PUBLIC LECTURE SERIES

Armchair Astrophysics: Finding Physics Far and Wide

Featuring Guest Speaker :

Quyen Hart

1
00:00:05,829 --> 00:00:04,470
welcome to the space telescope public

2
00:00:07,909 --> 00:00:05,839
lecture series

3
00:00:09,750 --> 00:00:07,919
tonight featuring tonight's talk

4
00:00:12,470 --> 00:00:09,760
armchair astrophysics

5
00:00:13,030 --> 00:00:12,480
finding physics far and wide by quinn

6
00:00:16,070 --> 00:00:13,040
hart

7
00:00:18,470 --> 00:00:16,080
of the space telescope science institute

8
00:00:19,269 --> 00:00:18,480
i'm your host dr frank summers of the

9
00:00:22,150 --> 00:00:19,279
office of public

10
00:00:23,750 --> 00:00:22,160
outreach and i want to remind you that

11
00:00:24,630 --> 00:00:23,760
the space telescope public lecture

12
00:00:27,029 --> 00:00:24,640
series will be

13
00:00:28,550 --> 00:00:27,039

online only for at least the rest of

14
00:00:31,109 --> 00:00:28,560
2020

15
00:00:32,150 --> 00:00:31,119
and because we are doing this online we

16
00:00:34,389 --> 00:00:32,160
have to put

17
00:00:36,069 --> 00:00:34,399
special thanks out to our wonderful tech

18
00:00:38,470 --> 00:00:36,079
team thomas marufu

19
00:00:39,590 --> 00:00:38,480
and grant justice who are taking this

20
00:00:43,510 --> 00:00:39,600
this stream

21
00:00:45,990 --> 00:00:43,520
and getting it to you to see live

22
00:00:48,229 --> 00:00:46,000
our upcoming talks next month in

23
00:00:51,590 --> 00:00:48,239
september on september 1st

24
00:00:53,910 --> 00:00:51,600
we have well a very long title sailing

25
00:00:56,229 --> 00:00:53,920
across the local universe with ulysses

26
00:00:57,430 --> 00:00:56,239
a hubble program to observe ultraviolet

27
00:01:00,310 --> 00:00:57,440
light from young

28
00:01:02,869 --> 00:01:00,320
stars by will fisher and this is

29
00:01:05,189 --> 00:01:02,879
actually a very exciting program

30
00:01:06,789 --> 00:01:05,199
one of the largest programs ever done

31
00:01:08,070 --> 00:01:06,799
with the hubble space telescope

32
00:01:10,469 --> 00:01:08,080
you're really going to want to see what

33
00:01:12,630 --> 00:01:10,479
that's about on october

34
00:01:14,390 --> 00:01:12,640
we will have a talk on the nancy grace

35
00:01:16,870 --> 00:01:14,400
roman space telescope

36
00:01:18,390 --> 00:01:16,880
this telescope was previously called w

37
00:01:20,710 --> 00:01:18,400
first for wide field

38
00:01:22,070 --> 00:01:20,720

infrared space telescope and was

39
00:01:23,749 --> 00:01:22,080
recently renamed

40
00:01:25,670 --> 00:01:23,759
to be the nancy grace roman space

41
00:01:28,469 --> 00:01:25,680
telescope they're having a

42
00:01:29,270 --> 00:01:28,479
conference here um or actually an online

43
00:01:31,830 --> 00:01:29,280
conference

44
00:01:32,550 --> 00:01:31,840
uh center space telescope science

45
00:01:35,030 --> 00:01:32,560
institute

46
00:01:35,830 --> 00:01:35,040
in october and one of the speakers from

47
00:01:38,069 --> 00:01:35,840
the conference

48
00:01:39,990 --> 00:01:38,079
will be presenting information on the

49
00:01:42,230 --> 00:01:40,000
roman space telescope

50
00:01:43,350 --> 00:01:42,240
and then in november we have a really

51
00:01:46,550 --> 00:01:43,360
cool talk for you

52
00:01:50,389 --> 00:01:46,560
it's called astronomify sonification

53
00:01:53,109 --> 00:01:50,399
of astronomical data what if you could

54
00:01:54,389 --> 00:01:53,119
listen to the sounds of the universe or

55
00:01:57,030 --> 00:01:54,399
the data of the universe

56
00:01:58,950 --> 00:01:57,040
turn it into sounds uh scott fleming and

