

1
00:00:00,000 --> 00:00:04,259
on the way in there's still plenty on

2
00:00:02,040 --> 00:00:08,400
the table over there get them on the way

3
00:00:04,259 --> 00:00:11,699
out our talk tonight a trip through the

4
00:00:08,400 --> 00:00:14,009
light fantastic by Frank summers of

5
00:00:11,699 --> 00:00:18,059
space telescope and I'll introduce him

6
00:00:14,009 --> 00:00:21,390
in just a minute let's say upcoming our

7
00:00:18,059 --> 00:00:22,979
talks I as I said I'm trying to get

8
00:00:21,390 --> 00:00:25,830
somebody from New Horizons to do the

9
00:00:22,980 --> 00:00:27,868
October talk but I haven't haven't had

10
00:00:25,829 --> 00:00:29,969
much success I was on vacation a lot

11
00:00:27,868 --> 00:00:32,729
this month so I am a little bit behind

12
00:00:29,969 --> 00:00:34,679
on things November we have mario livio

13
00:00:32,729 --> 00:00:36,209
and i know I looked in my email today

14
00:00:34,679 --> 00:00:38,460
and he still hadn't given me a talk

15
00:00:36,210 --> 00:00:40,350
title so I have to contact him tomorrow

16
00:00:38,460 --> 00:00:43,350
and say Mario give me a talk for

17
00:00:40,350 --> 00:00:46,829
November and in December Lucy McFadden

18
00:00:43,350 --> 00:00:49,558
from Goddard Space Flight Center one of

19
00:00:46,829 --> 00:00:51,570
the lead people on the dawn mission that

20
00:00:49,558 --> 00:00:54,659
went past Vesta a couple years ago went

21
00:00:51,570 --> 00:00:57,359
to Ceres is currently orbiting series

22
00:00:54,659 --> 00:00:59,669
will give a talk on dawn a journey to

23
00:00:57,359 --> 00:01:01,710
the early solar system in December I'm

24
00:00:59,670 --> 00:01:04,320
extremely excited to have Lucy come up

25
00:01:01,710 --> 00:01:07,159
here in December you want the latest

26
00:01:04,319 --> 00:01:10,438
information you can go to our website

27
00:01:07,159 --> 00:01:13,320
and you can do Hubble site Dargo talks

28
00:01:10,438 --> 00:01:15,118
or if you just put Hubble public lecture

29

00:01:13,319 --> 00:01:17,039
in your favorite search engine this

30
00:01:15,118 --> 00:01:19,438
should be the page that you get which

31
00:01:17,040 --> 00:01:22,860
lists our upcoming lectures and it also

32
00:01:19,438 --> 00:01:26,158
has a link to our wonderful STScl web

33
00:01:22,859 --> 00:01:28,950
casting team archive our web casting

34
00:01:26,159 --> 00:01:31,770
team has been as the archive of them all

35
00:01:28,950 --> 00:01:34,290
the way back to 2005 you've got ten

36
00:01:31,769 --> 00:01:36,719
years of public lecture and goodness to

37
00:01:34,290 --> 00:01:39,210
explore so if you've got a free weekend

38
00:01:36,719 --> 00:01:43,259
or a free few weeks you can watch them

39
00:01:39,209 --> 00:01:46,709
all back to 2005 all right if you would

40
00:01:43,259 --> 00:01:48,329
like announcements you sign up and this

41
00:01:46,709 --> 00:01:52,169
is new because we started this in the

42
00:01:48,328 --> 00:01:54,478
spring nail list that STScl dot edu okay

43
00:01:52,170 --> 00:01:56,700

and you look for public lecture

44

00:01:54,478 --> 00:01:58,200

announced I think there's only one or

45

00:01:56,700 --> 00:02:00,269

two mail lists that are public on that

46

00:01:58,200 --> 00:02:04,170

anyways just provide your email address

47

00:02:00,269 --> 00:02:06,569

and you will not be getting any spam or

48

00:02:04,170 --> 00:02:09,030

if you would like to have us sign you up

49

00:02:06,569 --> 00:02:12,598

for it you can contact us at public

50

00:02:09,030 --> 00:02:13,229

lecture at STScI edu you can sign up the

51

00:02:12,598 --> 00:02:15,539

announcements

52

00:02:13,229 --> 00:02:17,969

or if you have comments or questions you

53

00:02:15,539 --> 00:02:21,239

would like to ask please send them to

54

00:02:17,969 --> 00:02:23,489

that email address we have social media

55

00:02:21,239 --> 00:02:25,560

for those who do it of course we have

56

00:02:23,489 --> 00:02:26,550

facebook we have at two different

57

00:02:25,560 --> 00:02:29,848

Twitter feeds

58
00:02:26,550 --> 00:02:31,319
we have Google+ we have Pinterest for

59
00:02:29,848 --> 00:02:34,919
those who do that I think we probably

60
00:02:31,318 --> 00:02:36,750
even have oh what's the other one

61
00:02:34,919 --> 00:02:39,539
Instagram I don't know if we have that

62
00:02:36,750 --> 00:02:43,019
I'm sorry I only do so much i I do

63
00:02:39,539 --> 00:02:45,298
Facebook and Google+ and Twitter for my

64
00:02:43,019 --> 00:02:47,789
stuff unfortunately not as much as I

65
00:02:45,299 --> 00:02:49,620
should I just have so much stuff to do

66
00:02:47,789 --> 00:02:52,348
it's hard to keep up doing a lot of

67
00:02:49,620 --> 00:02:53,280
social media but I will try and keep up

68
00:02:52,348 --> 00:02:55,619
all right

69
00:02:53,280 --> 00:02:58,318
the observatory tonight the weather is

70
00:02:55,620 --> 00:03:00,989
permitting I got an email saying yes the

71
00:02:58,318 --> 00:03:02,578
observatory is on so after the lecture

72
00:03:00,989 --> 00:03:04,049
if you would like to go across the

73
00:03:02,579 --> 00:03:06,030
street to the Maryland Space Grant

74
00:03:04,049 --> 00:03:08,129
Observatory which looks something like

75
00:03:06,030 --> 00:03:11,879
this up on the physics and astronomy

76
00:03:08,129 --> 00:03:14,430
building across the street the person I

77
00:03:11,879 --> 00:03:16,469
believe it's Duncan is it Duncan he's

78
00:03:14,430 --> 00:03:18,840
not here right now obviously we'll be

79
00:03:16,469 --> 00:03:20,939
here afterwards come down meet here as a

80
00:03:18,840 --> 00:03:22,620
group and walk over across the street as

81
00:03:20,939 --> 00:03:24,060
a group you cannot go over on your own

82
00:03:22,620 --> 00:03:26,579
you have to go over with the group

83
00:03:24,060 --> 00:03:30,090
because he's got to let folks in certain

84
00:03:26,579 --> 00:03:31,799
doors etc okay all right normally I

85
00:03:30,090 --> 00:03:34,739
would be doing news from the universe

86

00:03:31,799 --> 00:03:37,430
for September 2015 but as is my

87
00:03:34,739 --> 00:03:40,289
tradition whenever I give the talk I

88
00:03:37,430 --> 00:03:41,730
don't have enough time to prepare a news

89
00:03:40,289 --> 00:03:44,159
summary it takes a little while to do

90
00:03:41,729 --> 00:03:47,068
that so as I promised I will make sure

91
00:03:44,159 --> 00:03:49,530
you get your full dose of Pluto next

92
00:03:47,068 --> 00:03:52,560
month okay alright we get lots of Pluto

93
00:03:49,530 --> 00:03:56,370
next month now I get to introduce our

94
00:03:52,560 --> 00:03:58,259
featured speaker and when I give the

95
00:03:56,370 --> 00:04:01,409
talk alright how many people are new

96
00:03:58,259 --> 00:04:02,909
here haven't been here before we got

97
00:04:01,409 --> 00:04:04,109
about a dozen alright so let me do my

98
00:04:02,909 --> 00:04:06,568
introduction the rest of you can close

99
00:04:04,109 --> 00:04:08,219
your eyes for a second I'm an astronomer

100
00:04:06,568 --> 00:04:12,509

in the office of public outreach here

101

00:04:08,219 --> 00:04:14,609

I've been here for 14 years I work on

102

00:04:12,509 --> 00:04:17,459

all things Hubble and weather

103

00:04:14,610 --> 00:04:19,859

they press releases or websites or

104

00:04:17,459 --> 00:04:22,319

educational activities or working with

105

00:04:19,858 --> 00:04:25,279

planet area my favorite things to do are

106

00:04:22,319 --> 00:04:29,009

astronomy visualizations right and so I

107

00:04:25,279 --> 00:04:30,750

you know got a history doing I'm an

108

00:04:29,009 --> 00:04:33,060

astronomer but actually I'm a

109

00:04:30,750 --> 00:04:35,009

professional outreach astronomer I have

110

00:04:33,060 --> 00:04:37,259

been doing outreach only for over a

111

00:04:35,009 --> 00:04:40,230

decade I've been about two decades worth

112

00:04:37,259 --> 00:04:41,310

of outreach astronomy so I don't do

113

00:04:40,230 --> 00:04:44,370

research anymore

114

00:04:41,310 --> 00:04:46,470

now but the rest of you when I do these

115
00:04:44,370 --> 00:04:48,629
talks since some of you who've been here

116
00:04:46,470 --> 00:04:50,669
have been here longer than I have coming

117
00:04:48,629 --> 00:04:52,259
for public lecture series I like to show

118
00:04:50,668 --> 00:04:55,229
you something that you didn't you may

119
00:04:52,259 --> 00:04:58,649
not remember about me so our speech

120
00:04:55,230 --> 00:05:00,600
speaker tonight when he was young this

121
00:04:58,649 --> 00:05:14,609
is a picture of the astrophysicist as a

122
00:05:00,600 --> 00:05:16,950
young man this is me in 1983 was it this

123
00:05:14,610 --> 00:05:19,770
is the paso doble costume I was a

124
00:05:16,949 --> 00:05:21,779
competitive ice dancer this photograph

125
00:05:19,769 --> 00:05:25,019
by David Leonardi the photographer of

126
00:05:21,779 --> 00:05:27,329
all the great ice skating stars and my

127
00:05:25,019 --> 00:05:29,939
skating partner sand sandy McGee

128
00:05:27,329 --> 00:05:33,180
Sanderlin McGee I was a competitive ice

129
00:05:29,939 --> 00:05:36,418
dancer for I don't know about a decade

130
00:05:33,180 --> 00:05:41,579
or so and I retired at the ripe old age

131
00:05:36,418 --> 00:05:44,490
of 20 or so I was ranked tenth in the

132
00:05:41,579 --> 00:05:46,019
United States when I retired so I like

133
00:05:44,490 --> 00:05:47,370
to show pictures like this to say hey

134
00:05:46,019 --> 00:05:49,259
you know what you can be an

135
00:05:47,370 --> 00:05:52,740
astrophysicist geek but you can also

136
00:05:49,259 --> 00:05:55,379
have an artistic background okay and so

137
00:05:52,740 --> 00:05:58,168
I was a competitive ice dancer before I

138
00:05:55,379 --> 00:06:00,269
became an astrophysicist the two are not

139
00:05:58,168 --> 00:06:03,839
mutually exclusive you have at least one

140
00:06:00,269 --> 00:06:10,668
example of that all right so let us

141
00:06:03,839 --> 00:06:10,668
switch windows and go to tonight's talk

142
00:06:11,240 --> 00:06:17,189
all right so tonight's talk is a trip

143

00:06:14,459 --> 00:06:19,199
through the light fantastic and as I

144
00:06:17,189 --> 00:06:21,300
said in my previous intro before this

145
00:06:19,199 --> 00:06:23,550
this is a talk that I have given to

146
00:06:21,300 --> 00:06:25,379
educators I've spiced it up a bit and

147
00:06:23,550 --> 00:06:26,980
changed it around just a little bit in

148
00:06:25,379 --> 00:06:31,899
terms to present it for the public

149
00:06:26,980 --> 00:06:35,050
but it is really it's a fundamental idea

150
00:06:31,899 --> 00:06:36,459
of the electromagnetic spectrum and the

151
00:06:35,050 --> 00:06:39,129
electromagnetic spectrum that underlies

152
00:06:36,459 --> 00:06:41,439
astronomy but also underlies lots of

153
00:06:39,129 --> 00:06:44,529
other sciences because it is used in

154
00:06:41,439 --> 00:06:47,410
physics it is used underlying chemistry

155
00:06:44,529 --> 00:06:50,349
and in biology understanding the idea of

156
00:06:47,410 --> 00:06:53,380
life and when you think about astronomy

157
00:06:50,350 --> 00:06:56,350

you might have that romantic notion that

158

00:06:53,379 --> 00:06:58,569

idea of the astronomer standing at the

159

00:06:56,350 --> 00:07:00,370

telescope looking through his giant

160

00:06:58,569 --> 00:07:03,310

telescope perhaps up on top of a

161

00:07:00,370 --> 00:07:06,850

mountaintop and that's just not how it

162

00:07:03,310 --> 00:07:10,030

is anymore that's how it was 150 years

163

00:07:06,850 --> 00:07:13,600

ago when this engraving was done this is

164

00:07:10,029 --> 00:07:15,549

from night from 1848 this is the

165

00:07:13,600 --> 00:07:17,860

telescope at the Cincinnati observatory

166

00:07:15,550 --> 00:07:18,840

which at the time was the second largest

167

00:07:17,860 --> 00:07:21,430

in the country

168

00:07:18,839 --> 00:07:24,819

Cincinnati second largest telescope in

169

00:07:21,430 --> 00:07:26,860

the country at that time but what do

170

00:07:24,819 --> 00:07:28,719

astronomers look like these days do they

171

00:07:26,860 --> 00:07:31,270

go they go up to the mountaintops yes

172
00:07:28,720 --> 00:07:34,060
but what do they do they sit in front of

173
00:07:31,269 --> 00:07:36,129
banks of computers okay they don't put

174
00:07:34,060 --> 00:07:38,620
their eye up to the telescope it's not

175
00:07:36,129 --> 00:07:40,269
that poetic anymore we have CCD

176
00:07:38,620 --> 00:07:42,310
detectors that do all that for them

177
00:07:40,269 --> 00:07:44,169
everything becomes digital it comes to

178
00:07:42,310 --> 00:07:45,970
the computers and you sit there at the

179
00:07:44,170 --> 00:07:47,980
keyboard with your notes and everything

180
00:07:45,970 --> 00:07:51,520
and very carefully taking taking

181
00:07:47,980 --> 00:07:54,970
advantage of it also astronomers have

182
00:07:51,519 --> 00:07:58,209
used other wavelengths now all right we

183
00:07:54,970 --> 00:07:59,950
do radio observations okay giant radio

184
00:07:58,209 --> 00:08:02,289
dishes and where are you gonna put your

185
00:07:59,949 --> 00:08:05,139
eye on this hmm are you actually gonna

186
00:08:02,290 --> 00:08:06,610
go there well well actually you know the

187
00:08:05,139 --> 00:08:09,519
Jodie Foster character from the movie

188
00:08:06,610 --> 00:08:11,319
contact notwithstanding and that the

189
00:08:09,519 --> 00:08:14,229
idea was that she was actually listening

190
00:08:11,319 --> 00:08:17,230
to the radio signals that were being

191
00:08:14,230 --> 00:08:17,950
detected by these dishes yeah doesn't

192
00:08:17,230 --> 00:08:20,800
happen okay

193
00:08:17,949 --> 00:08:24,279
nice poetic idea for the movie yeah

194
00:08:20,800 --> 00:08:26,980
doesn't happen so when we are looking in

195
00:08:24,279 --> 00:08:29,139
wavelengths that are I can't see of

196
00:08:26,980 --> 00:08:31,900
course we have to be doing detected uh

197
00:08:29,139 --> 00:08:34,418
if you're using detectors to do this and

198
00:08:31,899 --> 00:08:36,639
one of the great advances of 20th

199
00:08:34,418 --> 00:08:39,639
century astronomy was a hundred years

200

00:08:36,639 --> 00:08:41,069
ago all we were doing was looking with

201
00:08:39,639 --> 00:08:43,620
our eyes okay

202
00:08:41,070 --> 00:08:46,170
and we started to take photography in

203
00:08:43,620 --> 00:08:48,019
the late 1800s but we were using visible

204
00:08:46,169 --> 00:08:51,539
light astronomy

205
00:08:48,019 --> 00:08:54,328
until we started to exploit the other

206
00:08:51,539 --> 00:08:56,730
wavelengths radio waves came first but

207
00:08:54,328 --> 00:08:59,969
we now do astronomy across the entire

208
00:08:56,730 --> 00:09:01,680
electromagnetic spectrum and so that

209
00:08:59,970 --> 00:09:04,680
what is what this trip through the light

210
00:09:01,679 --> 00:09:06,929
fantastic is about is to show you the

211
00:09:04,679 --> 00:09:10,799
variety of ways that we look at the

212
00:09:06,929 --> 00:09:12,328
universe and remind you of the different

213
00:09:10,799 --> 00:09:14,939
things that we can see using the

214
00:09:12,328 --> 00:09:17,609

different types of light so let's begin

215

00:09:14,940 --> 00:09:19,940

with visible light visible light is of

216

00:09:17,610 --> 00:09:24,120

course the light that the human eye sees

217

00:09:19,940 --> 00:09:27,029

right and it is also the light that is

218

00:09:24,120 --> 00:09:30,139

given off most by our Sun this of course

219

00:09:27,028 --> 00:09:33,000

is not a coincidence if you want to see

220

00:09:30,139 --> 00:09:35,579

in the light of the Sun well it helps if

221

00:09:33,000 --> 00:09:37,860

your detector is tuned to the

222

00:09:35,578 --> 00:09:40,979

wavelengths to given off by that Sun

223

00:09:37,860 --> 00:09:44,699

here are three blackpot for blackbody

224

00:09:40,980 --> 00:09:46,829

curves of various stars so our Sun is

225

00:09:44,698 --> 00:09:48,659

approximately a 6,000 degree Kelvin star

226

00:09:46,828 --> 00:09:51,479

so it's this curve in here in the middle

227

00:09:48,659 --> 00:09:54,778

and the upper curve at 7,000 degrees

228

00:09:51,480 --> 00:09:57,060

Kelvin is a hotter star the 5000-year

229
00:09:54,778 --> 00:09:59,578
Kelvin is just a little cooler than the

230
00:09:57,059 --> 00:10:02,609
Sun and then the 3,000 degree Kelvin is

231
00:09:59,578 --> 00:10:05,039
a red dwarf much cooler than the Sun all

232
00:10:02,610 --> 00:10:06,539
right and so this is the emission all

233
00:10:05,039 --> 00:10:10,318
right the amount of emission on the

234
00:10:06,539 --> 00:10:12,958
y-axis by wavelength on the x-axis for

235
00:10:10,318 --> 00:10:15,149
various stars and where does the Sun

236
00:10:12,958 --> 00:10:17,219
peak right here in the visible

237
00:10:15,149 --> 00:10:19,318
wavelengths all right the hotter stars

238
00:10:17,220 --> 00:10:21,089
can move toward the ultraviolet the

239
00:10:19,318 --> 00:10:24,958
cooler stars actually have their peaks

240
00:10:21,089 --> 00:10:28,110
out in the infrared so visible light is

241
