PUBLIC LECTURE SERIES

A Drop in the Light Bucket:
How Do We Measure a Galaxy?

Featuring Guest Speaker:
Amanda Pagul

1
00:00:05,510 --> 00:00:04,190
welcome to the Space Telescope public

2
00:00:09,110 --> 00:00:05,520
lecture series

3
00:00:12,230 --> 00:00:09,120
tonight A Drop In The Light bucket how

4
00:00:16,310 --> 00:00:12,240
do we measure a Galaxy by Amanda pagul

5
00:00:18,830 --> 00:00:16,320
of the Space Telescope Science Institute

6
00:00:21,650 --> 00:00:18,840
I'm your host Dr Frank Summers of the

7
00:00:23,269 --> 00:00:21,660
Office of Public Outreach it is my

8
00:00:25,790 --> 00:00:23,279
pleasure to bring you the public lecture

9
00:00:28,910 --> 00:00:25,800
series each and every month along with

10
00:00:31,970 --> 00:00:28,920
our amazing Tech Team Thomas marufu and

11
00:00:33,709 --> 00:00:31,980
Grant Justice who enable this webcasting

12
00:00:36,290 --> 00:00:33,719
to go out both through the Space

13
00:00:37,370 --> 00:00:36,300

Telescope webcasting site and through

14
00:00:39,369 --> 00:00:37,380
YouTube

15
00:00:41,869 --> 00:00:39,379
I will remind you that the Space

16
00:00:44,389 --> 00:00:41,879
Telescope public lecture series will

17
00:00:48,369 --> 00:00:44,399
continue to be online only throughout

18
00:00:55,430 --> 00:00:52,910
our upcoming talks next month we have a

19
00:00:58,310 --> 00:00:55,440
special presentation for you this will

20
00:00:59,930 --> 00:00:58,320
be a special event during the Roman

21
00:01:01,310 --> 00:00:59,940
science conference that will be held

22
00:01:03,889 --> 00:01:01,320
here at the Space Telescope Science

23
00:01:06,770 --> 00:01:03,899
Institute therefore it is not on the

24
00:01:09,710 --> 00:01:06,780
first Tuesday as usual it is actually on

25
00:01:11,450 --> 00:01:09,720
the third Thursday or maybe that's the

26
00:01:16,730 --> 00:01:11,460
fourth Thursday

27
00:01:19,550 --> 00:01:16,740
um June 22nd at 4 30 p.m that is to

28
00:01:22,490 --> 00:01:19,560
correspond with their conference and you

29
00:01:25,190 --> 00:01:22,500
get two not just one you get two talks

30
00:01:27,710 --> 00:01:25,200
about the price of one on this they will

31
00:01:30,710 --> 00:01:27,720
have Joan Gordon speaking on the

32
00:01:33,649 --> 00:01:30,720
personal side of Nancy Grace Roman so

33
00:01:36,770 --> 00:01:33,659
that is the history behind the woman who

34
00:01:39,710 --> 00:01:36,780
the Space Telescope is named for and we

35
00:01:41,690 --> 00:01:39,720
have a speaker yet to be determined uh

36
00:01:43,910 --> 00:01:41,700
who will talk about the mission and the

37
00:01:46,789 --> 00:01:43,920
science that will be done with the Nancy

38
00:01:48,950 --> 00:01:46,799

Grace Roman Space Telescope so it's

39
00:01:50,870 --> 00:01:48,960
going to be what at least six weeks

40
00:01:53,210 --> 00:01:50,880
maybe seven weeks between this public

41
00:01:55,190 --> 00:01:53,220
lecture and the next public lecture but

42
00:01:56,830 --> 00:01:55,200
that's because we have a special event

43
00:02:00,710 --> 00:01:56,840
for you in June

44
00:02:03,830 --> 00:02:00,720
in July uh you have this guy named Frank

45
00:02:06,050 --> 00:02:03,840
Summers which would be me uh talking on

46
00:02:08,510 --> 00:02:06,060
a visualization that we have done and

47
00:02:10,490 --> 00:02:08,520
the detail science behind it and all of

48
00:02:13,430 --> 00:02:10,500
the multi-wavelength exploration that

49
00:02:15,770 --> 00:02:13,440
we've done with it uh Stefan's quintet a

50
00:02:19,210 --> 00:02:15,780
multi-wavelength exploration

51
00:02:22,790 --> 00:02:19,220
in August we have another special event

52
00:02:24,830 --> 00:02:22,800
because it will be just over one year

53
00:02:27,589 --> 00:02:24,840
that since the web Space Telescope

54
00:02:31,070 --> 00:02:27,599
started taking science observations so

55
00:02:33,949 --> 00:02:31,080
on August 1st we have a talk entitled

56
00:02:36,830 --> 00:02:33,959
web Space Telescope the first year of

57
00:02:40,250 --> 00:02:36,840
Science and unfortunately that speaker

58
00:02:41,930 --> 00:02:40,260
is also to be announced so look for that

59
00:02:44,630 --> 00:02:41,940
I know you're not going to want to miss

60
00:02:46,790 --> 00:02:44,640
that one if you want to follow along and

61
00:02:49,390 --> 00:02:46,800
find out about the lectures you can go

62
00:02:55,970 --> 00:02:52,850
www.stsci.edu public hyphen lectures

63
00:02:58,130 --> 00:02:55,980

that will take you to this webpage and

64
00:03:00,530 --> 00:02:58,140
you can see that our webcasts are in the

65
00:03:03,830 --> 00:03:00,540
lower left and if you'd like to sign up

66
00:03:06,949 --> 00:03:03,840
for our email announcements uh you can

67
00:03:09,229 --> 00:03:06,959
find them in the lower right also on

68
00:03:12,350 --> 00:03:09,239
that page are the list of the upcoming

69
00:03:14,149 --> 00:03:12,360
lectures and if you click on any one of

70
00:03:16,970 --> 00:03:14,159
those lectures it will give you the

71
00:03:19,670 --> 00:03:16,980
details including all of the description

72
00:03:21,890 --> 00:03:19,680
of about it as well as after it has been

73
00:03:25,130 --> 00:03:21,900
recorded links to the Space Telescope

74
00:03:27,550 --> 00:03:25,140
webcast as well as the webcast out on

75
00:03:33,710 --> 00:03:31,009
our email as I said the announcements uh

76
00:03:35,509 --> 00:03:33,720
you can sign up on the website you can

77
00:03:38,750 --> 00:03:35,519
also just subscribe to our YouTube

78
00:03:41,509 --> 00:03:38,760
channel youtube.com Hubble Space

79
00:03:44,210 --> 00:03:41,519
Telescope if you sign up for that you

80
00:03:47,390 --> 00:03:44,220
will get notices of our new videos and

81
00:03:49,490 --> 00:03:47,400
reminders of Live Events such as this

82
00:03:52,610 --> 00:03:49,500
also if you have comments or questions

83
00:03:56,120 --> 00:03:52,620
you can send them to our email which is

84
00:03:59,330 --> 00:03:56,130
public lecture all one word at stsci.edu

85
00:04:04,369 --> 00:04:01,250
if you would like to follow our

86
00:04:06,170 --> 00:04:04,379
Institute on social media we do social

87
00:04:08,570 --> 00:04:06,180
media channels for the Hubble Space

88
00:04:10,429 --> 00:04:08,580

Telescope for the web Space Telescope

89
00:04:12,710 --> 00:04:10,439
and for the Institute the Space

90
00:04:15,589 --> 00:04:12,720
Telescope Science Institute and we are

91
00:04:16,909 --> 00:04:15,599
on Facebook Twitter Youtube and

92
00:04:19,849 --> 00:04:16,919
Instagram

93
00:04:22,009 --> 00:04:19,859
I myself don't really do much social

94
00:04:24,469 --> 00:04:22,019
media but I have the accounts just in

95
00:04:30,530 --> 00:04:24,479
case I'm uh do a little bit on Facebook

96
00:04:36,530 --> 00:04:35,110
the news for the universe for May 2023

97
00:04:38,710 --> 00:04:36,540
[Music]

98
00:04:42,890 --> 00:04:38,720
our first story tonight

99
00:04:46,430 --> 00:04:42,900
33 years of Hubble yeah Hubble was

100
00:04:50,090 --> 00:04:46,440
launched in 1990 and just passed its

101
00:04:52,610 --> 00:04:50,100
33rd anniversary and as you can see in

102
00:04:56,749 --> 00:04:52,620
this image Hubble has produced a

103
00:04:58,550 --> 00:04:56,759
tremendous number of images and so many

104
00:05:02,450 --> 00:04:58,560
really cool images

105
00:05:04,490 --> 00:05:02,460
but we still try to come up with a

106
00:05:07,189 --> 00:05:04,500
really cool image for Hubble's annivers

107
00:05:08,990 --> 00:05:07,199
launch anniversary every year

108
00:05:10,850 --> 00:05:09,000
and it kind of gets harder and harder

109
00:05:12,909 --> 00:05:10,860
every year and you have to scratch ahead

110
00:05:16,030 --> 00:05:12,919
and work real hard to come up with ideas

111
00:05:19,550 --> 00:05:16,040
well it turns out a few three years ago

112
00:05:22,370 --> 00:05:19,560
on Hubble's 30th anniversary in 2020

113
00:05:25,310 --> 00:05:22,380

somebody had the cute idea to say hey

114
00:05:29,629 --> 00:05:25,320
let's go see what NGC 2020 looks like

115
00:05:32,270 --> 00:05:29,639
since it's 2020 go look at NGC 2020 and

116
00:05:36,830 --> 00:05:32,280
actually 2020 NGC 2020 is right next to

117
00:05:39,290 --> 00:05:36,840
NGC 2014 and together they made a

118
00:05:41,749 --> 00:05:39,300
tremendous image this was what we called

119
00:05:43,969 --> 00:05:41,759
Cosmic Reef so this sort of little bit

120
00:05:46,310 --> 00:05:43,979
of numerology kind of worked out for

121
00:05:48,890 --> 00:05:46,320
that well there's a little bit of

122
00:05:52,010 --> 00:05:48,900
numerology used here for the 33rd

123
00:05:54,409 --> 00:05:52,020
anniversary so almost 33rd anniversary

124
00:05:58,850 --> 00:05:54,419
2023 what are we going to do well let's

125
00:06:00,590 --> 00:05:58,860
try that NGC 2023 uh yeah Hubble has

126
00:06:01,969 --> 00:06:00,600
already done it before

127
00:06:04,670 --> 00:06:01,979
um and there's a major problem with it

128
00:06:06,350 --> 00:06:04,680
you see this big big spike this

129
00:06:08,029 --> 00:06:06,360
diffraction Spike stretching across the

130
00:06:11,330 --> 00:06:08,039
image if you actually want to look at

131
00:06:14,510 --> 00:06:11,340
NGC 2023 there's a huge honk and bright

132
00:06:16,610 --> 00:06:14,520
star there and um it's not really good

133
00:06:18,290 --> 00:06:16,620
for an anniversary image just you know

134
00:06:20,090 --> 00:06:18,300
you can't quite get it so it's a nice

135
00:06:21,770 --> 00:06:20,100
nebula nothing wrong with this nebula

136
00:06:23,090 --> 00:06:21,780
it's just got a really bright star in

137
00:06:25,730 --> 00:06:23,100
the field that doesn't quite work with

138
00:06:28,790 --> 00:06:25,740

it so then you say to yourself what were

139
00:06:32,330 --> 00:06:28,800
maybe 33 right there's this Messier

140
00:06:33,890 --> 00:06:32,340
catalog what's Messier 33

141
00:06:37,850 --> 00:06:33,900
um unfortunately we've already done

142
00:06:40,430 --> 00:06:37,860
Messier 33. Messier 33 is the triangulum

143
00:06:42,770 --> 00:06:40,440
Galaxy and Hubble has done this in

144
00:06:46,129 --> 00:06:42,780
Spades with hundreds and hundreds of

145
00:06:47,930 --> 00:06:46,139
millions of pixels so yeah we can't use

146
00:06:50,029 --> 00:06:47,940
that again we've already used that for

147
00:06:52,370 --> 00:06:50,039
it so you'll work hard and you'll think

148
00:06:55,270 --> 00:06:52,380
can you try a new gun in there and then

149
00:06:58,309 --> 00:06:55,280
you get to something called NGC

150
00:07:01,189 --> 00:06:58,319
1333 all right and Hubble had looked at

151
00:07:02,749 --> 00:07:01,199
that nebula before and here are two

152
00:07:05,689 --> 00:07:02,759
images from it and they're not terribly

153
00:07:08,090 --> 00:07:05,699
exciting because they're sort of in the

154
00:07:10,129 --> 00:07:08,100
outskirts of the nebula but when you

155
00:07:11,749 --> 00:07:10,139
look at the real nebula

156
00:07:13,909 --> 00:07:11,759
you got something

157
00:07:17,090 --> 00:07:13,919
so for this year's anniversary image

158
00:07:21,320 --> 00:07:17,100
Hubble created this image of NG the

159
00:07:25,670 --> 00:07:22,570
[Music]