57
00:02:02,469 --> 00:01:58,960
his team have worked on that

58
00:02:03,510 --> 00:02:02,479
with the uh uh astronomical archive at

59
00:02:04,870 --> 00:02:03,520
space telescope

60
00:02:06,789 --> 00:02:04,880
and he'll tell you about that in

61
00:02:08,469 --> 00:02:06,799
november

62
00:02:11,390 --> 00:02:08,479
you want to find out about this you go

63
00:02:14,470 --> 00:02:11,400

to our public lecture series webpage

64
00:02:17,589 --> 00:02:14,480
stsci.edu public hyphen

65
00:02:18,710 --> 00:02:17,599
lectures on it you will see the links to

66
00:02:21,830 --> 00:02:18,720
our webcast

67
00:02:24,550 --> 00:02:21,840
both on youtube and on the sdsci webcast

68
00:02:26,150 --> 00:02:24,560
archive and in the lower right you can

69
00:02:28,229 --> 00:02:26,160
see the subscription button

70
00:02:29,670 --> 00:02:28,239
for the email if you'd like to get

71
00:02:31,350 --> 00:02:29,680
reminders every month

72
00:02:33,910 --> 00:02:31,360
you can subscribe by just entering your

73
00:02:36,309 --> 00:02:33,920
email address there

74
00:02:37,750 --> 00:02:36,319
you can also find uh information about

75
00:02:41,830 --> 00:02:37,760
our upcoming talks

76
00:02:44,070 --> 00:02:41,840
each talk has its own page and when you

77
00:02:45,509 --> 00:02:44,080
look in that look at that page you will

78
00:02:48,070 --> 00:02:45,519
find the description

79
00:02:48,790 --> 00:02:48,080
um and the introductions as well as the

80
00:02:51,030 --> 00:02:48,800
links to

81
00:02:52,390 --> 00:02:51,040
after it's been archived onto the sdsci

82
00:02:57,589 --> 00:02:52,400
webcasting page

83
00:03:01,990 --> 00:02:59,750
our email announcements well as i said

84
00:03:03,910 --> 00:03:02,000
you can sign up at our website

85
00:03:05,589 --> 00:03:03,920
and also because we're doing this online

86
00:03:07,670 --> 00:03:05,599
and streaming to youtube you may want to

87
00:03:10,710 --> 00:03:07,680
subscribe to our youtube channel

88
00:03:12,229 --> 00:03:10,720

youtube.com hubble space telescope all

89
00:03:13,910 --> 00:03:12,239
one word

90
00:03:15,830 --> 00:03:13,920
if you are a subscriber you will get

91
00:03:17,670 --> 00:03:15,840
notices of our new videos

92
00:03:18,949 --> 00:03:17,680
as well as reminders of these live

93
00:03:21,110 --> 00:03:18,959
events

94
00:03:22,470 --> 00:03:21,120
finally if you have comments or

95
00:03:23,110 --> 00:03:22,480
questions about what you see here

96
00:03:25,869 --> 00:03:23,120
tonight

97
00:03:28,470 --> 00:03:25,879
you can send them to public lecture at

98
00:03:30,550 --> 00:03:28,480
stsci.edu

99
00:03:31,990 --> 00:03:30,560
our social media we have social media

100
00:03:34,149 --> 00:03:32,000
for the hubble space telescope

101
00:03:36,070 --> 00:03:34,159
for the web space telescope and first

102
00:03:37,910 --> 00:03:36,080
space telescope science institute

103
00:03:40,470 --> 00:03:37,920
i'm sure we'll have social media for the

104
00:03:42,550 --> 00:03:40,480
roman space telescope eventually

105
00:03:43,509 --> 00:03:42,560
we're on facebook we're on twitter we're

106
00:03:46,309 --> 00:03:43,519
on youtube and

107
00:03:47,910 --> 00:03:46,319
instagram and i myself am i'll do a

108
00:03:51,990 --> 00:03:47,920
little bit on facebook and twitter if

109
00:03:56,949 --> 00:03:54,949
now news from the universe for august

110
00:04:00,550 --> 00:03:56,959
2020

111
00:04:03,670 --> 00:04:00,560
our first story tonight saturn

112
00:04:05,750 --> 00:04:03,680
again now that sounds like i'm

113
00:04:07,750 --> 00:04:05,760

