I'm actually

1721

01:13:21,130 --> 01:13:19,430

working on an image of Jupiter that was

1722

01:13:23,680 --> 01:13:21,140

just taken a few weeks ago right now and

1723

01:13:24,220 --> 01:13:23,690

in that case yes I've been working on it

1724

01:13:26,860 --> 01:13:24,230

in black and white

1725

01:13:28,720 --> 01:13:26,870

the challenge with making an image of

1726

01:13:30,570 --> 01:13:28,730

Jupiter is that when Hubble takes the

1727

01:13:33,280 --> 01:13:30,580

three images to make a color image

1728

01:13:35,590 --> 01:13:33,290

Jupiter is moving so fast that it

1729

01:13:37,090 --> 01:13:35,600

changes while it's taking the data right

1730

01:13:38,860 --> 01:13:37,100

so to make a color image you have to

1731

01:13:41,170 --> 01:13:38,870

sort of account for this slight rotation

1732

01:13:44,020 --> 01:13:41,180

and the movement of Jupiter as it's

1733

01:13:45,460 --> 01:13:44,030

being photographed so that takes a lot

1734

01:13:46,540 --> 01:13:45,470

of work in black and white to get

1735

01:13:49,450 --> 01:13:46,550

everything lined up I mean I'm

1736

01:13:51,820 --> 01:13:49,460

essentially like warping clouds in

1737

01:13:54,760 --> 01:13:51,830

Jupiter and lining them up in black and

1738

01:13:56,830 --> 01:13:54,770

white and then applying color a question

1739

01:13:59,710 --> 01:13:56,840

from online what instrument do you play

1740

01:14:00,830 --> 01:13:59,720

and go ahead and plug your band if you'd

1741

01:14:03,470 --> 01:14:00,840

like

1742

01:14:03,980 --> 01:14:03,480

I play guitar my band is called riding

1743

01:14:16,220 --> 01:14:03,990

shotgun

1744

01:14:21,130 --> 01:14:16,230

plug are you related to the violist

1745

01:14:22,420 --> 01:14:21,140

Joseph de Pascua way no I get that a lot

1746

01:14:25,040 --> 01:14:22,430

[Applause]