160
00:07:27,850 --> 00:07:25,680
ah yeah this is really this is this is

161
00:07:31,249 --> 00:07:27,860
cool all right so

162
00:07:33,529 --> 00:07:31,259
NGC 1333 is technically just this blue

163
00:07:35,809 --> 00:07:33,539

region up at the top it's what's called

164
00:07:38,170 --> 00:07:35,819
a reflection nebula there's that bright

165
00:07:41,629 --> 00:07:38,180
star and the light of that bright star

166
00:07:44,510 --> 00:07:41,639
reflects off the gas around it okay and

167
00:07:45,950 --> 00:07:44,520
that gas shows up as blue all right so

168
00:07:46,670 --> 00:07:45,960
you've got a reflection nebula at the

169
00:07:49,550 --> 00:07:46,680
top

170
00:07:52,969 --> 00:07:49,560
but in the middle you see you have dark

171
00:07:56,029 --> 00:07:52,979
nebula this is an absorption nebula this

172
00:07:57,950 --> 00:07:56,039
is dark dense gas that's absorbing the

173
00:07:59,749 --> 00:07:57,960
light and so you have the bright spot

174
00:08:01,070 --> 00:07:59,759
behind it and the light that it's

175
00:08:04,670 --> 00:08:01,080
actually absorbing it so you see the

176
00:08:07,010 --> 00:08:04,680
dark nebula and then down bottom you

177
00:08:09,890 --> 00:08:07,020
have the bright nebula the emission

178
00:08:12,950 --> 00:08:09,900
nebula this is a region that's inside

179
00:08:15,290 --> 00:08:12,960
this dark gas where stars are forming

180
00:08:16,969 --> 00:08:15,300
and these newborn stars are shooting off

181
00:08:19,550 --> 00:08:16,979
Jets and such and so there's a lot of

182
00:08:21,710 --> 00:08:19,560
activity going on there and so that sort

183
00:08:23,930 --> 00:08:21,720
of makes this really cool is that you've

184
00:08:27,350 --> 00:08:23,940
got a reflection nebula an absorption

185
00:08:29,089 --> 00:08:27,360
nebula and an emission nebula all in the

186
00:08:31,490 --> 00:08:29,099
same image and that gives you this

187
00:08:32,630 --> 00:08:31,500
really cool kind of effect like I sort

188
00:08:34,550 --> 00:08:32,640

of think like that's sort of that that

189
00:08:36,649 --> 00:08:34,560
looks like the Moon Over the atmosphere

190
00:08:38,510 --> 00:08:36,659
and then there's a fire in the forest

191
00:08:39,829 --> 00:08:38,520
down below or something like that in a

192
00:08:42,589 --> 00:08:39,839
night thing it's just really this this

193
00:08:44,269 --> 00:08:42,599
cool contrast of the the blue up top to

194
00:08:47,750 --> 00:08:44,279
the dark in the middle to the red down

195
00:08:50,329 --> 00:08:47,760
bottom all right and so NGC 1333 makes

196
00:08:53,650 --> 00:08:50,339
for a nice image on this scale

197
00:08:59,030 --> 00:08:53,660
but I gotta say while researching NGC

198
00:09:01,070 --> 00:08:59,040
1333 I found this image from the space

199
00:09:03,170 --> 00:09:01,080
telescope and you see that little orange

200
00:09:05,509 --> 00:09:03,180
box that I drew in there that's the

201
00:09:08,389 --> 00:09:05,519
scale of the Hubble image and what you

202
00:09:11,030 --> 00:09:08,399
see below it all that green stuff those

203
00:09:12,889 --> 00:09:11,040
are those newborn stars that are

204
00:09:14,570 --> 00:09:12,899
shooting off these Jets there are these

205
00:09:17,030 --> 00:09:14,580
things called her big hero objects and

206
00:09:19,670 --> 00:09:17,040
there's like nine or ten of them uh in

207
00:09:21,530 --> 00:09:19,680
there and so I gotta say well the Hubble

208
00:09:24,110 --> 00:09:21,540
image is really cool and it makes for a

209
00:09:26,870 --> 00:09:24,120
great 33rd anniversary image

210
00:09:29,449 --> 00:09:26,880
I hope that sometime for Webb's

211
00:09:31,910 --> 00:09:29,459
anniversary that Webb will look at all

212
00:09:34,790 --> 00:09:31,920
this stuff down here and we get a really

213
00:09:36,650 --> 00:09:34,800

high detailed view of all those newborn

214
00:09:39,530 --> 00:09:36,660
stars and all those Jets coming out of

215
00:09:43,250 --> 00:09:39,540
it so maybe sometime in the future I can

216
00:09:48,230 --> 00:09:45,310
our second story tonight

217
00:09:49,310 --> 00:09:48,240
expanding our view of a supernova

218
00:09:51,410 --> 00:09:49,320
remnant

219
00:09:54,170 --> 00:09:51,420
and the Supernova Remnant in question

220
00:09:57,290 --> 00:09:54,180
here is one of the most famous it is

221
00:10:00,050 --> 00:09:57,300
called Cassiopeia a and here is the

222
00:10:03,850 --> 00:10:00,060
Hubble image of it from gosh like 20

223
00:10:08,030 --> 00:10:03,860
years ago okay and this is this circular

224
00:10:09,070 --> 00:10:08,040
bubble right because a supernova is when

225
00:10:12,050 --> 00:10:09,080
a star

226
00:10:15,350 --> 00:10:12,060
explodes and so what you're seeing here

227
00:10:17,750 --> 00:10:15,360
literally is the guts of the star blown

228
00:10:20,630 --> 00:10:17,760
out into Interstellar space this is

229
00:10:22,790 --> 00:10:20,640
about 10 light years across so it's uh

230
00:10:24,889 --> 00:10:22,800
it's been expanding for about 300 years

231
00:10:27,050 --> 00:10:24,899
the Supernova exploded about 300 years

232
00:10:29,570 --> 00:10:27,060
ago and here is the result that we see

233
00:10:31,910 --> 00:10:29,580
today and Hubble's image is cool don't

234
00:10:34,009 --> 00:10:31,920
get me wrong I really enjoy Hubble's

235
00:10:36,590 --> 00:10:34,019
image it's got all sorts of fine details

236
00:10:39,470 --> 00:10:36,600
but Supernova remnants are generally

237
00:10:43,070 --> 00:10:39,480
even more exciting when you look at them

238
00:10:45,410 --> 00:10:43,080

in the X-rays and so here is the X-ray

239
00:10:48,410 --> 00:10:45,420
image from Chandra the Chandra x-ray

240
00:10:50,870 --> 00:10:48,420
Observatory and because the gas in

241
00:10:53,569 --> 00:10:50,880
Supernova is heat it up to hundreds of

242
00:10:56,990 --> 00:10:53,579
thousands and millions of degrees it

243
00:10:58,850 --> 00:10:57,000
glows in x-rays so you can see all these

244
00:11:01,910 --> 00:10:58,860
elements that were created in the

245
00:11:03,829 --> 00:11:01,920
Supernova blown out across space and the

246
00:11:06,410 --> 00:11:03,839
different colors here actually represent

247
00:11:08,930 --> 00:11:06,420
different elements observed in the

248
00:11:11,810 --> 00:11:08,940
Supernova Remnant and so the x-rays are

249
00:11:14,389 --> 00:11:11,820
really cool here but it's also crazy

250
00:11:17,569 --> 00:11:14,399
about supernovae is that x-rays are high

251
00:11:21,470 --> 00:11:17,579
energy but Supernova actually also look

252
00:11:24,650 --> 00:11:21,480
pretty good in low energy radial ways so

253
00:11:27,410 --> 00:11:24,660
this is Radio light as observed by the

254
00:11:29,569 --> 00:11:27,420
very large array and again you get that

255
00:11:32,690 --> 00:11:29,579
beautiful bubble structure from the

256
00:11:34,550 --> 00:11:32,700
radial emission from Cassiopeia a

257
00:11:37,870 --> 00:11:34,560
the one place where we didn't have

258
00:11:41,990 --> 00:11:37,880
fantastic resolution to look at the

259
00:11:44,389 --> 00:11:42,000
Cassiopeia a was in infrared light this

260
00:11:46,730 --> 00:11:44,399
is the observations from the Spitzer

261
00:11:49,910 --> 00:11:46,740
Space Telescope and you know you can't

262
00:11:52,610 --> 00:11:49,920
blame Spitzer Spitzer has only a zero uh

263
00:11:54,350 --> 00:11:52,620

an 80 centimeter mirror okay it's a less

264
00:11:57,769 --> 00:11:54,360
than a meter Hubble has a two and a half

265
00:12:00,290 --> 00:11:57,779
meter mirror but the James Webb Space

266
00:12:03,110 --> 00:12:00,300
Telescope has a six and a half meter

267
00:12:07,670 --> 00:12:03,120
mirror so that's where I'm headed down

268
00:12:10,610 --> 00:12:07,680
here we now have a infrared view from

269
00:12:12,889 --> 00:12:10,620
the web Space Telescope of Cassiopeia a

270
00:12:16,850 --> 00:12:12,899
and even though I've been talking a long

271
00:12:18,889 --> 00:12:16,860
time it's worth waiting for

272
00:12:21,530 --> 00:12:18,899
ah

273
00:12:24,650 --> 00:12:21,540
this is the mid infrared view with a

274
00:12:27,470 --> 00:12:24,660
Miri instrument from web and you can see

275
00:12:30,290 --> 00:12:27,480
that finely grain structure that you see

276
00:12:33,170 --> 00:12:30,300
in the Hubble image but you also see all

277
00:12:35,810 --> 00:12:33,180
this other material that Hubble doesn't

278
00:12:38,210 --> 00:12:35,820
see all right so if I go to the Hubble

279
00:12:39,889 --> 00:12:38,220
image right you can see I called all

280
00:12:42,110 --> 00:12:39,899
this the guts of the star that are being

281
00:12:45,110 --> 00:12:42,120
blown out into space well those same

282
00:12:47,750 --> 00:12:45,120
guts of the star do appear in infrared

283
00:12:50,569 --> 00:12:47,760
but then you see all this orange and

284
00:12:52,910 --> 00:12:50,579
reddish gas out here along the top and

285
00:12:55,190 --> 00:12:52,920
the left side okay what is that that's

286
00:12:58,730 --> 00:12:55,200
the dust that has been expelled by the

287
00:13:00,949 --> 00:12:58,740
Supernova that's crashing into other

288
00:13:04,069 --> 00:13:00,959

material out there and heating up okay

289
00:13:06,829 --> 00:13:04,079
so that's warm dust material okay so

290
00:13:09,590 --> 00:13:06,839
that's the first wave of stuff then you

291
00:13:11,509 --> 00:13:09,600
got stuff from the Star the other thing

292
00:13:13,190 --> 00:13:11,519
that you'll notice is if I go back to

293
00:13:15,949 --> 00:13:13,200
that Hubble image

294
00:13:18,290 --> 00:13:15,959
oops I have to go forward to that help

295
00:13:19,790 --> 00:13:18,300
Loach right all right

296
00:13:21,230 --> 00:13:19,800
um and

297
00:13:22,490 --> 00:13:21,240
web

298
00:13:25,009 --> 00:13:22,500
Hubble

299
00:13:27,290 --> 00:13:25,019
web do you notice that the material

300
00:13:29,870 --> 00:13:27,300
looks like it's getting larger

301
00:13:31,190 --> 00:13:29,880
yes it is getting larger this is not

302
00:13:32,930 --> 00:13:31,200
just that I think there are plenty of

303
00:13:36,590 --> 00:13:32,940
stars in this image so I registered them

304
00:13:39,230 --> 00:13:36,600
correctly the the the the Supernova red

305
00:13:42,350 --> 00:13:39,240
has actually expanded over the 20 years

306
00:13:44,449 --> 00:13:42,360
between those two observations yeah this

307
00:13:46,790 --> 00:13:44,459
is only 300 years old it's still

308
00:13:49,910 --> 00:13:46,800
expanding so 20 years is a significant

309
00:13:52,970 --> 00:13:49,920
fraction of 300 years and so you're able

310
00:13:55,430 --> 00:13:52,980
to see actually see the expansion of the

311
00:13:57,829 --> 00:13:55,440
Supernova Remnant between these two

312
00:14:01,129 --> 00:13:57,839
epics

313
00:14:03,170 --> 00:14:01,139

all right the other really cool thing uh

314
00:14:06,170 --> 00:14:03,180
in this this web image that I want to

315
00:14:09,769 --> 00:14:06,180
point out is this sort of green bubble

316
00:14:10,670 --> 00:14:09,779
like curvy structure here okay

317
00:14:12,650 --> 00:14:10,680
um

318
00:14:15,050 --> 00:14:12,660
and we don't know what it is we haven't

319
00:14:18,170 --> 00:14:15,060
seen anything like this before it's

320
00:14:20,389 --> 00:14:18,180
really cool uh the press release said

321
00:14:23,690 --> 00:14:20,399
that the complexity of this structure is

322
00:14:26,030 --> 00:14:23,700
unexpected and poses difficulty for

323
00:14:28,670 --> 00:14:26,040
interpretation which is a very polite

324
00:14:30,530 --> 00:14:28,680
way of saying the astronomers even the

325
00:14:33,530 --> 00:14:30,540
experts in this object look at this and

326
00:14:35,150 --> 00:14:33,540
go what's that hmm we're going to need

327
00:14:39,050 --> 00:14:35,160
to study that to figure out what's going

328
00:14:42,050 --> 00:14:39,060
on there so uh not only has the web

329
00:14:43,790 --> 00:14:42,060
Space Telescope shown us the expansion

330
00:14:46,069 --> 00:14:43,800
of the um

331
00:14:48,110 --> 00:14:46,079
Supernova Remnant but it has also

332
00:14:50,870 --> 00:14:48,120
expanded the possibilities of what we

333
00:14:55,250 --> 00:14:50,880
can see in the infrared

334
00:15:01,910 --> 00:14:59,689
all right now to our featured speaker ah

335
00:15:05,389 --> 00:15:01,920
our speaker speech featured speaker

336
00:15:09,350 --> 00:15:05,399
tonight uh is Amanda pagul of the Space

337
00:15:13,069 --> 00:15:09,360
Telescope Science Institute uh she is a

338
00:15:15,290 --> 00:15:13,079

sdsci fellow and has only been here for

339
00:15:17,449 --> 00:15:15,300
six months okay which was really great

340
00:15:18,829 --> 00:15:17,459
because she like got here and said hey

341
00:15:20,689 --> 00:15:18,839
Frank I want to give a talk and I was

342
00:15:22,430 --> 00:15:20,699
like fantastic

343
00:15:26,329 --> 00:15:22,440
um I love it when new people uh

344
00:15:27,889 --> 00:15:26,339
volunteer to give talks uh she is

345
00:15:29,810 --> 00:15:27,899
um working

346
00:15:31,910 --> 00:15:29,820
uh well she'll tell you what what what

347
00:15:34,430 --> 00:15:31,920
what about what she's working on uh her

348
00:15:35,629 --> 00:15:34,440
history is that um she didn't like me

349
00:15:37,069 --> 00:15:35,639
she didn't grow up wanting to be an

350
00:15:39,470 --> 00:15:37,079
astronomer

351
00:15:42,829 --> 00:15:39,480
um I had no idea I'd become an

352
00:15:44,750 --> 00:15:42,839
astronomer she left it till kind of late

353
00:15:46,790 --> 00:15:44,760
um she was doing pre-med at the

354
00:15:48,590 --> 00:15:46,800
University of Chicago

355
00:15:51,110 --> 00:15:48,600
um and then she switched to astronomy

356
00:15:54,829 --> 00:15:51,120
for her graduate work at the University

357
00:15:57,829 --> 00:15:54,839
of California at Riverside and she has

358
00:16:01,370 --> 00:15:57,839
come here to help to work with us

359
00:16:03,710 --> 00:16:01,380
um in her spare time uh she actually

360
00:16:06,710 --> 00:16:03,720
does what I do but she doesn't get paid

361
00:16:08,090 --> 00:16:06,720
for it uh she does outreach and she

362
00:16:09,949 --> 00:16:08,100
worked with students at a small

363
00:16:12,410 --> 00:16:09,959

telescope to do Outreach projects and

364
00:16:15,110 --> 00:16:12,420
teach students how to observe the

365
00:16:17,810 --> 00:16:15,120
universe as well as she says to really

366
00:16:20,689 --> 00:16:17,820
relax uh she does some knitting and

367
00:16:22,610 --> 00:16:20,699
crocheting so Amanda if you'll start

368
00:16:37,670 --> 00:16:22,620
your screen share ladies and gentlemen

369
00:16:45,290 --> 00:16:39,170
I guess I'm

370
00:16:49,670 --> 00:16:47,269
okay can you hear me all right

371
00:16:53,030 --> 00:16:49,680
yes we can

372
00:16:57,470 --> 00:16:53,040
okay so slideshow

373
00:17:02,509 --> 00:17:00,470
yes we can okay thanks Frank sorry I

374
00:17:04,970 --> 00:17:02,519
just wanted to double check uh to make

375
00:17:08,150 --> 00:17:04,980
sure that everyone is is getting what

376
00:17:10,789 --> 00:17:08,160
what I want them to to see

377
00:17:12,169 --> 00:17:10,799
okay so thanks so much Frank for that

378
00:17:13,909 --> 00:17:12,179
introduction

379
00:17:18,289 --> 00:17:13,919
um like Fran Frank said my name is

380
00:17:20,449 --> 00:17:18,299
Amanda I'm currently a postdoc at the

381
00:17:22,250 --> 00:17:20,459
Space Telescope Institute started fairly

382
00:17:25,069 --> 00:17:22,260
recently

383
00:17:27,530 --> 00:17:25,079
um and my research work mostly focuses

384
00:17:31,310 --> 00:17:27,540
on understanding Galaxy formation and

385
00:17:33,470 --> 00:17:31,320
evolution I also help support one of the

386
00:17:36,490 --> 00:17:33,480
detectors on the Hubble Space Telescope

387
00:17:40,070 --> 00:17:36,500
called the wide field camera 3 with C3

388
00:17:41,690 --> 00:17:40,080

so I'm uh with with that I'm really

389
00:17:43,549 --> 00:17:41,700
excited to tell you a little bit about

390
00:17:47,029 --> 00:17:43,559
my research

391
00:17:49,669 --> 00:17:47,039
um of how we measure a Galaxy and so

392
00:17:51,950 --> 00:17:49,679
what I want you to get away from this is

393
00:17:55,430 --> 00:17:51,960
we've all seen these really beautiful

394
00:17:58,190 --> 00:17:55,440
images that are coming out of Hubble uh

395
00:18:01,430 --> 00:17:58,200
and now James Webb and so what I want to

396
00:18:04,070 --> 00:18:01,440
talk about is how do we go from those

397
00:18:06,710 --> 00:18:04,080
images and extract meaningful

398
00:18:08,750 --> 00:18:06,720
information from them so that includes

399
00:18:10,610 --> 00:18:08,760
things like how far away the the Galaxy

400
00:18:12,470 --> 00:18:10,620
is from us

401
00:18:14,990 --> 00:18:12,480
um what is its Stellar Mass how many

402
00:18:17,690 --> 00:18:15,000
stars does it have how many stars does

403
00:18:19,010 --> 00:18:17,700
it form so things like that how old it

404
00:18:20,690 --> 00:18:19,020
is ETC

405
00:18:21,470 --> 00:18:20,700
and so

406
00:18:24,169 --> 00:18:21,480
um

407
00:18:25,669 --> 00:18:24,179
I guess I'll just Dive Right In

408
00:18:26,630 --> 00:18:25,679
um

409
00:18:29,930 --> 00:18:26,640
okay

410
00:18:31,970 --> 00:18:29,940
so before I sort of started start with

411
00:18:34,789 --> 00:18:31,980
all of the technical information I

412
00:18:37,909 --> 00:18:34,799
wanted to show you the first picture I

413
00:18:41,330 --> 00:18:37,919

have ever seen through a telescope it's

414
00:18:42,890 --> 00:18:41,340
this picture of Saturn on the left and

415
00:18:46,210 --> 00:18:42,900
like Frank said I was never really

416
00:18:49,909 --> 00:18:46,220
interested in astronomy and astrophysics

417
00:18:51,770 --> 00:18:49,919
it was and I say that because it was

418
00:18:54,110 --> 00:18:51,780
never really an option to me I'm

419
00:18:56,330 --> 00:18:54,120
originally from New York City and I make

420
00:18:58,430 --> 00:18:56,340
the joke that in New York City the

421
00:19:00,169 --> 00:18:58,440
closest thing that you ever see to a

422
00:19:03,289 --> 00:19:00,179
star is a helicopter

423
00:19:05,570 --> 00:19:03,299
um so it was totally not on my radar

424
00:19:08,090 --> 00:19:05,580
um and when I was in college I was able

425
00:19:11,150 --> 00:19:08,100
to go to a place called the Yorkies

426
00:19:13,190 --> 00:19:11,160
Observatory which is home to the largest

427
00:19:14,990 --> 00:19:13,200
refracting telescope in the world you

428
00:19:16,370 --> 00:19:15,000
can see it on the right here so if

429
00:19:17,990 --> 00:19:16,380
you're looking through the eyepiece

430
00:19:21,289 --> 00:19:18,000
that's sort of what the bottom of the

431
00:19:23,810 --> 00:19:21,299
telescope looks like it's really like

432
00:19:26,510 --> 00:19:23,820
very impressive and if you're ever in

433
00:19:29,029 --> 00:19:26,520
the Williams Bay Wisconsin area

434
00:19:30,650 --> 00:19:29,039
I definitely encourage you to stop by

435
00:19:32,090 --> 00:19:30,660
The Observatory and check it out because

436
00:19:34,610 --> 00:19:32,100
it really is

437
00:19:37,070 --> 00:19:34,620
quite magical

438
00:19:39,890 --> 00:19:37,080

um and so so I I look through the

439
00:19:43,130 --> 00:19:39,900
telescope and I saw this image of Saturn

440
00:19:46,430 --> 00:19:43,140
and it was just uh the most sort of

441
00:19:49,010 --> 00:19:46,440
impressive feeling uh that I got

442
00:19:51,590 --> 00:19:49,020