not terribly excited about this but it

114
00:04:10,149 --> 00:04:07,760
really is exciting because

115
00:04:11,110 --> 00:04:10,159
we observe saturn just about every every

116
00:04:13,270 --> 00:04:11,120
year because

117
00:04:14,229 --> 00:04:13,280
as saturn and earth make their orbits

118
00:04:16,229 --> 00:04:14,239
around the sun

119
00:04:17,349 --> 00:04:16,239
whenever earth and saturn come into

120
00:04:18,390 --> 00:04:17,359
conjunction when they're at their

121
00:04:21,749 --> 00:04:18,400
closest point

122
00:04:24,629 --> 00:04:21,759
we get a picture of saturn and this year

123
00:04:25,990 --> 00:04:24,639
we got this image of saturn this is the

124
00:04:28,950 --> 00:04:26,000
2020 image

125
00:04:30,310 --> 00:04:28,960
of saturn from hubble and you got to

126
00:04:32,950 --> 00:04:30,320
think about this this is the

127
00:04:33,430 --> 00:04:32,960
best picture we can get being here at

128
00:04:35,110 --> 00:04:33,440
earth

129
00:04:37,030 --> 00:04:35,120
if we aren't going to fly across the

130
00:04:38,310 --> 00:04:37,040
solar system and get there like the

131
00:04:40,070 --> 00:04:38,320
cassini mission did

132
00:04:41,510 --> 00:04:40,080
this is the best we can do and this is

133
00:04:44,550 --> 00:04:41,520
really great image

134
00:04:46,310 --> 00:04:44,560
of saturn another cool thing about it is

135
00:04:48,390 --> 00:04:46,320
we can use ephemeris software

136
00:04:50,070 --> 00:04:48,400
to figure out where the moons are and

137
00:04:52,390 --> 00:04:50,080
these white dots here

138
00:04:53,350 --> 00:04:52,400

are they stars are they moons well we

139
00:04:56,390 --> 00:04:53,360
can figure them out

140
00:04:58,950 --> 00:04:56,400
actually there are one two three four

141
00:05:00,870 --> 00:04:58,960
five different moons in this image

142
00:05:03,990 --> 00:05:00,880
enceladus epimetheus

143
00:05:05,510 --> 00:05:04,000
mimos helene and pandora

144
00:05:07,749 --> 00:05:05,520
that we're able to identify in the

145
00:05:10,790 --> 00:05:07,759
hubble image and you can see all

146
00:05:12,710 --> 00:05:10,800
the details of the bit wavelength wave

147
00:05:16,310 --> 00:05:12,720
bands that we use to observe

148
00:05:18,950 --> 00:05:16,320
saturn but i call this saturn again

149
00:05:20,390 --> 00:05:18,960
because well if you're a follower of the

150
00:05:22,550 --> 00:05:20,400
public lecture series you may

151
00:05:23,990 --> 00:05:22,560
notice that i do a picture of saturn

152
00:05:26,150 --> 00:05:24,000
just about every year

153
00:05:28,629 --> 00:05:26,160
matter of fact last year in 2019 i

154
00:05:31,430 --> 00:05:28,639
showed you this image

155
00:05:32,310 --> 00:05:31,440
and then the year before that in 2018 i

156
00:05:35,670 --> 00:05:32,320
showed you

157
00:05:38,230 --> 00:05:35,680
this image and so we see saturn

158
00:05:39,670 --> 00:05:38,240
just about every year as it passes

159
00:05:43,990 --> 00:05:39,680
through conjunction

160
00:05:46,629 --> 00:05:44,000
and the point is that saturn's year

161
00:05:47,749 --> 00:05:46,639
lasts for about 29 and a half earth

162
00:05:51,029 --> 00:05:47,759
years

163
00:05:53,510 --> 00:05:51,039

so observing saturn every year

164
00:05:55,029 --> 00:05:53,520
it's it's really like looking at earth

165
00:05:58,070 --> 00:05:55,039
every two weeks

166
00:06:01,110 --> 00:05:58,080
and a a season on saturn lasts

167
00:06:01,430 --> 00:06:01,120
for seven and a half years so every year

168
00:06:03,749 --> 00:06:01,440
is

169
00:06:05,189 --> 00:06:03,759
not that strong of a cadence in order to

170