1747

01:14:26,450 --> 01:14:25,050

my dad is also Joseph D Pasquale and we

1748

01:14:30,980 --> 01:14:26,460

used to get phone calls when I was a kid

1749

01:14:32,840 --> 01:14:30,990

asking for the violinist all right just

1750

01:14:34,970 --> 01:14:32,850

a couple more questions here alright

1751

01:14:39,290 --> 01:14:34,980

well I guess I have a second one here so

1752

01:14:42,890 --> 01:14:39,300

I'm wondering if you have seen images

1753

01:14:44,660 --> 01:14:42,900

that then make you go hey wait this

1754

01:14:46,460 --> 01:14:44,670

doesn't agree with you know our current

1755

01:14:48,230 --> 01:14:46,470

understanding of physics and you know

1756

01:14:49,640 --> 01:14:48,240

how do you guys go about do you have to

1757

01:14:51,170 --> 01:14:49,650

like contact someone else

1758

01:14:54,500 --> 01:14:51,180

and say hey what do you guys think about

1759

01:14:58,730 --> 01:14:54,510

this and kind of like have you run into

1760

01:15:01,220 --> 01:14:58,740

anything like that in I know all the

1761

01:15:03,050 --> 01:15:01,230

stuff you've seen yes so I have a good

1762

01:15:04,930 --> 01:15:03,060

example with that I don't know how great

1763

01:15:09,440 --> 01:15:04,940

I can explain it without my head but

1764

01:15:11,870 --> 01:15:09,450

when there was a gravitational wave

1765

01:15:14,180 --> 01:15:11,880

event in August 2017

1766

01:15:15,500 --> 01:15:14,190

I will took some data of the object it

1767

01:15:17,990 --> 01:15:15,510

was a it's called a Killa Nova just

1768

01:15:20,560 --> 01:15:18,000

enormous explosion and it was looking at

1769

01:15:23,450 --> 01:15:20,570

infrared and two different filters and

1770

01:15:26,450 --> 01:15:23,460

we were making color images of that

1771

01:15:29,930 --> 01:15:26,460

object spaced out by a few days at a

1772

01:15:32,030 --> 01:15:29,940

time and what I noticed was the first

1773

01:15:32,480 --> 01:15:32,040

image the object appeared to be sort of

1774

01:15:34,250 --> 01:15:32,490

yellowish

1775

01:15:35,480 --> 01:15:34,260

and the second one it turned blue which

1776

01:15:36,680 --> 01:15:35,490

was kind of surprising and then the

1777

01:15:38,780 --> 01:15:36,690

third one it was back to being yellow

1778

01:15:40,790 --> 01:15:38,790

but dimmer and it turned out that in

1779

01:15:43,190 --> 01:15:40,800

that middle observation there was a

1780

01:15:44,690 --> 01:15:43,200

slight gap in between when the two

1781

01:15:45,890 --> 01:15:44,700

different filters were taken and it was

1782

01:15:47,570 --> 01:15:45,900

just long enough that the object had

1783

01:15:49,130 --> 01:15:47,580

actually dimmed enough to allow the

1784

01:15:51,410 --> 01:15:49,140

shorter wavelengths to be brighter than

1785

01:15:54,440 --> 01:15:51,420

the longer wavelength and so the color

1786

01:15:56,780 --> 01:15:54,450

changed and that was a surprise and so

1787

01:15:58,430 --> 01:15:56,790

we usually are working with the we call

1788

01:15:59,810 --> 01:15:58,440

the principal investigator the scientist

1789

01:16:03,050 --> 01:15:59,820

who took the data when we make these

1790

01:16:05,030 --> 01:16:03,060

press release out images so we went back

1791

01:16:06,590 --> 01:16:05,040

and forth with the investigators and

1792

01:16:08,870 --> 01:16:06,600

determined that yeah there was this

1793

01:16:10,070 --> 01:16:08,880

issue where there was a separation that

1794

01:16:11,780 --> 01:16:10,080

shouldn't have been there but

1795

01:16:14,090 --> 01:16:11,790

unfortunately was that caused this

1796

01:16:14,720 --> 01:16:14,100

change in the color that's not intrinsic

1797

01:16:18,380 --> 01:16:14,730

to the object

1798

01:16:20,360 --> 01:16:18,390

it was just because of that break yeah

1799

01:16:21,620 --> 01:16:20,370

and so that was a case where you know

1800

01:16:22,790 --> 01:16:21,630

there was something surprising we talked

1801
01:16:24,020 --> 01:16:22,800
to the scientists about it we figured it

1802
01:16:24,980 --> 01:16:24,030
out and then we ended up just really

1803
01:16:26,660 --> 01:16:24,990
seeing it as a black-and-white because

1804