um I was very I was so blown away I

443
00:19:55,669 --> 00:19:51,600
couldn't believe that you know this this

444
00:19:58,130 --> 00:19:55,679
planet that's so far away from us right

445
00:20:00,890 --> 00:19:58,140
um maybe by cosmological distances you

446
00:20:03,110 --> 00:20:00,900
wouldn't call it far away but but but in

447
00:20:06,230 --> 00:20:03,120
absolute terms it really is very far

448
00:20:07,730 --> 00:20:06,240
away it's around 940 million miles away

449
00:20:10,130 --> 00:20:07,740
from us

450
00:20:12,409 --> 00:20:10,140
um and so I was so impressed by the fact

451
00:20:14,570 --> 00:20:12,419
that we can actually get uh we can

452
00:20:17,630 --> 00:20:14,580
actually see it and that the photons or

453
00:20:20,630 --> 00:20:17,640
the light particles that are uh being

454
00:20:21,770 --> 00:20:20,640
reflected off of Saturn from the sun is

455
00:20:26,270 --> 00:20:21,780
actually

456
00:20:28,370 --> 00:20:26,280
coming to us traveling those 940 million

457
00:20:31,130 --> 00:20:28,380
miles through the telescope through that

458
00:20:32,870 --> 00:20:31,140
eyepiece to hit your retina

459
00:20:35,630 --> 00:20:32,880
um your retina and also my phone camera

460
00:20:37,789 --> 00:20:35,640
I kind of like put my phone up to the

461
00:20:39,590 --> 00:20:37,799
eyepiece to to try to get a picture of

462
00:20:40,970 --> 00:20:39,600
it and and that's what you see on the

463
00:20:43,070 --> 00:20:40,980

left

464
00:20:44,690 --> 00:20:43,080
um so it really is like it really was a

465
00:20:46,909 --> 00:20:44,700
special moment and it totally kind of

466
00:20:48,830 --> 00:20:46,919
kick-started my career in astronomy and

467
00:20:51,350 --> 00:20:48,840
astrophysics and I decided to no longer

468
00:20:53,570 --> 00:20:51,360
be pre-med after that

469
00:20:56,270 --> 00:20:53,580
um here's another picture of it I mean I

470
00:20:58,850 --> 00:20:56,280
mean just being in that like uh the Dome

471
00:21:01,789 --> 00:20:58,860
was inexperienced in and of itself and

472
00:21:03,890 --> 00:21:01,799
then looking through a telescope uh for

473
00:21:06,950 --> 00:21:03,900
the first time was just it was so

474
00:21:10,190 --> 00:21:06,960
incredible and I have to say not bad for

475
00:21:12,830 --> 00:21:10,200
a first telescope right

476
00:21:15,529 --> 00:21:12,840
um so this sort of got me thinking about

477
00:21:19,010 --> 00:21:15,539
what does it mean for us to measure

478
00:21:21,049 --> 00:21:19,020
light how does light travel

479
00:21:23,510 --> 00:21:21,059
um what is a photon right so when I say

480
00:21:24,950 --> 00:21:23,520
Photon I'm referring to basically a

481
00:21:27,470 --> 00:21:24,960
particle of light

482
00:21:31,669 --> 00:21:27,480
I want to show you this video

483
00:21:34,610 --> 00:21:31,679
um this is a is a visualization of what

484
00:21:38,090 --> 00:21:34,620
the very early Universe looked like so

485
00:21:42,350 --> 00:21:38,100
this is around 300 000 years after the

486
00:21:44,210 --> 00:21:42,360
big bang and in the blue you see these

487
00:21:47,750 --> 00:21:44,220
um the photons so the blue is the

488
00:21:50,090 --> 00:21:47,760

photons and in the red and the green you

489
00:21:53,090 --> 00:21:50,100
see protons and electrons and the

490
00:21:55,430 --> 00:21:53,100
photons I'll start the video are

491
00:21:57,049 --> 00:21:55,440
bouncing all around the electrons are

492
00:21:58,310 --> 00:21:57,059
bouncing all around between the

493
00:22:02,090 --> 00:21:58,320
electrons

494
00:22:04,669 --> 00:22:02,100
and oh sorry

495
00:22:07,549 --> 00:22:04,679
um and the reason for this is that the

496
00:22:10,789 --> 00:22:07,559
Universe at that time was so hot and

497
00:22:12,770 --> 00:22:10,799
dense that it wasn't that atoms weren't

498
00:22:16,190 --> 00:22:12,780
able to form so you basically had

499
00:22:18,590 --> 00:22:16,200
charged particles or ionized plasma

500
00:22:20,630 --> 00:22:18,600
basically and that's just a fancy way to

501
00:22:23,870 --> 00:22:20,640
say you had a bunch of protons and

502
00:22:26,330 --> 00:22:23,880
electrons swimming around and it caused

503
00:22:29,029 --> 00:22:26,340
the universe to be opaque you can see

504
00:22:31,909 --> 00:22:29,039
why because light had re uh had trouble

505
00:22:34,330 --> 00:22:31,919
trying to escape uh it kept bouncing

506
00:22:37,250 --> 00:22:34,340
back and forth on the electrons

507
00:22:39,710 --> 00:22:37,260
eventually it cooled down the universe

508
00:22:42,169 --> 00:22:39,720
cooled down enough such that those

509
00:22:46,130 --> 00:22:42,179
protons electrons

510
00:22:49,190 --> 00:22:46,140
uh got together and created a neutral

511
00:22:52,310 --> 00:22:49,200
universe and finally the electron the

512
00:22:55,490 --> 00:22:52,320
photon was able to free stream out and

513
00:22:58,250 --> 00:22:55,500

that is sort of the first light that we

514
00:23:00,649 --> 00:22:58,260
can detect with our telescopes called

515
00:23:03,590 --> 00:23:00,659
The Cosmic microwave background

516
00:23:06,409 --> 00:23:03,600
and this happened so that was 300 000

517
00:23:08,930 --> 00:23:06,419
years after the big bang right and we're

518
00:23:12,710 --> 00:23:08,940
at what around 14 billion years after

519
00:23:15,830 --> 00:23:12,720
the big bang so this Photon uh traveled

520
00:23:17,450 --> 00:23:15,840
pretty much uninterrupted I'm sorry I

521
00:23:19,970 --> 00:23:17,460
keep like I'm trying to pause it and

522
00:23:23,270 --> 00:23:19,980
it's not um this Photon traveled

523
00:23:26,570 --> 00:23:23,280
basically uninterrupted for around uh

524
00:23:29,570 --> 00:23:26,580
throughout our universe's history so it

525
00:23:31,669 --> 00:23:29,580
saw the first Stars

526
00:23:33,470 --> 00:23:31,679
um it looked it saw the first galaxies

527
00:23:36,470 --> 00:23:33,480
they traveled as the galaxies were

528
00:23:39,950 --> 00:23:36,480
forming again mostly uninterrupted just

529
00:23:42,409 --> 00:23:39,960
to show how sort of vast spaces it

530
00:23:45,710 --> 00:23:42,419
traveled through uh it saw the creation

531
00:23:48,770 --> 00:23:45,720
of the first clusters of galaxies

532
00:23:51,649 --> 00:23:48,780
um and and in the meantime our our solar

533
00:23:55,850 --> 00:23:51,659
system was being formed our Earth was

534
00:23:58,310 --> 00:23:55,860
being formed and we finally were able to

535
00:24:02,690 --> 00:23:58,320
create these detectors to measure this

536
00:24:06,409 --> 00:24:02,700
Photon that's been traveling for so long

537
00:24:09,110 --> 00:24:06,419
um to give an imprint of our uh to give

538
00:24:10,370 --> 00:24:09,120

an imprint of the very beginning of the

539
00:24:11,930 --> 00:24:10,380
universe

540
00:24:14,270 --> 00:24:11,940
um and so you can see

541
00:24:17,510 --> 00:24:14,280
it reaches our detector and it finishes

542
00:24:19,430 --> 00:24:17,520
its incredibly long journey to give us

543
00:24:21,529 --> 00:24:19,440
some information about the very

544
00:24:23,630 --> 00:24:21,539
beginning of our universe but I think

545
00:24:25,909 --> 00:24:23,640
that's sort of that's really incredible

546
00:24:28,730 --> 00:24:25,919
that it's just traveled for so long and

547
00:24:32,570 --> 00:24:28,740
we're able to detect that

548
00:24:35,770 --> 00:24:32,580
um I talked about the sort of hot dense

549
00:24:38,930 --> 00:24:35,780
uh time in our universe's early history

550
00:24:40,669 --> 00:24:38,940
something similar happens in the cores

551
00:24:44,090 --> 00:24:40,679
of stars

552
00:24:46,490 --> 00:24:44,100
um in the core you also have uh these

553
00:24:48,590 --> 00:24:46,500
charged particles and it's really hard

554
00:24:51,350 --> 00:24:48,600
for this Photon to escape it actually

555
00:24:54,169 --> 00:24:51,360
takes on the order of something like 10

556
00:24:57,409 --> 00:24:54,179
000 years for the photon that's created

557
00:25:00,590 --> 00:24:57,419
in the core to even just get out of the

558
00:25:03,289 --> 00:25:00,600
Star right and then to free stream to us

559
00:25:05,450 --> 00:25:03,299
for millions of years right so it's

560
00:25:09,169 --> 00:25:05,460
really like quite incredible that we're

561
00:25:11,149 --> 00:25:09,179
able to even measure this right

562
00:25:13,490 --> 00:25:11,159
um so we're in the business of sort of

563
00:25:15,409 --> 00:25:13,500

collecting photons right our detectors

564
00:25:20,029 --> 00:25:15,419
collect photons and you can think of

565
00:25:22,669 --> 00:25:20,039
them as uh our detectors the pixels on

566
00:25:24,169 --> 00:25:22,679
our detectors being buckets and you can

567
00:25:27,529 --> 00:25:24,179
think of the photons or the light

568
00:25:30,710 --> 00:25:27,539
particles as being raindrops and our

569
00:25:33,230 --> 00:25:30,720
detector is work by constantly staring

570
00:25:36,649 --> 00:25:33,240
at an object for a really long time and

571
00:25:39,529 --> 00:25:36,659
to collect enough photons or raindrops

572
00:25:40,310 --> 00:25:39,539
to get an image

573
00:25:43,610 --> 00:25:40,320
um

574
00:25:45,049 --> 00:25:43,620
kind of an aside that I wanted to say is

575
00:25:45,830 --> 00:25:45,059
that

576
00:25:48,649 --> 00:25:45,840
um

577
00:25:53,510 --> 00:25:48,659
for example our star creates 10

578
00:25:54,669 --> 00:25:53,520
generates 10 to the 42 photons per

579
00:25:59,230 --> 00:25:54,679
second

580
00:26:02,810 --> 00:25:59,240
at a Galaxy

581
00:26:05,390 --> 00:26:02,820
so before I before I go 10 to the 42

582
00:26:08,570 --> 00:26:05,400
looks like this so it's a one followed

583
00:26:10,269 --> 00:26:08,580
by 42 zeros so it creates this many

584
00:26:13,490 --> 00:26:10,279
photons per second

585
00:26:15,950 --> 00:26:13,500
and there are around 100 billion stars

586
00:26:20,269 --> 00:26:15,960
in a galaxy so if you are looking at a

587
00:26:23,630 --> 00:26:20,279
Galaxy you can add 9 11 more zeros to

588
00:26:25,850 --> 00:26:23,640

this and so there's so much energy in

589
00:26:29,810 --> 00:26:25,860
the universe and the fact that we're

590
00:26:33,350 --> 00:26:29,820
only really able to catch to capture a

591
00:26:36,350 --> 00:26:33,360
few hundreds thousands maybe millions of

592
00:26:40,310 --> 00:26:36,360
these counts that we call them really

593
00:26:43,370 --> 00:26:40,320
sort of a testament to how just big

594
00:26:45,409 --> 00:26:43,380
right our universe is because when a

595
00:26:47,269 --> 00:26:45,419
star like the sun emits photons it goes

596
00:26:51,110 --> 00:26:47,279
in all directions right and it's

597
00:26:52,730 --> 00:26:51,120
traveling for so long uh and where with

598
00:26:54,710 --> 00:26:52,740
our you know like with our space

599
00:26:56,330 --> 00:26:54,720
telescopes and ground-based telescopes

600
00:26:58,610 --> 00:26:56,340
we have these detectors and we're

601
00:27:00,710 --> 00:26:58,620
capturing some of these photons to

602
00:27:01,549 --> 00:27:00,720
create a picture

603
00:27:04,130 --> 00:27:01,559
um

604
00:27:07,250 --> 00:27:04,140
but I wanted to show you sort of how

605
00:27:09,169 --> 00:27:07,260
galaxies come into view uh in the first

606
00:27:12,350 --> 00:27:09,179
place

607
00:27:13,909 --> 00:27:12,360
so let's see if I can

608
00:27:16,789 --> 00:27:13,919
uh

609
00:27:18,289 --> 00:27:16,799
re-share this

610
00:27:22,669 --> 00:27:18,299
um

611
00:27:25,130 --> 00:27:22,679
okay so here is uh just an example of

612
00:27:26,870 --> 00:27:25,140
this visualization that's created by the

613
00:27:29,510 --> 00:27:26,880

folks at Space Telescope Science

614
00:27:33,230 --> 00:27:29,520
Institute of the Hubble Ultra Deep Field

615
00:27:35,630 --> 00:27:33,240
so like I said we are looking at we are

616
00:27:38,149 --> 00:27:35,640
staring at an object for a really long

617
00:27:41,090 --> 00:27:38,159
time and you can see the slider on the

618
00:27:43,070 --> 00:27:41,100
bottom that kind of goes through

619
00:27:46,070 --> 00:27:43,080
um how long we're staring at that object

620
00:27:48,649 --> 00:27:46,080
for right so if we look if we point our

621
00:27:51,470 --> 00:27:48,659
telescopes at an object like a Galaxy

622
00:27:53,330 --> 00:27:51,480
for 1 15th of a second we're not going

623
00:27:54,950 --> 00:27:53,340
to see very much there aren't any

624
00:27:56,690 --> 00:27:54,960
visible stars and there aren't any

625
00:28:00,409 --> 00:27:56,700
visible galaxies

626
00:28:02,990 --> 00:28:00,419
as we continue observing some of these

627
00:28:06,110 --> 00:28:03,000
fuzzy blobs come into view

628
00:28:08,990 --> 00:28:06,120
so at 20 minutes you start to see these

629
00:28:11,930 --> 00:28:09,000
objects kind of popping out right but

630
00:28:15,409 --> 00:28:11,940
you also see a lot of artifacts there's

631
00:28:16,970 --> 00:28:15,419
a lot of noise uh there's and and it's

632
00:28:19,610 --> 00:28:16,980
hard to sometimes tell whether or not

633
00:28:21,590 --> 00:28:19,620
that noise is a real object or just an

634
00:28:24,529 --> 00:28:21,600
artifact or coming from somewhere else

635
00:28:27,049 --> 00:28:24,539
uh in the galaxy

636
00:28:30,470 --> 00:28:27,059
um but you can kind of suppress that

637
00:28:33,950 --> 00:28:30,480
noise if you continue observing

638
00:28:36,289 --> 00:28:33,960

um so here's at 81 minutes you can see a

639
00:28:38,870 --> 00:28:36,299
distant spiral galaxy you can see that

640
00:28:41,090 --> 00:28:38,880
the noise is much smaller

641
00:28:42,950 --> 00:28:41,100
um and most of these fuzzy blobs are

642
00:28:45,950 --> 00:28:42,960
actually galaxies like with the

643
00:28:48,529 --> 00:28:45,960
exception of this random star that's in

644
00:28:51,409 --> 00:28:48,539
the Milky Way and if You observe long

645
00:28:54,049 --> 00:28:51,419
enough so in this case nine nearly 100

646
00:28:56,510 --> 00:28:54,059
hours of collecting light you can start

647
00:28:58,070 --> 00:28:56,520
seeing the really faintest smallest

648
00:28:59,570 --> 00:28:58,080
stuff especially when you observe from

649
00:29:01,430 --> 00:28:59,580
space

650
00:29:04,549 --> 00:29:01,440
um you can see the faint galaxies

651
00:29:06,710 --> 00:29:04,559
clusters of galaxies irregular galaxies

652
00:29:10,070 --> 00:29:06,720
that are really young

653
00:29:12,350 --> 00:29:10,080
in their formation or that have merged

654
00:29:14,090 --> 00:29:12,360
um and all together this paints us a

655
00:29:16,730 --> 00:29:14,100
picture of

656
00:29:18,830 --> 00:29:16,740
all of the galaxies that we see

657
00:29:21,529 --> 00:29:18,840
um in this field so

658
00:29:23,570 --> 00:29:21,539
something that we do as astronomers

659
00:29:26,210 --> 00:29:23,580
there are a lot of sort of surveys and

660
00:29:28,370 --> 00:29:26,220
and telescopes that are kind of that a

661
00:29:30,950 --> 00:29:28,380
lot of people are working on

662
00:29:34,250 --> 00:29:30,960
um astronomers need to try to find the

663
00:29:36,950 --> 00:29:34,260

balance between either looking for a

664
00:29:38,990 --> 00:29:36,960
shorter amount of time at the same part

665
00:29:41,029 --> 00:29:39,000
of space

666
00:29:45,889 --> 00:29:41,039
um to get these really faint young

667
00:29:48,529 --> 00:29:45,899
things uh galaxies Stars Etc or they can

668
00:29:52,250 --> 00:29:48,539
look at the whole sky

669
00:29:55,070 --> 00:29:52,260
and and but observe them for less time

670
00:29:57,350 --> 00:29:55,080
so you you get statistics or you get

671
00:30:00,830 --> 00:29:57,360
information about how like what our

672
00:30:02,870 --> 00:30:00,840
structure Cosmic web looks like but you

673
00:30:05,510 --> 00:30:02,880
get much less detail for every

674
00:30:06,889 --> 00:30:05,520
individual Galaxy usually this actually

675
00:30:09,710 --> 00:30:06,899
happens from these sorts of

676
00:30:12,289 --> 00:30:09,720
observatories typically take data from

677
00:30:14,870 --> 00:30:12,299
Earth but there's an upcoming telescope

678
00:30:16,490 --> 00:30:14,880
at Space Telescope uh called the Roman

679
00:30:19,430 --> 00:30:16,500
Space Telescope which will have a very

680
00:30:20,870 --> 00:30:19,440
large field of view as well

681
00:30:22,970 --> 00:30:20,880
um so this is the balance that

682
00:30:24,590 --> 00:30:22,980
astronomers face that they try to figure

683
00:30:28,490 --> 00:30:24,600
out what their science is and how we can

684
00:30:33,529 --> 00:30:31,010
um okay so going back to the

685
00:30:33,539 --> 00:30:39,710
um

686
00:30:42,889 --> 00:30:41,090
okay

687
00:30:47,870 --> 00:30:42,899
so

688
00:30:50,930 --> 00:30:47,880

um the brief outline that I wanted to

689
00:30:53,269 --> 00:30:50,940
make this talk about is first how do we

690
00:30:56,870 --> 00:30:53,279
observe galaxies which I kind of gave an

691
00:30:58,850 --> 00:30:56,880
introduction here then taking what we

692
00:31:00,889 --> 00:30:58,860
observed how do we measure those

693
00:31:03,169 --> 00:31:00,899
galaxies and then taking those

694
00:31:05,810 --> 00:31:03,179
measurements how do we analyze Galaxy

695
00:31:12,950 --> 00:31:08,870
so observing galaxies we are collecting

696
00:31:16,070 --> 00:31:12,960
these light photons to fill our buckets

697
00:31:20,090 --> 00:31:16,080
um so since Yorkie's Observatory I've

698
00:31:22,269 --> 00:31:20,100
upgraded to the Hubble Space Telescope

699
00:31:26,149 --> 00:31:22,279
um the Hubble Space Telescope is really

700
00:31:29,029 --> 00:31:26,159
uh like a Marvel of uh scientific

701
00:31:32,210 --> 00:31:29,039
engineering it really helped us discover

702
00:31:35,570 --> 00:31:32,220
a lot about our universe and it's quite

703
00:31:37,730 --> 00:31:35,580
remarkable the depth to which it can see

704
00:31:40,549 --> 00:31:37,740
galaxies

705
00:31:45,049 --> 00:31:40,559
um at its most basic it's basically like

706
00:31:47,870 --> 00:31:45,059
a floating uh school bus in space

707
00:31:52,130 --> 00:31:47,880
um it weighs around 27 000 pounds and

708
00:31:54,350 --> 00:31:52,140
it's 13.3 meters long so a school bus

709
00:31:56,529 --> 00:31:54,360
um it has a pointing accuracy and this

710
00:31:59,149 --> 00:31:56,539
is important of around

711
00:32:01,070 --> 00:31:59,159
.007 Arc seconds

712
00:32:03,350 --> 00:32:01,080
uh what does that mean it's very

713
00:32:05,750 --> 00:32:03,360

impressive it's if

714
00:32:08,450 --> 00:32:05,760
one of you viewers who are watching

715
00:32:10,610 --> 00:32:08,460
right now are in Pittsburgh and you

716
00:32:13,549 --> 00:32:10,620
which is around 200 miles away from

717
00:32:17,090 --> 00:32:13,559
Baltimore and you hold up a dime like a

718
00:32:17,750 --> 00:32:17,100
coin and I shine a laser at it

719
00:32:20,750 --> 00:32:17,760
um

720
00:32:23,029 --> 00:32:20,760
it would directly point in the middle of

721
00:32:25,909 --> 00:32:23,039
that laser so the it's the ability to

722
00:32:26,810 --> 00:32:25,919
shine a laser beam on a dime 200 miles

723
00:32:29,990 --> 00:32:26,820
away

724
00:32:32,510 --> 00:32:30,000
so hi friends in Pittsburgh

725
00:32:35,090 --> 00:32:32,520
um it contains more than a hundred

726
00:32:37,190 --> 00:32:35,100
terabytes of data so it currently

727
00:32:39,409 --> 00:32:37,200
produces around 10 terabytes of data a

728
00:32:42,950 --> 00:32:39,419
year so that's why we need so many

729
00:32:45,470 --> 00:32:42,960
amazing scientists uh to to reduce all