00:10:24,958 --> 00:10:30,479
where our Sun emits most of its light

242
00:10:28,110 --> 00:10:33,740
and if you know anything about our Sun

243
00:10:30,480 --> 00:10:39,269
you know that we call it a yellow star

244
00:10:33,740 --> 00:10:42,839
however this is wrong okay our Sun may

245
00:10:39,269 --> 00:10:46,409
be called a yellow star but it is not a

246
00:10:42,839 --> 00:10:48,899
yellow star we do not see a yellow star

247
00:10:46,409 --> 00:10:51,448
you have been lied to your entire life

248
00:10:48,899 --> 00:10:52,830
because they draw a blue sky with a

249
00:10:51,448 --> 00:10:55,049
yellow Sun in it okay

250
00:10:52,830 --> 00:10:57,480
that's not what the Sun looks like if

251
00:10:55,049 --> 00:10:59,609
you look at the Sun and you measure its

252
00:10:57,480 --> 00:11:02,370
color as perceived by the human eye

253
00:10:59,610 --> 00:11:05,129
you take that blackbody curve you map it

254
00:11:02,370 --> 00:11:08,450
through the RGB cones of your eye the

255
00:11:05,129 --> 00:11:12,720
color you'll get is something like this

256
00:11:08,450 --> 00:11:15,810
our Sun is mostly white okay it may be

257

00:11:12,720 --> 00:11:17,550
called a yellow star but in its white

258
00:11:15,809 --> 00:11:19,469
light actually you know if you do it

259
00:11:17,549 --> 00:11:21,929
really carefully I I see a little bit of

260
00:11:19,470 --> 00:11:23,700
peach in it okay there's it's mostly

261
00:11:21,929 --> 00:11:26,009
white with a little bit of peach now

262
00:11:23,700 --> 00:11:28,500
this color comes from my monitor to the

263
00:11:26,009 --> 00:11:30,360
projector to the screen etc so there's

264
00:11:28,500 --> 00:11:33,139
no real color fidelity here I can't show

265
00:11:30,360 --> 00:11:37,230
you exactly exact color matching here

266
00:11:33,139 --> 00:11:39,958
but basically the Sun is mostly white

267
00:11:37,230 --> 00:11:43,680
okay now of course white light itself

268
00:11:39,958 --> 00:11:46,528
can be broken down into all the colors

269
00:11:43,679 --> 00:11:48,419
of the rainbow okay that red orange

270
00:11:46,528 --> 00:11:50,909
yellow green blue violet of that rainbow

271
00:11:48,419 --> 00:11:52,828

is really just breaking up the sun's

272

00:11:50,909 --> 00:11:54,958

light into its component wavelengths to

273

00:11:52,828 --> 00:11:57,989

see those various colors

274

00:11:54,958 --> 00:11:59,578

alright so Sun emits white light white

275

00:11:57,990 --> 00:12:01,980

light is actually composed of many

276

00:11:59,578 --> 00:12:05,088

different colors now we see a lot of

277

00:12:01,980 --> 00:12:08,009

things in astronomy using visible light

278

00:12:05,089 --> 00:12:10,020

so we look at the moon and here's a

279

00:12:08,009 --> 00:12:13,019

gorgeous picture of the full moon out

280

00:12:10,019 --> 00:12:16,500

over the ocean but the moon doesn't emit

281

00:12:13,019 --> 00:12:19,319

light okay the moon only reflects the

282

00:12:16,500 --> 00:12:20,940

light of the Sun okay it's important to

283

00:12:19,320 --> 00:12:23,430

recognize that the Sun emits the light

284

00:12:20,940 --> 00:12:27,329

but the moon only sees by reflected

285

00:12:23,429 --> 00:12:29,278

light Jupiter also invisible light we

286
00:12:27,328 --> 00:12:31,649
don't actually see it we it does not

287
00:12:29,278 --> 00:12:33,838
emit visible light but it reflects the

288
00:12:31,649 --> 00:12:35,839
light of the Sun Jupiter as I'll show

289
00:12:33,839 --> 00:12:39,209
you a little bit later actually does

290
00:12:35,839 --> 00:12:41,339
emit some infrared light it actually is

291
00:12:39,208 --> 00:12:43,828
glowing in infrared but it is not

292
00:12:41,339 --> 00:12:46,670
glowing in visible light it is just

293
00:12:43,828 --> 00:12:50,069
reflecting the light of the Sun

294
00:12:46,669 --> 00:12:52,049
asteroids they're not glowing they're

295
00:12:50,070 --> 00:12:53,810
just reflecting the light of Sun what

296
00:12:52,049 --> 00:12:56,309
about comets

297
00:12:53,809 --> 00:12:58,229
comets are really cool they look like

298
00:12:56,309 --> 00:12:59,669
they're actually glowing like they're

299
00:12:58,230 --> 00:13:02,879
actually emitting light but again

300
00:12:59,669 --> 00:13:04,528
they're also just reflecting light okay

301
00:13:02,879 --> 00:13:06,610
so most of the things we see in the

302
00:13:04,528 --> 00:13:10,149
solar system are just reflecting

303
00:13:06,610 --> 00:13:12,970
the light of the Sun the Sun is our is

304
00:13:10,149 --> 00:13:14,879
our source of visible light if we look

305
00:13:12,970 --> 00:13:16,629
at other stars are they emitting light

306
00:13:14,879 --> 00:13:18,278
yes of course

307
00:13:16,629 --> 00:13:21,959
right but I like to show the Pleiades

308
00:13:18,278 --> 00:13:25,600
because all this blue gas around here

309
00:13:21,958 --> 00:13:27,938
it's called a reflection nebula that gas

310
00:13:25,600 --> 00:13:29,499
is not glowing because it's hot it's

311
00:13:27,938 --> 00:13:32,078
glowing because it's reflecting the

312
00:13:29,499 --> 00:13:34,178
light of the stars around it

313
00:13:32,078 --> 00:13:36,458
the plea DS are relatively young star

314

00:13:34,178 --> 00:13:38,139
cluster the gas from which they're that

315
00:13:36,458 --> 00:13:40,359
which they were formed hasn't fully

316
00:13:38,139 --> 00:13:43,360
dissipated away and so you're seeing

317
00:13:40,360 --> 00:13:46,239
some of the gas around them

318
00:13:43,360 --> 00:13:49,298
reflecting the light of the stars if

319
00:13:46,239 --> 00:13:51,278
instead you go to the Orion Nebula well

320
00:13:49,298 --> 00:13:54,428
the hot stars at the core of the Orion

321
00:13:51,278 --> 00:13:56,708
Nebula have heated this gas so the gas

322
00:13:54,428 --> 00:13:58,720
and this nebula is glowing it's heated

323
00:13:56,708 --> 00:14:00,308
up to high enough temperature that the

324
00:13:58,720 --> 00:14:02,459
gas itself is glowing

325
00:14:00,308 --> 00:14:05,379
alright so it's important to recognize

326
00:14:02,458 --> 00:14:07,268
as an astronomer when something is

327
00:14:05,379 --> 00:14:08,619
actually glowing in that light and when

328
00:14:07,269 --> 00:14:11,619

it is just reflecting the light around

329

00:14:08,619 --> 00:14:15,489

it we have to analyze the situation

330

00:14:11,619 --> 00:14:19,959

and for things like a supernova remnant

331

00:14:15,489 --> 00:14:21,220

this is the Crab supernova the interior

332

00:14:19,958 --> 00:14:23,888

of this was actually heated to millions

333

00:14:21,220 --> 00:14:26,829

of degrees this is a visible light image

334

00:14:23,889 --> 00:14:28,720

of specific wavelengths detecting

335

00:14:26,828 --> 00:14:30,969

specific elements in the out and the

336

00:14:28,720 --> 00:14:33,999

external parts of the supernova remnant

337

00:14:30,970 --> 00:14:37,028

of this of course is also gas that is

338

00:14:33,999 --> 00:14:39,819

glowing there also gas that is absorbing

339

00:14:37,028 --> 00:14:42,100

that is easily seen in this image of the

340

00:14:39,818 --> 00:14:43,479

Whirlpool Galaxy so we have these pink

341

00:14:42,100 --> 00:14:45,639

regions which are the star forming

342

00:14:43,480 --> 00:14:47,829

regions we have the blue stars and the

343
00:14:45,639 --> 00:14:50,619
yellow stars on in here but we also see

344
00:14:47,828 --> 00:14:52,868
this marbling this dark stuff here well

345
00:14:50,619 --> 00:14:55,329
that's gasps that's not emitting light

346
00:14:52,869 --> 00:14:57,129
that is absorbing the light it's

347
00:14:55,328 --> 00:14:59,918
blocking the light so we have bright

348
00:14:57,129 --> 00:15:02,499
nebula we have reflection nebula we have

349
00:14:59,918 --> 00:15:04,088
emission nebula we also have dark nebula

350
00:15:02,499 --> 00:15:07,119
that we can't see that's actually

351
00:15:04,089 --> 00:15:09,369
blocking the light of other stars so

352
00:15:07,119 --> 00:15:11,980
when we consider visible light our base

353
00:15:09,369 --> 00:15:14,619
spacing how do we remember it well

354
00:15:11,980 --> 00:15:17,230
probably in school you learn something

355
00:15:14,619 --> 00:15:19,649
like Roy G Boop now how many of you

356
00:15:17,230 --> 00:15:22,090
actually had indigo in there VI D

357
00:15:19,649 --> 00:15:24,340
yes the older kids even the younger ones

358
00:15:22,090 --> 00:15:28,840
okay your textbooks having been updated

359
00:15:24,340 --> 00:15:31,899
lately ad they uh-huh I don't know when

360
00:15:28,840 --> 00:15:35,290
indigo was removed from this but it was

361
00:15:31,899 --> 00:15:39,970
many decades ago I thought a lot of

362
00:15:35,289 --> 00:15:42,370
people learned roy gb IV the indigo was

363
00:15:39,970 --> 00:15:45,250
no longer used so it's just red orange

364
00:15:42,370 --> 00:15:47,080
yellow green blue and violet for the

365
00:15:45,250 --> 00:15:49,870
colors of the spectrum of visible light

366
00:15:47,080 --> 00:15:52,720
and the important point about this is

367
00:15:49,870 --> 00:15:54,929
recognizing that these are all the same

368
00:15:52,720 --> 00:15:57,070
phenomenon of light but they have one

369
00:15:54,929 --> 00:15:58,659
characteristic different and you can

370
00:15:57,070 --> 00:16:01,470
consider that characteristic of energy

371

00:15:58,659 --> 00:16:04,629
that red is lower energy than violet or

372
00:16:01,470 --> 00:16:06,580
frequency or wavelength okay and

373
00:16:04,629 --> 00:16:09,850
wavelength actually increases the

374
00:16:06,580 --> 00:16:11,440
opposite direction of frequency now on

375
00:16:09,850 --> 00:16:13,570
this next slide I'm going to get into an

376
00:16:11,440 --> 00:16:15,850
equation this is something that I

377
00:16:13,570 --> 00:16:17,110
definitely do for the teachers but since

378
00:16:15,850 --> 00:16:19,029
some teachers will probably watch this

379
00:16:17,110 --> 00:16:22,019
in the archive let's I want to put it up

380
00:16:19,029 --> 00:16:24,009
there okay so for the fundamental

381
00:16:22,019 --> 00:16:26,350
equations alright the fundamental

382
00:16:24,009 --> 00:16:29,019
properties of light to understand is

383
00:16:26,350 --> 00:16:30,460
that it it's a wave okay all right and

384
00:16:29,019 --> 00:16:32,500
the energy of the wave is proportional

385
00:16:30,460 --> 00:16:35,769

to the frequency the higher the

386

00:16:32,500 --> 00:16:38,980

frequency the more energy you can have a

387

00:16:35,769 --> 00:16:41,529

slow frequency your low energy all right

388

00:16:38,980 --> 00:16:43,899

then you get up that's higher energy

389

00:16:41,529 --> 00:16:45,789

makes sense right and the

390

00:16:43,899 --> 00:16:47,110

proportionality constant is called

391

00:16:45,789 --> 00:16:50,319

Planck's constant that's what this

392

00:16:47,110 --> 00:16:54,580

little H is here this is the this V is

393

00:16:50,320 --> 00:16:56,620

traditionally a Greek letter nu for the

394

00:16:54,580 --> 00:16:59,230

oscillations per second measured in

395

00:16:56,620 --> 00:17:01,659

hertz okay and then the other thing to

396

00:16:59,230 --> 00:17:03,700

recognize is the other equation that we

397

00:17:01,659 --> 00:17:06,069

need to know for life is that frequency

398

00:17:03,700 --> 00:17:08,319

times wavelength is equal to the speed

399

00:17:06,069 --> 00:17:10,689

of light okay they're inversely

400
00:17:08,319 --> 00:17:12,819
proportional to one another so we've got

401
00:17:10,690 --> 00:17:15,000
this frequency which is nu the

402
00:17:12,819 --> 00:17:17,948
wavelength is represented by lambda

403
00:17:15,000 --> 00:17:19,480
together they combine to make the speed

404
00:17:17,949 --> 00:17:22,209
of light and this is constant throughout

405
00:17:19,480 --> 00:17:24,789
it okay so that as frequency goes up

406
00:17:22,209 --> 00:17:26,529
wavelength has to go down as wavelength

407
00:17:24,789 --> 00:17:28,059
goes up frequency has to go out they're

408
00:17:26,529 --> 00:17:30,670
inversely proportional to one another

409
00:17:28,059 --> 00:17:33,200
all right so if you want to make a real

410
00:17:30,670 --> 00:17:42,110
geek joke somebody says hey what's

411
00:17:33,200 --> 00:17:44,210
do you say C over lambda it takes a

412
00:17:42,109 --> 00:17:45,769
while for that one synced yes okay so

413
00:17:44,210 --> 00:17:47,960
that's your physics joke for the night

414
00:17:45,769 --> 00:17:53,179
there are actually a few more jokes here

415
00:17:47,960 --> 00:17:55,579
leave that alone so when we think about

416
00:17:53,179 --> 00:17:57,889
this visible spectrum we're now taking

417
00:17:55,579 --> 00:18:00,138
an increasing wavelength here okay so

418
00:17:57,888 --> 00:18:01,479
longer wavelengths are over here all

419
00:18:00,138 --> 00:18:04,219
right so we reversed it from the ROYGBIV

420
00:18:01,480 --> 00:18:06,288
all right but the visible spectrum is

421
00:18:04,220 --> 00:18:09,528
only a tiny part of the entire

422
00:18:06,288 --> 00:18:11,058
electromagnetic spectrum okay so those

423
00:18:09,528 --> 00:18:12,528
are the different properties of visible

424
00:18:11,058 --> 00:18:15,079
light but they are also the same

425
00:18:12,528 --> 00:18:17,210
properties of the entire electromagnetic

426
00:18:15,079 --> 00:18:20,509
spectrum which includes gamma rays

427
00:18:17,210 --> 00:18:23,600
x-rays ultraviolet infrared microwave

428

00:18:20,509 --> 00:18:25,990
and radio waves the whole point is that

429
00:18:23,599 --> 00:18:28,548
all of these are the exact same

430
00:18:25,990 --> 00:18:30,558
phenomenon just having different

431
00:18:28,548 --> 00:18:33,349
wavelengths or different frequencies or

432
00:18:30,558 --> 00:18:36,829
different energies okay so when we think

433
00:18:33,349 --> 00:18:38,750
of the electromagnetic spectrum we don't

434
00:18:36,829 --> 00:18:40,428
think that x-rays are something totally

435
00:18:38,750 --> 00:18:42,648
crazy different from the normal visible

436
00:18:40,429 --> 00:18:45,559
light or that radio waves are something

437
00:18:42,648 --> 00:18:48,199
you know unfathomable comparative is

438
00:18:45,558 --> 00:18:50,658
like they're all the same thing but

439
00:18:48,200 --> 00:18:53,028
these have shorter wavelength higher

440
00:18:50,659 --> 00:18:55,100
frequency and larger energy these have

441
00:18:53,028 --> 00:18:58,250
longer wavelength lower frequency and

442
00:18:55,099 --> 00:19:00,469

smaller energies that's the point of the

443

00:18:58,250 --> 00:19:02,210

arc magnetic spectrum so let's take a

444

00:19:00,470 --> 00:19:04,220

trip across this electromagnetic

445

00:19:02,210 --> 00:19:07,009

spectrum and see what we see we're gonna

446

00:19:04,220 --> 00:19:10,069

start with the low energy and the long

447

00:19:07,009 --> 00:19:12,829

wavelengths radio waves okay wavelengths

448

00:19:10,069 --> 00:19:14,480

roughly and I gotta say these divisions

449

00:19:12,829 --> 00:19:16,638

aren't set in stone

450

00:19:14,480 --> 00:19:18,558

here are some rough rough divisions the

451

00:19:16,638 --> 00:19:21,589

wavelength is longer than a meter okay

452

00:19:18,558 --> 00:19:25,308

so this is a wave about that long okay

453

00:19:21,589 --> 00:19:27,319

and longer and longer this is why we

454

00:19:25,308 --> 00:19:30,379

need giant radio dishes okay

455

00:19:27,319 --> 00:19:33,859

the frequency is low frequency less than

456

00:19:30,380 --> 00:19:36,950

300 million Hertz yeah 300 million Hertz

457
00:19:33,859 --> 00:19:38,719
is low frequency folks okay could we get

458
00:19:36,950 --> 00:19:40,340
up to other things it'll be and it'll

459
00:19:38,720 --> 00:19:42,440
get unfathomable and actually I'll stop

460
00:19:40,339 --> 00:19:45,099
using frequencies so when we think of

461
00:19:42,440 --> 00:19:48,130
radio in our everyday life well we think

462
00:19:45,099 --> 00:19:50,619
radio this is actually a multiband radio

463
00:19:48,130 --> 00:19:52,840
that has not only your familiar AM and

464
00:19:50,619 --> 00:19:55,989
FM channels but also a bunch of

465
00:19:52,839 --> 00:20:00,220
shortwave and and other wave channels

466
00:19:55,990 --> 00:20:02,470
across here if we look at the AM n FM

467
00:20:00,220 --> 00:20:05,380
that you're used to a M stands for

468
00:20:02,470 --> 00:20:08,650
amplitude modulation and that's 540 to

469
00:20:05,380 --> 00:20:13,000
1600 kilohertz okay Killough meaning a

470
00:20:08,650 --> 00:20:16,150
thousand so the most listened-to AM

471
00:20:13,000 --> 00:20:21,220
radio station in the country is WABC AM

472
00:20:16,150 --> 00:20:23,890
770 that's 770 kilohertz or 770,000

473
00:20:21,220 --> 00:20:25,929
Hertz so the oscillations are going

474
00:20:23,890 --> 00:20:28,600
seven hundred seventy thousand times a

475
00:20:25,929 --> 00:20:30,880
second in order for you to listen to

476
00:20:28,599 --> 00:20:32,709
that from that radio station that's a

477
00:20:30,880 --> 00:20:35,380
lot of frequencies okay that's a lot of

478
00:20:32,710 --> 00:20:37,600
up and down FM radio which uses

479
00:20:35,380 --> 00:20:41,080
frequency modulation to send it's a