01:16:31,430 --> 01:16:26,670
the whole goal was to show that it was

1805
01:16:42,560 --> 01:16:31,440
dimming over time quickly I hope that

1806
01:16:44,900 --> 01:16:42,570
made sense okay one comment from online

1807
01:16:56,390 --> 01:16:44,910
says riding shotgun could use a good

1808
01:16:59,000 --> 01:16:56,400
tuba player I love the Internet yeah so

1809
01:17:00,710 --> 01:16:59,010
so we have all these telescope that we

1810
01:17:02,960 --> 01:17:00,720
can take a look at pretty deep and

1811
01:17:05,420 --> 01:17:02,970
faraway object in space what do you

1812
01:17:07,130 --> 01:17:05,430
think personally is the most important

1813
01:17:10,040 --> 01:17:07,140

takeaway work most important thing we

1814

01:17:11,930 --> 01:17:10,050

can learn from these from these images

1815

01:17:14,210 --> 01:17:11,940

because they're pretty far away and we

1816

01:17:16,360 --> 01:17:14,220

probably won't get to them that easily

1817

01:17:19,070 --> 01:17:16,370

so what do you think it's the most

1818

01:17:21,470 --> 01:17:19,080

valuable thing that we can study from it

1819

01:17:23,470 --> 01:17:21,480

well I think every time we look at

1820

01:17:25,370 --> 01:17:23,480

something where we're just trying to

1821

01:17:28,430 --> 01:17:25,380

deepen our understanding of the universe

1822

01:17:30,350 --> 01:17:28,440

in general I mean you're familiar with

1823

01:17:33,200 --> 01:17:30,360

this Carl Sagan quote that we are star

1824

01:17:34,790 --> 01:17:33,210

stuff we're made of the materials that

1825

01:17:36,410 --> 01:17:34,800

were generated forged in the hearts of

1826

01:17:40,070 --> 01:17:36,420

the stars that exploded billions of

1827

01:17:42,110 --> 01:17:40,080

years ago and also taking that a step

1828

01:17:44,030 --> 01:17:42,120

further we are the universe trying to

1829

01:17:46,160 --> 01:17:44,040

understand itself and I really love that

1830

01:17:47,810 --> 01:17:46,170

concept of the material of the universe

1831

01:17:49,640 --> 01:17:47,820

becoming conscious and tried to

1832

01:17:51,980 --> 01:17:49,650

understand itself and looking out and

1833

01:17:53,930 --> 01:17:51,990

peering into into space so it's sort of

1834

01:17:55,250 --> 01:17:53,940

a way of humanity trying to understand

1835

01:17:57,170 --> 01:17:55,260

itself the universe trying to understand

1836

01:17:58,250 --> 01:17:57,180

itself well sort of wrapped into one so

1837

01:18:01,490 --> 01:17:58,260

it's you know it's like the most

1838

01:18:02,900 --> 01:18:01,500

fundamental questions that we have we're

1839

01:18:11,390 --> 01:18:02,910

trying to find answers to when we look

1840

01:18:12,980 --> 01:18:11,400

in the space okay we got one two three

1841

01:18:14,960 --> 01:18:12,990

and then we're done okay cuz we're get

1842

01:18:16,430 --> 01:18:14,970

where you are going going I know we

1843

01:18:18,320 --> 01:18:16,440

could get these guys asking questions

1844

01:18:19,970 --> 01:18:18,330

forever but go ahead so what were your

1845

01:18:21,470 --> 01:18:19,980

thoughts on the black hole image that we

1846

01:18:23,180 --> 01:18:21,480

recently got earlier in the year I

1847

01:18:25,850 --> 01:18:23,190

thought that was incredible

1848

01:18:27,980 --> 01:18:25,860

that was an amazing image I wish that

1849

01:18:28,580 --> 01:18:27,990

there was a little more providing

1850

01:18:31,339 --> 01:18:28,590

context

1851

01:18:33,649 --> 01:18:31,349

of where in the universe this object

1852

01:18:35,089 --> 01:18:33,659

actually was and what it looks like in

1853

01:18:37,310 --> 01:18:35,099

other wavelengths because I work so much

1854

01:18:39,589 --> 01:18:37,320

in multi-wavelength I wanted to see that

1855

01:18:41,359 --> 01:18:39,599

that image of the doughnut in context

1856

01:18:42,800 --> 01:18:41,369

with everything else around it but

1857

01:18:44,120 --> 01:18:42,810

otherwise yeah I was just an incredible

1858

01:18:49,149 --> 01:18:44,130

achievement to be able to take that

1859

01:18:52,339 --> 01:18:49,159

image all right so I was just wondering

1860

01:18:55,700 --> 01:18:52,349

you said it had like terabytes of data