730
00:32:48,409 --> 00:32:45,480
that data and to analyze it

731
00:32:50,149 --> 00:32:48,419
um and there's a lot of science that has

732
00:32:53,750 --> 00:32:50,159
been published with Hubble data I mean

733
00:32:55,970 --> 00:32:53,760
it's it really sort of revolutionized uh

734
00:32:58,190 --> 00:32:55,980
astronomy

735
00:33:00,049 --> 00:32:58,200
but kind of gave you a brief overview of

736
00:33:02,149 --> 00:33:00,059
what makes Hubble so extraordinary but I

737
00:33:05,090 --> 00:33:02,159
wanted to drive the point home what

738
00:33:07,190 --> 00:33:05,100

makes Hubble so extraordinary apart from

739
00:33:09,950 --> 00:33:07,200
the pictures that you see these

740
00:33:11,630 --> 00:33:09,960
beautiful images that look like this

741
00:33:14,690 --> 00:33:11,640
which is my favorite cluster by the way

742
00:33:17,690 --> 00:33:14,700
this is a field of Max 1149 and it's the

743
00:33:18,409 --> 00:33:17,700
best I have it like on a blanket

744
00:33:21,769 --> 00:33:18,419
um

745
00:33:25,669 --> 00:33:23,810
or videos

746
00:33:27,889 --> 00:33:25,679
like this

747
00:33:30,350 --> 00:33:27,899
um so or or helping us generate these

748
00:33:33,110 --> 00:33:30,360
visualizations uh like like you see here

749
00:33:35,570 --> 00:33:33,120
this is a visualization that actually

750
00:33:38,330 --> 00:33:35,580
Frank Summers worked on uh which is

751
00:33:40,789 --> 00:33:38,340
really cool it is a visualization for

752
00:33:43,669 --> 00:33:40,799
Hubble's 25th anniversary where they did

753
00:33:46,190 --> 00:33:43,679
a fly through of the star cluster

754
00:33:48,889 --> 00:33:46,200
westerlyn too and as we're going through

755
00:33:52,310 --> 00:33:48,899
this star cluster as we're going on this

756
00:33:53,029 --> 00:33:52,320
flyby you're seeing all of this gas

757
00:33:55,430 --> 00:33:53,039
um

758
00:33:58,850 --> 00:33:55,440
this is like a stellar Nursery this is

759
00:34:02,389 --> 00:33:58,860
where stars are being born and as you go

760
00:34:07,250 --> 00:34:02,399
close to the center of this cluster you

761
00:34:07,789 --> 00:34:07,260
see uh these really beautiful stars

762
00:34:10,849 --> 00:34:07,799
um

763
00:34:13,730 --> 00:34:10,859

so so Hubble has done a lot uh has has

764
00:34:14,629 --> 00:34:13,740
created so many beautiful images

765
00:34:17,450 --> 00:34:14,639
um

766
00:34:19,609 --> 00:34:17,460
and it has helped us answer some of

767
00:34:22,609 --> 00:34:19,619
those fundamental questions that we have

768
00:34:25,369 --> 00:34:22,619
in astronomy and astrophysics from the

769
00:34:28,970 --> 00:34:25,379
smallest scales uh so size of our solar

770
00:34:30,889 --> 00:34:28,980
system to the cosmic origins of the

771
00:34:33,829 --> 00:34:30,899
universe the very beginning of our

772
00:34:36,169 --> 00:34:33,839
universe but here's an example uh it

773
00:34:40,550 --> 00:34:36,179
elbow was the first to spot Aurora's on

774
00:34:43,190 --> 00:34:40,560
Jupiter exploding stars or supernovae in

775
00:34:46,129 --> 00:34:43,200
the Milky Way distant galaxies merging

776
00:34:50,030 --> 00:34:46,139
and the early universe so it really like

777
00:34:51,950 --> 00:34:50,040
covered a large swath of time and helped

778
00:34:56,510 --> 00:34:51,960
us understand all of these different

779
00:35:02,510 --> 00:34:59,930
um with Hubble we've also as I've shown

780
00:35:06,770 --> 00:35:02,520
you we've looked really deep and really

781
00:35:10,130 --> 00:35:06,780
far and I want to just give you uh the

782
00:35:13,130 --> 00:35:10,140
scale that we're looking at so

783
00:35:17,810 --> 00:35:16,370
let's see if it'll start okay so I

784
00:35:20,089 --> 00:35:17,820
wanted to show you what the Hubble Deep

785
00:35:23,870 --> 00:35:20,099
Field looks like and the way that this

786
00:35:26,510 --> 00:35:23,880
program was imagined was that uh the

787
00:35:28,550 --> 00:35:26,520
direct the director has discretionary

788
00:35:31,310 --> 00:35:28,560

time that they can use to look at

789
00:35:34,010 --> 00:35:31,320
whatever they want more or less uh with

790
00:35:37,010 --> 00:35:34,020
Hubble has 10 directors discretionary

791
00:35:39,650 --> 00:35:37,020
time and uh

792
00:35:44,030 --> 00:35:39,660
Robert Williams decided to look at

793
00:35:45,589 --> 00:35:44,040
nothing uh so we picked a dark spot in

794
00:35:47,750 --> 00:35:45,599
the sky

795
00:35:49,670 --> 00:35:47,760
um or we I'm saying we as if I

796
00:35:53,030 --> 00:35:49,680
participated in this I didn't it was the

797
00:35:55,069 --> 00:35:53,040
work of very very impressive scientists

798
00:35:57,829 --> 00:35:55,079
uh before

799
00:35:59,569 --> 00:35:57,839
um so we looked at this dark patch of

800
00:36:01,370 --> 00:35:59,579
sky where we expected that there would

801
00:36:01,970 --> 00:36:01,380
be nothing there

802
00:36:04,370 --> 00:36:01,980
um

803
00:36:06,109 --> 00:36:04,380
and we didn't Point next to the Moon the

804
00:36:09,109 --> 00:36:06,119
Moon is just there for size comparison

805
00:36:10,730 --> 00:36:09,119
just to show you how small that patch

806
00:36:13,430 --> 00:36:10,740
really is

807
00:36:15,890 --> 00:36:13,440
um and it's around 113 millionth of the

808
00:36:18,950 --> 00:36:15,900
total area of the sky and we fully

809
00:36:20,870 --> 00:36:18,960
expected not seeing anything there

810
00:36:25,010 --> 00:36:20,880
and when we looked

811
00:36:27,410 --> 00:36:25,020
out came all of these beautiful galaxies

812
00:36:29,810 --> 00:36:27,420
thousands of galaxies in what is now

813
00:36:32,210 --> 00:36:29,820

known to be as the Hubble Deep Field so

814
00:36:34,970 --> 00:36:32,220
we just pointed our telescopes in that

815
00:36:37,310 --> 00:36:34,980
direction and looked for a really long

816
00:36:41,290 --> 00:36:37,320
time and were able to see this so each

817
00:36:44,630 --> 00:36:41,300
of these specs is a Galaxy containing

818
00:36:46,970 --> 00:36:44,640
I'm averaging like a hundred billion

819
00:36:48,650 --> 00:36:46,980
stars each one of these little smudges

820
00:36:51,290 --> 00:36:48,660
on the screen

821
00:36:53,569 --> 00:36:51,300
and so this totally revolutionized right

822
00:36:55,910 --> 00:36:53,579
our understanding of how big our

823
00:36:57,410 --> 00:36:55,920
universe is how many galaxies there are

824
00:36:59,569 --> 00:36:57,420
in the universe

825
00:37:02,210 --> 00:36:59,579
um how far we can see

826
00:37:04,550 --> 00:37:02,220
and so here's just another visualization

827
00:37:06,890 --> 00:37:04,560
of one of the successors to the Hubble

828
00:37:08,210 --> 00:37:06,900
Deep Field called the Hubble Ultra Deep

829
00:37:08,870 --> 00:37:08,220
Field

830
00:37:11,210 --> 00:37:08,880
um

831
00:37:14,210 --> 00:37:11,220
I'm gonna play this just to again show

832
00:37:16,310 --> 00:37:14,220
you the scale so we start with seeing

833
00:37:19,370 --> 00:37:16,320
the constellations and the whole kind of

834
00:37:20,750 --> 00:37:19,380
part of a big chunk of the night sky and

835
00:37:25,910 --> 00:37:20,760
we're zooming in

836
00:37:27,170 --> 00:37:25,920
and we are continuing to zoom in very

837
00:37:29,990 --> 00:37:27,180
very far

838
00:37:32,390 --> 00:37:30,000

and we see the Hubble

839
00:37:35,270 --> 00:37:32,400
Ultra Deep Field

840
00:37:36,650 --> 00:37:35,280
and so these are some of the youngest

841
00:37:39,290 --> 00:37:36,660
galaxies

842
00:37:42,589 --> 00:37:39,300
um that we can observe that really give

843
00:37:45,410 --> 00:37:42,599
us some understanding of the beginnings

844
00:37:47,450 --> 00:37:45,420
of our universe

845
00:37:48,589 --> 00:37:47,460
okay

846
00:37:50,150 --> 00:37:48,599
so

847
00:37:52,790 --> 00:37:50,160
scientists

848
00:37:55,370 --> 00:37:52,800
um just uh after doing all of this and

849
00:37:59,270 --> 00:37:55,380
and kind of this being really impactful

850
00:38:00,829 --> 00:37:59,280
work you know uh scientists at Space

851
00:38:04,130 --> 00:38:00,839
Telescope and elsewhere thought well

852
00:38:06,770 --> 00:38:04,140
okay how can we push even farther than

853
00:38:10,430 --> 00:38:06,780
that right so you can see that you have

854
00:38:13,130 --> 00:38:10,440
the Hubble Deep Field kind of pushing uh

855
00:38:15,650 --> 00:38:13,140
at like 1.5

856
00:38:17,870 --> 00:38:15,660
when the universe was 1.5 billion years

857
00:38:19,910 --> 00:38:17,880
old so we see galaxies when the universe

858
00:38:22,069 --> 00:38:19,920
was 1.5 billion years old

859
00:38:24,829 --> 00:38:22,079
um the Hubble Ultra Deep Field pushed to

860
00:38:27,050 --> 00:38:24,839
the age of the universe of around 0.9

861
00:38:29,390 --> 00:38:27,060
billion years old so we are looking even

862
00:38:31,190 --> 00:38:29,400
farther and we're seeing even smaller uh

863
00:38:34,990 --> 00:38:31,200

even younger galaxies

864
00:38:39,589 --> 00:38:35,000
so what can we do to probe even farther

865
00:38:43,730 --> 00:38:39,599
other than just staring for longer

866
00:38:47,030 --> 00:38:43,740
um so some people came up with a project

867
00:38:50,089 --> 00:38:47,040
called the Hubble Frontier fields so the

868
00:38:53,510 --> 00:38:50,099
Hubble Frontier Fields is a survey of

869
00:38:56,089 --> 00:38:53,520
six really massive clusters leveraging

870
00:38:59,630 --> 00:38:56,099
something called gravitational lensing

871
00:39:02,089 --> 00:38:59,640
or Nature's magnifying glass that allows

872
00:39:03,170 --> 00:39:02,099
us to push even beyond the limits of

873
00:39:05,810 --> 00:39:03,180
Hubble

874
00:39:07,010 --> 00:39:05,820
how so before I get into how I just

875
00:39:09,470 --> 00:39:07,020
wanted to show you what they look like

876
00:39:13,010 --> 00:39:09,480
so these are the six clusters that I

877
00:39:15,710 --> 00:39:13,020
basically did my PhD thesis on

878
00:39:18,109 --> 00:39:15,720
um and then on the bottom you see six

879
00:39:20,150 --> 00:39:18,119
sort of what we call ancillary fields

880
00:39:22,670 --> 00:39:20,160
which is just a field that's separated

881
00:39:23,810 --> 00:39:22,680
by some distance from the center of the

882
00:39:27,109 --> 00:39:23,820
cluster

883
00:39:29,810 --> 00:39:27,119
so how do we use this data to leverage

884
00:39:31,430 --> 00:39:29,820
Nature's magnifying glass so what is

885
00:39:34,670 --> 00:39:31,440
graph so it's called gravitational

886
00:39:36,890 --> 00:39:34,680
lensing what is that

887
00:39:40,370 --> 00:39:36,900
um you can see kind of in the schematic

888
00:39:43,490 --> 00:39:40,380

here you have the Observer telescope on

889
00:39:46,370 --> 00:39:43,500
the left you have a foreground galaxy in

890
00:39:50,210 --> 00:39:46,380
the middle and a background Galaxy uh in

891
00:39:52,910 --> 00:39:50,220
the back and basically what happens is

892
00:39:54,650 --> 00:39:52,920
that the foreground Galaxy or Galaxy

893
00:39:57,290 --> 00:39:54,660
clusters

894
00:39:59,150 --> 00:39:57,300
um warp space in such a way that it

895
00:40:02,510 --> 00:39:59,160
bends the light that's coming out from

896
00:40:04,730 --> 00:40:02,520
this guy over here so that we see we get

897
00:40:07,370 --> 00:40:04,740
more of the light from this background

898
00:40:09,890 --> 00:40:07,380
Galaxy and we're able to see to push

899
00:40:13,310 --> 00:40:09,900
really really faint

900
00:40:15,589 --> 00:40:13,320
um a nice schematic of how this works so

901
00:40:18,470 --> 00:40:15,599
imagine you can actually do this at home

902
00:40:20,810 --> 00:40:18,480
if you take a candle and you take the

903
00:40:22,609 --> 00:40:20,820
base of a wine glass and you put it in

904
00:40:25,250 --> 00:40:22,619
front of the candle depending on the

905
00:40:27,770 --> 00:40:25,260
Tilt that you put the base of the wine

906
00:40:29,290 --> 00:40:27,780
glass you can see it creates these sort

907
00:40:32,270 --> 00:40:29,300
of arcs

908
00:40:34,490 --> 00:40:32,280
and depending on the angle it changes

909
00:40:37,069 --> 00:40:34,500
the way that the light is distributed

910
00:40:39,290 --> 00:40:37,079
once you're looking at it from the base

911
00:40:40,730 --> 00:40:39,300
of the candles perspective

912
00:40:42,710 --> 00:40:40,740
um so if you you can see that if you're

913
00:40:44,810 --> 00:40:42,720

looking at it straight on you're

914
00:40:47,750 --> 00:40:44,820
creating this basically what comes out

915
00:40:49,849 --> 00:40:47,760
is this ring around the base of the wine

916
00:40:53,450 --> 00:40:49,859
glass and you can see that it looks

917
00:40:55,670 --> 00:40:53,460
brighter right than the original candle

918
00:40:57,890 --> 00:40:55,680
um so the same kind of principle applies

919
00:41:00,410 --> 00:40:57,900
for gravitational lensing it can give

920
00:41:03,470 --> 00:41:00,420
you another example if you imagine a

921
00:41:05,930 --> 00:41:03,480
trampoline right and you roll a ball on

922
00:41:08,930 --> 00:41:05,940
the trampoline at a 45 degree angle

923
00:41:10,970 --> 00:41:08,940
it'll probably if you if you throw it or

924
00:41:13,250 --> 00:41:10,980
if you roll it straight enough it'll

925
00:41:16,550 --> 00:41:13,260
probably just fall off of the trampoline

926
00:41:18,650 --> 00:41:16,560
right now let's say you take a really

927
00:41:21,829 --> 00:41:18,660
heavy bowling ball if you have one at

928
00:41:24,170 --> 00:41:21,839
home and you put it in the center of

929
00:41:26,390 --> 00:41:24,180
that trampoline and you throw the same

930
00:41:28,550 --> 00:41:26,400
ball where you roll the same ball it'll

931
00:41:29,810 --> 00:41:28,560
probably do like a curve and if there's

932
00:41:32,150 --> 00:41:29,820
someone on the other side of the

933
00:41:34,910 --> 00:41:32,160
trampoline they'll be able to get it

934
00:41:36,650 --> 00:41:34,920
right so in the same way that all of the

935
00:41:38,650 --> 00:41:36,660
light that was coming out in like kind

936
00:41:41,270 --> 00:41:38,660
of radially outward

937
00:41:43,130 --> 00:41:41,280
gravitational lensing warps space in

938
00:41:45,829 --> 00:41:43,140

such a way that it's able to focus that

939
00:41:49,130 --> 00:41:45,839
light to The Observer and what we see

940
00:41:50,270 --> 00:41:49,140
looks like this kind of similar to this

941
00:41:52,910 --> 00:41:50,280
wine glass

942
00:41:55,130 --> 00:41:52,920
so it's just some facts the typical

943
00:41:57,950 --> 00:41:55,140
magnification is around 10 times so you

944
00:41:59,510 --> 00:41:57,960
can see galaxies uh 10 times brighter

945
00:42:02,630 --> 00:41:59,520
than they would be if they weren't

946
00:42:05,329 --> 00:42:02,640
distorted by this gravitational lensing

947
00:42:08,930 --> 00:42:05,339
it preserves surface brightness and the

948
00:42:11,569 --> 00:42:08,940
lensing is achromatic so what does that

949
00:42:14,810 --> 00:42:11,579
mean it means that it doesn't change the

950
00:42:16,069 --> 00:42:14,820
color of the Galaxy or the source that

951
00:42:17,930 --> 00:42:16,079
we're observing

952
00:42:19,790 --> 00:42:17,940
you'll see why this is important in a

953
00:42:22,430 --> 00:42:19,800
little bit but just as the teaser color

954
00:42:25,430 --> 00:42:22,440
gives us a lot of information about the

955
00:42:27,770 --> 00:42:25,440
physical properties of a galaxy and so

956
00:42:29,870 --> 00:42:27,780
and gravitational lensing is purely a

957
00:42:32,630 --> 00:42:29,880
geometric effect so it doesn't change

958
00:42:37,670 --> 00:42:32,640
the the sort of the color of the Galaxy

959
00:42:42,109 --> 00:42:40,190
um here's another kind of a more

960
00:42:46,010 --> 00:42:42,119
practical example of gravitational

961
00:42:49,010 --> 00:42:46,020
lensing out in the wild you can see the

962
00:42:52,370 --> 00:42:49,020
Galaxy cluster right in the middle and

963
00:42:54,650 --> 00:42:52,380

you can see this sort of blue arc shaped

964
00:42:57,890 --> 00:42:54,660
Galaxy and all of these things that are

965
00:42:59,349 --> 00:42:57,900
circled are from the light from the same

966
00:43:01,670 --> 00:42:59,359
galaxy

967
00:43:04,550 --> 00:43:01,680
and you can see that it's being

968
00:43:07,550 --> 00:43:04,560
stretched out it's being magnified in

969
00:43:09,550 --> 00:43:07,560
brightness and you're able to measure so

970
00:43:13,010 --> 00:43:09,560
the nice thing about this stretching out

971
00:43:14,930 --> 00:43:13,020
uh feature of gravitational lensing is

972
00:43:17,450 --> 00:43:14,940
that you can really measure things on

973
00:43:19,130 --> 00:43:17,460
small spatial scales of what happens in

974
00:43:20,990 --> 00:43:19,140
that Galaxy

975
00:43:23,210 --> 00:43:21,000
um right because it's so stretched out

976
00:43:25,430 --> 00:43:23,220
you can kind of see what's happening at

977
00:43:26,870 --> 00:43:25,440
every part of that Galaxy whereas if it

978
00:43:28,790 --> 00:43:26,880
were just a point source or a little

979
00:43:31,430 --> 00:43:28,800
smudge you wouldn't really know what's

980
00:43:33,530 --> 00:43:31,440
happening in the center versus uh versus

981
00:43:35,089 --> 00:43:33,540
the edge of it

982
00:43:37,910 --> 00:43:35,099
um there are people who work on

983
00:43:39,710 --> 00:43:37,920
reconstructing these galaxies

984
00:43:41,630 --> 00:43:39,720
um so here's an example of that there's

985
00:43:43,309 --> 00:43:41,640
this team that worked on reconstructing

986
00:43:46,069 --> 00:43:43,319
what the Galaxy might have looked like

987
00:43:48,170 --> 00:43:46,079
had it not been warped by the central

988
00:43:52,609 --> 00:43:48,180

cluster

989
00:43:56,450 --> 00:43:52,619
um and also uh figured out where it

990
00:43:58,370 --> 00:43:56,460
might be if it weren't warped by a

991
00:44:00,050 --> 00:43:58,380
cluster so in this case it looks like

992
00:44:02,450 --> 00:44:00,060
that the original position if there

993
00:44:05,390 --> 00:44:02,460
wasn't any warping happening the cluster

994
00:44:06,829 --> 00:44:05,400
would have been somewhere here right in

995
00:44:09,710 --> 00:44:06,839
the same way that

996
00:44:11,750 --> 00:44:09,720
when you look here the Galaxy's actually

997
00:44:14,150 --> 00:44:11,760
directly behind this foreground Galaxy

998
00:44:18,170 --> 00:44:14,160
but it looks to us when we observe it

999
00:44:19,190 --> 00:44:18,180
kind of in this ring around the Galaxy

1000
00:44:22,790 --> 00:44:19,200
okay

1001
00:44:25,190 --> 00:44:22,800
so we have this amazing data set this

1002
00:44:27,950 --> 00:44:25,200
really deep data set where we can push

1003
00:44:30,770 --> 00:44:27,960
Hubble really far

1004
00:44:32,809 --> 00:44:30,780
um and I guess the basic question that

1005
00:44:36,230 --> 00:44:32,819
we're asking is

1006
00:44:39,650 --> 00:44:36,240
how do we go from these really beautiful

1007
00:44:40,790 --> 00:44:39,660
images of the jewels Galaxy jewels in

1008
00:44:41,870 --> 00:44:40,800
the sky

1009
00:44:43,430 --> 00:44:41,880
um so something that looks like the

1010
00:44:44,870 --> 00:44:43,440
picture on the left

1011
00:44:47,210 --> 00:44:44,880
do something that looks like the picture

1012
00:44:50,089 --> 00:44:47,220
on the right which is admittedly less

1013
00:44:53,089 --> 00:44:50,099

beautiful but still very important for

1014
00:44:56,569 --> 00:44:53,099
our understanding of Galaxy properties

1015
00:44:59,089 --> 00:44:56,579
um so this is what I did my PhD on I I

1016