480
00:20:37,599 --> 00:20:45,428
signal of the sound is 88 to 108

481
00:20:41,079 --> 00:20:47,408
megahertz alright and again the this is

482
00:20:45,429 --> 00:20:49,000
a New York City radio station we have

483
00:20:47,409 --> 00:20:51,750
another New York City radio station

484
00:20:49,000 --> 00:20:54,460
that's number one in the rankings for FM

485

00:20:51,750 --> 00:20:56,829
WPLJ ninety five point five megahertz

486
00:20:54,460 --> 00:21:00,190
which is ninety five and a half million

487
00:20:56,829 --> 00:21:02,349
Hertz alright so these are the

488
00:21:00,190 --> 00:21:04,090
frequencies that you're used to you're

489
00:21:02,349 --> 00:21:06,038
working with them all the time whenever

490
00:21:04,089 --> 00:21:08,139
you turn your radio dial your getting

491
00:21:06,038 --> 00:21:11,048
either hundreds of thousands or millions

492
00:21:08,140 --> 00:21:13,929
of cycles a second when you turn on that

493
00:21:11,048 --> 00:21:15,519
radio dial astronomers when we turn on

494
00:21:13,929 --> 00:21:18,759
that radio down while I showed you one

495
00:21:15,519 --> 00:21:21,308
giant radio dish we can also tune it

496
00:21:18,759 --> 00:21:24,279
even larger this is the Very Large Array

497
00:21:21,308 --> 00:21:26,379
in Socorro New Mexico which has a whole

498
00:21:24,279 --> 00:21:30,250
bunch of these dishes

499
00:21:26,380 --> 00:21:33,700

alright arranged out in a Y formation so

500

00:21:30,250 --> 00:21:36,519

we can set them apart to synthesize a

501

00:21:33,700 --> 00:21:37,990

telescope that's even larger as I said

502

00:21:36,519 --> 00:21:40,210

radio waves we're talking a metre or

503

00:21:37,990 --> 00:21:42,759

larger this we're talking things that

504

00:21:40,210 --> 00:21:44,558

can be set across distances of miles and

505

00:21:42,759 --> 00:21:47,440

actually astronomy uses something called

506

00:21:44,558 --> 00:21:50,619

very large baseline interferometry where

507

00:21:47,440 --> 00:21:53,950

we have astronomy radio dishes across

508

00:21:50,619 --> 00:21:55,899

the globe acting as a single telescope

509

00:21:53,950 --> 00:21:57,080

to try and do really really large

510

00:21:55,900 --> 00:21:59,660

baseline

511

00:21:57,079 --> 00:22:01,970

Ronna me okay so radio waves can we can

512

00:21:59,660 --> 00:22:05,090

it can get up as far as you can set a

513

00:22:01,970 --> 00:22:08,000

standard pace for them what do we see

514
00:22:05,089 --> 00:22:08,869
well here is a picture of Jupiter in

515
00:22:08,000 --> 00:22:11,599
visible light

516
00:22:08,869 --> 00:22:14,179
okay now Jupiter has a very large

517
00:22:11,599 --> 00:22:16,279
magnetic field that's actually a very

518
00:22:14,180 --> 00:22:19,220
it's actually the size of its magnetic

519
00:22:16,279 --> 00:22:21,740
field is larger than our entire Sun and

520
00:22:19,220 --> 00:22:23,870
in terms of it but inside that magnetic

521
00:22:21,740 --> 00:22:26,720
field there are electrons bouncing up

522
00:22:23,869 --> 00:22:28,549
and down those magnetic field lines and

523
00:22:26,720 --> 00:22:32,269
when we look in radio waves

524
00:22:28,549 --> 00:22:35,659
Jupiter looks like this where you can

525
00:22:32,269 --> 00:22:37,819
see those magnetic field lines all right

526
00:22:35,660 --> 00:22:40,640
and what we call the Decca metric radio

527
00:22:37,819 --> 00:22:43,129
wavelengths of the electrons bouncing up

528
00:22:40,640 --> 00:22:45,700
and down inside those magnetic field

529
00:22:43,130 --> 00:22:50,450
lines so the magnetic field of Jupiter

530
00:22:45,700 --> 00:22:52,340
emits a lot in radio the Whirlpool

531
00:22:50,450 --> 00:22:54,440
Galaxy the galaxy that I showed you

532
00:22:52,339 --> 00:22:57,049
before all right this is what it looks

533
00:22:54,440 --> 00:22:59,570
like in visible light I'm gonna shrink

534
00:22:57,049 --> 00:23:01,639
it down to this size this is a Hubble

535
00:22:59,569 --> 00:23:05,029
image with visible light and I'm gonna

536
00:23:01,640 --> 00:23:07,100
show you what we see in radio waves in

537
00:23:05,029 --> 00:23:08,509
radio noise you can see the visible

538
00:23:07,099 --> 00:23:11,929
light you can see these beautiful spiral

539
00:23:08,509 --> 00:23:14,750
pattern but in radio waves we can see

540
00:23:11,930 --> 00:23:16,789
the gas that extends off of it all right

541
00:23:14,750 --> 00:23:20,240
you can see that there's a lot more gas

542

00:23:16,789 --> 00:23:23,299
stretching out here this is the neutral

543
00:23:20,240 --> 00:23:25,400
hydrogen gas that you can see that

544
00:23:23,299 --> 00:23:29,180
there's evidence here of a lot more

545
00:23:25,400 --> 00:23:31,250
dynamic ISM happening due to what we can

546
00:23:29,180 --> 00:23:32,690
see in the radio waves so what this is

547
00:23:31,250 --> 00:23:34,970
this is actually a composite image with

548
00:23:32,690 --> 00:23:37,400
a ground-based visible light composited

549
00:23:34,970 --> 00:23:40,339
onto the radio ways and you can see that

550
00:23:37,400 --> 00:23:42,620
there are in radio we can detect a lot

551
00:23:40,339 --> 00:23:46,819
more gas extending well beyond the

552
00:23:42,619 --> 00:23:49,309
visible extent of a Whirlpool Galaxy one

553
00:23:46,819 --> 00:23:52,669
other example for radio we'll talk about

554
00:23:49,309 --> 00:23:55,099
a supernova remnant okay so this is the

555
00:23:52,670 --> 00:23:57,440
supernova remnant Cassiopeia A the

556
00:23:55,099 --> 00:24:00,289

result of the star that just blew itself

557

00:23:57,440 --> 00:24:03,140

apart okay so in visible light we can

558

00:24:00,289 --> 00:24:06,829

see that shell the shell of material of

559

00:24:03,140 --> 00:24:09,320

a star that blew itself apart in radio

560

00:24:06,829 --> 00:24:09,939

waves we can see a lot more complex

561

00:24:09,319 --> 00:24:13,450

structure

562

00:24:09,940 --> 00:24:15,159

all right because visible light gets

563

00:24:13,450 --> 00:24:17,230

things that are at thousands of degrees

564

00:24:15,159 --> 00:24:19,059

or tens of thousands of degrees if you

565

00:24:17,230 --> 00:24:20,740

are heated up to thousands to tens of

566

00:24:19,058 --> 00:24:23,740

thousands of degrees you are hot enough

567

00:24:20,740 --> 00:24:25,538

and you radiate invisible light radio

568

00:24:23,740 --> 00:24:27,878

waves will take the lower energy stuff

569

00:24:25,538 --> 00:24:31,000

and see a lot more structure throughout

570

00:24:27,878 --> 00:24:33,219

the surrounding of that supernova

571
00:24:31,000 --> 00:24:35,648
remnant oh what I actually I forgot that

572
00:24:33,220 --> 00:24:37,389
I had one more one more of these the

573
00:24:35,648 --> 00:24:40,750
other thing that's fun to do is to take

574
00:24:37,388 --> 00:24:43,778
a visible light image and compare it to

575
00:24:40,750 --> 00:24:46,028
a radio image now here is a composite

576
00:24:43,778 --> 00:24:48,638
image from Hubble and the Very Large

577
00:24:46,028 --> 00:24:50,740
Array so what we've got here is we've

578
00:24:48,638 --> 00:24:53,740
got a galaxy a giant elliptical galaxy

579
00:24:50,740 --> 00:24:56,169
at the core of that giant elliptical

580
00:24:53,740 --> 00:24:59,319
galaxy there's a super massive black

581
00:24:56,169 --> 00:25:03,250
hole and that supermassive black hole is

582
00:24:59,319 --> 00:25:05,439
spewing out high-energy radiation okay

583
00:25:03,250 --> 00:25:07,808
around that supermassive black hole

584
00:25:05,440 --> 00:25:09,580
they're oppositely directed jets spewing

585
00:25:07,808 --> 00:25:11,798
out from that supermassive black hole

586
00:25:09,579 --> 00:25:13,720
and that although that supermassive

587
00:25:11,798 --> 00:25:16,869
black hole is on the scale of a solar

588
00:25:13,720 --> 00:25:18,819
system those Jets of radiation extend

589
00:25:16,869 --> 00:25:22,569
not only across the solar system scale

590
00:25:18,819 --> 00:25:26,168
not only across stellar scales but

591
00:25:22,569 --> 00:25:29,829
across the entire galaxy and outside the

592
00:25:26,169 --> 00:25:31,929
galaxy as seen in this radial image so

593
00:25:29,829 --> 00:25:34,000
there is something in here that's on

594
00:25:31,929 --> 00:25:36,669
order of a solar system scale spewing

595
00:25:34,000 --> 00:25:39,929
out Jets that extend five times further

596
00:25:36,669 --> 00:25:44,740
than the visible extent of this galaxy

597
00:25:39,929 --> 00:25:46,929
so if you want to see the power of a

598
00:25:44,740 --> 00:25:49,960
supermassive black hole you don't use

599

00:25:46,929 --> 00:25:52,480
visible light you go to radio where you

600
00:25:49,960 --> 00:25:54,940
see these radio galaxies and these giant

601
00:25:52,480 --> 00:25:56,620
radio lobes spewed out from the

602
00:25:54,940 --> 00:26:00,100
supermassive black holes at the core of

603
00:25:56,619 --> 00:26:01,808
these galaxies kind of cool all right

604
00:26:00,099 --> 00:26:04,359
radio wavelengths get us all sorts of

605
00:26:01,808 --> 00:26:05,408
fun stuff but that's not the only place

606
00:26:04,359 --> 00:26:08,500
we're gonna go we're gonna go to

607
00:26:05,409 --> 00:26:10,600
microwaves now radio waves were longer

608
00:26:08,500 --> 00:26:12,579
than a meter for microwaves we're going

609
00:26:10,599 --> 00:26:14,378
to go from a meter down to about a

610
00:26:12,579 --> 00:26:17,378
millimeter okay so it's about a factor

611
00:26:14,378 --> 00:26:19,569
of a thousand in scale per millimeter

612
00:26:17,378 --> 00:26:21,158
and here we're getting frequency in

613
00:26:19,569 --> 00:26:23,480

again a factor of thousand in frequency

614

00:26:21,159 --> 00:26:25,370
from 300 million Hertz to 300

615

00:26:23,480 --> 00:26:27,740
gigahertz all right you might have heard

616

00:26:25,369 --> 00:26:30,469
the phrase gigahertz used in some some

617

00:26:27,740 --> 00:26:32,420
things in particularly you might have

618

00:26:30,470 --> 00:26:34,490
heard it related to what do we think of

619

00:26:32,420 --> 00:26:37,640
microwaves right where do you go

620

00:26:34,490 --> 00:26:40,390
microwave ovens all right and microwave

621

00:26:37,640 --> 00:26:42,590
ovens heat your food by basically

622

00:26:40,390 --> 00:26:44,540
heating the water all right it's

623

00:26:42,589 --> 00:26:46,369
dielectric heating it causes basically

624

00:26:44,539 --> 00:26:48,829
the water molecules to spin because

625

00:26:46,369 --> 00:26:50,599
water molecules are not C₂h symmetry symmetric

626

00:26:48,829 --> 00:26:52,099
in terms of their electric charge

627

00:26:50,599 --> 00:26:54,319
they're electrically neutral but that's

628
00:26:52,099 --> 00:26:57,589
not symmetry and you can get those water

629
00:26:54,319 --> 00:27:00,769
molecules to spin by either exciting

630
00:26:57,589 --> 00:27:03,889
them with a 2.5 gigahertz or a 12

631
00:27:00,769 --> 00:27:05,480
centimeter so it's about 12 centers

632
00:27:03,890 --> 00:27:08,600
that's about 12 centimeter a 12

633
00:27:05,480 --> 00:27:10,549
centimeter wavelength or a 915 megahertz

634
00:27:08,599 --> 00:27:13,099
which is about a 32 centimeter

635
00:27:10,549 --> 00:27:14,690
wavelength okay using that you can

636
00:27:13,099 --> 00:27:16,879
excite though the water molecules in

637
00:27:14,690 --> 00:27:19,759
your food which causes them to heat up

638
00:27:16,880 --> 00:27:22,660
all right so microwave ovens do use

639
00:27:19,759 --> 00:27:24,379
microwaves to heat your food

640
00:27:22,660 --> 00:27:26,420
astronomers when we want to look at

641
00:27:24,380 --> 00:27:28,550
microwaves well we use something similar

642
00:27:26,420 --> 00:27:31,880
to what we use for radio but they can be

643
00:27:28,549 --> 00:27:33,829
smaller dishes this is the Atacama Large

644
00:27:31,880 --> 00:27:36,920
millimeter ray or otherwise known as

645
00:27:33,829 --> 00:27:40,849
Alma it's on the atacama plateau in

646
00:27:36,920 --> 00:27:44,300
Chile which is up at like 15,000 feet

647
00:27:40,849 --> 00:27:47,869
all right and it's incredibly dry and

648
00:27:44,299 --> 00:27:50,569
this is a place where you actually you

649
00:27:47,869 --> 00:27:52,369
can't breathe very well okay I like to

650
00:27:50,569 --> 00:27:55,519
make the joke that astronomers now need

651
00:27:52,369 --> 00:27:57,529
Sherpas in order to do astronomy because

652
00:27:55,519 --> 00:27:59,809
the astronomers you know can't think

653
00:27:57,529 --> 00:28:01,069
very well this numbers when they go to

654
00:27:59,809 --> 00:28:03,409
this telescope they don't go to this

655
00:28:01,069 --> 00:28:06,139
telescope they go down the mountain and

656

00:28:03,410 --> 00:28:08,330
there are about 9,000 feet okay the same

657
00:28:06,140 --> 00:28:10,130
is true on Mauna Kea when you go to that

658
00:28:08,329 --> 00:28:11,839
telescope you're at 9,000 feet the

659
00:28:10,130 --> 00:28:15,680
telescope's are much much higher above

660
00:28:11,839 --> 00:28:19,129
you but only the workers who trained

661
00:28:15,680 --> 00:28:21,350
trained and can use this are working up

662
00:28:19,130 --> 00:28:23,000
there the astronomers all stayed down so

663
00:28:21,349 --> 00:28:25,969
you really don't go to the telescopes

664
00:28:23,000 --> 00:28:28,279
well when they're this high but Alma has

665
00:28:25,970 --> 00:28:30,259
produced and we'll be producing some

666
00:28:28,279 --> 00:28:32,420
amazing images I'm going to show you one

667
00:28:30,259 --> 00:28:33,990
of its most amazing coming forward so

668
00:28:32,420 --> 00:28:36,600
let's return to that

669
00:28:33,990 --> 00:28:38,400
Whirlpool Galaxy and take a look in

670
00:28:36,599 --> 00:28:40,049

millimeter wavelengths okay

671

00:28:38,400 --> 00:28:42,120
so when we look in millimeter

672

00:28:40,049 --> 00:28:45,539
wavelengths you can see all that dark

673

00:28:42,119 --> 00:28:47,699
gas in here all right that gas is dark

674

00:28:45,539 --> 00:28:51,359
with visible light and millimeter

675

00:28:47,700 --> 00:28:54,179
wavelengths it shows up really strongly

676

00:28:51,359 --> 00:28:58,079
what we're seeing in here is the really

677

00:28:54,179 --> 00:29:01,380
dense cold gas that very densest coldest

678

00:28:58,079 --> 00:29:03,928
gas along those spiral arms these are

679

00:29:01,380 --> 00:29:06,090
the densest cloud regions along inside

680

00:29:03,929 --> 00:29:08,540
inside this galaxy so if I go back here

681

00:29:06,089 --> 00:29:11,369
you can see the densest regions

682

00:29:08,539 --> 00:29:14,250
all right the densest regions an

683

00:29:11,369 --> 00:29:16,558
invisible light all right show up as the

684

00:29:14,250 --> 00:29:18,808
brightest regions in millimeter

685
00:29:16,558 --> 00:29:22,859
wavelengths so if we want to study the

686
00:29:18,808 --> 00:29:25,980
molecular gas in a galaxy we go to the

687
00:29:22,859 --> 00:29:28,349
the millimeter microwave region in order

688
00:29:25,980 --> 00:29:32,029
to see the details of what's going on

689
00:29:28,349 --> 00:29:35,579
inside we can also do the same thing for

690
00:29:32,029 --> 00:29:40,769
just around stars now this is a Hubble

691
00:29:35,579 --> 00:29:43,769
image of the disc around a star 107 1 4

692
00:29:40,769 --> 00:29:45,029
6 HD 107 146 I always have to read that

693
00:29:43,769 --> 00:29:48,029
because I can't memorize these phone

694
00:29:45,029 --> 00:29:50,549
numbers now what we've done here is that

695
00:29:48,029 --> 00:29:53,639
we blocked out the light of the star in

696
00:29:50,549 --> 00:29:56,159
order to see that the material in a disc

697
00:29:53,640 --> 00:29:59,220
so this is basically a base on disc a

698
00:29:56,160 --> 00:30:01,830
thin disc around a forming star all

699
00:29:59,220 --> 00:30:04,500
right and in that disc is where we

700
00:30:01,829 --> 00:30:07,529
expect to see planets form all right and

701
00:30:04,500 --> 00:30:10,440
so Hubble can see that these discs

702
00:30:07,529 --> 00:30:13,889
exists but it can't see a lot of the

703
00:30:10,440 --> 00:30:17,308
details microwaves can actually show us

704
00:30:13,890 --> 00:30:21,330
a lot more so this is a star called HL

705
00:30:17,308 --> 00:30:23,670
Tauri it is Hubble's view of it and HL

706
00:30:21,329 --> 00:30:25,829
Tauri is in here and it's all shrouded

707
00:30:23,670 --> 00:30:28,558
by all sorts of dust we really can't see

708
00:30:25,829 --> 00:30:31,500
much about HL Tauri in visible light but

709
00:30:28,558 --> 00:30:35,940
if you go to the Alma array and you take

710
00:30:31,500 --> 00:30:39,119
a picture you get this image here this

711
00:30:35,940 --> 00:30:41,070
is not an artist's illustration all

712
00:30:39,119 --> 00:30:42,808
right this looks to me like it's an

713

00:30:41,069 --> 00:30:45,299
artist drew these concentric circles

714
00:30:42,808 --> 00:30:46,019
this is an actual image from the Alma

715
00:30:45,299 --> 00:30:50,129
array

716
00:30:46,019 --> 00:30:52,558
looking at a disk around HL Tauri and we

717
00:30:50,130 --> 00:30:56,400
can see that there are these wonderful

718
00:30:52,558 --> 00:30:59,460
beautiful concentric disk gaps in the