1861

01:18:58,970 --> 01:18:55,710

and stuff so I was wondering how long it

1862

01:19:03,020 --> 01:18:58,980

takes to transmit all that data from the

1863

01:19:07,129 --> 01:19:03,030

telescope to the computer that you're

1864

01:19:09,050 --> 01:19:07,139

using to process the images right so the

1865

01:19:12,439 --> 01:19:09,060

data actually on the telescope is stored

1866

01:19:14,240 --> 01:19:12,449

on there's hard basically hard drives on

1867

01:19:16,010 --> 01:19:14,250

the telescope and it's not terabytes of

1868

01:19:19,010 --> 01:19:16,020

data that are stored on the telescope

1869

01:19:20,899 --> 01:19:19,020

it's just over 29 years worth of

1870

01:19:23,510 --> 01:19:20,909

observations we now have terabytes of

1871

01:19:25,280 --> 01:19:23,520

data at any given time there's probably

1872

01:19:27,080 --> 01:19:25,290

megabytes to gigabytes of data on the

1873

01:19:29,390 --> 01:19:27,090

telescope itself that are transmitted

1874

01:19:31,939 --> 01:19:29,400

down through NASA's Deep Space Network a

1875

01:19:34,370 --> 01:19:31,949

series of satellite dishes and then they

1876

01:19:36,229 --> 01:19:34,380

make their way here to the multi mission

1877

01:19:38,419 --> 01:19:36,239

the Mikulski archive at Space Telescope

1878

01:19:40,280 --> 01:19:38,429

mast and that data is available to

1879

01:19:43,669 --> 01:19:40,290

anyone who wants to take a look at it

1880

01:19:46,790 --> 01:19:43,679

mass test es e IE d you I think that's

1881

01:19:49,760 --> 01:19:46,800

the URL it is however a very geek

1882

01:19:52,310 --> 01:19:49,770

friendly website it's not a user

1883

01:19:57,459 --> 01:19:52,320

friendly website for scientists by

1884

01:19:59,890 --> 01:19:57,469

scientists all right there was one hmm

1885

01:20:03,439 --> 01:19:59,900

yeah the context of the black hole I put

1886

01:20:06,109 --> 01:20:03,449

it's on our Hubble site YouTube channel

1887

01:20:08,870 --> 01:20:06,119

so on our Hubble Space Telescope YouTube

1888

01:20:11,990 --> 01:20:08,880

channel I made a video zooming in just

1889

01:20:13,149 --> 01:20:12,000

to what this series of stills actually I

1890

01:20:16,129 --> 01:20:13,159

showed it at the public lecture series

1891

01:20:18,320 --> 01:20:16,139

just to give context on that because we

1892

01:20:20,899 --> 01:20:18,330

here were unhappy that it didn't that

1893

01:20:24,649 --> 01:20:20,909

the press release that from the official

1894

01:20:26,750 --> 01:20:24,659

team did not have enough context yeah

1895

01:20:30,589 --> 01:20:26,760

last question so you stitch together

1896

01:20:32,390 --> 01:20:30,599

images in color so how because Hubble

1897

01:20:34,040 --> 01:20:32,400

takes images in black and white would

1898

01:20:36,620 --> 01:20:34,050

you say the color images that you stitch

1899

01:20:38,060 --> 01:20:36,630

together are more or less useful than

1900

01:20:42,600 --> 01:20:38,070

the black and white images that are

1901
01:20:44,910 --> 01:20:42,610
taken by Hubble that's a good question

1902
01:20:47,040 --> 01:20:44,920
so the scientists the black-and-white

1903
01:20:49,140 --> 01:20:47,050
the data the raw data is what they're

1904
01:20:51,180 --> 01:20:49,150
looking for it's the most useful for

1905
01:20:53,880 --> 01:20:51,190
them but there have been cases where

1906
01:20:55,380 --> 01:20:53,890
I've worked directly with scientists to

1907
01:20:57,530 --> 01:20:55,390
make an image that it's then used for

1908
01:21:00,120 --> 01:20:57,540
analysis or it becomes a part of a paper

1909
01:21:02,520 --> 01:21:00,130
so it goes both ways sometimes the color

1910
01:21:04,050 --> 01:21:02,530
image reveals details that are not

1911
01:21:06,060 --> 01:21:04,060
immediately obvious by looking at the

1912
01:21:08,760 --> 01:21:06,070
black and white data because you have

1913
01:21:12,360 --> 01:21:08,770

more than one image together you can

1914

01:21:14,940 --> 01:21:12,370

actually see more at one time so kind of

1915

01:21:17,240 --> 01:21:14,950

goes both ways all right I'm sorry I

1916

01:21:26,910 --> 01:21:17,250

don't have to cut it off there but