00:45:00,950 --> 00:44:59,099
was generating Galaxy catalogs or Source

1017
00:45:03,410 --> 00:45:00,960
catalogs for these for the Hubble

1018
00:45:05,270 --> 00:45:03,420
Frontier fields I'll show you an example

1019
00:45:05,930 --> 00:45:05,280
of that

1020
00:45:09,050 --> 00:45:05,940
um

1021
00:45:11,630 --> 00:45:09,060
these are the images that I worked on on

1022
00:45:14,569 --> 00:45:11,640
a regular basis so I don't work on like

1023
00:45:16,849 --> 00:45:14,579
color images really remember how think

1024
00:45:19,910 --> 00:45:16,859
back to how I said that our detectors

1025
00:45:22,430 --> 00:45:19,920
basically collect photons in a bucket

1026
00:45:25,250 --> 00:45:22,440
right so what you have is a sort of in

1027
00:45:27,109 --> 00:45:25,260
every pixel the camera tells you is

1028
00:45:30,230 --> 00:45:27,119
there a photon is there a raindrop

1029
00:45:32,089 --> 00:45:30,240
Photon here or is there not and so this

1030
00:45:34,370 --> 00:45:32,099
is really kind of like a grayscale like

1031
00:45:36,950 --> 00:45:34,380
black and white image and this is

1032
00:45:38,510 --> 00:45:36,960
observed in a single filter which I'll

1033
00:45:41,329 --> 00:45:38,520
talk about in a bit

1034
00:45:43,930 --> 00:45:41,339
it's okay so I run this

1035
00:45:48,550 --> 00:45:43,940
um algorithm called Source extractor

1036
00:45:51,290 --> 00:45:48,560
which extracts sources so very uh

1037
00:45:54,650 --> 00:45:51,300
self-explanatory and basically what it

1038
00:45:58,130 --> 00:45:54,660

does is it scans kind of line by line to

1039
00:46:01,250 --> 00:45:58,140
see where is there something bright and

1040
00:46:04,010 --> 00:46:01,260
where is there nothing right and we can

1041
00:46:05,870 --> 00:46:04,020
get a list of sources from after running

1042
00:46:06,970 --> 00:46:05,880
this algorithm so this is what that

1043
00:46:11,630 --> 00:46:06,980
looks like

1044
00:46:12,710 --> 00:46:11,640
every single Blue Dot here is a detected

1045
00:46:14,569 --> 00:46:12,720
source

1046
00:46:16,849 --> 00:46:14,579
I wish I could see you guys in front of

1047
00:46:18,890 --> 00:46:16,859
me to ask you how many galaxies you

1048
00:46:22,430 --> 00:46:18,900
think is in this image but I'll just

1049
00:46:25,670 --> 00:46:22,440
tell you there's around 3 500 galaxies

1050
00:46:27,650 --> 00:46:25,680
just in this small piece of sky

1051
00:46:30,770 --> 00:46:27,660
and it might not look like it so why

1052
00:46:34,910 --> 00:46:30,780
don't we zoom in so let's zoom in uh to

1053
00:46:37,970 --> 00:46:34,920
this area so here again to remind you

1054
00:46:40,670 --> 00:46:37,980
every single blue circle is a source

1055
00:46:44,390 --> 00:46:40,680
every single smudge is

1056
00:46:45,890 --> 00:46:44,400
mostly on average a Galaxy and I just

1057
00:46:48,290 --> 00:46:45,900
wanted to point out these sort of

1058
00:46:50,870 --> 00:46:48,300
remember how I was saying that uh

1059
00:46:53,750 --> 00:46:50,880
gravitational lensing distorts galaxy

1060
00:46:57,530 --> 00:46:53,760
background galaxies you can see that

1061
00:46:59,569 --> 00:46:57,540
kind of happening here these arcs so

1062
00:47:01,309 --> 00:46:59,579
that's not what the background galaxies

1063
00:47:04,250 --> 00:47:01,319

look like they're actually pretty

1064
00:47:06,470 --> 00:47:04,260
distorted and stretched out

1065
00:47:09,050 --> 00:47:06,480
um and it's not usually A Perfect Circle

1066
00:47:10,609 --> 00:47:09,060
right or it's not usually that those

1067
00:47:13,150 --> 00:47:10,619
galaxies are kind of like perfectly

1068
00:47:16,849 --> 00:47:13,160
perfectly circular around the center

1069
00:47:19,190 --> 00:47:16,859
it depends on what is distorting your

1070
00:47:20,870 --> 00:47:19,200
space in the foreground right so if you

1071
00:47:22,970 --> 00:47:20,880
have a bunch of different galaxies doing

1072
00:47:24,530 --> 00:47:22,980
that it won't be spherically symmetric

1073
00:47:28,370 --> 00:47:24,540
but you'll you'll see

1074
00:47:29,390 --> 00:47:28,380
these arcs appear in your images

1075
00:47:31,730 --> 00:47:29,400
okay

1076
00:47:34,370 --> 00:47:31,740
so we can zoom in even more just to

1077
00:47:37,790 --> 00:47:34,380
drive that point home

1078
00:47:39,829 --> 00:47:37,800
um here's again an example

1079
00:47:41,750 --> 00:47:39,839
um every single little smudge is a

1080
00:47:44,170 --> 00:47:41,760
Galaxy and every blue circle is where

1081
00:47:47,329 --> 00:47:44,180
we've detected that Galaxy

1082
00:47:50,030 --> 00:47:47,339
I think that this is pretty good I think

1083
00:47:52,849 --> 00:47:50,040
I did a pretty good job but you might

1084
00:47:55,309 --> 00:47:52,859
say for all those eagle-eyed people in

1085
00:47:57,290 --> 00:47:55,319
the audience you might say well I'm

1086
00:48:00,109 --> 00:47:57,300
seeing some sources missing you know

1087
00:48:01,910 --> 00:48:00,119
maybe there's one here next to this

1088
00:48:04,250 --> 00:48:01,920

really bright object maybe there's one

1089
00:48:06,170 --> 00:48:04,260
here next to this really bright object

1090
00:48:08,750 --> 00:48:06,180
and so

1091
00:48:10,730 --> 00:48:08,760
um this kind of this is on very small

1092
00:48:14,930 --> 00:48:10,740
scales but on large scales this happens

1093
00:48:18,290 --> 00:48:14,940
because we have uh these really massive

1094
00:48:21,170 --> 00:48:18,300
galaxies that are really bright uh and

1095
00:48:23,030 --> 00:48:21,180
so there's the problem even with all of

1096
00:48:25,790 --> 00:48:23,040
this amazingness of gravitational

1097
00:48:27,710 --> 00:48:25,800
lensing there's this problem that these

1098
00:48:29,870 --> 00:48:27,720
galaxies are really bright and can

1099
00:48:31,430 --> 00:48:29,880
obscure the light from the really faint

1100
00:48:33,589 --> 00:48:31,440
stuff behind it

1101
00:48:36,589 --> 00:48:33,599
so detecting galaxies and cluster Fields

1102
00:48:38,150 --> 00:48:36,599
is difficult it's difficult because you

1103
00:48:40,309 --> 00:48:38,160
can see this sort of mess that's

1104
00:48:41,870 --> 00:48:40,319
happening in this cluster there's the

1105
00:48:46,790 --> 00:48:41,880
really bright stuff and there's also

1106
00:48:49,730 --> 00:48:46,800
this kind of amorphous gas that is uh is

1107
00:48:52,069 --> 00:48:49,740
just basically hot gas and stars that

1108
00:48:54,230 --> 00:48:52,079
are uh floated free-floating between the

1109
00:48:56,270 --> 00:48:54,240
cluster galaxies

1110
00:49:00,349 --> 00:48:56,280
um and so well one thing that we can do

1111
00:49:03,109 --> 00:49:00,359
is try to model it and remove it right

1112
00:49:06,170 --> 00:49:03,119
um so here's another example of one of

1113
00:49:08,450 --> 00:49:06,180

the Galaxy clusters this is uh another

1114
00:49:11,030 --> 00:49:08,460
example of one of the Galaxy clusters

1115
00:49:12,890 --> 00:49:11,040
um here the coloring even though it's

1116
00:49:15,050 --> 00:49:12,900
sort of purple and yellow it's just

1117
00:49:18,530 --> 00:49:15,060
false coloring this is the same sort of

1118
00:49:20,930 --> 00:49:18,540
grayscale Type image that we saw earlier

1119
00:49:22,510 --> 00:49:20,940
of a different cluster because I want to

1120
00:49:25,849 --> 00:49:22,520
see them all shine

1121
00:49:27,589 --> 00:49:25,859
and where the purple stuff or the purple

1122
00:49:30,829 --> 00:49:27,599
pixels are where there's

1123
00:49:33,170 --> 00:49:30,839
very little light or less light and the

1124
00:49:34,730 --> 00:49:33,180
yellow parts are where there's a lot of

1125
00:49:37,190 --> 00:49:34,740
light right

1126
00:49:40,550 --> 00:49:37,200
and so we know some stuff some stuff

1127
00:49:42,230 --> 00:49:40,560
about galaxies we can kind of model them

1128
00:49:45,230 --> 00:49:42,240
with a

1129
00:49:48,490 --> 00:49:45,240
uh this is we can kind of approximately

1130
00:49:50,990 --> 00:49:48,500
model them with an analytic profile

1131
00:49:53,510 --> 00:49:51,000
and so that's what I did I tried to

1132
00:49:55,190 --> 00:49:53,520
model the really bright stuff

1133
00:49:57,470 --> 00:49:55,200
so that's what that looks like the

1134
00:50:00,290 --> 00:49:57,480
bright stuff and the faint kind of

1135
00:50:04,430 --> 00:50:00,300
diffused light that is around it

1136
00:50:05,750 --> 00:50:04,440
and we can subtract out that model and

1137
00:50:08,569 --> 00:50:05,760
we get something that looks like this

1138
00:50:12,230 --> 00:50:08,579

they can see that all of this excess

1139
00:50:15,950 --> 00:50:12,240
light has been removed and now has been

1140
00:50:17,630 --> 00:50:15,960
removed because for us for me it was uh

1141
00:50:19,550 --> 00:50:17,640
kind of preventing me from doing my job

1142
00:50:21,410 --> 00:50:19,560
but probably for the cluster people if

1143
00:50:22,849 --> 00:50:21,420
they're very essential to do their

1144
00:50:25,069 --> 00:50:22,859
science right because they need those

1145
00:50:27,050 --> 00:50:25,079
cluster galaxies

1146
00:50:29,450 --> 00:50:27,060
um and you can see kind of all of the

1147
00:50:32,809 --> 00:50:29,460
small faint stuff in the background so

1148
00:50:35,510 --> 00:50:32,819
here's just that whole process from left

1149
00:50:40,130 --> 00:50:35,520
to right where you have the original

1150
00:50:41,930 --> 00:50:40,140
image model and the subtracted out model

1151
00:50:43,250 --> 00:50:41,940
where you can get to the really faint

1152
00:50:44,270 --> 00:50:43,260
stuff

1153
00:50:46,970 --> 00:50:44,280
okay

1154
00:50:47,990 --> 00:50:46,980
up until now I've been sort of telling

1155
00:50:48,829 --> 00:50:48,000
you about

1156
00:50:50,990 --> 00:50:48,839
um

1157
00:50:54,170 --> 00:50:51,000
measure looking at a single image and

1158
00:50:58,069 --> 00:50:54,180
the single image is uh being looked at

1159
00:50:59,990 --> 00:50:58,079
in one filter so this is an example of

1160
00:51:01,549 --> 00:51:00,000
just a single image being looked through

1161
00:51:04,010 --> 00:51:01,559
one filter

1162
00:51:05,750 --> 00:51:04,020
for the Hubble Frontier Fields this

1163
00:51:07,849 --> 00:51:05,760

looks kind of complicated but but don't

1164
00:51:10,490 --> 00:51:07,859
worry the only thing you need to know is

1165
00:51:12,849 --> 00:51:10,500
that each one of these graphs or each

1166
00:51:15,589 --> 00:51:12,859
one of these like colored

1167
00:51:20,450 --> 00:51:15,599
sections correspond to a different

1168
00:51:22,730 --> 00:51:20,460
filter that goes from really uh or from

1169
00:51:24,170 --> 00:51:22,740
that goes from the mid or the near

1170
00:51:27,589 --> 00:51:24,180
ultraviolet

1171
00:51:29,870 --> 00:51:27,599
to the near infrared so we're going from

1172
00:51:31,670 --> 00:51:29,880
you can see kind of this like rainbow of

1173
00:51:35,569 --> 00:51:31,680
color on the bottom so it's going from

1174
00:51:38,750 --> 00:51:35,579
kind of purple all the way to red and we

1175
00:51:40,549 --> 00:51:38,760
looked at the same object in each one of

1176
00:51:42,950 --> 00:51:40,559
these different filters remember I told

1177
00:51:45,410 --> 00:51:42,960
you that color is important it tells us

1178
00:51:47,589 --> 00:51:45,420
different things about the processes

1179
00:51:50,569 --> 00:51:47,599
that are happening in the galaxy

1180
00:51:53,750 --> 00:51:50,579
and so we observe these uh these

1181
00:51:57,470 --> 00:51:53,760
Frontier field clusters in count them

1182
00:51:59,990 --> 00:51:57,480
three six nine wave bands

1183
00:52:01,370 --> 00:52:00,000
um to tell us about the physics that is

1184
00:52:03,770 --> 00:52:01,380
happening at each one of these

1185
00:52:05,150 --> 00:52:03,780
wavelengths so I just wanted to show you

1186
00:52:07,609 --> 00:52:05,160
this for a second and I'm going to go

1187
00:52:10,730 --> 00:52:07,619
into it more right now

1188
00:52:12,290 --> 00:52:10,740

uh the multi-wavelength universe more

1189
00:52:15,470 --> 00:52:12,300
than meets the eye so we're going to

1190
00:52:18,730 --> 00:52:15,480
talk about color and wavelength and how

1191
00:52:21,770 --> 00:52:18,740
that tells us information about galaxies

1192
00:52:24,109 --> 00:52:21,780
okay so if you've ever been to a place

1193
00:52:26,990 --> 00:52:24,119
where the sky is dark enough that you

1194
00:52:29,270 --> 00:52:27,000
can see the Milky Way which I have not

1195
00:52:31,730 --> 00:52:29,280
until three years ago again for the same

1196
00:52:34,790 --> 00:52:31,740
reason as I mentioned earlier that in

1197
00:52:35,930 --> 00:52:34,800
New York you don't see Dark Skies

1198
00:52:39,710 --> 00:52:35,940
um

1199
00:52:40,670 --> 00:52:39,720
but if you have if you were able to do

1200
00:52:43,849 --> 00:52:40,680
that

1201
00:52:45,890 --> 00:52:43,859
like this right this is uh sort of

1202
00:52:47,990 --> 00:52:45,900
looking towards the center of our Milky

1203
00:52:50,450 --> 00:52:48,000
Way uh and you can see that it looks

1204
00:52:52,250 --> 00:52:50,460
very dusty right with a lot of Starlight

1205
00:52:53,210 --> 00:52:52,260
around it

1206
00:52:55,370 --> 00:52:53,220
um

1207
00:52:57,290 --> 00:52:55,380
that's what it looks like uh it's really

1208
00:52:58,970 --> 00:52:57,300
it's really cool it's really like quite

1209
00:53:01,910 --> 00:52:58,980
impressive when I saw it for the first

1210
00:53:04,430 --> 00:53:01,920
time it was at Joshua Tree uh also if

1211
00:53:07,430 --> 00:53:04,440
you for folks in California Joshua tree

1212
00:53:11,569 --> 00:53:07,440
is so pretty to see the Milky Way from

1213
00:53:14,990 --> 00:53:11,579

okay so if we take that Milky Way and we

1214
00:53:17,630 --> 00:53:15,000
kind of like rotate it uh this is known

1215
00:53:21,589 --> 00:53:17,640
as the galactic plane right so now you

1216
00:53:23,690 --> 00:53:21,599
see our Galaxy Edge on the Milky Way

1217
00:53:26,270 --> 00:53:23,700
um where you have in the center you have

1218
00:53:28,130 --> 00:53:26,280
uh the center of our galaxy which also

1219
00:53:33,109 --> 00:53:28,140
happens to host a supermassive black

1220
00:53:36,589 --> 00:53:33,119
hole and the spiral arms are out here

1221
00:53:40,549 --> 00:53:36,599
and so I think that you are somewhere

1222
00:53:43,730 --> 00:53:40,559
there uh which is around 7.5 kiloparsecs

1223
00:53:47,030 --> 00:53:43,740
away from the center of uh of our Milky

1224
00:53:52,190 --> 00:53:47,040
Way which corresponds to around 1.4

1225
00:53:55,790 --> 00:53:52,200
times 10 to the 17 miles so one and set

1226
00:53:57,170 --> 00:53:55,800
one and a half and 16 zeros after that

1227
00:54:00,530 --> 00:53:57,180
Miles Away

1228
00:54:02,569 --> 00:54:00,540
so wave high uh to yourself

1229
00:54:05,630 --> 00:54:02,579
um so this is just something that we

1230
00:54:07,250 --> 00:54:05,640
would see right uh you know if you went

1231
00:54:08,809 --> 00:54:07,260
to something like Joshua Tree you would

1232
00:54:10,790 --> 00:54:08,819
see something that looks like this so

1233
00:54:13,190 --> 00:54:10,800
we're seeing it in the optical Wave band

1234
00:54:15,589 --> 00:54:13,200
which is what our eyes are sensitive to

1235
00:54:16,569 --> 00:54:15,599
but you may have heard that there is a

1236
00:54:18,770 --> 00:54:16,579
lot of different types of

1237
00:54:20,930 --> 00:54:18,780
electromagnetic radiation right so

1238
00:54:23,630 --> 00:54:20,940

there's the visible light which is what

1239
00:54:25,309 --> 00:54:23,640
we can see and then there's things like

1240
00:54:27,890 --> 00:54:25,319
the ultraviolet which is why you need to

1241
00:54:31,270 --> 00:54:27,900
wear glass sunglasses x-rays when you go

1242
00:54:34,190 --> 00:54:31,280
to the dentist there's also infrared

1243
00:54:36,410 --> 00:54:34,200
which you can't see but you can feel

1244
00:54:38,150 --> 00:54:36,420
because it comes off as heat I don't

1245
00:54:40,309 --> 00:54:38,160
know if you've ever been to any of those

1246
00:54:41,990 --> 00:54:40,319
science museums where they have like an

1247
00:54:45,170 --> 00:54:42,000
infrared camera and you stand in front

1248
00:54:48,290 --> 00:54:45,180
of it and like your core is like really

1249
00:54:51,829 --> 00:54:48,300
bright but your hands and feet are are

1250
00:54:54,970 --> 00:54:51,839
like Bluer because they're less hot and

1251
00:54:57,549 --> 00:54:54,980
so even though we can't see any of these

1252
00:55:01,150 --> 00:54:57,559
wavelengths other than the visible one

1253
00:55:04,490 --> 00:55:01,160
they all tell us information about

1254
00:55:06,109 --> 00:55:04,500
what's going on they all hold some

1255
00:55:08,390 --> 00:55:06,119
secrets about the physics that's

1256
00:55:10,250 --> 00:55:08,400
happening in our universe and so if you

1257
00:55:11,690 --> 00:55:10,260
take that same Milky Way that I just

1258
00:55:13,609 --> 00:55:11,700
showed you

1259
00:55:16,250 --> 00:55:13,619
you can observe it in a bunch of

1260
00:55:18,230 --> 00:55:16,260
different wavelengths and when I say

1261
00:55:21,770 --> 00:55:18,240
wavelength I want you just to think

1262
00:55:24,410 --> 00:55:21,780
about an energy right so when things are

1263
00:55:27,950 --> 00:55:24,420

really blue so at the very bottom here

1264
00:55:28,970 --> 00:55:27,960
gamma ray short wavelengths correspond

1265
00:55:31,309 --> 00:55:28,980
to

1266
00:55:34,430 --> 00:55:31,319
really energetic stuff

1267
00:55:36,530 --> 00:55:34,440
and long wavelengths correspond to much

1268
00:55:39,410 --> 00:55:36,540
less energetic stuff and then there's

1269
00:55:42,530 --> 00:55:39,420
everything in between right so in the

1270
00:55:45,470 --> 00:55:42,540
optical which is right here you see this

1271
00:55:47,990 --> 00:55:45,480
band of our like Galactic plane but then

1272
00:55:50,589 --> 00:55:48,000
if you look outward right you can see in

1273
00:55:53,510 --> 00:55:50,599
the gamma ray the most uh the most

1274
00:55:54,950 --> 00:55:53,520
energetic parts of the Milky Way so that

1275
00:55:56,870 --> 00:55:54,960
tells you about the energy like very

1276
00:55:58,549 --> 00:55:56,880
energetic and hot physics that's

1277
00:56:00,589 --> 00:55:58,559
happening

1278
00:56:03,410 --> 00:56:00,599
um and the infrared you can say

1279
00:56:05,210 --> 00:56:03,420
something about uh star formation so you

1280
00:56:07,670 --> 00:56:05,220
can see like different clumps come out

1281
00:56:09,790 --> 00:56:07,680
and dust and you can see that this milk

1282
00:56:11,990 --> 00:56:09,800
that our Milky Way looks very different

1283
00:56:15,349 --> 00:56:12,000
depending on which wavelength you look

1284
00:56:17,150 --> 00:56:15,359
at it from right I mean these are all

1285
00:56:19,790 --> 00:56:17,160
false colored but sort of the features

1286
00:56:21,290 --> 00:56:19,800
that come out look different and this is

1287
00:56:23,750 --> 00:56:21,300
kind of related to what Frank was

1288
00:56:25,190 --> 00:56:23,760

talking about in his introduction and I

1289
00:56:27,890 --> 00:56:25,200
promise we didn't coordinate that but

1290
00:56:31,250 --> 00:56:27,900
that was really like nice like good good

1291
00:56:33,290 --> 00:56:31,260
timing because at different wavelengths

1292
00:56:34,849 --> 00:56:33,300
it tells you about different energetic

1293
00:56:37,630 --> 00:56:34,859
processes that are happening within

1294
00:56:40,609 --> 00:56:37,640