719
00:30:56,400 --> 00:31:01,530
disk around HL Tauri this is exactly

720
00:30:59,460 --> 00:31:04,259
what we expect from planet formation

721
00:31:01,529 --> 00:31:06,660
when you start to form planets you get

722
00:31:04,259 --> 00:31:08,970
gravitational perturbations and the

723
00:31:06,660 --> 00:31:11,519
material flows onto these planets and

724
00:31:08,970 --> 00:31:13,799
they will pull out these gaps inside

725
00:31:11,519 --> 00:31:15,240
these disks now we can't say that

726
00:31:13,799 --> 00:31:17,579
there's a planet inside every one of

727
00:31:15,240 --> 00:31:18,960

these gaps because of course what we get

728

00:31:17,579 --> 00:31:21,779

is not only just the gaps where the

729

00:31:18,960 --> 00:31:23,370

planets form but you also get gaps in

730

00:31:21,779 --> 00:31:25,859

terms of resonances gravitational

731

00:31:23,369 --> 00:31:28,379

resonances in that same disk so if

732

00:31:25,859 --> 00:31:30,689

you're you know if if this thing orbits

733

00:31:28,380 --> 00:31:32,670

one twice for every time this orbits

734

00:31:30,690 --> 00:31:34,558

once you get a resonance there and you

735

00:31:32,670 --> 00:31:36,900

can actually get a gap not where the

736

00:31:34,558 --> 00:31:40,230

planet is but where a resonance for that

737

00:31:36,900 --> 00:31:42,330

planet is so in using the idea the Alma

738

00:31:40,230 --> 00:31:44,009

array they're able to get this amazing

739

00:31:42,329 --> 00:31:46,259

image this is one of the first images

740

00:31:44,009 --> 00:31:47,819

released from Alma and shows that there

741

00:31:46,259 --> 00:31:50,819

should be some amazing more things

742
00:31:47,819 --> 00:31:52,769
coming up one other thing that I have to

743
00:31:50,819 --> 00:31:55,169
go through from microwaves is taking a

744
00:31:52,769 --> 00:31:57,089
look at some all-sky photographs now I

745
00:31:55,170 --> 00:31:59,308
want to prep you for that by showing you

746
00:31:57,089 --> 00:32:01,379
an image of Earth okay

747
00:31:59,308 --> 00:32:03,149
we know that Earth is a globe but when

748
00:32:01,380 --> 00:32:04,710
we want to put it onto a map we

749
00:32:03,150 --> 00:32:07,470
generally have to distort it to put it

750
00:32:04,710 --> 00:32:09,720
onto a map right the Mercator projection

751
00:32:07,470 --> 00:32:12,150
is all things all sorts of distorted

752
00:32:09,720 --> 00:32:14,190
Greenland looks way too huge so when we

753
00:32:12,150 --> 00:32:15,840
try to take a sphere and put it on a

754
00:32:14,190 --> 00:32:18,299
flat piece of paper we use various

755
00:32:15,839 --> 00:32:21,089
projections this is one called an eighth

756
00:32:18,299 --> 00:32:24,269
off projection okay which takes a sphere

757
00:32:21,089 --> 00:32:24,629
and roughly distorts things less all

758
00:32:24,269 --> 00:32:26,429
right

759
00:32:24,630 --> 00:32:28,770
creates a nice oval out of the sphere

760
00:32:26,429 --> 00:32:30,630
and distorts things a little less than

761
00:32:28,769 --> 00:32:31,619
other projections all right so

762
00:32:30,630 --> 00:32:34,470
everything I'm going to show you from

763
00:32:31,619 --> 00:32:37,169
here on in is not the earth but it's the

764
00:32:34,470 --> 00:32:40,950
entire sphere of the sky projected in

765
00:32:37,170 --> 00:32:44,360
this 8th off projection alright so now I

766
00:32:40,950 --> 00:32:50,580
have for you an amazing image an image

767
00:32:44,359 --> 00:32:54,449
worthy of two two Nobel prizes okay this

768
00:32:50,579 --> 00:32:59,178
next image led to two Nobel prizes you

769
00:32:54,450 --> 00:32:59,179
ready for it there it is

770

00:33:02,359 --> 00:33:08,939
that's two Nobel prizes worth okay let

771
00:33:05,669 --> 00:33:13,110
me explain this is an image of the

772
00:33:08,940 --> 00:33:15,330
Cosmic Microwave Background okay as we

773
00:33:13,109 --> 00:33:18,658
look out into space we're also looking

774
00:33:15,329 --> 00:33:20,609
back into time okay when the universe

775
00:33:18,659 --> 00:33:24,120
was really really young and really

776
00:33:20,609 --> 00:33:26,908
really small and really really hot it

777
00:33:24,119 --> 00:33:28,219
actually glowed and the light from what

778
00:33:26,909 --> 00:33:31,590
we call the surface of last scattering

779
00:33:28,220 --> 00:33:33,470
has free streamed across the universe it

780
00:33:31,589 --> 00:33:35,908
started out at several thousand degrees

781
00:33:33,470 --> 00:33:38,399
but because of the expansion of the

782
00:33:35,909 --> 00:33:41,850
universe it has cooled down to about

783
00:33:38,398 --> 00:33:44,308
three degrees all right and the house

784
00:33:41,849 --> 00:33:47,639

that it's at three degrees that means

785

00:33:44,308 --> 00:33:51,990

it's emission is now observable in the

786

00:33:47,640 --> 00:33:55,770

microwaves so Penzias and Wilson at Bell

787

00:33:51,990 --> 00:33:58,169

Labs found a radio signal in their

788

00:33:55,769 --> 00:34:01,710

microwave antenna that they couldn't

789

00:33:58,169 --> 00:34:03,509

identify and it was uniform across the

790

00:34:01,710 --> 00:34:07,319

entire sky which is why this is such a

791

00:34:03,509 --> 00:34:11,159

boring image k but this is the remnant

792

00:34:07,319 --> 00:34:13,409

radiation of the early universe from

793

00:34:11,159 --> 00:34:16,588

about half a million years 400,000 years

794

00:34:13,409 --> 00:34:19,559

after the Big Bang as the universe

795

00:34:16,588 --> 00:34:22,230

expanded and cooled there's a surface at

796

00:34:19,559 --> 00:34:24,119

which the last light leaves and that

797

00:34:22,230 --> 00:34:26,128

light comes across universe and it's

798

00:34:24,119 --> 00:34:27,570

available in every direction because in

799

00:34:26,128 --> 00:34:30,029

every direction we're looking out into

800

00:34:27,570 --> 00:34:32,338

space we're looking back into time we're

801

00:34:30,030 --> 00:34:35,909

seeing the relics of the early universe

802

00:34:32,338 --> 00:34:37,769

and so just getting this discovering

803

00:34:35,909 --> 00:34:39,750

this three degree Kelvin microwave

804

00:34:37,769 --> 00:34:42,838

background radiation was worthy of a

805

00:34:39,750 --> 00:34:44,969

Nobel Prize the second Nobel Prize comes

806

00:34:42,838 --> 00:34:47,668

when you look deeper into this image so

807

00:34:44,969 --> 00:34:49,259

let's take that average that average

808

00:34:47,668 --> 00:34:51,148

three degrees I'd like to point seven

809

00:34:49,260 --> 00:34:53,550

three degrees and we'll subtract it off

810

00:34:51,148 --> 00:34:55,679

to see what we get okay so we get taken

811

00:34:53,550 --> 00:34:58,380

rid of the average and we come and we

812

00:34:55,679 --> 00:35:00,059

get a cosmic yin-yang symbol well that's

813
00:34:58,380 --> 00:35:01,650
not actually what you're seeing what

814
00:35:00,059 --> 00:35:03,329
you're seeing here is it's a little bit

815
00:35:01,650 --> 00:35:05,608
hotter in this direction a little bit

816
00:35:03,329 --> 00:35:07,529
colder in this direction because the

817
00:35:05,608 --> 00:35:09,088
Milky Way galaxy is moving through the

818
00:35:07,530 --> 00:35:11,730
universe okay

819
00:35:09,088 --> 00:35:14,130
so that actually is what

820
00:35:11,730 --> 00:35:16,230
we're seeing is as actually the Doppler

821
00:35:14,130 --> 00:35:18,269
shift of the galaxy moving through the

822
00:35:16,230 --> 00:35:19,980
universe so this isn't really any any

823
00:35:18,269 --> 00:35:21,989
cosmic signal it's just due to the

824
00:35:19,980 --> 00:35:25,170
motion of our galaxy so let's subtract

825
00:35:21,989 --> 00:35:27,509
that off and what do we see we see this

826
00:35:25,170 --> 00:35:30,090
big red line across here well that

827

00:35:27,510 --> 00:35:32,790
actually is the emission from stuff

828
00:35:30,090 --> 00:35:33,780
inside our galaxy that has nothing to do

829
00:35:32,789 --> 00:35:35,730
with the cosmos

830
00:35:33,780 --> 00:35:37,950
that's just our galaxy so we work really

831
00:35:35,730 --> 00:35:39,690
really hard to model the emission of our

832
00:35:37,949 --> 00:35:42,809
galaxy in microwaves and then we

833
00:35:39,690 --> 00:35:44,480
subtract that off and what do we get we

834
00:35:42,809 --> 00:35:47,130
get the result from the Coby satellite

835
00:35:44,480 --> 00:35:49,079
okay so you're taking out the average

836
00:35:47,130 --> 00:35:50,849
you've taken out the Doppler motion of

837
00:35:49,079 --> 00:35:52,739
the galaxy you've taken out the emission

838
00:35:50,849 --> 00:35:56,909
from the galaxy and what you are left

839
00:35:52,739 --> 00:35:58,729
with is the tiny variations in the

840
00:35:56,909 --> 00:36:01,829
cosmic microwave background radiation

841
00:35:58,730 --> 00:36:04,108

all right so you're seeing the universe

842

00:36:01,829 --> 00:36:06,329

as it was half a million years after the

843

00:36:04,108 --> 00:36:09,029

Big Bang and now you're seeing that it

844

00:36:06,329 --> 00:36:11,819

has tiny little variations those tiny

845

00:36:09,030 --> 00:36:13,859

little variations are actually density

846

00:36:11,820 --> 00:36:15,840

variations it's a little bit more dense

847

00:36:13,858 --> 00:36:18,480

here a little bit less dense there

848

00:36:15,840 --> 00:36:20,608

you're seeing the seeds of structure

849

00:36:18,480 --> 00:36:22,679

formation these are the tiny tiny seeds

850

00:36:20,608 --> 00:36:24,929

of structure formation that will then

851

00:36:22,679 --> 00:36:27,809

grow into galaxies and clusters of

852

00:36:24,929 --> 00:36:30,059

galaxies and superclusters of galaxies

853

00:36:27,809 --> 00:36:32,250

and this is so important it's not just

854

00:36:30,059 --> 00:36:34,559

the Coby satellite but we followed that

855

00:36:32,250 --> 00:36:36,750

with aw Maps satellite and that was

856
00:36:34,559 --> 00:36:40,259
followed up but the Planck satellite in

857
00:36:36,750 --> 00:36:42,480
order to get more and more detail in the

858
00:36:40,260 --> 00:36:44,730
Cosmic Microwave Background we're

859
00:36:42,480 --> 00:36:47,280
studying the seeds of structure

860
00:36:44,730 --> 00:36:50,280
formation in the universe in microwaves

861
00:36:47,280 --> 00:36:53,040
and not just this and just bursts of the

862
00:36:50,280 --> 00:36:54,090
initial discovery of it merited a Nobel

863
00:36:53,039 --> 00:36:56,820
Prize but the discovery of the

864
00:36:54,090 --> 00:36:59,730
variations in it also merited a Nobel

865
00:36:56,820 --> 00:37:01,890
Prize seeing the beginnings of structure

866
00:36:59,730 --> 00:37:04,409
forming in the universe that's what we

867
00:37:01,889 --> 00:37:06,529
see in microwaves all right let's move

868
00:37:04,409 --> 00:37:09,719
on to a little bit longer infrared light

869
00:37:06,530 --> 00:37:12,960
okay so let's see we've got about one

870
00:37:09,719 --> 00:37:15,358
millimeter down to about 700 nanometers

871
00:37:12,960 --> 00:37:18,059
so that's a little over a factor of a

872
00:37:15,358 --> 00:37:19,469
thousand for infrared light now when you

873
00:37:18,059 --> 00:37:20,608
think about infrared light in your daily

874
00:37:19,469 --> 00:37:24,029
life all right

875
00:37:20,608 --> 00:37:25,559
anybody here computer gamers okay and

876
00:37:24,030 --> 00:37:28,080
you play call of duty and

877
00:37:25,559 --> 00:37:30,599
that mode that you know we can see

878
00:37:28,079 --> 00:37:33,000
things in the dark right okay that's

879
00:37:30,599 --> 00:37:34,889
called night vision and a lot of people

880
00:37:33,000 --> 00:37:37,590
think that that's infrared vision all

881
00:37:34,889 --> 00:37:39,329
right and it's not night vision

882
00:37:37,590 --> 00:37:41,250
especially as it would be used in call

883
00:37:39,329 --> 00:37:43,349
of duty or anything it's just enhanced

884

00:37:41,250 --> 00:37:45,750
low-light vision okay so when you see a

885
00:37:43,349 --> 00:37:47,699
picture like this you're amplifying the

886
00:37:45,750 --> 00:37:49,800
light around it okay it's not infrared

887
00:37:47,699 --> 00:37:52,500
light there is some infrared light that

888
00:37:49,800 --> 00:37:54,600
you can use like that but really when

889
00:37:52,500 --> 00:37:56,639
you want to look at the infrared you're

890
00:37:54,599 --> 00:37:58,589
gonna get pictures like this okay so

891
00:37:56,639 --> 00:38:00,929
this is a visible light image of a

892
00:37:58,590 --> 00:38:03,630
firefighter all right and the same

893
00:38:00,929 --> 00:38:06,329
infrared image of that firefighter shows

894
00:38:03,630 --> 00:38:09,599
him glowing but also shows that human

895
00:38:06,329 --> 00:38:11,819
person on the floor glowing all right

896
00:38:09,599 --> 00:38:15,269
using infrared light you're seeing heat

897
00:38:11,820 --> 00:38:17,100
radiation okay all right and where

898
00:38:15,269 --> 00:38:19,860

things may be obscured in visible light

899

00:38:17,099 --> 00:38:22,529

the heat radiation can go through you

900

00:38:19,860 --> 00:38:25,289

are all emitting infrared radiation

901

00:38:22,530 --> 00:38:28,740

right now okay objects at room

902

00:38:25,289 --> 00:38:30,360

temperature emit infrared radiation okay

903

00:38:28,739 --> 00:38:32,429

all right they're at hundreds of degrees

904

00:38:30,360 --> 00:38:34,110

in Kelvin you are emitting infrared

905

00:38:32,429 --> 00:38:36,179

radiation if you're thousands of Riis

906

00:38:34,110 --> 00:38:38,000

Kelvin you're emitting visible light you

907

00:38:36,179 --> 00:38:41,239

aren't that hot I hope not okay

908

00:38:38,000 --> 00:38:45,059

sincerely hope you're not that hot but

909

00:38:41,239 --> 00:38:47,579

you are emitting infrared radiation now

910

00:38:45,059 --> 00:38:50,670

for astronomers infrared radiation has a

911

00:38:47,579 --> 00:38:52,289

variety of ways that we detect it some

912

00:38:50,670 --> 00:38:53,940

infrared radiation makes it through our

913
00:38:52,289 --> 00:38:56,429
atmosphere to the ground so we can

914
00:38:53,940 --> 00:38:58,559
observe infrared radiation with normal

915
00:38:56,429 --> 00:39:00,359
telescopes okay so these are the twin

916
00:38:58,559 --> 00:39:02,489
tech telescopes that talk Mauna Kea

917
00:39:00,360 --> 00:39:04,980
alright they're giant light buckets

918
00:39:02,489 --> 00:39:07,709
really really good for observing in the

919
00:39:04,980 --> 00:39:09,599
infrared however if you get up above

920
00:39:07,710 --> 00:39:11,220
higher in the atmosphere the higher in

921
00:39:09,599 --> 00:39:13,199
the atmosphere you get the better your

922
00:39:11,219 --> 00:39:16,379
view is so why not take an infrared

923
00:39:13,199 --> 00:39:18,210
telescope and put it on a plane okay

924
00:39:16,380 --> 00:39:20,640
this is Sofia the stratospheric

925
00:39:18,210 --> 00:39:22,920
Observatory for infrared astronomy and

926
00:39:20,639 --> 00:39:26,039
that is the hatch that is open for an

927
00:39:22,920 --> 00:39:28,530
infrared telescope you fly it up at high

928
00:39:26,039 --> 00:39:31,320
plane altitudes you get a better view of

929
00:39:28,530 --> 00:39:33,600
the universe okay and of course you can

930
00:39:31,320 --> 00:39:36,539
go up into space you can take it further

931
00:39:33,599 --> 00:39:37,909
up into space and you can have the

932
00:39:36,539 --> 00:39:40,190
Spitzer Space Telescope which

933
00:39:37,909 --> 00:39:42,019
an infrared telescope and the upcoming

934
00:39:40,190 --> 00:39:44,960
James Webb Space Telescope that will

935
00:39:42,019 --> 00:39:47,780
launch in 2018 also an infrared Space

936
00:39:44,960 --> 00:39:49,490
Observatory all right so I'm Freret is

937
00:39:47,780 --> 00:39:51,890
able to do from the ground from

938
00:39:49,489 --> 00:39:54,199
airplanes and from space oh by the way I

939
00:39:51,889 --> 00:39:56,269
will also note that these two are not to

940
00:39:54,199 --> 00:40:00,108
scale okay

941

00:39:56,269 --> 00:40:02,298
the the main mirror of keV of Spitzer is

942
00:40:00,108 --> 00:40:05,598
smaller than one of these mirrors for

943
00:40:02,298 --> 00:40:08,059
James Webb okay so this is a point eight

944
00:40:05,599 --> 00:40:10,280
meter telescope mirror telescope this is

945
00:40:08,059 --> 00:40:11,869
a six and a half meter telescope so you

946
00:40:10,280 --> 00:40:14,510
can see what an incredible improvement

947
00:40:11,869 --> 00:40:18,019
this will be over that for infrared for

948
00:40:14,510 --> 00:40:20,299
infrared space astronomy so I told you

949
00:40:18,019 --> 00:40:23,420
to Pater's actually glowing in the

950
00:40:20,298 --> 00:40:26,449
infrared this is a visible light view of

951
00:40:23,420 --> 00:40:28,579
Jupiter and here is an infrared view of

952
00:40:26,449 --> 00:40:31,250
Jupiter all right and you can see the

953
00:40:28,579 --> 00:40:33,109
emission coming from coming from the

954
00:40:31,250 --> 00:40:35,659
internal of Jupiter and in particular

955
00:40:33,108 --> 00:40:39,019

one of my favorite things is that the

956

00:40:35,659 --> 00:40:41,808

Great Red Spot as well as Red Spot jr.