whatever you're looking at

1295
00:56:43,430 --> 00:56:40,619
here's just another example of that so

1296
00:56:47,150 --> 00:56:43,440
this is called the whirlpool Galaxy then

1297
00:56:49,010 --> 00:56:47,160
the optical you have a optical light

1298
00:56:50,930 --> 00:56:49,020
that comes from Stars which are around

1299
00:56:52,309 --> 00:56:50,940
the sides of the Sun so we can get

1300
00:56:55,630 --> 00:56:52,319
physics on that

1301
00:56:58,670 --> 00:56:55,640
in the x-rays which is really energetic

1302
00:57:01,130 --> 00:56:58,680
you get information about the hottest

1303
00:57:04,210 --> 00:57:01,140
regions of gas where atoms are ionized

1304
00:57:06,829 --> 00:57:04,220
and remember that ionize just means that

1305
00:57:10,130 --> 00:57:06,839
atoms are charged or that you have

1306
00:57:12,230 --> 00:57:10,140
charged particles and then in the on the

1307
00:57:15,770 --> 00:57:12,240
other on the opposite end of that you

1308
00:57:17,870 --> 00:57:15,780
have cold gas in the radio so radio

1309
00:57:20,930 --> 00:57:17,880
waves reveal regions of gas cool enough

1310
00:57:23,210 --> 00:57:20,940
for something like CO2 molecules to

1311
00:57:25,849 --> 00:57:23,220
exist so all of these things tell you

1312
00:57:27,349 --> 00:57:25,859
something different about about whatever

1313
00:57:30,349 --> 00:57:27,359

you're looking at

1314
00:57:32,390 --> 00:57:30,359
that's also why you have I don't know if

1315
00:57:34,069 --> 00:57:32,400
you've heard of all of these different

1316
00:57:36,410 --> 00:57:34,079
telescopes but if you have you might be

1317
00:57:38,030 --> 00:57:36,420
wondering why do we need so many well we

1318
00:57:41,510 --> 00:57:38,040
need so many because we want to cover

1319
00:57:43,730 --> 00:57:41,520
the whole like sort of gamut right of

1320
00:57:46,250 --> 00:57:43,740
um of wavelengths and of energies to

1321
00:57:48,890 --> 00:57:46,260
tell us things about about whatever

1322
00:57:51,650 --> 00:57:48,900
we're looking at about our universe

1323
00:57:56,089 --> 00:57:51,660
um so you can see Hubble is right in the

1324
00:57:57,309 --> 00:57:56,099
center uh in around the near UV to the

1325
00:58:00,710 --> 00:57:57,319
near ir

1326
00:58:02,390 --> 00:58:00,720
and the other two telescopes uh that so

1327
00:58:05,150 --> 00:58:02,400
we have James Webb that you all have

1328
00:58:08,690 --> 00:58:05,160
heard a lot about and also Roman that

1329
00:58:10,309 --> 00:58:08,700
will be launched soon that will do

1330
00:58:12,530 --> 00:58:10,319
really cool science on really large

1331
00:58:14,930 --> 00:58:12,540
scales looking in these sort of

1332
00:58:16,430 --> 00:58:14,940
wavelengths and similar wavelengths and

1333
00:58:18,170 --> 00:58:16,440
then you have others that fill in the

1334
00:58:20,750 --> 00:58:18,180
gaps for different signs that people

1335
00:58:21,589 --> 00:58:20,760
want to do

1336
00:58:23,930 --> 00:58:21,599
um

1337
00:58:26,030 --> 00:58:23,940
but here's another link

1338
00:58:28,970 --> 00:58:26,040

um I'm I'm going to skip this but I

1339
00:58:33,470 --> 00:58:28,980
encourage you to look at it so the view

1340
00:58:35,930 --> 00:58:33,480
csci's view Space is really cool it has

1341
00:58:37,490 --> 00:58:35,940
a lot of cool visualizations a lot of

1342
00:58:39,589 --> 00:58:37,500
cool like there's bars at the bottom

1343
00:58:41,390 --> 00:58:39,599
where you can like you can look at you

1344
00:58:43,609 --> 00:58:41,400
know merging galaxies you can look at

1345
00:58:44,349 --> 00:58:43,619
how colors affect

1346
00:58:47,450 --> 00:58:44,359
um

1347
00:58:49,910 --> 00:58:47,460
what your in what your picture looks

1348
00:58:53,450 --> 00:58:49,920
like like Frank was showing with Crab

1349
00:58:54,890 --> 00:58:53,460
Nebula and others and so I really

1350
00:58:56,030 --> 00:58:54,900
encourage you to take a look at this I

1351
00:58:57,890 --> 00:58:56,040
just don't want to stop sharing my

1352
00:58:59,930 --> 00:58:57,900
screen and re-sharing it and

1353
00:59:03,049 --> 00:58:59,940
Etc

1354
00:59:05,930 --> 00:59:03,059
um okay so what does that actually look

1355
00:59:08,150 --> 00:59:05,940
like right when we are trying to measure

1356
00:59:10,130 --> 00:59:08,160
the brightness of something in different

1357
00:59:12,530 --> 00:59:10,140
wavelengths but what does that look like

1358
00:59:14,390 --> 00:59:12,540
meaningfully right what do we actually

1359
00:59:15,829 --> 00:59:14,400
sit down at our desks use our computers

1360
00:59:18,530 --> 00:59:15,839
to analyze

1361
00:59:22,130 --> 00:59:18,540
so here is an example and this is really

1362
00:59:26,270 --> 00:59:22,140
just forget about uh don't be scared

1363
00:59:28,849 --> 00:59:26,280

um this was going from uh the UV or

1364
00:59:31,970 --> 00:59:28,859
sorry from the X-ray all the way to the

1365
00:59:34,130 --> 00:59:31,980
radio wave uh radio spect part of the

1366
00:59:36,710 --> 00:59:34,140
spectrum so let's strip this down into

1367
00:59:40,190 --> 00:59:36,720
only things that we care about right to

1368
00:59:42,770 --> 00:59:40,200
simplify this so on the y-axis you have

1369
00:59:44,750 --> 00:59:42,780
the brightness and on the x-axis you

1370
00:59:48,049 --> 00:59:44,760
have the wavelength and remember that

1371
00:59:49,490 --> 00:59:48,059
wavelength is just a proxy for energy uh

1372
00:59:51,829 --> 00:59:49,500
so on the left you're going for we're

1373
00:59:54,710 --> 00:59:51,839
going from the X-ray to the UV to the

1374
00:59:56,990 --> 00:59:54,720
optical to the IR to the sub millimeter

1375
00:59:58,609 --> 00:59:57,000
to the radio so from the shortest to the

1376
01:00:01,309 --> 00:59:58,619
longest wavelengths

1377
01:00:03,710 --> 01:00:01,319
and we measure a brightness of this one

1378
01:00:05,870 --> 01:00:03,720
Galaxy

1379
01:00:08,750 --> 01:00:05,880
um at all of these different wavelengths

1380
01:00:10,370 --> 01:00:08,760
so in the X-ray for example you can see

1381
01:00:14,270 --> 01:00:10,380
that there's some kind of trend there

1382
01:00:17,210 --> 01:00:14,280
and those points that brightness is

1383
01:00:19,250 --> 01:00:17,220
telling us about the really uh the

1384
01:00:21,829 --> 01:00:19,260
supermassive black hole at the center of

1385
01:00:25,250 --> 01:00:21,839
that Galaxy which is really emitting

1386
01:00:26,870 --> 01:00:25,260
which is emitting a ton of energy and so

1387
01:00:29,270 --> 01:00:26,880
that tells us something about the black

1388
01:00:31,730 --> 01:00:29,280

hole if you're moving

1389
01:00:34,370 --> 01:00:31,740
towards if you're moving redder right so

1390
01:00:36,309 --> 01:00:34,380
you're moving towards the optical that

1391
01:00:38,390 --> 01:00:36,319
starts to tell us about

1392
01:00:41,390 --> 01:00:38,400
Stars something called the Stellar

1393
01:00:43,910 --> 01:00:41,400
Continuum in that Galaxy and if you move

1394
01:00:46,549 --> 01:00:43,920
farther to the IR where you see these

1395
01:00:48,770 --> 01:00:46,559
like green points that is actually again

1396
01:00:51,289 --> 01:00:48,780
similar to what Frank was saying earlier

1397
01:00:53,870 --> 01:00:51,299
that is connected to the supermassive

1398
01:00:56,349 --> 01:00:53,880
black hole that is emitting these really

1399
01:01:01,670 --> 01:00:56,359
energetic photons it's getting

1400
01:01:03,710 --> 01:01:01,680
reabsorbed by the gas that's around the

1401
01:01:06,470 --> 01:01:03,720
the dust and the gas that's uh in the

1402
01:01:10,430 --> 01:01:06,480
galaxy and then that is being re-emitted

1403
01:01:13,130 --> 01:01:10,440
and that re-emission is in the red in

1404
01:01:14,930 --> 01:01:13,140
the IR and so just from this sort of

1405
01:01:16,849 --> 01:01:14,940
these data points you can say something

1406
01:01:19,849 --> 01:01:16,859
about all of the different physical

1407
01:01:22,910 --> 01:01:19,859
processes that are happening there and

1408
01:01:24,650 --> 01:01:22,920
then I'm totally not a radio expert but

1409
01:01:26,750 --> 01:01:24,660
I think the radio has something to do

1410
01:01:29,270 --> 01:01:26,760
with the supermassive black hole as well

1411
01:01:31,430 --> 01:01:29,280
I think you guys heard about that in

1412
01:01:33,049 --> 01:01:31,440
some of the previous uh public lecture

1413
01:01:37,190 --> 01:01:33,059

series talks

1414
01:01:39,230 --> 01:01:37,200
okay so I hope that you know that I I

1415
01:01:41,690 --> 01:01:39,240
convinced you that you are able to look

1416
01:01:43,849 --> 01:01:41,700
at these complicated plots right and get

1417
01:01:45,890 --> 01:01:43,859
some information from them so how do we

1418
01:01:48,289 --> 01:01:45,900
actually know about that physic how do

1419
01:01:50,809 --> 01:01:48,299
we know that you know black holes emit

1420
01:01:53,270 --> 01:01:50,819
should emit at this wavelength and and

1421
01:01:55,250 --> 01:01:53,280
star should emit at this wavelength we

1422
01:01:57,530 --> 01:01:55,260
have models right because we know

1423
01:02:00,410 --> 01:01:57,540
something about the fundamental physics

1424
01:02:02,390 --> 01:02:00,420
that are that's happening and what that

1425
01:02:04,430 --> 01:02:02,400
physics should look like right so if we

1426
01:02:07,010 --> 01:02:04,440
know that okay we have really energetic

1427
01:02:09,349 --> 01:02:07,020
photons then probably we're going to

1428
01:02:11,930 --> 01:02:09,359
observe it in the X-ray something like

1429
01:02:14,210 --> 01:02:11,940
that and so we create models so going

1430
01:02:17,270 --> 01:02:14,220
back to this plot that is hopefully less

1431
01:02:20,150 --> 01:02:17,280
scary now in each of these like you can

1432
01:02:22,730 --> 01:02:20,160
see like there's the blue curve the red

1433
01:02:25,430 --> 01:02:22,740
curve the green one the purple one the

1434
01:02:28,430 --> 01:02:25,440
orange one Etc all of these are models

1435
01:02:30,770 --> 01:02:28,440
that were able to fit our data to

1436
01:02:34,130 --> 01:02:30,780
um to say something about our galaxy

1437
01:02:35,990 --> 01:02:34,140
right and so because we're able to kind

1438
01:02:38,270 --> 01:02:36,000

of tweak the parameters of the models

1439
01:02:41,390 --> 01:02:38,280
based on the physics that we know we're

1440
01:02:43,670 --> 01:02:41,400
able to say okay uh this galaxy has a

1441
01:02:45,950 --> 01:02:43,680
supermassive black hole it also has this

1442
01:02:48,470 --> 01:02:45,960
many stars it's you know this massive

1443
01:02:50,270 --> 01:02:48,480
it's this old

1444
01:02:55,190 --> 01:02:50,280
etc etc

1445
01:02:58,490 --> 01:02:55,200
so I work mainly in the optical so I

1446
01:02:59,950 --> 01:02:58,500
work with HST wave bands so from the UV

1447
01:03:02,990 --> 01:02:59,960
to the IR

1448
01:03:05,630 --> 01:03:03,000
and here is just again this might look

1449
01:03:08,630 --> 01:03:05,640
scary but I promise we can do this so

1450
01:03:11,150 --> 01:03:08,640
let's do it together so each one of

1451
01:03:14,690 --> 01:03:11,160
these colored curves is a filter right

1452
01:03:16,309 --> 01:03:14,700
so and we get so in this case if we

1453
01:03:19,069 --> 01:03:16,319
looked at an image we would observe it

1454
01:03:21,109 --> 01:03:19,079
in four filters and in each filter we

1455
01:03:23,630 --> 01:03:21,119
can get a different measurement for the

1456
01:03:26,870 --> 01:03:23,640
brightness of the Galaxy all right so we

1457
01:03:29,270 --> 01:03:26,880
have four points and this black thing

1458
01:03:32,450 --> 01:03:29,280
that's kind of moving is the Spectra

1459
01:03:34,910 --> 01:03:32,460
it's sort of our model of what a Galaxy

1460
01:03:36,470 --> 01:03:34,920
should look like or how much energy a

1461
01:03:39,770 --> 01:03:36,480
Galaxy should emit as a function of

1462
01:03:41,750 --> 01:03:39,780
wavelength and we can use that model to

1463
01:03:43,490 --> 01:03:41,760

fit our four data points to say

1464
01:03:45,849 --> 01:03:43,500
something about in this case how far

1465
01:03:48,650 --> 01:03:45,859
away the Galaxy is

1466
01:03:51,950 --> 01:03:48,660
okay so one more kind of complicated

1467
01:03:54,890 --> 01:03:51,960
plot but again stick with me so forget

1468
01:03:57,470 --> 01:03:54,900
about everything here in this plot just

1469
01:04:00,710 --> 01:03:57,480
focus on the fact that the y-axis is the

1470
01:04:03,289 --> 01:04:00,720
brightness in the top two panels and the

1471
01:04:04,549 --> 01:04:03,299
x-axis is the wavelength and again we're

1472
01:04:09,049 --> 01:04:04,559
going from

1473
01:04:10,970 --> 01:04:09,059
uh Bluer from the UV to uh well this is

1474
01:04:13,309 --> 01:04:10,980
actually to the optical and I just

1475
01:04:15,530 --> 01:04:13,319
wanted to show you this because it shows

1476
01:04:17,329 --> 01:04:15,540
four different images so kind of putting

1477
01:04:20,510 --> 01:04:17,339
together the images and what we measure

1478
01:04:23,210 --> 01:04:20,520
it shows four different images of this

1479
01:04:25,190 --> 01:04:23,220
of looking at the same part of the sky

1480
01:04:26,750 --> 01:04:25,200
right

1481
01:04:28,910 --> 01:04:26,760
um and so you can see how they look

1482
01:04:31,089 --> 01:04:28,920
different in these different filters

1483
01:04:34,190 --> 01:04:31,099
because we're probing different physics

1484
01:04:36,589 --> 01:04:34,200
uh of of whatever system they're looking

1485
01:04:38,809 --> 01:04:36,599
at in this case and so we get a data

1486
01:04:40,730 --> 01:04:38,819
point per filter so we can measure the

1487
01:04:43,130 --> 01:04:40,740
brightness with that Source extractor

1488
01:04:45,289 --> 01:04:43,140

software code that I talked to you about

1489
01:04:49,130 --> 01:04:45,299
earlier and we can measure the

1490
01:04:52,370 --> 01:04:49,140
brightness in each filter band and put

1491
01:04:54,470 --> 01:04:52,380
it on a plot of our model of galaxies

1492
01:04:57,650 --> 01:04:54,480
and say something again about the Galaxy

1493
01:05:01,190 --> 01:04:57,660
how far away it is how old is it

1494
01:05:03,109 --> 01:05:01,200
um what's the Stellar Mass etc etc

1495
01:05:05,030 --> 01:05:03,119
um and so this is what I do with the

1496
01:05:07,010 --> 01:05:05,040
frontier fields

1497
01:05:08,870 --> 01:05:07,020
I'm going to wrap this up so no more

1498
01:05:11,450 --> 01:05:08,880
complicated plots

1499
01:05:13,970 --> 01:05:11,460
um sorry about that just to show you

1500
01:05:16,789 --> 01:05:13,980
kind of how exciting it is to currently

1501
01:05:19,430 --> 01:05:16,799
to be an astronomer

1502
01:05:23,030 --> 01:05:19,440
right now and how exciting it is

1503
01:05:25,370 --> 01:05:23,040
hopefully for uh for you all to follow

1504
01:05:28,490 --> 01:05:25,380
astronomy news

1505
01:05:31,130 --> 01:05:28,500
um because we a Space Telescope just

1506
01:05:33,349 --> 01:05:31,140
recently launched jwst we talk about it

1507
01:05:35,030 --> 01:05:33,359
a lot it's really cool

1508
01:05:37,010 --> 01:05:35,040
um but you can see here that it's

1509
01:05:39,890 --> 01:05:37,020
probing kind of there's some overlap

1510
01:05:43,069 --> 01:05:39,900
with HST and so this is why HSC is still

1511
01:05:45,829 --> 01:05:43,079
very important but it overlaps a little

1512
01:05:48,829 --> 01:05:45,839
bit with HST and it's probing kind of a

1513
01:05:50,870 --> 01:05:48,839

different part of uh of the

1514
01:05:54,589 --> 01:05:50,880
electromagnetic Spectra but tell us

1515
01:05:57,470 --> 01:05:54,599
things about the oldest galaxies

1516
01:06:00,289 --> 01:05:57,480
uh here is just kind of a summary of of

1517
01:06:01,970 --> 01:06:00,299
that kind of a summary of the history of

1518
01:06:03,890 --> 01:06:01,980
the different surveys that people have

1519
01:06:07,430 --> 01:06:03,900
that scientists really talented people

1520
01:06:09,230 --> 01:06:07,440
have done uh over decades so in the 90s

1521
01:06:11,089 --> 01:06:09,240
you had ground-based Observatory and you

1522
01:06:13,730 --> 01:06:11,099
still do and they're they're looking at

1523
01:06:15,349 --> 01:06:13,740
a really large swaths of the sky instead

1524
01:06:17,650 --> 01:06:15,359
of going really deep

1525
01:06:20,510 --> 01:06:17,660
um but they were able to see up to

1526
01:06:23,150 --> 01:06:20,520
galaxies that were at six billion years

1527
01:06:26,390 --> 01:06:23,160
after the big bang the Hubble Deep Field

1528
01:06:28,370 --> 01:06:26,400
you saw uh it pro galaxies 1.5 billion

1529
01:06:30,470 --> 01:06:28,380
years after the big bang the Hubble

1530
01:06:32,809 --> 01:06:30,480
Ultra Deep Field probed even younger

1531
01:06:34,670 --> 01:06:32,819
galaxies at 800 million years after the

1532
01:06:37,069 --> 01:06:34,680
big bang

1533
01:06:39,710 --> 01:06:37,079
um and this is kind of this is an old

1534
01:06:42,289 --> 01:06:39,720
graphic because it says future but jwst

1535
01:06:44,329 --> 01:06:42,299
is already doing this and it's seeing

1536
01:06:48,410 --> 01:06:44,339
stuff between

1537
01:06:51,170 --> 01:06:48,420
um 200 and 500 maybe not 200 million

1538
01:06:53,930 --> 01:06:51,180

years after the big bang yet but around

1539
01:06:56,870 --> 01:06:53,940
500 million years after the big bang and

1540
01:07:01,010 --> 01:06:56,880
it's seeing the first uh the universe's

1541
01:07:02,510 --> 01:07:01,020
first stars and and first galaxies

1542
01:07:05,510 --> 01:07:02,520
um and so I'll leave you with this I

1543
01:07:08,210 --> 01:07:05,520
think that again this is a very uh sort

1544
01:07:10,069 --> 01:07:08,220
of exciting time to be part of this

1545
01:07:11,870 --> 01:07:10,079
field and to and to follow the field and

1546
01:07:14,690 --> 01:07:11,880
the news and that space telescope and at

1547
01:07:16,430 --> 01:07:14,700
your local observatories or or other

1548
01:07:17,150 --> 01:07:16,440
places

1549
01:07:20,029 --> 01:07:17,160
um

1550
01:07:21,770 --> 01:07:20,039
I think uh I'll leave I'll end with this

1551
01:07:23,750 --> 01:07:21,780
that one of my favorite Parts about

1552
01:07:26,870 --> 01:07:23,760
being an astronomer is that you're

1553
01:07:29,390 --> 01:07:26,880
really sort of able to say something

1554
01:07:32,569 --> 01:07:29,400
about the evolution of the universe

1555
01:07:35,809 --> 01:07:32,579
through Cosmic time right so we really

1556
01:07:38,089 --> 01:07:35,819
are sort of we're Time Travelers uh that

1557
01:07:40,430 --> 01:07:38,099
is that are able to to say something

1558
01:07:42,890 --> 01:07:40,440
about what the beginning of our universe

1559
01:07:46,130 --> 01:07:42,900
looked like up until now

1560
01:07:48,410 --> 01:07:46,140
um and and sort of we really are the

1561
01:07:50,690 --> 01:07:48,420
universe observing itself and that's

1562
01:07:51,349 --> 01:07:50,700
pretty incredible

1563
01:07:56,510 --> 01:07:51,359

um

1564
01:08:05,049 --> 01:08:00,549
okay thank you Amanda that was wonderful

1565
01:08:07,789 --> 01:08:05,059
uh really you know uh deep in in in

1566
01:08:10,250 --> 01:08:07,799
places but you know in order to really

1567
01:08:12,490 --> 01:08:10,260
understand how we get derive these uh

1568
01:08:15,529 --> 01:08:12,500
Galaxy parameters

1569
01:08:16,690 --> 01:08:15,539
it would it wouldn't be observing of PhD

1570
01:08:19,490 --> 01:08:16,700
if it wasn't deep right

1571
01:08:20,570 --> 01:08:19,500
[Laughter]