957

00:40:39,019 --> 00:40:44,298

okay Great Red Spot and Red Spot jr. are

958

00:40:41,809 --> 00:40:47,660

sources where infrared light is escaping

959

00:40:44,298 --> 00:40:50,088

from the internal on Jupiter if you look

960

00:40:47,659 --> 00:40:52,368

at infrared one of my favorite infrared

961

00:40:50,088 --> 00:40:54,528

images you can see how bright it is here

962

00:40:52,369 --> 00:40:56,900

and the end the Great Red Spot and for

963

00:40:54,528 --> 00:40:59,900

Red Spot jr. in terms of seeing the

964

00:40:56,900 --> 00:41:03,980

infrared light coming from them what a

965

00:40:59,900 --> 00:41:05,720

gorgeous infrared view infrared is also

966

00:41:03,980 --> 00:41:07,608

incredibly useful we're not just looking

967

00:41:05,719 --> 00:41:10,759

at the planets but in terms of looking

968

00:41:07,608 --> 00:41:12,619

at nebulae this is one of the famous

969

00:41:10,760 --> 00:41:16,819

images we released for servicing mission

970
00:41:12,619 --> 00:41:18,920
4 in 2009 and here we have the pillar in

971
00:41:16,818 --> 00:41:20,538
the Carina Nebula and you can see that

972
00:41:18,920 --> 00:41:22,639
you've got a good number of stars around

973
00:41:20,539 --> 00:41:25,430
it but you can see there's all this gas

974
00:41:22,639 --> 00:41:28,068
emission well infrared light has longer

975
00:41:25,429 --> 00:41:30,259
wavelengths than visible light so the

976
00:41:28,068 --> 00:41:33,528
wavelengths penetrate through that gas

977
00:41:30,260 --> 00:41:37,359
all right and so the infrared version of

978
00:41:33,528 --> 00:41:40,489
this image from Hubble is this all right

979
00:41:37,358 --> 00:41:43,250
there's the visible light there's the

980
00:41:40,489 --> 00:41:45,379
infra red look at all the stars you see

981
00:41:43,250 --> 00:41:48,679
because you are peering through some of

982
00:41:45,380 --> 00:41:51,470
that gas furthermore if you go in in

983
00:41:48,679 --> 00:41:54,289
detail there is a star forming in

984
00:41:51,469 --> 00:41:57,108
here okay there is a star forming inside

985
00:41:54,289 --> 00:41:59,150
there that is not clearly visible in

986
00:41:57,108 --> 00:42:02,929
visible light yeah visible invisible

987
00:41:59,150 --> 00:42:05,780
light recognizable in optical light how

988
00:42:02,929 --> 00:42:08,358
about that okay but if we go to the

989
00:42:05,780 --> 00:42:11,359
infrared there you see it right there

990
00:42:08,358 --> 00:42:14,420
okay there is a star you can see the jet

991
00:42:11,358 --> 00:42:16,279
of emission from that newborn star we go

992
00:42:14,420 --> 00:42:18,050
back you can see that there's a little

993
00:42:16,280 --> 00:42:21,050
bit of something here that you can see

994
00:42:18,050 --> 00:42:23,869
with visible light but there you can see

995
00:42:21,050 --> 00:42:26,119
the star so if you want to study star

996
00:42:23,869 --> 00:42:28,579
formation all right you want to go to

997
00:42:26,119 --> 00:42:30,380
the infrared this is one of the main

998

00:42:28,579 --> 00:42:33,170
tasks of the James Webb Space Telescope

999
00:42:30,380 --> 00:42:36,079
will be to look at places where stars

1000
00:42:33,170 --> 00:42:39,200
are forming to peer into that that dense

1001
00:42:36,079 --> 00:42:41,750
gas and see deeper in to see the

1002
00:42:39,199 --> 00:42:44,419
structure of star formation in the

1003
00:42:41,750 --> 00:42:46,579
infrared let's go back to the Whirlpool

1004
00:42:44,420 --> 00:42:49,130
Galaxy this is not that Hubble image of

1005
00:42:46,579 --> 00:42:51,409
it because we're going to compare it to

1006
00:42:49,130 --> 00:42:54,320
an infrared Spitzer image this is a

1007
00:42:51,409 --> 00:42:56,420
ground-based image from the National

1008
00:42:54,320 --> 00:42:58,070
optical Astronomy Observatory and here

1009
00:42:56,420 --> 00:42:59,930
you can see that beautiful pattern of

1010
00:42:58,070 --> 00:43:03,080
the Whirlpool again let's highlight

1011
00:42:59,929 --> 00:43:06,319
those dark dust lanes because in the

1012
00:43:03,079 --> 00:43:09,650

infrared though those dust lanes are

1013

00:43:06,320 --> 00:43:13,099

glowing all right there's the visible

1014

00:43:09,650 --> 00:43:14,990

light there's the infrared all right if

1015

00:43:13,099 --> 00:43:19,190

you look right along here you can see

1016

00:43:14,989 --> 00:43:21,769

visible light infrared all right those

1017

00:43:19,190 --> 00:43:23,960

got instead of C being dominated by the

1018

00:43:21,769 --> 00:43:26,480

stars and the bright stars in the galaxy

1019

00:43:23,960 --> 00:43:29,119

you are now not that this view is

1020

00:43:26,480 --> 00:43:30,889

dominated by the cool gas in the galaxy

1021

00:43:29,119 --> 00:43:33,789

the warm gas in the galaxy not the very

1022

00:43:30,889 --> 00:43:34,940

cold gas the dense gas that we saw in

1023

00:43:33,789 --> 00:43:37,369

microwaves

1024

00:43:34,940 --> 00:43:39,050

all right millimeter observations but

1025

00:43:37,369 --> 00:43:43,190

instead this is slightly warmer than

1026

00:43:39,050 --> 00:43:44,390

that for that again infrared is

1027
00:43:43,190 --> 00:43:47,059
generally hundreds of degrees

1028
00:43:44,389 --> 00:43:49,848
temperature in the gas so we can see

1029
00:43:47,059 --> 00:43:52,369
different phases of the gas by looking

1030
00:43:49,849 --> 00:43:54,140
in different wavelengths of light okay

1031
00:43:52,369 --> 00:43:57,019
so now we've gone half way through we've

1032
00:43:54,139 --> 00:43:58,279
got up to visible light and what I want

1033
00:43:57,019 --> 00:43:59,239
to notice above this will like is I've

1034
00:43:58,280 --> 00:44:01,220
already talked about visibly

1035
00:43:59,239 --> 00:44:04,919
observations is that it only goes from

1036
00:44:01,219 --> 00:44:07,139
400 to 700 nanometers

1037
00:44:04,920 --> 00:44:08,760
than a factor of two we were talking

1038
00:44:07,139 --> 00:44:10,769
about factories about thousand for these

1039
00:44:08,760 --> 00:44:12,980
wavelength regions all right when we

1040
00:44:10,769 --> 00:44:16,050
look at the electromagnetic spectrum

1041
00:44:12,980 --> 00:44:19,380
just drawing in all these colors over

1042
00:44:16,050 --> 00:44:21,660
States the size of visible light in that

1043
00:44:19,380 --> 00:44:24,480
it's not that important or region

1044
00:44:21,659 --> 00:44:26,489
the only reason reason that visible

1045
00:44:24,480 --> 00:44:28,559
light is important is because it happens

1046
00:44:26,489 --> 00:44:32,069
to be the region with which we see it's

1047
00:44:28,559 --> 00:44:35,070
a tiny tiny region within the

1048
00:44:32,070 --> 00:44:36,660
electromagnetic spectrum because most of

1049
00:44:35,070 --> 00:44:40,140
the other regions are much much larger

1050
00:44:36,659 --> 00:44:42,149
than that in terms of the the size of

1051
00:44:40,139 --> 00:44:43,650
wavelengths that they cover all right

1052
00:44:42,150 --> 00:44:46,590
but since it's ours

1053
00:44:43,650 --> 00:44:48,030
well we'll keep it as a real segment but

1054
00:44:46,590 --> 00:44:49,980
you know it's not really a respectable

1055

00:44:48,030 --> 00:44:51,240
one okay you know we've kicked Pluto out

1056
00:44:49,980 --> 00:44:53,070
as a planet maybe we should kick

1057
00:44:51,239 --> 00:44:54,809
visible-light out as a as a band of the

1058
00:44:53,070 --> 00:44:56,640
wavelengths right you know it just

1059
00:44:54,809 --> 00:45:00,559
should be a subset of infrared or a

1060
00:44:56,639 --> 00:45:00,559
subset of an ultraviolet right maybe

1061
00:45:03,019 --> 00:45:07,650
ultra violet light from ten nine years

1062
00:45:06,420 --> 00:45:10,170
to four hundred entries you can see

1063
00:45:07,650 --> 00:45:12,720
that's a factor of 40 okay so a factor

1064
00:45:10,170 --> 00:45:15,210
of two for visible light that's my point

1065
00:45:12,719 --> 00:45:17,669
all right we think of ultraviolet light

1066
00:45:15,210 --> 00:45:19,740
in our everyday we start thinking about

1067
00:45:17,670 --> 00:45:21,960
going to the beach and going out in the

1068
00:45:19,739 --> 00:45:23,989
Sun and getting a tan and everything

1069
00:45:21,960 --> 00:45:25,860

okay and of course when we think about

1070

00:45:23,989 --> 00:45:28,979

ultraviolet we talk about ultraviolet

1071

00:45:25,860 --> 00:45:31,470

protection and what's the UV blockage of

1072

00:45:28,980 --> 00:45:34,050

your sunglasses and does your

1073

00:45:31,469 --> 00:45:37,579

broad-spectrum sunscreen protect you

1074

00:45:34,050 --> 00:45:39,630

against the ultraviolet rays well I

1075

00:45:37,579 --> 00:45:41,610

happen to have kind of you know

1076

00:45:39,630 --> 00:45:44,670

sensitive skin okay I need to use lots

1077

00:45:41,610 --> 00:45:47,579

and lots of lots of sunblock okay but

1078

00:45:44,670 --> 00:45:50,369

I'm really really glad that we have an

1079

00:45:47,579 --> 00:45:53,519

atmosphere because our atmosphere

1080

00:45:50,369 --> 00:45:57,329

actually absorbs most of the ultraviolet

1081

00:45:53,519 --> 00:46:00,210

radiation okay we cannot do ultraviolet

1082

00:45:57,329 --> 00:46:02,909

astronomy from the ground all right you

1083

00:46:00,210 --> 00:46:06,780

can see by this diagram here is the of

1084
00:46:02,909 --> 00:46:07,920
the penetration depth of the various

1085
00:46:06,780 --> 00:46:10,530
wavelengths you can see without the

1086
00:46:07,920 --> 00:46:12,900
optical window we have the radio window

1087
00:46:10,530 --> 00:46:15,150
you can see how all true infrared get

1088
00:46:12,900 --> 00:46:17,250
some gets to the ground some you know

1089
00:46:15,150 --> 00:46:17,849
can go there but we really still need to

1090
00:46:17,250 --> 00:46:19,349
do in for

1091
00:46:17,849 --> 00:46:22,380
to do it Fred right you got to go to

1092
00:46:19,349 --> 00:46:24,539
space well for ultraviolet and longer

1093
00:46:22,380 --> 00:46:26,579
you got to go to space to do astronomy

1094
00:46:24,539 --> 00:46:28,529
all right which also means that if we

1095
00:46:26,579 --> 00:46:30,960
didn't have that atmosphere there it

1096
00:46:28,530 --> 00:46:32,400
would be really really bad because you

1097
00:46:30,960 --> 00:46:35,480
know we get some serious serious

1098
00:46:32,400 --> 00:46:38,400
sunburns okay where we go up into space

1099
00:46:35,480 --> 00:46:39,690
we have one of the telescopes up there

1100
00:46:38,400 --> 00:46:44,340
is the galaxy

1101
00:46:39,690 --> 00:46:45,750
the Galaxy Evolution Explorer and infra

1102
00:46:44,340 --> 00:46:48,360
telescope that seems to have only one

1103
00:46:45,750 --> 00:46:50,190
press release drawing of it I was

1104
00:46:48,360 --> 00:46:54,599
looking around saying this is kind of

1105
00:46:50,190 --> 00:46:56,639
you know overdone a little bit with with

1106
00:46:54,599 --> 00:46:58,529
the the Sun peeking over there I was

1107
00:46:56,639 --> 00:46:59,699
trying to find another galaxy but that's

1108
00:46:58,530 --> 00:47:02,430
it that's all I could find on the

1109
00:46:59,699 --> 00:47:04,439
internet today for Galax in terms of

1110
00:47:02,429 --> 00:47:07,079
being I think but this is an ultraviolet

1111
00:47:04,440 --> 00:47:09,179
telescope and as you may know the Hubble

1112

00:47:07,079 --> 00:47:12,059
Space Telescope observes a little bit of

1113
00:47:09,179 --> 00:47:15,899
the ultraviolet so you can use normal

1114
00:47:12,059 --> 00:47:17,309
optics to absorb ultraviolet and so and

1115
00:47:15,900 --> 00:47:19,710
this is of course tune with the

1116
00:47:17,309 --> 00:47:22,920
ultraviolet detectors to see in the

1117
00:47:19,710 --> 00:47:25,199
ultraviolet with Galax so what is our

1118
00:47:22,920 --> 00:47:27,930
favorite targets astronomical targets in

1119
00:47:25,199 --> 00:47:30,960
the ultraviolet one of them is our Sun

1120
00:47:27,929 --> 00:47:33,389
now our Sun and visible light looks kind

1121
00:47:30,960 --> 00:47:35,970
of boring okay it's just kind of smooth

1122
00:47:33,389 --> 00:47:37,980
and it has a few freckles right you put

1123
00:47:35,969 --> 00:47:40,919
that you observe it in ultraviolet and

1124
00:47:37,980 --> 00:47:43,730
then you start to see the energy in the

1125
00:47:40,920 --> 00:47:46,769
Sun so these are four different

1126
00:47:43,730 --> 00:47:48,900

wavelength bands four different

1127

00:47:46,769 --> 00:47:51,449
observation reading regions within the

1128

00:47:48,900 --> 00:47:53,190
ultraviolet okay and one of the great

1129

00:47:51,449 --> 00:47:55,889
things these solar astronomers have done

1130

00:47:53,190 --> 00:47:58,500
they they've decided that for the

1131

00:47:55,889 --> 00:48:01,170
various wavelengths they're going to use

1132

00:47:58,500 --> 00:48:03,599
single colors so whenever you see this

1133

00:48:01,170 --> 00:48:07,740
red you can know that it's 30.4

1134

00:48:03,599 --> 00:48:11,429
nanometers or 304 angstroms okay I think

1135

00:48:07,739 --> 00:48:13,109
this blue is as 19.1 I can't remember

1136

00:48:11,429 --> 00:48:15,629
all of them all right but you can see

1137

00:48:13,110 --> 00:48:18,329
the structure and you can also see the

1138

00:48:15,630 --> 00:48:20,309
magnetic storms that are going on with

1139

00:48:18,329 --> 00:48:21,299
those sunspots those sunspots with

1140

00:48:20,309 --> 00:48:24,059
visible light they just look like

1141
00:48:21,300 --> 00:48:26,220
freckles on the Sun here you can see the

1142
00:48:24,059 --> 00:48:28,889
energy that is in the magnetic

1143
00:48:26,219 --> 00:48:30,629
concentration around those sunspots the

1144
00:48:28,889 --> 00:48:32,219
energy that is that

1145
00:48:30,630 --> 00:48:35,099
is working through here and if you ever

1146
00:48:32,219 --> 00:48:37,348
see anything with you know with magnetic

1147
00:48:35,099 --> 00:48:39,059
storms on the Sun and there's exciting

1148
00:48:37,349 --> 00:48:41,640
images well you're looking in the

1149
00:48:39,059 --> 00:48:43,559
ultraviolet matter-of-fact ultraviolet

1150
00:48:41,639 --> 00:48:45,989
because of the ultraviolet images gotten

1151
00:48:43,559 --> 00:48:47,880
so popular you'll see a lot in textbooks

1152
00:48:45,989 --> 00:48:49,649
that says that the art director will say

1153
00:48:47,880 --> 00:48:51,660
oh I want to use that image all right

1154
00:48:49,650 --> 00:48:53,099
because it's the ultraviolet of course

1155
00:48:51,659 --> 00:48:55,018
you know have to make sure people mark

1156
00:48:53,099 --> 00:48:57,420
it as ultraviolet so that you know if

1157
00:48:55,018 --> 00:48:59,008
you see the Sun looking exciting you're

1158
00:48:57,420 --> 00:49:01,710
probably looking at an ultraviolet image

1159
00:48:59,009 --> 00:49:03,298
of the Sun another thing that we've can

1160
00:49:01,710 --> 00:49:05,809
see in ultraviolet that we can't see in

1161
00:49:03,298 --> 00:49:08,699
visible light is the Aurora on Saturn

1162
00:49:05,809 --> 00:49:10,619
now this is a composite image okay these

1163
00:49:08,699 --> 00:49:13,379
are three images of Saturn composited

1164
00:49:10,619 --> 00:49:16,230
together their visible light images of

1165
00:49:13,380 --> 00:49:18,539
Saturn added on to it is ultraviolet

1166
00:49:16,230 --> 00:49:22,230
images that show off the Aurora of

1167
00:49:18,539 --> 00:49:24,240
Saturn now our Aurora on earth we can

1168
00:49:22,230 --> 00:49:28,048
see what have you how many people here

1169

00:49:24,239 --> 00:49:29,838
have seen the Aurora okay I highly

1170
00:49:28,048 --> 00:49:31,500
recommend it if you can get North

1171
00:49:29,838 --> 00:49:34,230
sometimes you don't have to go too far

1172
00:49:31,500 --> 00:49:35,969
north to make an effort to see it

1173
00:49:34,230 --> 00:49:40,909
because it's really great to stash or to

1174
00:49:35,969 --> 00:49:43,679
see the shimmering misguide I was on a

1175
00:49:40,909 --> 00:49:44,759
cruise back from Alaska and we're

1176
00:49:43,679 --> 00:49:47,429
standing on the back of the boat just

1177
00:49:44,759 --> 00:49:49,619
watching the Aurora dance in the sky it

1178
00:49:47,429 --> 00:49:52,500
was really great so I highly recommend

1179
00:49:49,619 --> 00:49:54,000
taking the effort okay alright take the

1180
00:49:52,500 --> 00:49:55,619
effort to go out and see see these

1181
00:49:54,000 --> 00:49:56,969
things because you know you live in

1182
00:49:55,619 --> 00:49:58,920
cities with lights and all that stuff

1183
00:49:56,969 --> 00:50:01,288

you don't get to really experience the

1184

00:49:58,920 --> 00:50:03,509