1572
01:08:23,630 --> 01:08:20,580
so

1573
01:08:26,150 --> 01:08:23,640
people in our audience would have all

1574
01:08:28,910 --> 01:08:26,160
right so in doing this you're getting

1575
01:08:31,610 --> 01:08:28,920
the uh the brightness in like these nine

1576
01:08:33,289 --> 01:08:31,620
different filters that you showed okay

1577
01:08:35,809 --> 01:08:33,299
um you're getting from that you're able

1578
01:08:39,470 --> 01:08:35,819
to get a a photometric redshift which is

1579
01:08:43,130 --> 01:08:39,480
a measure of the distance what do you

1580
01:08:45,070 --> 01:08:43,140
also do about the Galaxy shapes you know

1581
01:08:48,050 --> 01:08:45,080
people were chatting here about a

1582
01:08:49,550 --> 01:08:48,060
spirals versus ellipticals and they're

1583
01:08:51,470 --> 01:08:49,560
actually wondering why most things are

1584
01:08:52,970 --> 01:08:51,480
spirals but that's not quite your

1585
01:08:55,610 --> 01:08:52,980
expertise

1586
01:08:58,010 --> 01:08:55,620
um so do you get good characteristics on

1587
01:09:01,189 --> 01:08:58,020
the shapes of these galaxies as well

1588
01:09:05,269 --> 01:09:01,199

yeah so uh thanks for thanks for that

1589
01:09:07,370 --> 01:09:05,279
Frank um yeah so I showed you that we

1590
01:09:09,769 --> 01:09:07,380
were able to model some of that Galaxy

1591
01:09:11,209 --> 01:09:09,779
some of those galaxies when I was trying

1592
01:09:13,910 --> 01:09:11,219
to model them and remove the

1593
01:09:17,090 --> 01:09:13,920
contaminating cluster light

1594
01:09:18,829 --> 01:09:17,100
um from my images so we are able we are

1595
01:09:21,530 --> 01:09:18,839
able to model it

1596
01:09:23,990 --> 01:09:21,540
um there's they their shapes look

1597
01:09:27,349 --> 01:09:24,000
different as a function of wavelength um

1598
01:09:29,689 --> 01:09:27,359
so they do so you will see

1599
01:09:31,849 --> 01:09:29,699
um you know star forming regions in one

1600
01:09:34,010 --> 01:09:31,859
filter and maybe like this the Bulge of

1601
01:09:35,570 --> 01:09:34,020
the Galaxy and another filter and you

1602
01:09:37,249 --> 01:09:35,580
put that together to say something about

1603
01:09:39,229 --> 01:09:37,259
the Galaxy

1604
01:09:41,090 --> 01:09:39,239
um but it's true right now when what

1605
01:09:42,950 --> 01:09:41,100
we're or what we were doing was just

1606
01:09:44,570 --> 01:09:42,960
drawing kind of circles or apertures

1607
01:09:47,209 --> 01:09:44,580
around each Galaxy to say something

1608
01:09:48,709 --> 01:09:47,219
about the total flux but you can model

1609
01:09:50,990 --> 01:09:48,719
them and we've been modeling them

1610
01:09:53,930 --> 01:09:51,000
analytically because we kind of know

1611
01:09:56,750 --> 01:09:53,940
what a Galaxy should look like

1612
01:10:00,650 --> 01:09:56,760
um and so we're able to to approximate

1613
01:10:03,229 --> 01:10:00,660

it as uh as an analytic function and do

1614
01:10:05,810 --> 01:10:03,239
that modeling and those modeling

1615
01:10:07,970 --> 01:10:05,820
parameters that we actually extract

1616
01:10:10,669 --> 01:10:07,980
change right as a function of wavelength

1617
01:10:13,250 --> 01:10:10,679
so you need to fit different models for

1618
01:10:16,850 --> 01:10:13,260
each image in each different filter

1619
01:10:18,770 --> 01:10:16,860
I don't know if that yeah I mean I'm

1620
01:10:21,050 --> 01:10:18,780
trying to get it get it get it uh

1621
01:10:23,510 --> 01:10:21,060
explained for the public on the flat

1622
01:10:26,930 --> 01:10:23,520
level because you know I'm

1623
01:10:29,090 --> 01:10:26,940
you know you you you you're able to from

1624
01:10:31,189 --> 01:10:29,100
the the shape of the of the spectrum of

1625
01:10:34,610 --> 01:10:31,199
of an elliptical galaxy versus the shape

1626
01:10:36,830 --> 01:10:34,620
of the spectrum of a spiral galaxy but

1627
01:10:39,290 --> 01:10:36,840
um just to reiterate in terms of the

1628
01:10:40,790 --> 01:10:39,300
redshift and the red shifting as it goes

1629
01:10:43,070 --> 01:10:40,800
across um just make sure people

1630
01:10:45,229 --> 01:10:43,080
understand how that the the that

1631
01:10:47,990 --> 01:10:45,239
Spectrum as you showed in that animation

1632
01:10:49,790 --> 01:10:48,000
just sort of moves up to longer and

1633
01:10:51,470 --> 01:10:49,800
longer wavelength and of course great

1634
01:10:54,610 --> 01:10:51,480
reason why we need the web Space

1635
01:10:57,229 --> 01:10:54,620
Telescope right yep

1636
01:10:58,550 --> 01:10:57,239
okay uh Grant

1637
01:11:02,510 --> 01:10:58,560
um you've been following the YouTube

1638
01:11:04,490 --> 01:11:02,520

channel a little more uh tightly than me

1639
01:11:06,290 --> 01:11:04,500
um why don't you come and join us and

1640
01:11:08,330 --> 01:11:06,300
see if you've got some uh good questions

1641
01:11:09,830 --> 01:11:08,340
from our audience out there

1642
01:11:11,090 --> 01:11:09,840
absolutely

1643
01:11:13,189 --> 01:11:11,100
um you did a very thorough job

1644
01:11:14,630 --> 01:11:13,199
explaining so people are having less

1645
01:11:16,790 --> 01:11:14,640
questions than normal which is a very

1646
01:11:20,510 --> 01:11:16,800
good thing

1647
01:11:22,490 --> 01:11:20,520
that's a job um so we'll start off uh

1648
01:11:23,990 --> 01:11:22,500
kind of piggybacking off of what Frank

1649
01:11:26,450 --> 01:11:24,000
said

1650
01:11:29,510 --> 01:11:26,460
um how is it that you differentiate a

1651
01:11:31,729 --> 01:11:29,520
Target that has redshifted versus one

1652
01:11:34,790 --> 01:11:31,739
that is simply closer at a different

1653
01:11:36,470 --> 01:11:34,800
original color or temp if they seem if

1654
01:11:38,510 --> 01:11:36,480
they appear to be similar how do you

1655
01:11:41,450 --> 01:11:38,520
tell the distance apart

1656
01:11:43,310 --> 01:11:41,460
yeah so that's a great question right I

1657
01:11:45,649 --> 01:11:43,320
kind of tried I was driving home the

1658
01:11:47,510 --> 01:11:45,659
point that color matters uh but if you

1659
01:11:50,090 --> 01:11:47,520
have something in the foreground that is

1660
01:11:52,070 --> 01:11:50,100
red and something in the background uh

1661
01:11:55,370 --> 01:11:52,080
that is really far away that that looks

1662
01:11:57,709 --> 01:11:55,380
red you you might have some issues right

1663
01:12:00,530 --> 01:11:57,719

um the way we do that is I talked about

1664
01:12:04,430 --> 01:12:00,540
the Spectra right these models that we

1665
01:12:07,850 --> 01:12:04,440
fit to our galaxy fluxes the Galaxy that

1666
01:12:10,669 --> 01:12:07,860
is really far away will typically have a

1667
01:12:13,310 --> 01:12:10,679
different Spectra than a Galaxy that's

1668
01:12:15,950 --> 01:12:13,320
very close by in red

1669
01:12:19,490 --> 01:12:15,960
um and so you can you can if you fit

1670
01:12:21,890 --> 01:12:19,500
your models to your fluxes or to your

1671
01:12:23,930 --> 01:12:21,900
Galaxy brightnesses you'll see that they

1672
01:12:26,390 --> 01:12:23,940
actually look different

1673
01:12:28,250 --> 01:12:26,400
one will be the redshifted one the one

1674
01:12:32,450 --> 01:12:28,260
that's far away will be redshifted

1675
01:12:34,430 --> 01:12:32,460
towards the redder side because uh as

1676
01:12:36,410 --> 01:12:34,440
space expands and you know I didn't talk

1677
01:12:39,050 --> 01:12:36,420
much about redshifts and maybe I should

1678
01:12:42,530 --> 01:12:39,060
have but as space expands it stretches

1679
01:12:46,010 --> 01:12:42,540
out a photon right causing it to look

1680
01:12:48,590 --> 01:12:46,020
redder and so fundamentally the the

1681
01:12:50,570 --> 01:12:48,600
light that's emitted from that Galaxy is

1682
01:12:52,970 --> 01:12:50,580
still you know intrinsically one thing

1683
01:12:55,010 --> 01:12:52,980
and we just see it as redder because of

1684
01:12:57,770 --> 01:12:55,020
this redshift thing and so all you have

1685
01:13:01,130 --> 01:12:57,780
is the Spectra just being moved over to

1686
01:13:02,390 --> 01:13:01,140
the redder part of uh to the redder

1687
01:13:07,310 --> 01:13:02,400
filters

1688
01:13:09,770 --> 01:13:07,320

um yeah yeah so so it's it's really uh

1689
01:13:11,990 --> 01:13:09,780
important that you have um I don't know

1690
01:13:13,490 --> 01:13:12,000
how many base models in terms of what a

1691
01:13:15,110 --> 01:13:13,500
spiral looks like an elliptical looks

1692
01:13:16,850 --> 01:13:15,120
like or other things you have like I

1693
01:13:19,189 --> 01:13:16,860
don't know a set of half a dozen of

1694
01:13:21,890 --> 01:13:19,199
those something like that but each one

1695
01:13:24,110 --> 01:13:21,900
of those then has to be redshifted to

1696
01:13:26,750 --> 01:13:24,120
try try and fit so you've got this this

1697
01:13:28,550 --> 01:13:26,760
your bit your base models plus all of

1698
01:13:30,590 --> 01:13:28,560
the redshifted versions of every one of

1699
01:13:32,750 --> 01:13:30,600
those base models to try and fit to your

1700
01:13:37,010 --> 01:13:32,760
data right

1701
01:13:40,189 --> 01:13:37,020
yep exactly okay so based on that The

1702
01:13:42,649 --> 01:13:40,199
More You observe the more complex and

1703
01:13:46,010 --> 01:13:42,659
accurate the models can become

1704
01:13:47,689 --> 01:13:46,020
okay okay and this ties back into what

1705
01:13:50,510 --> 01:13:47,699
you meant about gravitational lensing

1706
01:13:53,990 --> 01:13:50,520
being a chromatic

1707
01:13:56,270 --> 01:13:54,000
um that that it doesn't change the the

1708
01:13:59,390 --> 01:13:56,280
character of the light right

1709
01:14:02,209 --> 01:13:59,400
yep that's right it retains its color

1710
01:14:06,950 --> 01:14:04,490
but of course it does change the uh the

1711
01:14:08,689 --> 01:14:06,960
shape of it right and so

1712
01:14:10,550 --> 01:14:08,699
um trying to figure out whether it's a

1713
01:14:13,790 --> 01:14:10,560

spiral or an elliptical or an irregular

1714
01:14:14,810 --> 01:14:13,800
uh of her lens galaxies obviously quite

1715
01:14:17,510 --> 01:14:14,820
difficult

1716
01:14:19,130 --> 01:14:17,520
yeah exactly it changes it changes the

1717
01:14:20,870 --> 01:14:19,140
brightness but it doesn't because it

1718
01:14:24,050 --> 01:14:20,880
magnifies it but it doesn't change the

1719
01:14:26,630 --> 01:14:24,060
relative brightnesses between uh each

1720
01:14:28,610 --> 01:14:26,640
like wavelength all right so therefore

1721
01:14:30,250 --> 01:14:28,620
all these relative brightnesses that you

1722
01:14:33,290 --> 01:14:30,260
showed in that that wonderful animation

1723
01:14:37,130 --> 01:14:33,300
still hold true

1724
01:14:38,209 --> 01:14:37,140
yep exactly cool thank you all right um

1725
01:14:40,729 --> 01:14:38,219
okay

1726
01:14:43,850 --> 01:14:40,739
in doing gravitational lensing and

1727
01:14:46,610 --> 01:14:43,860
mapping how were the images how were the

1728
01:14:49,189 --> 01:14:46,620
image selections made to find possible

1729
01:14:53,390 --> 01:14:49,199
image arcs or were they already known

1730
01:14:56,870 --> 01:14:53,400
areas with gravitational lensing present

1731
01:14:58,970 --> 01:14:56,880
so uh these were known errors so how did

1732
01:15:00,770 --> 01:14:58,980
we file decide which clusters to point

1733
01:15:03,590 --> 01:15:00,780
at like

1734
01:15:06,290 --> 01:15:03,600
or or how do I think he's asking

1735
01:15:09,310 --> 01:15:06,300
um when you're doing when you're dealing

1736
01:15:11,390 --> 01:15:09,320
with gravitational lensing do you select

1737
01:15:14,270 --> 01:15:11,400
places or images that you know

1738
01:15:16,669 --> 01:15:14,280

gravitational lensing has taken place or

1739
01:15:19,850 --> 01:15:16,679
is it something that you do kind of on

1740
01:15:22,130 --> 01:15:19,860
the fly as you notice it in your data

1741
01:15:24,530 --> 01:15:22,140
that was returned sure

1742
01:15:26,149 --> 01:15:24,540
um yeah so that's a great question

1743
01:15:29,750 --> 01:15:26,159
um in in the case of the Hubble Frontier

1744
01:15:31,610 --> 01:15:29,760
Fields uh we pointed and again by we I

1745
01:15:33,229 --> 01:15:31,620
mean the scientists at Space Telescope

1746
01:15:38,149 --> 01:15:33,239
but not me

1747
01:15:41,050 --> 01:15:38,159
um pointed to known massive clusters

1748
01:15:43,550 --> 01:15:41,060
um there are efforts by you know

1749
01:15:45,709 --> 01:15:43,560
collaborations by other collaborations

1750
01:15:47,330 --> 01:15:45,719
like the Reuben Observatory if you've

1751
01:15:50,510 --> 01:15:47,340
heard of that or the dark energy survey

1752
01:15:54,169 --> 01:15:50,520
or whatever to do uh to find lenses and

1753
01:15:55,669 --> 01:15:54,179
to find kind of where uh lensing might

1754
01:15:58,189 --> 01:15:55,679
be occurring to say something about

1755
01:16:00,350 --> 01:15:58,199
again the the cosmic web and the

1756
01:16:01,850 --> 01:16:00,360
structure of the universe but but for

1757
01:16:04,729 --> 01:16:01,860
the case of the frontier fields we

1758
01:16:07,250 --> 01:16:04,739
pointed directly at six known massive

1759
01:16:10,310 --> 01:16:07,260
clusters that didn't have a lot a whole

1760
01:16:12,950 --> 01:16:10,320
lot of stars to contaminate the field

1761
01:16:15,830 --> 01:16:12,960
I think the the the question might also

1762
01:16:17,689 --> 01:16:15,840
be saying when you see an image that's

1763
01:16:19,490 --> 01:16:17,699

stretched out you know I mean you can

1764
01:16:21,530 --> 01:16:19,500
have stretched out elliptical galaxies

1765
01:16:26,090 --> 01:16:21,540
you know really long ellipticals how do

1766
01:16:31,610 --> 01:16:29,090
that's another great question

1767
01:16:34,430 --> 01:16:31,620
yes

1768
01:16:36,410 --> 01:16:34,440
we have an audience that that has come

1769
01:16:38,630 --> 01:16:36,420
comes faithfully and asks asks good

1770
01:16:40,910 --> 01:16:38,640
questions yeah that's awesome

1771
01:16:43,010 --> 01:16:40,920
um yeah that's a great question

1772
01:16:45,770 --> 01:16:43,020
they're very like they're obvious right

1773
01:16:48,050 --> 01:16:45,780
like the color is it's blue you can kind

1774
01:16:50,270 --> 01:16:48,060
of pick out like features that uh that

1775
01:16:52,910 --> 01:16:50,280
were of a spiral galaxy but you can see

1776
01:16:56,149 --> 01:16:52,920
that it's just like stretched out

1777
01:16:59,390 --> 01:16:56,159
um it's usually pretty apparent in these

1778
01:17:01,550 --> 01:16:59,400
really massive cluster Fields

1779
01:17:03,910 --> 01:17:01,560
um there's something else called weak

1780
01:17:08,270 --> 01:17:03,920
lensing which is just

1781
01:17:11,270 --> 01:17:08,280
galaxies being lensed slightly by all of

1782
01:17:14,510 --> 01:17:11,280
the matter between that Galaxy and us

1783
01:17:16,550 --> 01:17:14,520
the Observer there it becomes much

1784
01:17:18,229 --> 01:17:16,560
harder to tell whether or not the Galaxy

1785
01:17:21,169 --> 01:17:18,239
is actually being lensed or that's just

1786
01:17:23,510 --> 01:17:21,179
that's just what it looks like

1787
01:17:25,790 --> 01:17:23,520
um and so that is really a game of

1788
01:17:28,430 --> 01:17:25,800

statistics and simulations so there are

1789
01:17:30,890 --> 01:17:28,440
people who look at this on like large

1790
01:17:33,050 --> 01:17:30,900
very large scales

1791
01:17:35,689 --> 01:17:33,060
um and and they see okay well probably

1792
01:17:38,530 --> 01:17:35,699
there's a lot of matter here and that's

1793
01:17:41,570 --> 01:17:38,540
why it's it is lensed ever so slightly

1794
01:17:44,330 --> 01:17:41,580
and and there's this much matter in this

1795
01:17:46,970 --> 01:17:44,340
part of the sky but but for the purposes

1796
01:17:48,530 --> 01:17:46,980
here they're mostly distorted enough

1797
01:17:51,110 --> 01:17:48,540
that you can tell that they're being

1798
01:17:53,689 --> 01:17:51,120
that they were lensed

1799
01:17:55,490 --> 01:17:53,699
I know we've had a couple people come on

1800
01:17:57,350 --> 01:17:55,500
and talk about gravitational lensing

1801
01:17:59,330 --> 01:17:57,360
with Hubble

1802
01:18:02,630 --> 01:17:59,340
um I'm interested to know what is it

1803
01:18:03,950 --> 01:18:02,640
that you look for in the data from web

1804
01:18:05,450 --> 01:18:03,960
that tells you that it might be

1805
01:18:08,510 --> 01:18:05,460
gravitational lensing because it's not

1806
01:18:10,430 --> 01:18:08,520
necessarily everyone's mind they think

1807
01:18:12,350 --> 01:18:10,440
astronomy they think pictures they think

1808
01:18:13,729 --> 01:18:12,360
Hubble even though Hubble had other

1809
01:18:16,310 --> 01:18:13,739
instruments it's just the common

1810
01:18:19,010 --> 01:18:16,320
Inception there what is it that you pick

1811
01:18:22,910 --> 01:18:19,020
out of the data that tells you oh this

1812
01:18:28,610 --> 01:18:26,030
um yeah so I mean firstly a lot of these

1813
01:18:31,729 --> 01:18:28,620

like the frontier fields for example are

1814
01:18:34,610 --> 01:18:31,739
also being observed with web so we

1815
01:18:36,709 --> 01:18:34,620
already know that the the galaxies there

1816
01:18:38,570 --> 01:18:36,719
we kind of know that like okay these are

1817
01:18:40,850 --> 01:18:38,580
lens galaxies

1818
01:18:42,770 --> 01:18:40,860
um we have a lot of information about or

1819
01:18:44,810 --> 01:18:42,780
or we extract and measure a lot of

1820
01:18:46,550 --> 01:18:44,820
information about how massive things are

1821
01:18:48,350 --> 01:18:46,560
right so if we know that there's a

1822
01:18:50,330 --> 01:18:48,360
really massive Galaxy we can probably

1823
01:18:53,270 --> 01:18:50,340
assume that the things behind it are

1824
01:19:00,250 --> 01:18:53,930
um

1825
01:19:03,410 --> 01:19:00,260
I personally like don't uh my work just

1826
01:19:07,669 --> 01:19:03,420
involves detecting and measuring those

1827
01:19:10,970 --> 01:19:07,679
objects I don't search for lenses but

1828
01:19:14,810 --> 01:19:10,980
you should have kind of similar

1829
01:19:17,209 --> 01:19:14,820
um similar distortions of galaxies that

1830
01:19:19,430 --> 01:19:17,219
will show that they're lensed

1831
01:19:20,810 --> 01:19:19,440
and also doesn't it the the appearance

1832
01:19:24,530 --> 01:19:20,820
of multiple objects with the same

1833
01:19:27,830 --> 01:19:24,540
redshift and similar color uh color

1834
01:19:28,970 --> 01:19:27,840
ratios indicates a lensing right yeah

1835
01:19:30,169 --> 01:19:28,980
good point

1836
01:19:32,930 --> 01:19:30,179
right

1837
01:19:34,550 --> 01:19:32,940
so somebody commented that when you were

1838
01:19:36,470 --> 01:19:34,560

doing the subtraction of the intra

1839
01:19:39,169 --> 01:19:36,480
cluster light

1840
01:19:40,970 --> 01:19:39,179
um that it's sort of like uh finding a

1841
01:19:43,430 --> 01:19:40,980
planet around a star looking for

1842
01:19:46,490 --> 01:19:43,440
exoplanets and subtracting off the point

1843
01:19:48,649 --> 01:19:46,500
spread function of a star I it's not

1844
01:19:52,189 --> 01:19:48,659
anywhere near the the contrast ratio but

1845
01:19:57,890 --> 01:19:54,950
um yeah I I don't know anything about

1846
01:19:59,530 --> 01:19:57,900
exoplanets other than what you just said

1847
01:20:02,990 --> 01:19:59,540
um but

1848
01:20:04,430 --> 01:20:03,000
uh yeah I mean the comment is that it's

1849
01:20:08,990 --> 01:20:04,440
a really hard job

1850
01:20:11,689 --> 01:20:09,000
and it's important to get right

1851
01:20:13,490 --> 01:20:11,699
um and yeah there's like a lot goes into

1852
01:20:15,110 --> 01:20:13,500
it but but you're totally right that

1853
01:20:17,270 --> 01:20:15,120
connection is great it's kind of a

1854
01:20:18,890 --> 01:20:17,280
similar process a concept right you're

1855
01:20:21,350 --> 01:20:18,900
trying to remove something really bright

1856
01:20:24,050 --> 01:20:21,360
to get to something really faint and how

1857
01:20:26,209 --> 01:20:24,060
can you remove something really bright

1858
01:20:28,490 --> 01:20:26,219
um you can try modeling it and and

1859
01:20:31,669 --> 01:20:28,500
taking that out because otherwise it's

1860
01:20:36,970 --> 01:20:31,679
uh yeah it just contaminates what you're

1861
01:20:40,910 --> 01:20:39,410
I guess when this comment was made I was

1862
01:20:42,770 --> 01:20:40,920
I was thinking to myself what's the

1863
01:20:45,110 --> 01:20:42,780

contrast ratio between the bright Galaxy

1864
01:20:47,630 --> 01:20:45,120
and the faint galaxies that you can pull

1865
01:20:50,510 --> 01:20:47,640
out because I mean Galaxy modeling can't

1866
01:20:52,189 --> 01:20:50,520
be quite as clean as psf modeling all

1867
01:20:54,350 --> 01:20:52,199
right we've got huge amounts of data for

1868
01:20:56,209 --> 01:20:54,360
point spread function modeling so what's

1869
01:20:57,830 --> 01:20:56,219
the sort of contrast ratio is it a

1870
01:20:59,750 --> 01:20:57,840
thousand to One Ten Thousand to one or

1871
01:21:00,770 --> 01:20:59,760
something that you can get yeah that's a

1872
01:21:02,750 --> 01:21:00,780
good question

1873
01:21:03,649 --> 01:21:02,760
um so one thing that I will say first is

1874
01:21:07,370 --> 01:21:03,659
that

1875
01:21:09,050 --> 01:21:07,380
um again this is it's a it's hard to do

1876
01:21:11,030 --> 01:21:09,060
um one way we can kind of make sure that

1877
01:21:14,390 --> 01:21:11,040
we're doing it right is by simulating

1878
01:21:17,149 --> 01:21:14,400
galaxies and like putting that in like

1879
01:21:19,430 --> 01:21:17,159
in the image and then seeing like after

1880
01:21:22,010 --> 01:21:19,440
we do this modeling do we recover what

1881
01:21:24,410 --> 01:21:22,020
we what we know that simulated Galaxy's

1882
01:21:26,330 --> 01:21:24,420
brightness should be so we have to do a

1883
01:21:30,110 --> 01:21:26,340
lot of these checks

1884
01:21:33,890 --> 01:21:30,120
um the galaxies in the cluster are at

1885
01:21:40,070 --> 01:21:33,900
around between magnitude like 16 and 19.