sky make the effort to see it so see the

1185

00:50:01,289 --> 00:50:06,359

aurora on earth but i can't tell you to

1186

00:50:03,509 --> 00:50:09,019

go do that on Saturn because on Saturn

1187

00:50:06,358 --> 00:50:11,818

it's not visible light Aurora its

1188

00:50:09,018 --> 00:50:14,008

ultraviolet Aurora you cannot see that

1189

00:50:11,818 --> 00:50:15,989

of that Aurora on Saturn unless you have

1190

00:50:14,009 --> 00:50:18,838

an ultraviolet detector which is why

1191

00:50:15,989 --> 00:50:20,548

these are Hubble images from from Hubble

1192

00:50:18,838 --> 00:50:22,558

up in space to be able to do the

1193

00:50:20,548 --> 00:50:26,009

ultraviolet astronomy to see the Aurora

1194

00:50:22,559 --> 00:50:27,930

on Saturn we can also look at galaxies

1195

00:50:26,009 --> 00:50:30,358

in the ultraviolet again we're getting

1196

00:50:27,929 --> 00:50:32,608

to higher energy here so instead of

1197

00:50:30,358 --> 00:50:34,288

looking at that low dense that that cold

1198
00:50:32,608 --> 00:50:36,328
gas will be getting at the higher energy

1199
00:50:34,289 --> 00:50:39,349
the hotter stuff and so this is the

1200
00:50:36,329 --> 00:50:42,660
visible light image of a galaxy called

1201
00:50:39,349 --> 00:50:43,890
m74 and in ultraviolet

1202
00:50:42,659 --> 00:50:46,259
you only see

1203
00:50:43,889 --> 00:50:49,379
the star forming regions okay you see

1204
00:50:46,260 --> 00:50:51,750
the high-energy regions because it is as

1205
00:50:49,380 --> 00:50:53,760
I talked about those hotter stars that

1206
00:50:51,750 --> 00:50:55,920
actually emit in the ultraviolet and

1207
00:50:53,760 --> 00:50:58,950
those hot stars are the more massive

1208
00:50:55,920 --> 00:51:01,440
stars those very massive stars only live

1209
00:50:58,949 --> 00:51:03,899
short lives so they don't get outside of

1210
00:51:01,440 --> 00:51:06,450
their star forming regions so studying

1211
00:51:03,900 --> 00:51:09,420
star forming regions in galaxies you can

1212
00:51:06,449 --> 00:51:12,179
find them very easily just by looking in

1213
00:51:09,420 --> 00:51:14,940
the ultraviolet moving up an energy

1214
00:51:12,179 --> 00:51:18,328
scale we go to x-rays which from roughly

1215
00:51:14,940 --> 00:51:20,548
10 nanometers down to 1/100 of a

1216
00:51:18,329 --> 00:51:23,700
nanometer again about a factor of a

1217
00:51:20,548 --> 00:51:27,298
thousand in wavelength region and for

1218
00:51:23,699 --> 00:51:30,328
our purposes we think of x-rays as being

1219
00:51:27,298 --> 00:51:32,130
these medical observations and as you

1220
00:51:30,329 --> 00:51:35,099
can see that there is a fracture here in

1221
00:51:32,130 --> 00:51:38,700
one of these bones now are these bones

1222
00:51:35,099 --> 00:51:41,579
emitting x-rays no the bones are not

1223
00:51:38,699 --> 00:51:44,778
emitting x-rays rather the x-rays are

1224
00:51:41,579 --> 00:51:47,490
created by a machine that pass through

1225
00:51:44,778 --> 00:51:50,099
the skin and the bones right

1226

00:51:47,489 --> 00:51:51,868
the ara the x-rays are actually absorbed

1227
00:51:50,099 --> 00:51:53,400
by the bones and what you are seeing

1228
00:51:51,869 --> 00:51:56,880
you're seeing the bones in shadow

1229
00:51:53,400 --> 00:51:58,289
because the bones actually are absorbing

1230
00:51:56,880 --> 00:52:00,390
the x-rays whereas the skin and

1231
00:51:58,289 --> 00:52:03,539
soft-tissue let the x-rays pass through

1232
00:52:00,389 --> 00:52:05,909
right so what you are seeing here is not

1233
00:52:03,539 --> 00:52:09,660
an emission of x-rays but rather an

1234
00:52:05,909 --> 00:52:12,538
absorption of x-rays so knowing that can

1235
00:52:09,659 --> 00:52:15,049
anybody explain to me how Superman has

1236
00:52:12,539 --> 00:52:19,500
x-ray vision

1237
00:52:15,050 --> 00:52:21,570
because ya are his eyes x-ray detectors

1238
00:52:19,500 --> 00:52:23,340
or are the x-ray emitters and if their

1239
00:52:21,570 --> 00:52:24,990
x-ray emitters are the x-rays sort of

1240
00:52:23,340 --> 00:52:27,329

somehow coming back to and so that it

1241

00:52:24,989 --> 00:52:31,289

can inject them it's never made any

1242

00:52:27,329 --> 00:52:34,230

sense whatsoever okay but astronomers

1243

00:52:31,289 --> 00:52:36,900

truly do have x-ray vision all right and

1244

00:52:34,230 --> 00:52:40,949

our favorite x-ray vision satellite is

1245

00:52:36,900 --> 00:52:43,320

the Chandra x-ray Observatory and x-ray

1246

00:52:40,949 --> 00:52:45,179

observatories on is really cool looping

1247

00:52:43,320 --> 00:52:47,340

orbit around Earth it's got this big

1248

00:52:45,179 --> 00:52:50,579

long elliptical orbit alright and

1249

00:52:47,340 --> 00:52:52,260

observing x-rays is not like observing

1250

00:52:50,579 --> 00:52:55,079

with visible light because we usually

1251

00:52:52,260 --> 00:52:56,520

bounce light off a mirror right well you

1252

00:52:55,079 --> 00:52:58,500

take x-rays you it's going to go

1253

00:52:56,519 --> 00:53:01,530

straight through the mirror okay so you

1254

00:52:58,500 --> 00:53:03,960

can't use a standard mirror to observe

1255
00:53:01,530 --> 00:53:06,360
an x-rays but you do use mirrors and

1256
00:53:03,960 --> 00:53:09,510
instead what you use are what we call

1257
00:53:06,360 --> 00:53:11,970
grazing incidence mirrors okay so the

1258
00:53:09,510 --> 00:53:14,550
light comes in and it just deflects a

1259
00:53:11,969 --> 00:53:17,159
little bit off of these mirrors okay so

1260
00:53:14,550 --> 00:53:20,580
you can see this is a concentric cone of

1261
00:53:17,159 --> 00:53:25,710
mirrors that are graduated down to focus

1262
00:53:20,579 --> 00:53:27,299
the x-rays on to the detector all right

1263
00:53:25,710 --> 00:53:28,349
so instead of bouncing things off

1264
00:53:27,300 --> 00:53:30,060
mirrors you're just trying to give them

1265
00:53:28,349 --> 00:53:31,079
just all tiny little deflection you're

1266
00:53:30,059 --> 00:53:33,059
giving them a nudge

1267
00:53:31,079 --> 00:53:36,480
all right to try and eventually focus

1268
00:53:33,059 --> 00:53:38,130
them to focus focus x-rays so I thought

1269
00:53:36,480 --> 00:53:40,940
that was a kind of a kind of cool thing

1270
00:53:38,130 --> 00:53:46,170
so they have these basically these big

1271
00:53:40,940 --> 00:53:49,260
concentric cones of mirrors that that

1272
00:53:46,170 --> 00:53:52,289
allow us to observe in x-rays and we can

1273
00:53:49,260 --> 00:53:54,390
look in x-rays at things like this oh we

1274
00:53:52,289 --> 00:53:56,730
can look at the Sun okay like we

1275
00:53:54,389 --> 00:53:58,679
observed ultraviolet which is where most

1276
00:53:56,730 --> 00:54:00,659
of the activity is there's still some

1277
00:53:58,679 --> 00:54:04,109
even higher energy activity on the Sun

1278
00:54:00,659 --> 00:54:06,329
that shows up in x-rays and this is from

1279
00:54:04,110 --> 00:54:08,430
the Yoko satellite which observed for

1280
00:54:06,329 --> 00:54:11,639
several years and the Yoko satellite

1281
00:54:08,429 --> 00:54:14,190
also observe prefer over the course of a

1282
00:54:11,639 --> 00:54:16,139
solar cycle and so here you can see the

1283

00:54:14,190 --> 00:54:19,380
high energy activity during a solar

1284
00:54:16,139 --> 00:54:21,719
maximum and then the low energy during a

1285
00:54:19,380 --> 00:54:24,780
solar minimum our Sun goes through these

1286
00:54:21,719 --> 00:54:26,309
cycles of activity right and on when we

1287
00:54:24,780 --> 00:54:27,950
look at visible light we just see more

1288
00:54:26,309 --> 00:54:30,409
sunspots or fewer Sun

1289
00:54:27,949 --> 00:54:33,649
spots okay lots of sunspots and almost

1290
00:54:30,409 --> 00:54:35,779
no sunspots right here it's much more

1291
00:54:33,650 --> 00:54:38,599
apparent you can see that's a seething

1292
00:54:35,780 --> 00:54:40,070
cauldron of activity and this is kind of

1293
00:54:38,599 --> 00:54:42,440
boring okay let's go check back next

1294
00:54:40,070 --> 00:54:45,950
week all right so this was a really nice

1295
00:54:42,440 --> 00:54:48,139
in the 1990s to see the vivid

1296
00:54:45,949 --> 00:54:51,289
illustration of the solar cycle observed

1297
00:54:48,139 --> 00:54:54,319

in x-rays we can also go back to that

1298

00:54:51,289 --> 00:54:57,079

supernova remnant Cassiopeia A which I

1299

00:54:54,320 --> 00:54:58,789

showed you in radio but this time let's

1300

00:54:57,079 --> 00:55:01,190

take that visible light which is just

1301

00:54:58,789 --> 00:55:04,159

the shell at the edge and let's take a

1302

00:55:01,190 --> 00:55:07,369

look in x-rays and in x-rays you see all

1303

00:55:04,159 --> 00:55:09,949

the heated gas interior to it because

1304

00:55:07,369 --> 00:55:12,349

this is a star that has exploded its

1305

00:55:09,949 --> 00:55:14,539

guts across space it stuff has been

1306

00:55:12,349 --> 00:55:16,849

moving at tens of millions of miles an

1307

00:55:14,539 --> 00:55:19,969

hour across space it's heated up to

1308

00:55:16,849 --> 00:55:24,619

millions of degrees and in millions of

1309

00:55:19,969 --> 00:55:27,169

degrees you emit x-rays okay so this is

1310

00:55:24,619 --> 00:55:29,599

the gas that's interior this shows you

1311

00:55:27,170 --> 00:55:31,579

just the edge of the bubble this shows

1312
00:55:29,599 --> 00:55:34,190
you the gas and the interior bubble

1313
00:55:31,579 --> 00:55:37,068
emitting x-rays so supernova remnants

1314
00:55:34,190 --> 00:55:40,099
are much more interesting to view in

1315
00:55:37,068 --> 00:55:43,880
x-ray light another thing that shows up

1316
00:55:40,099 --> 00:55:46,068
in x-ray light is the gas in clusters of

1317
00:55:43,880 --> 00:55:48,050
galaxies all right so this is going to

1318
00:55:46,068 --> 00:55:51,289
take a little bit of comprehension here

1319
00:55:48,050 --> 00:55:53,780
so we look at this image of a galaxy

1320
00:55:51,289 --> 00:55:55,369
cluster I forget which one this one is I

1321
00:55:53,780 --> 00:55:57,170
think this is one of the max clusters

1322
00:55:55,369 --> 00:55:59,930
all right and you can see all these

1323
00:55:57,170 --> 00:56:02,358
galaxies here and if you look at those

1324
00:55:59,929 --> 00:56:04,068
galaxies all right and you say okay well

1325
00:56:02,358 --> 00:56:06,108
each galaxy has a certain amount of mass

1326
00:56:04,068 --> 00:56:08,599
associated with it and you can come up

1327
00:56:06,108 --> 00:56:12,469
with a mass map okay and so we're gonna

1328
00:56:08,599 --> 00:56:15,650
color the mass in blue so based upon all

1329
00:56:12,469 --> 00:56:17,328
the galaxies out there okay that you can

1330
00:56:15,650 --> 00:56:20,389
see and identify as part of this cluster

1331
00:56:17,329 --> 00:56:23,030
here is a rough bass map of that cluster

1332
00:56:20,389 --> 00:56:25,789
based upon the light all right we can

1333
00:56:23,030 --> 00:56:28,700
also look at this cluster in x-rays and

1334
00:56:25,789 --> 00:56:30,800
when you form a cluster of galaxies you

1335
00:56:28,699 --> 00:56:32,929
bring in not just the visible light of

1336
00:56:30,800 --> 00:56:35,780
the galaxies but all the associated gas

1337
00:56:32,929 --> 00:56:37,730
associated with it and you bring galaxy

1338
00:56:35,780 --> 00:56:40,160
after galaxy swooshing together to make

1339
00:56:37,730 --> 00:56:41,219
this really big cluster that intra

1340

00:56:40,159 --> 00:56:44,039
cluster gas

1341
00:56:41,219 --> 00:56:45,839
heats up it heats up to hundreds of

1342
00:56:44,039 --> 00:56:48,840
thousands and millions of degrees and

1343
00:56:45,840 --> 00:56:50,340
actually glows in x-rays so when you

1344
00:56:48,840 --> 00:56:54,059
look at a cluster of galaxies like this

1345
00:56:50,340 --> 00:56:56,390
and you look in x-rays you see a what we

1346
00:56:54,059 --> 00:56:59,309
call and what we call here a red blob

1347
00:56:56,389 --> 00:57:02,429
alright that is the gas between the

1348
00:56:59,309 --> 00:57:04,079
galaxies very low-density gas that has

1349
00:57:02,429 --> 00:57:06,118
been heated up to hundreds of thousands

1350
00:57:04,079 --> 00:57:08,250
and millions of degrees and glows in

1351
00:57:06,119 --> 00:57:10,530
x-rays which gives you another measure

1352
00:57:08,250 --> 00:57:13,050
of the structure of the material in the

1353
00:57:10,530 --> 00:57:15,090
galaxies and the extent of this cluster

1354
00:57:13,050 --> 00:57:19,050

of galaxies so if we put them all

1355

00:57:15,090 --> 00:57:21,480

together we've got the galaxy image and

1356

00:57:19,050 --> 00:57:23,670

the yellowish stuff we got the blue for

1357

00:57:21,480 --> 00:57:27,599

the mass and we've got the red for the

1358

00:57:23,670 --> 00:57:29,730

x-ray gas all right and shows us that by

1359

00:57:27,599 --> 00:57:33,180

looking in x-rays we can discover the

1360

00:57:29,730 --> 00:57:35,250

true extent of a cluster of galaxies of

1361

00:57:33,179 --> 00:57:37,139

all the stuff can cluster of galaxies it

1362

00:57:35,250 --> 00:57:39,090

actually gives us another check on how

1363

00:57:37,139 --> 00:57:41,250

we can compare the mass that is in

1364

00:57:39,090 --> 00:57:43,410

visible light to the total mass that's

1365

00:57:41,250 --> 00:57:47,369

in the entire cluster measured by the

1366

00:57:43,409 --> 00:57:48,989

x-ray gas all right last wavelength

1367

00:57:47,369 --> 00:57:51,390

region the gamma rays

1368

00:57:48,989 --> 00:57:54,299

all right wavelengths less than 100 one

1369
00:57:51,389 --> 00:57:57,809
hundredth of a nanometer and we don't

1370
00:57:54,300 --> 00:58:00,810
have a lot o everyday experience with

1371
00:57:57,809 --> 00:58:02,400
gamma rays but to do get them a little

1372
00:58:00,809 --> 00:58:03,329
bit gamma rays can be produced by

1373
00:58:02,400 --> 00:58:05,369
lightning strikes

1374
00:58:03,329 --> 00:58:07,769
all right lightning strikes can produce

1375
00:58:05,369 --> 00:58:09,240
just a little bit of gamma rays of

1376
00:58:07,769 --> 00:58:11,369
course where do we normally think of

1377
00:58:09,239 --> 00:58:13,829
gamma rays besides the Incredible Hulk

1378
00:58:11,369 --> 00:58:16,019
and you know mutants like that ok we

1379
00:58:13,829 --> 00:58:21,480
think of it with nuclear explosions ok

1380
00:58:16,019 --> 00:58:26,190
in only in the highest energy events do

1381
00:58:21,480 --> 00:58:27,570
we get gamma rays and so where would you

1382
00:58:26,190 --> 00:58:29,159
get them in the universe how would you

1383
00:58:27,570 --> 00:58:30,750
look for them in the universe ok

1384
00:58:29,159 --> 00:58:33,449
well of course you have to go up into

1385
00:58:30,750 --> 00:58:36,059
into space and the current gamma ray

1386
00:58:33,449 --> 00:58:37,980
Observatory is called Famy it used to be

1387
00:58:36,059 --> 00:58:40,139
called classed gamma ray large area

1388
00:58:37,980 --> 00:58:42,630
space telescope and now it's the Fermi

1389
00:58:40,139 --> 00:58:45,750
gamma-ray Space Telescope and here is a

1390
00:58:42,630 --> 00:58:48,869
drawing of it and in this cube are lots

1391
00:58:45,750 --> 00:58:51,059
of detectors for measuring the gamma ray

1392
00:58:48,869 --> 00:58:52,740
radiation okay and in particular when

1393
00:58:51,059 --> 00:58:54,279
you get up to these high energies you're

1394
00:58:52,739 --> 00:58:56,079
not measuring particularly the

1395
00:58:54,280 --> 00:58:57,910
raise themselves you're measuring the

1396
00:58:56,079 --> 00:59:00,579
gamma rays are absorbed and they create

1397

00:58:57,909 --> 00:59:02,859
follow on radiation showers of radiation

1398
00:59:00,579 --> 00:59:04,569
as they're absorbed and you're actually

1399
00:59:02,860 --> 00:59:06,640
detecting some of that showers or

1400
00:59:04,570 --> 00:59:08,140
radiation not necessarily the gamma rays

1401
00:59:06,639 --> 00:59:10,059
themselves but you know you can

1402
00:59:08,139 --> 00:59:13,509
calibrate it really really well to see

1403
00:59:10,059 --> 00:59:17,369
it so here is some of the results from

1404
00:59:13,510 --> 00:59:22,870
Fermi this is an all-sky image from fami

1405
00:59:17,369 --> 00:59:26,980
alright before and after and after when

1406
00:59:22,869 --> 00:59:28,509
we see this giant Squatch okay this is a

1407
00:59:26,980 --> 00:59:33,639
gamma-ray burst

1408
00:59:28,510 --> 00:59:36,810
okay it is a single point of gamma rays

1409
00:59:33,639 --> 00:59:40,289
emitted from somewhere in the universe

1410
00:59:36,809 --> 00:59:41,650
secret astronomers didn't discover these

1411
00:59:40,289 --> 00:59:44,710

all right

1412

00:59:41,650 --> 00:59:47,860

because gamma rays come from nuclear

1413

00:59:44,710 --> 00:59:51,190

test explosions all right the Department

1414

00:59:47,860 --> 00:59:53,620

of Defense put up gamma-ray satellites

1415

00:59:51,190 --> 00:59:55,269

Cameron area detectors to monitor

1416

00:59:53,619 --> 00:59:57,279

whether or not there were nuclear

1417

00:59:55,269 --> 01:00:02,050

explosions going around around the world

1418

00:59:57,280 --> 01:00:04,510

and they saw bursts and they saw another

1419

01:00:02,050 --> 01:00:09,490

burst and they saw approximately one

1420

01:00:04,510 --> 01:00:11,350

burst every single day how many nuclear

1421

01:00:09,489 --> 01:00:14,769

bombs were there the world to get an

1422

01:00:11,349 --> 01:00:16,150

explosion every single day well they

1423

01:00:14,769 --> 01:00:17,440

quickly determined that no they weren't

1424

01:00:16,150 --> 01:00:19,750

coming from Earth they're actually

1425

01:00:17,440 --> 01:00:20,920

coming from space and of course this was

1426
01:00:19,750 --> 01:00:22,659
classified so they didn't bother telling

1427
01:00:20,920 --> 01:00:24,970
astronomers but we put up our own

1428
01:00:22,659 --> 01:00:26,739
satellites and found it ourselves so

1429
01:00:24,969 --> 01:00:28,629
we've got these gamma-ray bursts

1430
01:00:26,739 --> 01:00:31,239
coming from somewhere these are huge

1431
01:00:28,630 --> 01:00:32,829
incredible energetic events all right

1432
01:00:31,239 --> 01:00:35,859
and there's not just one of them okay

1433
01:00:32,829 --> 01:00:37,719
there are lots of them here are two

1434
01:00:35,860 --> 01:00:39,970
thousand observed by the Compton

1435
01:00:37,719 --> 01:00:42,639
gamma-ray Observatory with the Batsy

1436
01:00:39,969 --> 01:00:46,389
experiment all right two thousand of

1437
01:00:42,639 --> 01:00:48,129
these all across the sky and remember

1438
01:00:46,389 --> 01:00:51,039
when we're looking at this projection of

1439
01:00:48,130 --> 01:00:53,530
the sky the galaxy is right across the

1440
01:00:51,039 --> 01:00:57,009
center so you can see these gamma-ray

1441
01:00:53,530 --> 01:00:59,680
bursts are not associated with our

1442
01:00:57,010 --> 01:01:02,200
galaxy they're either really close to us

1443
01:00:59,679 --> 01:01:04,480
in space all right around us within our

1444
01:01:02,199 --> 01:01:06,879
small portion of the galaxy therefore

1445
01:01:04,480 --> 01:01:07,190
they can appear isotropic or they're

1446
01:01:06,880 --> 01:01:09,920
much

1447
01:01:07,190 --> 01:01:11,360
further beyond our galaxy and it's a

1448
01:01:09,920 --> 01:01:14,150
further beyond our galaxy they have to

1449
01:01:11,360 --> 01:01:16,309
be incredible energies okay because the

1450
01:01:14,150 --> 01:01:17,809
further away they are the more energetic

1451
01:01:16,309 --> 01:01:20,360
they have to be in order for us to see

1452
01:01:17,809 --> 01:01:23,539
them in gamma raised here well it turns

1453
01:01:20,360 --> 01:01:26,360
out they are actually at cosmological

1454

01:01:23,539 --> 01:01:29,329
distances all right here is a picture of

1455
01:01:26,360 --> 01:01:32,000
a gamma-ray burst and visible light can

1456
01:01:29,329 --> 01:01:35,569
you see it yeah I wouldn't know unless I

1457
01:01:32,000 --> 01:01:38,119
put this arrow in okay this is an object

1458
01:01:35,570 --> 01:01:40,910
that produced a gamma-ray burst so after

1459
01:01:38,119 --> 01:01:43,519
seeing a gamma-ray burst in in gamma

1460
01:01:40,909 --> 01:01:45,559
rays they they put out the coordinates

1461
01:01:43,519 --> 01:01:47,809
and we take you take images to try and

1462
01:01:45,559 --> 01:01:50,210
see what you can find Hubble has looked

1463
01:01:47,809 --> 01:01:52,190
to see what it can find at the positions

1464
01:01:50,210 --> 01:01:56,800
of these gamma-ray bursts and what does

1465
01:01:52,190 --> 01:02:00,619
it find it finds very distant galaxies

1466
01:01:56,800 --> 01:02:03,350
these gamma-ray bursts are incredibly

1467
01:02:00,619 --> 01:02:05,119
energetic events coming to us from

1468
01:02:03,349 --> 01:02:06,799

cosmological distances we're talking

1469

01:02:05,119 --> 01:02:09,099

billions of light years hundreds of

1470

01:02:06,800 --> 01:02:12,950

millions to billions of light-years away

1471

01:02:09,099 --> 01:02:14,839

okay all right what we surmise them to

1472

01:02:12,949 --> 01:02:18,559

be or something called not just a

1473

01:02:14,840 --> 01:02:24,260

supernova not a nova not a supernova but

1474

01:02:18,559 --> 01:02:27,170

a hyper nova okay which would be an

1475

01:02:24,260 --> 01:02:28,550

incredible burst burst of energy such

1476

01:02:27,170 --> 01:02:31,460

that we can observe gamma rays from

1477

01:02:28,550 --> 01:02:33,680

billions of light-years away across in

1478

01:02:31,460 --> 01:02:35,480

this and that's why they are produced

1479

01:02:33,679 --> 01:02:37,879

all the way across the sky so it's an

1480

01:02:35,480 --> 01:02:40,159

amazing and astounding idea that we can

1481

01:02:37,880 --> 01:02:42,110

see these gamma rays from across the

1482

01:02:40,159 --> 01:02:44,299

universe from these absolutely

1483
01:02:42,110 --> 01:02:45,800
incredible explosions and of course

1484
01:02:44,300 --> 01:02:50,060
that's not the only thing we see in

1485
01:02:45,800 --> 01:02:53,870
gamma rays here is an all-sky map above

1486
01:02:50,059 --> 01:02:55,549
a hundred million electron volts which

1487
01:02:53,869 --> 01:02:58,549
is a really high energy let me just say

1488
01:02:55,550 --> 01:03:00,410
that and what we see a lot in that you

1489
01:02:58,550 --> 01:03:03,530
here you can see the structure of our

1490
01:03:00,409 --> 01:03:05,679
galaxy because we start seeing the x-ray

1491
01:03:03,530 --> 01:03:08,300
binaries we start seeing pulsars

1492
01:03:05,679 --> 01:03:10,039
basically black holes all of those

1493
01:03:08,300 --> 01:03:12,320
things that can produce really high

1494
01:03:10,039 --> 01:03:14,630
energies are the only things that are

1495
01:03:12,320 --> 01:03:16,670
going to be able to produce these these

1496
01:03:14,630 --> 01:03:18,990
gamma rays that we see with gamma-ray

1497
01:03:16,670 --> 01:03:20,309
telescopes all right

1498
01:03:18,989 --> 01:03:22,859
we've covered the electromagnetic

1499
01:03:20,309 --> 01:03:25,079
spectrum alright we've gone across all

1500
01:03:22,860 --> 01:03:27,570
these wavelengths let's summarize in

1501
01:03:25,079 --> 01:03:29,190
terms of what do we get out of it ok

1502
01:03:27,570 --> 01:03:32,430
you've seen that we see lots of things

1503
01:03:29,190 --> 01:03:35,099
in lots of different different ideas of

1504
01:03:32,429 --> 01:03:37,349
light we have three Great observatories

1505
01:03:35,099 --> 01:03:39,089
currently operating the Compton gamma

1506
01:03:37,349 --> 01:03:41,130
ray Observatory isn't operating anymore

1507
01:03:39,090 --> 01:03:43,920
Hubble which is mostly visible Spitzer's

1508
01:03:41,130 --> 01:03:46,530
infrared Chandra x-ray we've done a

1509
01:03:43,920 --> 01:03:49,250
variety of presentations where we take

1510
01:03:46,530 --> 01:03:52,230
the state observations with the with the

1511

01:03:49,250 --> 01:03:55,650
with these telescopes of the same object

1512
01:03:52,230 --> 01:03:58,199
I like to show this one here which is a

1513
01:03:55,650 --> 01:04:01,170
supernova remnant supernovae 1604 also

1514
01:03:58,199 --> 01:04:03,569
called Kepler supernova because here is

1515
01:04:01,170 --> 01:04:05,579
where Hubble has the wimpiest of all the

1516
01:04:03,570 --> 01:04:08,370
images we're so used to elbow having the

1517
01:04:05,579 --> 01:04:10,019
most beautiful images well when it comes

1518
01:04:08,369 --> 01:04:12,779
to supernova remnants at least this one

1519
01:04:10,019 --> 01:04:15,030
here even Spitzer in the infrared has

1520
01:04:12,780 --> 01:04:17,730
more detail and more in traditional

1521
01:04:15,030 --> 01:04:20,310
interest and Chandra of course getting

1522
01:04:17,730 --> 01:04:22,769
that hot x-ray gas inside the supernova

1523
01:04:20,309 --> 01:04:25,170
in it has the most interesting ok so

1524
01:04:22,769 --> 01:04:27,150
Hubble doesn't always have the most

1525
01:04:25,170 --> 01:04:29,940

beautiful image but even when Hubble

1526

01:04:27,150 --> 01:04:31,950

does have a beautiful image such as for

1527

01:04:29,940 --> 01:04:33,750

the crab supernova remnant all right

1528

01:04:31,949 --> 01:04:37,109

then when we look in other wavelengths

1529

01:04:33,750 --> 01:04:40,139

we get a lot more information ok in

1530

01:04:37,110 --> 01:04:42,269

terms of the from the radio the various

1531

01:04:40,139 --> 01:04:44,009

infrared bands from Spitzer we've got

1532

01:04:42,269 --> 01:04:46,199

the visible light here we've got the

1533

01:04:44,010 --> 01:04:48,450

ultraviolet in here and down in the

1534

01:04:46,199 --> 01:04:50,279

x-ray we can actually see the disk of

1535

01:04:48,449 --> 01:04:53,339

material around the pulsar at the core

1536

01:04:50,280 --> 01:04:55,620

of the Crab Nebula all right this is

1537

01:04:53,340 --> 01:04:57,480

what astronomy is progressive - it's

1538

01:04:55,619 --> 01:04:59,699

being able to look in these various

1539

01:04:57,480 --> 01:05:02,460

wavelengths of light and get different

1540
01:04:59,699 --> 01:05:04,469
aspects of the same objects in these

1541
01:05:02,460 --> 01:05:06,599
different wavelength regions and I'm

1542
01:05:04,469 --> 01:05:07,859
gonna finish with my favorite object to

1543
01:05:06,599 --> 01:05:09,869
do for this which is of course the

1544
01:05:07,860 --> 01:05:10,860
Whirlpool Galaxy I've shown you the

1545
01:05:09,869 --> 01:05:13,349
Hubble invisible

1546
01:05:10,860 --> 01:05:16,890
the Spitzer infrared here is the

1547
01:05:13,349 --> 01:05:18,630
ultraviolet image I believe that sale

1548
01:05:16,889 --> 01:05:20,940
for violet image from galaxy and here's

1549
01:05:18,630 --> 01:05:23,599
the x-ray image from Chandra we're able

1550
01:05:20,940 --> 01:05:26,220
to see different structures

1551
01:05:23,599 --> 01:05:27,809
understanding it together and so this is

1552
01:05:26,219 --> 01:05:30,318
a poster that we produced in the office

1553
01:05:27,809 --> 01:05:32,808
of public outreach where we work

1554
01:05:30,318 --> 01:05:36,469
through it to try and help express the

1555
01:05:32,809 --> 01:05:38,089
idea that over the last century we have

1556
01:05:36,469 --> 01:05:39,829
gone from just visible light

1557
01:05:38,088 --> 01:05:42,349
observations with the normal telescopes

1558
01:05:39,829 --> 01:05:44,509
that you think about adding in radio and

1559
01:05:42,349 --> 01:05:46,548
infrared and ultraviolet and cross the

1560
01:05:44,509 --> 01:05:50,509
entire electromagnetic spectrum

1561
01:05:46,548 --> 01:05:53,449
so astronomy has grown up to explore the

1562
01:05:50,509 --> 01:05:55,639
entire spectrum and there truly is more

1563
01:05:53,449 --> 01:05:58,659
to the universe than meets the eye

1564
01:05:55,639 --> 01:05:58,659
thank you very

1565
01:06:09,469 --> 01:06:16,349
so I filled with all sorts of things all

1566
01:06:12,809 --> 01:06:19,079
around happiness on happy Russian music

1567
01:06:16,349 --> 01:06:22,170
yes nice never thought this question

1568

01:06:19,079 --> 01:06:25,440
until I see this presentation for the

1569
01:06:22,170 --> 01:06:28,010
visible spectrum it's pretty obvious but

1570
01:06:25,440 --> 01:06:30,690
for all these other named spectrums are

1571
01:06:28,010 --> 01:06:34,110
there scientific properties that define

1572
01:06:30,690 --> 01:06:36,809
the edges for did Steve discover x-rays

1573
01:06:34,110 --> 01:06:48,210
I'm playing this set of spectrum for

1574
01:06:36,809 --> 01:06:50,820
x-rays and that's it I would say that

1575
01:06:48,210 --> 01:06:53,789
they're more defined by the detectors

1576
01:06:50,820 --> 01:06:55,740
and they would be by the way okay so a

1577
01:06:53,789 --> 01:06:57,509
detector that can detect you know

1578
01:06:55,739 --> 01:07:00,029
wavelengths from here to here well that

1579
01:06:57,510 --> 01:07:03,480
would define a region right so if x-rays

1580
01:07:00,030 --> 01:07:10,800
you you have a detector that can detect

1581
01:07:03,480 --> 01:07:12,750
the x-rays you can see we have

1582
01:07:10,800 --> 01:07:15,150

near-infrared min infrared and far

1583

01:07:12,750 --> 01:07:16,559

infrared we use slightly different type

1584

01:07:15,150 --> 01:07:18,660

of detectors for each one of those

1585

01:07:16,559 --> 01:07:20,039

regions okay we talked about millimeter

1586

01:07:18,659 --> 01:07:22,319

wave and microwave which are really the

1587

01:07:20,039 --> 01:07:23,820

same thing but you know there's

1588

01:07:22,320 --> 01:07:26,039

different ways that that you use to

1589

01:07:23,820 --> 01:07:28,980

detect them okay as you're working

1590

01:07:26,039 --> 01:07:30,599

through them yeah the visible light yet

1591

01:07:28,980 --> 01:07:33,469

it's defined by what the human eye can

1592

01:07:30,599 --> 01:07:36,420

see but the other ones they're more

1593

01:07:33,469 --> 01:07:38,879

analytic a types of the detectors that

1594

01:07:36,420 --> 01:07:40,470

kind of carved that out for that one

1595

01:07:38,880 --> 01:07:41,130

spectrum and then somebody gave it the

1596

01:07:40,469 --> 01:07:45,689

name x-rays

1597
01:07:41,130 --> 01:07:46,980
sure let's go back the names for them I

1598
01:07:45,690 --> 01:07:50,280
really don't know the history about

1599
01:07:46,980 --> 01:07:52,599
Holly got named for that but really you

1600
01:07:50,280 --> 01:07:54,970
know what you're gonna

1601
01:07:52,599 --> 01:07:56,739
that I truly believe it's the detectors

1602
01:07:54,969 --> 01:08:00,279
that sort of carved out the regions for

1603
01:07:56,739 --> 01:08:02,409
that yes you showed a slide of the black

1604
01:08:00,280 --> 01:08:05,350
hole and some radio waves emitting from

1605
01:08:02,409 --> 01:08:11,230
yeah black hole such a strong

1606
01:08:05,349 --> 01:08:13,599
gravitational pull the escapes okay so

1607
01:08:11,230 --> 01:08:16,210
what happening is it's not black holes

1608
01:08:13,599 --> 01:08:17,949
in it it's the material around the

1609
01:08:16,210 --> 01:08:19,090
supermassive black hole that's this

1610
01:08:17,949 --> 01:08:20,829
you've got this disk of material

1611
01:08:19,090 --> 01:08:21,310
spinning around the supermassive black

1612
01:08:20,829 --> 01:08:22,659
holes

1613
01:08:21,310 --> 01:08:24,430
you've got magnetic fields and they're

1614
01:08:22,659 --> 01:08:26,619
being spun up like this and you have

1615
01:08:24,430 --> 01:08:29,380
material being flung off those magnetic

1616
01:08:26,619 --> 01:08:31,059
fields okay so it's not it's not the

1617
01:08:29,380 --> 01:08:32,890
emission isn't coming from a black hole

1618
01:08:31,060 --> 01:08:37,830
itself it's coming from the region

1619
01:08:32,890 --> 01:08:37,829
around it okay so very good question I

1620
01:08:43,289 --> 01:08:48,460
had a picture up there of collection of

1621
01:08:46,239 --> 01:08:52,329
galaxies and then you did a picture of

1622
01:08:48,460 --> 01:08:55,329
it in x-rays and it was a red block yes

1623
01:08:52,329 --> 01:08:58,149
you use the term hundreds of thousands

1624
01:08:55,329 --> 01:09:03,729
degrees for all this gas yes quite a

1625

01:08:58,149 --> 01:09:07,179
five the gas is at very low density okay

1626
01:09:03,729 --> 01:09:10,000
but the temperature is basically

1627
01:09:07,180 --> 01:09:12,130
measurement of its motion in that okay

1628
01:09:10,000 --> 01:09:13,810
so if we were a hundred thousand degrees

1629
01:09:12,130 --> 01:09:15,850
that the density of earth it would be

1630
01:09:13,810 --> 01:09:17,620
really really hot right but really

1631
01:09:15,850 --> 01:09:20,890
really low density you're just measuring

1632
01:09:17,619 --> 01:09:23,079
what the temperature of a gas is a

1633
01:09:20,890 --> 01:09:25,000
statistical measure of how fast on

1634
01:09:23,079 --> 01:09:27,279
average the molecules are moving so you

1635
01:09:25,000 --> 01:09:30,189
can have now one particle per cubic

1636
01:09:27,279 --> 01:09:32,619
centimeter or one particle per cubic

1637
01:09:30,189 --> 01:09:34,989
mile and they're moving at the same

1638
01:09:32,619 --> 01:09:37,779
speed they have the same temperature but