1886
01:21:42,649 --> 01:21:40,080
so pretty bright and we push really deep

1887
01:21:44,930 --> 01:21:42,659
um so part of that is thanks to Hubble's

1888
01:21:47,689 --> 01:21:44,940

resolution right like we can resolve

1889
01:21:50,510 --> 01:21:47,699
really small things so

1890
01:21:52,430 --> 01:21:50,520
um we're able to find it but we just

1891
01:21:55,669 --> 01:21:52,440
need to make sure that it's not biased

1892
01:21:58,370 --> 01:21:55,679
from that like looming brightness from

1893
01:22:00,169 --> 01:21:58,380
the the really bright galaxies right so

1894
01:22:01,669 --> 01:22:00,179
we're typically able to find it we can

1895
01:22:03,110 --> 01:22:01,679
find more when we take it out but we're

1896
01:22:04,850 --> 01:22:03,120
able when we take out the cluster

1897
01:22:06,470 --> 01:22:04,860
galaxies but we're able to find small

1898
01:22:10,310 --> 01:22:06,480
stuff

1899
01:22:12,950 --> 01:22:10,320
um the the ratio so again between 16 and

1900
01:22:15,110 --> 01:22:12,960
19 is the brightness of the Clusters and

1901
01:22:17,510 --> 01:22:15,120
I would say like the galaxies that we

1902
01:22:21,410 --> 01:22:17,520
can detect behind it are like magnitude

1903
01:22:23,750 --> 01:22:21,420
24 25 yeah

1904
01:22:25,370 --> 01:22:23,760
cool so a factor of several hundred at

1905
01:22:26,689 --> 01:22:25,380
least yeah

1906
01:22:30,970 --> 01:22:26,699
all right

1907
01:22:37,910 --> 01:22:30,980
okay so nobody knows what that actually

1908
01:22:41,090 --> 01:22:39,590
appreciate you Frank I know the audience

1909
01:22:43,490 --> 01:22:41,100
does too

1910
01:22:45,950 --> 01:22:43,500
um okay would you expect to see fewer

1911
01:22:48,229 --> 01:22:45,960
lensing objects the further back in time

1912
01:22:53,090 --> 01:22:48,239
you look as there may there might be

1913
01:22:57,770 --> 01:22:54,169

um

1914
01:22:59,990 --> 01:22:57,780
that's a great question uh let's see so

1915
01:23:02,510 --> 01:23:00,000
if You observe so right now we're not

1916
01:23:05,390 --> 01:23:02,520
really able to observe Galaxy clusters

1917
01:23:07,010 --> 01:23:05,400
very far away Galaxy clusters that we're

1918
01:23:09,110 --> 01:23:07,020
looking at are actually

1919
01:23:15,110 --> 01:23:09,120
pretty close to us

1920
01:23:18,169 --> 01:23:15,120
um a red shift of like 0.3 to 0.5

1921
01:23:21,290 --> 01:23:18,179
um so it's fairly close

1922
01:23:25,250 --> 01:23:21,300
um I guess if you were able to resolve a

1923
01:23:26,930 --> 01:23:25,260
Galaxy cluster that's very very far away

1924
01:23:30,830 --> 01:23:26,940
um I don't know if you would be able to

1925
01:23:34,250 --> 01:23:30,840
to even see much of the lensing but if

1926
01:23:35,689 --> 01:23:34,260
there there's less massive stuff so you

1927
01:23:37,370 --> 01:23:35,699
would still see the sort of micro

1928
01:23:39,350 --> 01:23:37,380
lensing right like you would still see

1929
01:23:41,270 --> 01:23:39,360
lensing no matter what if there's matter

1930
01:23:42,649 --> 01:23:41,280
there you will see lensing and that's

1931
01:23:44,209 --> 01:23:42,659
kind of that's what we were talking

1932
01:23:46,010 --> 01:23:44,219
that's what I was saying earlier about

1933
01:23:47,570 --> 01:23:46,020
weak lensing

1934
01:23:50,930 --> 01:23:47,580
um yeah you probably wouldn't see it as

1935
01:23:52,850 --> 01:23:50,940
pronounced and you might see less of it

1936
01:23:55,070 --> 01:23:52,860
and I think that question also hits on

1937
01:23:57,830 --> 01:23:55,080
upon the fact that it takes time for a

1938
01:24:00,470 --> 01:23:57,840

massive Galaxy cluster to form so I mean

1939
01:24:03,169 --> 01:24:00,480
we don't expect massive Galaxy clusters

1940
01:24:04,610 --> 01:24:03,179
it's redshift seven or eight right but

1941
01:24:06,649 --> 01:24:04,620
you know that's one thing that Webb will

1942
01:24:08,930 --> 01:24:06,659
be able to actually see more clearly

1943
01:24:10,370 --> 01:24:08,940
than Hubble did is when do we first

1944
01:24:12,890 --> 01:24:10,380
start getting these massive Galaxy

1945
01:24:14,930 --> 01:24:12,900
clusters and well of course well how do

1946
01:24:17,229 --> 01:24:14,940
you define what a massive Galaxy cluster

1947
01:24:22,750 --> 01:24:20,270
yeah yes but I mean that they should get

1948
01:24:25,010 --> 01:24:22,760
larger over time because gravity just

1949
01:24:25,750 --> 01:24:25,020
assembles more

1950
01:24:28,610 --> 01:24:25,760
um

1951
01:24:30,830 --> 01:24:28,620
and then there's also the fact that you

1952
01:24:33,290 --> 01:24:30,840
know like uh if I'm if I'm correct sort

1953
01:24:35,030 --> 01:24:33,300
of the the prime lensing distance is

1954
01:24:36,709 --> 01:24:35,040
like twice the distance to the cluster

1955
01:24:39,470 --> 01:24:36,719
right

1956
01:24:41,270 --> 01:24:39,480
so if the further away it is from us

1957
01:24:43,490 --> 01:24:41,280
then the further away the stuff that's

1958
01:24:46,490 --> 01:24:43,500
going to get lensed has to be right

1959
01:24:49,490 --> 01:24:46,500
okay yep okay

1960
01:24:53,990 --> 01:24:51,169
all right so let me grab another

1961
01:24:55,430 --> 01:24:54,000
question here all right

1962
01:24:56,810 --> 01:24:55,440
let me go through my notes see if there

1963
01:24:58,970 --> 01:24:56,820

were any other questions that I noted

1964
01:25:01,610 --> 01:24:58,980
down

1965
01:25:03,290 --> 01:25:01,620
hmm oh I like this this isn't quite your

1966
01:25:04,630 --> 01:25:03,300
food but I'm throwing this to both of

1967
01:25:07,189 --> 01:25:04,640
you anyway

1968
01:25:09,470 --> 01:25:07,199
what would you what would you define the

1969
01:25:12,410 --> 01:25:09,480
difference between a telescope and a

1970
01:25:16,850 --> 01:25:15,050
and why would you need two separate

1971
01:25:22,310 --> 01:25:16,860
instruments aside from capturing

1972
01:25:29,149 --> 01:25:25,010
guess in the in the story that I tried

1973
01:25:31,270 --> 01:25:29,159
to paint a telescope is a subset of the

1974
01:25:34,130 --> 01:25:31,280
collector of the broad collector

1975
01:25:36,410 --> 01:25:34,140
collects photons

1976
01:25:38,630 --> 01:25:36,420
um your eyes I guess you can also call

1977
01:25:39,470 --> 01:25:38,640
collectors

1978
01:25:41,630 --> 01:25:39,480
um

1979
01:25:43,370 --> 01:25:41,640
yeah so telescope in the subset why

1980
01:25:46,669 --> 01:25:43,380
would you need different cameras or

1981
01:25:49,669 --> 01:25:46,679
instruments uh precisely for what you

1982
01:25:53,390 --> 01:25:49,679
mentioned because every detector is

1983
01:25:54,770 --> 01:25:53,400
sensitive to some specific wavelength

1984
01:25:56,930 --> 01:25:54,780
um

1985
01:25:59,209 --> 01:25:56,940
and yeah and we need those wavelengths

1986
01:26:00,890 --> 01:25:59,219
to to say things about our universe

1987
01:26:04,010 --> 01:26:00,900
that's one of the reason I think that

1988
01:26:07,669 --> 01:26:04,020

Hubble and jwst are working so well

1989
01:26:08,810 --> 01:26:07,679
together is they overlap a little but

1990
01:26:10,490 --> 01:26:08,820
they're able to look at different

1991
01:26:12,229 --> 01:26:10,500
wavelengths and give us significantly

1992
01:26:15,350 --> 01:26:12,239
different information even though they

1993
01:26:18,950 --> 01:26:15,360
are both collector type

1994
01:26:21,290 --> 01:26:18,960
of your raise I suppose stations

1995
01:26:23,030 --> 01:26:21,300
um you know that's one of the things you

1996
01:26:25,669 --> 01:26:23,040
refer to with the uh the view space

1997
01:26:27,470 --> 01:26:25,679
sliders where the the Eagle Nebula where

1998
01:26:30,709 --> 01:26:27,480
you can slide from visible to infrared

1999
01:26:32,750 --> 01:26:30,719
and such or take Cassiopeia you could do

2000
01:26:35,330 --> 01:26:32,760
a slider for that it's going from all

2001
01:26:37,129 --> 01:26:35,340
the way from Radio to x-ray having

2002
01:26:38,870 --> 01:26:37,139
multiple telescopes in multiple

2003
01:26:41,090 --> 01:26:38,880
wavelengths is you made this point

2004
01:26:45,050 --> 01:26:41,100
farewell with the galaxy shows you

2005
01:26:49,010 --> 01:26:47,209
so I had a question that I thought

2006
01:26:51,709 --> 01:26:49,020
people might have

2007
01:26:53,030 --> 01:26:51,719
um when you did the original thing with

2008
01:26:55,450 --> 01:26:53,040
the view space and doing the long

2009
01:26:57,649 --> 01:26:55,460
exposure of the Deep Field

2010
01:27:00,129 --> 01:26:57,659
when you started out there there was

2011
01:27:02,870 --> 01:27:00,139
that chip Gap seam and everything okay

2012
01:27:04,610 --> 01:27:02,880
but you didn't really explain how all

2013
01:27:07,610 --> 01:27:04,620

these all these exposures gets rid of

2014
01:27:09,169 --> 01:27:07,620
some of these uh things so uh can you

2015
01:27:11,090 --> 01:27:09,179
talk about the co-atting of images and

2016
01:27:13,669 --> 01:27:11,100
and the dithering and such just so

2017
01:27:16,310 --> 01:27:13,679
people understand how the that you don't

2018
01:27:21,669 --> 01:27:16,320
just open the telescope exposure for 97

2019
01:27:28,310 --> 01:27:25,790
yeah so what you uh people have you know

2020
01:27:31,129 --> 01:27:28,320
again like really talented people have

2021
01:27:34,310 --> 01:27:31,139
come up with different ways to reduce

2022
01:27:37,129 --> 01:27:34,320
the noise in your image and to get your

2023
01:27:38,750 --> 01:27:37,139
your galaxies to shine brightly

2024
01:27:41,629 --> 01:27:38,760
um one way that we get rid of the

2025
01:27:44,890 --> 01:27:41,639
artifacts is by if we move if we take an

2026
01:27:47,390 --> 01:27:44,900
exposure and we're looking at our galaxy

2027
01:27:50,209 --> 01:27:47,400
we can and we know that there's a chip

2028
01:27:53,209 --> 01:27:50,219
Gap or some kind of artifact right in

2029
01:27:55,669 --> 01:27:53,219
the center if we do something called

2030
01:27:57,830 --> 01:27:55,679
dithering if we if we move it a little

2031
01:28:01,310 --> 01:27:57,840
bit up or a little to the side or rotate

2032
01:28:04,669 --> 01:28:01,320
it or rotate our camera a little bit

2033
01:28:08,149 --> 01:28:04,679
um we'll get another exposure of that

2034
01:28:11,209 --> 01:28:08,159
same galaxy but but shifted and so now

2035
01:28:13,430 --> 01:28:11,219
that artifact is in a different part of

2036
01:28:16,189 --> 01:28:13,440
your original image and if you do this

2037
01:28:18,229 --> 01:28:16,199
enough times you can stack those images

2038
01:28:21,110 --> 01:28:18,239

together that were taken kind of

2039
01:28:22,669 --> 01:28:21,120
slightly offset from each other and you

2040
01:28:25,669 --> 01:28:22,679
can get rid of those artifacts because

2041
01:28:27,110 --> 01:28:25,679
they fall on different parts of the

2042
01:28:28,910 --> 01:28:27,120
Galaxy

2043
01:28:32,030 --> 01:28:28,920
um and and they'll fall out once you

2044
01:28:34,129 --> 01:28:32,040
stack those images together

2045
01:28:35,590 --> 01:28:34,139
so this is a place where dithering is a

2046
01:28:38,209 --> 01:28:35,600
good thing

2047
01:28:40,129 --> 01:28:38,219
my wife and I discussed dithering is a

2048
01:28:41,870 --> 01:28:40,139
bad thing when we're trying to choose a

2049
01:28:43,490 --> 01:28:41,880
movie for streaming and she's dithering

2050
01:28:46,070 --> 01:28:43,500
about which toy which one she wants to

2051
01:28:47,390 --> 01:28:46,080
watch but dithering in astronomy is a

2052
01:28:49,910 --> 01:28:47,400
different thing and it's much much much

2053
01:28:55,189 --> 01:28:52,669
yeah Grant you have uh one more question

2054
01:28:57,070 --> 01:28:55,199
yes uh do we want it to be a serious

2055
01:28:59,450 --> 01:28:57,080
question or a personal question

2056
01:29:01,490 --> 01:28:59,460
it's up to you

2057
01:29:03,290 --> 01:29:01,500
you are in control

2058
01:29:05,930 --> 01:29:03,300
I like this one I like this when we're

2059
01:29:08,570 --> 01:29:05,940
doing it hypothetically if you were

2060
01:29:11,270 --> 01:29:08,580
gifted a whole week of personal use with

2061
01:29:13,669 --> 01:29:11,280
any telescope what would you use and

2062
01:29:14,150 --> 01:29:13,679
what would be your specific observation

2063
01:29:16,250 --> 01:29:14,160

Target

2064
01:29:17,709 --> 01:29:16,260
[Music]

2065
01:29:21,110 --> 01:29:17,719
well

2066
01:29:23,510 --> 01:29:21,120
hijack the attack if I could leave

2067
01:29:27,229 --> 01:29:23,520
have directors discretionary time and

2068
01:29:28,490 --> 01:29:27,239
just look at it look at anything

2069
01:29:30,410 --> 01:29:28,500
um

2070
01:29:31,790 --> 01:29:30,420
that's a great question

2071
01:29:33,250 --> 01:29:31,800
yeah what

2072
01:29:36,410 --> 01:29:33,260
the ghoul time

2073
01:29:38,390 --> 01:29:36,420
yeah I don't know like interesting

2074
01:29:40,790 --> 01:29:38,400
enough and prepared for a lot of things

2075
01:29:41,270 --> 01:29:40,800
but not for that for that question

2076
01:29:42,169 --> 01:29:41,280
[Music]

2077
01:29:44,450 --> 01:29:42,179
um

2078
01:29:48,890 --> 01:29:44,460
I guess

2079
01:29:52,129 --> 01:29:48,900
I would look at is it boring to say I

2080
01:29:54,290 --> 01:29:52,139
would look at say kind of like with the

2081
01:29:57,770 --> 01:29:54,300
Hubble Deep Field people did just looked

2082
01:29:59,570 --> 01:29:57,780
at the same point of the sky the whole

2083
01:30:04,070 --> 01:29:59,580
time

2084
01:30:06,830 --> 01:30:04,080
um to see if to see how faint oh how

2085
01:30:09,169 --> 01:30:06,840
faint of galaxies we can get the the

2086
01:30:11,649 --> 01:30:09,179
cool thing about this is that we have

2087
01:30:14,870 --> 01:30:11,659
kind of we have a good good

2088
01:30:16,910 --> 01:30:14,880

understanding of Galaxy uh that are

2089
01:30:19,970 --> 01:30:16,920
close to us

2090
01:30:22,070 --> 01:30:19,980
um but the Way galaxies look and the Way

2091
01:30:24,470 --> 01:30:22,080
galaxies form

2092
01:30:26,390 --> 01:30:24,480
um really far away from us so at the

2093
01:30:29,629 --> 01:30:26,400
beginning of the universe look very

2094
01:30:32,629 --> 01:30:29,639
different or or substantially different

2095
01:30:34,129 --> 01:30:32,639
let's say a lot of them do so you can

2096
01:30:37,189 --> 01:30:34,139
have so right now we think about

2097
01:30:39,649 --> 01:30:37,199
ellipticals and spirals right

2098
01:30:45,729 --> 01:30:39,659
um very young galaxies typically look

2099
01:30:48,890 --> 01:30:45,739
like uh blobs they're like irregular

2100
01:30:51,229 --> 01:30:48,900
and right now there's like ongoing

2101
01:30:54,350 --> 01:30:51,239
science about these really faint

2102
01:30:56,410 --> 01:30:54,360
galaxies these really young galaxies and

2103
01:31:00,790 --> 01:30:56,420
trying to understand will they break

2104
01:31:03,229 --> 01:31:00,800
Lambda cold dark matter or will they not

2105
01:31:06,830 --> 01:31:03,239
does it match what we expect the

2106
01:31:09,050 --> 01:31:06,840
beginning of our universe to do

2107
01:31:11,689 --> 01:31:09,060
so I think that that would be my answer

2108
01:31:13,970 --> 01:31:11,699
and maybe yeah I think that would be my

2109
01:31:15,709 --> 01:31:13,980
answer just to look even farther uh

2110
01:31:18,169 --> 01:31:15,719
stare at a part of space for a really

2111
01:31:20,570 --> 01:31:18,179
long time and see what comes out of it

2112
01:31:23,209 --> 01:31:20,580
well I don't know if you will get that

2113
01:31:25,550 --> 01:31:23,219

time but eventually the web is going to

2114
01:31:27,530 --> 01:31:25,560
do that in in in in in some way at least

2115
01:31:29,810 --> 01:31:27,540
in aggregate over over the years we will

2116
01:31:32,450 --> 01:31:29,820
get uh some great stuff and I too look

2117
01:31:34,070 --> 01:31:32,460
forward to that um you know the uh

2118
01:31:36,129 --> 01:31:34,080
question is how quickly can galaxies

2119
01:31:38,750 --> 01:31:36,139
form how quickly can these clusters form

2120
01:31:40,189 --> 01:31:38,760
and it's really fun that in the next

2121
01:31:41,810 --> 01:31:40,199
decade we're going to get those kind of

2122
01:31:48,350 --> 01:31:41,820
answers so

2123
01:31:53,450 --> 01:31:49,970
there's just another

2124
01:31:56,689 --> 01:31:53,460
um if we can figure out a way to look at

2125
01:31:59,990 --> 01:31:56,699
um really before like the CMB right so

2126
01:32:02,090 --> 01:32:00,000
before 200 000 years uh when the

2127
01:32:03,890 --> 01:32:02,100
universe was 300 000 years old that

2128
01:32:06,350 --> 01:32:03,900
would be really cool

2129
01:32:08,390 --> 01:32:06,360
um and and things that are are able to I

2130
01:32:10,610 --> 01:32:08,400
mean this is not Imaging anymore this is

2131
01:32:13,070 --> 01:32:10,620
like purely like hypothetical but things

2132
01:32:15,470 --> 01:32:13,080
that are able to escape from before the

2133
01:32:18,530 --> 01:32:15,480
CMB are like neutrinos for example they

2134
01:32:21,410 --> 01:32:18,540
don't go craft in the like ionized

2135
01:32:23,209 --> 01:32:21,420
plasma that photons do and so if we can

2136
01:32:24,410 --> 01:32:23,219
like observe like neutrinos for a really

2137
01:32:27,310 --> 01:32:24,420
long time maybe we can say something

2138
01:32:31,250 --> 01:32:27,320

about it the even earlier universe

2139
01:32:34,129 --> 01:32:31,260
that's another like sci-fi uh sci-fi yes

2140
01:32:37,270 --> 01:32:34,139
right now neutrino astrophysics is um

2141
01:32:41,270 --> 01:32:37,280
yeah neutrino observational astronomy is

2142
01:32:43,070 --> 01:32:41,280
science fiction for now

2143
01:32:46,669 --> 01:32:43,080
all right thank you Amanda that was

2144
01:32:50,270 --> 01:32:46,679
wonderful we have run out of time

2145
01:32:54,290 --> 01:32:50,280
um so well thank you and everybody next

2146
01:32:56,810 --> 01:32:54,300
month uh is not until June 22nd we will

2147
01:32:59,090 --> 01:32:56,820
have two talks on the Nancy Grace Roman

2148
01:33:02,149 --> 01:32:59,100
Space Telescope one talk about Nancy

2149
01:33:04,070 --> 01:33:02,159
Grace Roman and the second talk about

2150
01:33:06,649 --> 01:33:04,080
the mission and the science that will be