1639
01:09:34,989 --> 01:09:39,219

the the the way you and I would

1640
01:09:37,779 --> 01:09:41,460
experience temperature would be totally

1641
01:09:39,220 --> 01:09:46,119
different for those okay thank you okay

1642
01:09:41,460 --> 01:09:48,850
yes the gamma bursts from long ago and

1643
01:09:46,119 --> 01:09:49,278
far away if they're obscene a billion

1644
01:09:48,850 --> 01:09:51,650
light years

1645
01:09:49,279 --> 01:09:55,730
away they were happened a billion years

1646
01:09:51,649 --> 01:10:00,788
ago every stop so we ever see the in

1647
01:09:55,729 --> 01:10:00,788
racist stop oh

1648
01:10:04,210 --> 01:10:09,439
the gamma ray person I know are you know

1649
01:10:07,819 --> 01:10:11,389
hundreds of millions to billions of

1650
01:10:09,439 --> 01:10:14,828
light years away I'm not an expert on

1651
01:10:11,389 --> 01:10:20,359
that but I don't know of any that are

1652
01:10:14,828 --> 01:10:25,759
that nearby okay that were cool yeah I

1653
01:10:20,359 --> 01:10:30,618
would say in infrared with the center

1654
01:10:25,760 --> 01:10:32,900
thing pretty much like red what sound

1655
01:10:30,618 --> 01:10:37,460
like what color is that brighter or

1656
01:10:32,899 --> 01:10:40,609
dimmer okay so in the mixer of view of

1657
01:10:37,460 --> 01:10:44,480
the whole galaxy alright so these blue

1658
01:10:40,609 --> 01:10:45,259
here is actually going to be hotter in

1659
01:10:44,479 --> 01:10:47,509
the infrared

1660
01:10:45,260 --> 01:10:49,460
okay a lot of times what they will do is

1661
01:10:47,510 --> 01:10:52,010
for the infrared which doesn't have any

1662
01:10:49,460 --> 01:10:54,800
colors right so they'll take the lower

1663
01:10:52,010 --> 01:10:57,349
energy and bread and map it to red and

1664
01:10:54,800 --> 01:11:00,050
the higher energy map it to blue so just

1665
01:10:57,349 --> 01:11:01,699
sort of corresponding to and so these

1666
01:11:00,050 --> 01:11:04,070
are actually this is the satellite

1667
01:11:01,698 --> 01:11:19,868
galaxy okay and what you're seeing there

1668
01:11:04,069 --> 01:11:23,630
are the stars from this team okay

1669
01:11:19,868 --> 01:11:28,429
yes right there Oh seems like James Webb

1670
01:11:23,630 --> 01:11:31,630
is infrared Jessica why why is that so

1671
01:11:28,429 --> 01:11:36,739
important now that wavelength okay so

1672
01:11:31,630 --> 01:11:38,900
look at this our main look into see of

1673
01:11:36,738 --> 01:11:40,578
the formation of stars and planets okay

1674
01:11:38,899 --> 01:11:42,738
because you'll be looking through the

1675
01:11:40,578 --> 01:11:44,808
dense gas the public for example can't

1676
01:11:42,738 --> 01:11:47,000
look through the other thing that why

1677
01:11:44,809 --> 01:11:48,590
infrared is really important is to look

1678
01:11:47,000 --> 01:11:51,859
at this very distant regions of the

1679
01:11:48,590 --> 01:11:53,929
universe because as the universe expands

1680
01:11:51,859 --> 01:11:55,788
light waves the traveling across the

1681
01:11:53,929 --> 01:11:57,920
universe gets stretched along with the

1682

01:11:55,788 --> 01:12:00,139
expansion of the universe so light that

1683
01:11:57,920 --> 01:12:00,859
started out in visible light gets

1684
01:12:00,139 --> 01:12:02,659
trapped

1685
01:12:00,859 --> 01:12:08,569
it becomes infrared by the time we

1686
01:12:02,659 --> 01:12:11,300
observe it okay no okay this is the

1687
01:12:08,569 --> 01:12:12,769
expansion of light especially like the

1688
01:12:11,300 --> 01:12:16,550
stretching of light due to the expansion

1689
01:12:12,770 --> 01:12:19,820
of the universe all right and so observe

1690
01:12:16,550 --> 01:12:22,279
the universe in Bermondsey all radiation

1691
01:12:19,819 --> 01:12:25,429
from various universe that light has

1692
01:12:22,279 --> 01:12:28,789
been stretched now to the infrared so we

1693
01:12:25,430 --> 01:12:31,670
have you see there are some things

1694
01:12:28,789 --> 01:12:33,439
Hubble can observe simply because their

1695
01:12:31,670 --> 01:12:35,569
light has been stretched beyond Hubble's

1696
01:12:33,439 --> 01:12:39,159

observing wavelengths that's another

1697

01:12:35,569 --> 01:12:42,409

reason why i jst will be so important

1698

01:12:39,159 --> 01:12:45,170

hey I got a question if you're a way way

1699

01:12:42,409 --> 01:12:51,309

out of space and look back at our galaxy

1700

01:12:45,170 --> 01:12:51,310

and you want to look into our telescope

1701

01:13:24,399 --> 01:13:32,659

which only shines like like have a

1702

01:13:27,560 --> 01:13:41,539

little bit of vision but mostly one see

1703

01:13:32,659 --> 01:13:44,090

that we see the light really far away in

1704

01:13:41,539 --> 01:13:46,010

the cosmological expansion stretches

1705

01:13:44,090 --> 01:13:48,640

that with those wavelengths then they

1706

01:13:46,010 --> 01:13:52,640

would go towards the infrared right okay

1707

01:13:48,640 --> 01:13:55,250

so our our solar system doesn't have a

1708

01:13:52,640 --> 01:13:56,630

lot of dust and gas in it like the HL

1709

01:13:55,250 --> 01:13:59,210

Tauri system that i showed you from that

1710

01:13:56,630 --> 01:14:01,520

ama observation that's a pot system

1711
01:13:59,210 --> 01:14:02,220
still in formation there's still lots of

1712
01:14:01,520 --> 01:14:04,260
dusting

1713
01:14:02,220 --> 01:14:06,510
and colds and stuff floating around in

1714
01:14:04,260 --> 01:14:10,110
that system so you that's why I'm using

1715
01:14:06,510 --> 01:14:12,000
the millimeter already better but since

1716
01:14:10,109 --> 01:14:14,189
ours is a system that's ultimately

1717
01:14:12,000 --> 01:14:18,119
devoid of that stuff you'd want to use

1718
01:14:14,189 --> 01:14:19,739
visible or infrared okay great

1719
01:14:18,119 --> 01:14:23,069
most of what you've been talking about

1720
01:14:19,739 --> 01:14:24,599
our objects are emitting light at these

1721
01:14:23,069 --> 01:14:26,849
various wavelengths man now what about

1722
01:14:24,600 --> 01:14:29,780
observing objects that are reflecting

1723
01:14:26,850 --> 01:14:35,640
light at these various wavelengths and

1724
01:14:29,779 --> 01:14:40,710
does observing at some of these shorter

1725
01:14:35,640 --> 01:14:47,310
wavelengths give you more detail than at

1726
01:14:40,710 --> 01:14:49,409
the longer wavelengths Wow let's see so

1727
01:14:47,310 --> 01:14:51,539
first of all there's only there are only

1728
01:14:49,409 --> 01:14:54,059
a few cases where we observe reflective

1729
01:14:51,539 --> 01:14:56,460
light and get a lot of get a lot of it

1730
01:14:54,060 --> 01:15:02,070
okay I showed you the reflection nebula

1731
01:14:56,460 --> 01:15:04,500
around the Pleiades etc around around

1732
01:15:02,069 --> 01:15:06,119
supermassive black holes where there's a

1733
01:15:04,500 --> 01:15:08,220
light that when there's energy being

1734
01:15:06,119 --> 01:15:11,010
emitted from those that hits a disc of

1735
01:15:08,220 --> 01:15:12,780
material that this ends up reradiating

1736
01:15:11,010 --> 01:15:16,470
that can absorb it and reradiates so

1737
01:15:12,779 --> 01:15:18,750
that can also be reflected in there but

1738
01:15:16,470 --> 01:15:20,280
not a tub not a ton of cases where

1739

01:15:18,750 --> 01:15:22,979
there's a lot of reflected light to it

1740
01:15:20,279 --> 01:15:25,649
to observe do you see my point that it

1741
01:15:22,979 --> 01:15:28,289
with the shorter wavelengths you would

1742
01:15:25,649 --> 01:15:31,109
be able to see more detail than with

1743
01:15:28,289 --> 01:15:32,880
longer wavelengths is that so this is

1744
01:15:31,109 --> 01:15:34,380
not a thing to recognize especially

1745
01:15:32,880 --> 01:15:36,239
mature in terms of the James Webb Space

1746
01:15:34,380 --> 01:15:38,609
Telescope the James Webb Space Telescope

1747
01:15:36,239 --> 01:15:40,500
being six and a half meters Hubble is

1748
01:15:38,609 --> 01:15:44,250
only two Knack meters but the resolution

1749
01:15:40,500 --> 01:15:45,720
is roughly the same because this is jus

1750
01:15:44,250 --> 01:15:47,220
T's that infrared wavelength which the

1751
01:15:45,720 --> 01:15:49,800
longer wavelength so the shorter

1752
01:15:47,220 --> 01:15:52,170
wavelengths do give you higher

1753
01:15:49,800 --> 01:15:54,210

resolution on things like that however

1754

01:15:52,170 --> 01:15:56,460
the fact that we can get a radio

1755

01:15:54,210 --> 01:15:58,920
telescope to stretch across miles and

1756

01:15:56,460 --> 01:15:59,739
miles and miles actually gives radio

1757

01:15:58,920 --> 01:16:04,868
some

1758

01:15:59,738 --> 01:16:08,319
the highest resolution alright versus

1759

01:16:04,868 --> 01:16:12,189
the size right that gives you your

1760

01:16:08,319 --> 01:16:15,819
resolution so if you have you know gamma

1761

01:16:12,189 --> 01:16:17,558
rays are hard to pinpoint etc it goes

1762

01:16:15,819 --> 01:16:22,149
they guess we get scattered if you're

1763

01:16:17,559 --> 01:16:24,369
observing him the the way we detect them

1764

01:16:22,149 --> 01:16:26,679
doesn't doesn't in point them exactly

1765

01:16:24,368 --> 01:16:28,448
right because we see that there's a

1766

01:16:26,679 --> 01:16:29,859
shower coming up coming off of them it

1767

01:16:28,448 --> 01:16:32,379
doesn't give you that that hyperfine

1768
01:16:29,859 --> 01:16:37,359
resolution the way a mirror observation

1769
01:16:32,380 --> 01:16:39,578
would okay so but radios by having these

1770
01:16:37,359 --> 01:16:41,229
very very large arrays alright which

1771
01:16:39,578 --> 01:16:43,090
simulated a telescope having a car

1772
01:16:41,229 --> 01:16:44,558
through that big compared to the

1773
01:16:43,090 --> 01:16:47,498
wavelength can actually give you

1774
01:16:44,559 --> 01:16:48,849
extremely high resolution imagery so

1775
01:16:47,498 --> 01:16:50,618
when we say hull is the highest

1776
01:16:48,849 --> 01:16:52,389
resolution right it's the highest

1777
01:16:50,618 --> 01:16:53,979
resolution visible light telescope out

1778
01:16:52,389 --> 01:16:57,038
there that's not the highest resolution

1779
01:16:53,979 --> 01:16:58,718
telescope at all up there you can see

1780
01:16:57,038 --> 01:17:02,590
that the Alma array has much higher

1781
01:16:58,719 --> 01:17:05,288
resolution do you get more information

1782
01:17:02,590 --> 01:17:08,139
from the VLA with the fact that it's

1783
01:17:05,288 --> 01:17:33,279
moving around as the Earth rotates and

1784
01:17:08,139 --> 01:17:34,900
as the earth moves around the Sun so the

1785
01:17:33,279 --> 01:17:39,099
wavefront can be correlated between the

1786
01:17:34,899 --> 01:17:43,719
tool alright any other questions yes

1787
01:17:39,099 --> 01:17:48,550
down front there good question visible

1788
01:17:43,719 --> 01:17:51,368
life yes is it possible to utilize for a

1789
01:17:48,550 --> 01:17:52,900
very very distant objects across the

1790
01:17:51,368 --> 01:17:57,578
Google as a website for the sake of

1791
01:17:52,899 --> 01:18:00,368
argument different frequencies we use

1792
01:17:57,578 --> 01:18:02,649
some expect spectroscopy is not limited

1793
01:18:00,368 --> 01:18:05,139
to just visible light okay we can take

1794
01:18:02,649 --> 01:18:06,738
infrared spectra we can take ultraviolet

1795
01:18:05,139 --> 01:18:10,279
spectrum

1796

01:18:06,738 --> 01:18:13,729
we're looking for the when we're looking

1797
01:18:10,279 --> 01:18:16,609
at the the atmospheres of extrasolar

1798
01:18:13,729 --> 01:18:20,000
planets right we want to take a spectra

1799
01:18:16,609 --> 01:18:21,859
of in the infrared to try and identify

1800
01:18:20,000 --> 01:18:23,988
the molecules in the atmosphere and

1801
01:18:21,859 --> 01:18:25,399
control a planet so to see the details

1802
01:18:23,988 --> 01:18:28,309
of the juicy details that we want

1803
01:18:25,399 --> 01:18:30,589
they're actually in the infrared okay so

1804
01:18:28,310 --> 01:18:35,300
we can do spectra across across the

1805
01:18:30,590 --> 01:18:37,670
spectrum and their various things a lot

1806
01:18:35,300 --> 01:18:39,560
of them in some of the weight bands it's

1807
01:18:37,670 --> 01:18:41,840
just unity you take a detection here

1808
01:18:39,560 --> 01:18:44,090
adaptation here detection here you sort

1809
01:18:41,840 --> 01:18:45,469
of synthesize a spectrum through it as

1810
01:18:44,090 --> 01:18:46,810

opposed to taking many many many

1811
01:18:45,469 --> 01:18:51,980
wavelengths as we do with visible light

1812
01:18:46,810 --> 01:18:53,960
okay all right we know that visible

1813
01:18:51,979 --> 01:18:58,129
light is affected by gravity

1814
01:18:53,960 --> 01:19:01,219
I assume all energies now would one

1815
01:18:58,130 --> 01:19:03,710
movie star there this one is no

1816
01:19:01,219 --> 01:19:12,079
different from the red light on my life

1817
01:19:03,710 --> 01:19:14,569
though Hey so look the liquid one one

1818
01:19:12,079 --> 01:19:16,340
end of the spectrum be heavier than the

1819
01:19:14,569 --> 01:19:20,479
other in other word he would be more

1820
01:19:16,340 --> 01:19:21,739
bent worthless if it affects the effect

1821
01:19:20,479 --> 01:19:23,389
that you're talking about is dependent

1822
01:19:21,738 --> 01:19:27,769
upon energy yes

1823
01:19:23,390 --> 01:19:30,140
all right so then life high energy

1824
01:19:27,770 --> 01:19:32,060
wavelengths are refracted more than

1825
01:19:30,140 --> 01:19:34,400
lower anyway like when you create a

1826
01:19:32,060 --> 01:19:38,000
spectrum with a prism all right the red

1827
01:19:34,399 --> 01:19:50,809
light is diffracted less than the violet

1828
01:19:38,000 --> 01:19:53,899
light visible light you have the

1829
01:19:50,810 --> 01:19:56,570
gravitational lenses those like the blue

1830
01:19:53,899 --> 01:19:59,779
works you get images like that in the

1831
01:19:56,569 --> 01:20:00,829
other wavelengths so I'm not I said the

1832
01:19:59,779 --> 01:20:03,079
question is doing it gravitational

1833
01:20:00,829 --> 01:20:05,238
lensing in other wavelengths the answer

1834
01:20:03,079 --> 01:20:06,859
would be yes we should theoretically

1835
01:20:05,238 --> 01:20:10,669
there's no reason we shouldn't get

1836
01:20:06,859 --> 01:20:13,939
gravitational I do not know that I've

1837
01:20:10,670 --> 01:20:14,840
seen you sure because you need it we

1838
01:20:13,939 --> 01:20:20,388
need really high

1839
01:20:14,840 --> 01:20:22,069
I mean Hubble's amazing invisible I like

1840
01:20:20,389 --> 01:20:24,050
left okay

1841
01:20:22,069 --> 01:20:27,439
and it's gonna get it's gonna be

1842
01:20:24,050 --> 01:20:29,889
affected by the gravity even if it's a

1843
01:20:27,439 --> 01:20:31,609
different wavelength yes you should get

1844
01:20:29,889 --> 01:20:33,560
gravitational lensing I know we get

1845
01:20:31,609 --> 01:20:35,420
gravitational lensing of infrared okay

1846
01:20:33,560 --> 01:20:36,770
even Hubble's observations the inbred

1847
01:20:35,420 --> 01:20:39,260
sees gravitational lensing in the

1848
01:20:36,770 --> 01:20:41,000
infrared but I can't say I've seen it in

1849
01:20:39,260 --> 01:20:43,250
other wavelengths beyond visible and

1850
01:20:41,000 --> 01:20:53,448
infrared it's late a wave or a particle

1851
01:20:43,250 --> 01:20:55,488
yeah no not just an observation

1852
01:20:53,448 --> 01:21:10,698
thank you for more accurately locating

1853

01:20:55,488 --> 01:21:15,169
the EPL in columbia as opposed to yeah

1854
01:21:10,698 --> 01:21:19,238
because the gerrymandered zip code it's

1855
01:21:15,170 --> 01:21:19,239
actually in the laurel zip code but

1856
01:21:39,038 --> 01:21:42,800
if you would like to go to the

1857
01:21:40,998 --> 01:21:45,288
observatory we have our observatory

1858
01:21:42,800 --> 01:21:47,300
person here yes over here this gentleman

1859
01:21:45,288 --> 01:21:49,389
in the brown shirt if you would like to

1860
01:21:47,300 --> 01:21:51,739
go to Maryland Space Grant Observatory

1861
01:21:49,389 --> 01:21:53,118
come down here and talk to him he'll

1862
01:21:51,738 --> 01:21:56,078
take you across the street for the

1863
01:21:53,118 --> 01:21:56,078
observing tonight

1864
01:22:15,590 --> 01:22:26,029
see if gravitational waves so what we've

1865
01:22:23,210 --> 01:22:28,969
got such good observations of it we can

1866
01:22:26,029 --> 01:22:30,920
now look for tiny variations in way and

1867
01:22:28,969 --> 01:22:33,489

so one of the ways we can look at it is

1868

01:22:30,920 --> 01:22:33,489

look for powers