00:06:07,990 --> 00:06:05,199
follow the developments

171
00:06:10,550 --> 00:06:08,000
on saturn and if you look at how it

172
00:06:14,070 --> 00:06:10,560
progresses from 2018

173
00:06:15,830 --> 00:06:14,080
to 2019 to 2020

174
00:06:17,510 --> 00:06:15,840
you can first see that the tilt of the

175
00:06:20,150 --> 00:06:17,520
rings changes but

176
00:06:21,189 --> 00:06:20,160
look at the atmosphere and the banding

177
00:06:23,830 --> 00:06:21,199
structure

178
00:06:25,029 --> 00:06:23,840
and even the hexagon on the top there

179
00:06:28,390 --> 00:06:25,039
are small but

180
00:06:30,870 --> 00:06:28,400
subtle changes every year in saturn

181
00:06:32,710 --> 00:06:30,880
that astronomers are following using the

182
00:06:35,350 --> 00:06:32,720
hubble space telescope

183
00:06:36,629 --> 00:06:35,360
this is actually a program called opal

184
00:06:39,189 --> 00:06:36,639
opal

185
00:06:39,990 --> 00:06:39,199
the outer planet's atmosphere legacy

186
00:06:42,950 --> 00:06:40,000
program

187
00:06:44,230 --> 00:06:42,960
and is one of the very important solar

188
00:06:46,790 --> 00:06:44,240

system programs

189
00:06:47,590 --> 00:06:46,800
that gets time on hubble every year to

190
00:06:50,550 --> 00:06:47,600
follow

191
00:06:53,270 --> 00:06:50,560
how the changes in the large planets our

192
00:06:57,510 --> 00:06:55,510
the second story for you tonight is

193
00:07:00,710 --> 00:06:57,520
planetary nebulae

194
00:07:02,070 --> 00:07:00,720
again and what does that mean well

195
00:07:04,150 --> 00:07:02,080
i think it means that i was a little

196
00:07:06,150 --> 00:07:04,160
lazy when i was writing the titles of my

197
00:07:08,550 --> 00:07:06,160
stories tonight but it means we're going

198
00:07:10,230 --> 00:07:08,560
to talk about planetary nebulae

199
00:07:14,070 --> 00:07:10,240
and the first planetary nebula we're

200
00:07:16,629 --> 00:07:14,080
going to talk about is ngc7027

201
00:07:17,270 --> 00:07:16,639
that doesn't have a pretty name all

202
00:07:20,469 --> 00:07:17,280
right but

203
00:07:23,510 --> 00:07:20,479
what is a planetary nebula first it is a

204
00:07:25,909 --> 00:07:23,520
dying star it's a medium-sized star

205
00:07:28,390 --> 00:07:25,919
and when these stars die they actually

206
00:07:30,070 --> 00:07:28,400
blow off their outer layers

207
00:07:31,670 --> 00:07:30,080
and you can see the star at the center

208
00:07:33,909 --> 00:07:31,680
of this image

209
00:07:35,510 --> 00:07:33,919
and that the the material that has been

210
00:07:38,150 --> 00:07:35,520
blown off from the star

211
00:07:38,790 --> 00:07:38,160
is outside it is being illuminated by

212
00:07:42,070 --> 00:07:38,800
the hot

213
00:07:45,029 --> 00:07:42,080

core of the star this is a very

214
00:07:46,309 --> 00:07:45,039
young planetary nebula it is just in the

215
00:07:48,550 --> 00:07:46,319
beginning stages

216
00:07:49,909 --> 00:07:48,560
of blowing off its outer layers and this

217
00:07:53,350 --> 00:07:49,919
is what hubble saw

218
00:07:55,430 --> 00:07:53,360
back in 1998 um in with an

219
00:07:57,189 --> 00:07:55,440
infrared instrument called nikmos the

220
00:07:58,550 --> 00:07:57,199
near infrared camera multi-object

221
00:08:01,110 --> 00:07:58,560
spectrograph

222
00:08:01,830 --> 00:08:01,120
and we had also had an image in visible

223
00:08:05,589 --> 00:08:01,840
light

224
00:08:06,469 --> 00:08:05,599
from 1996 and back in 1998 we combined

225
00:08:08,550 --> 00:08:06,479
the two

226
00:08:10,950 --> 00:08:08,560
and you got this really cool image of

227
00:08:12,309 --> 00:08:10,960
this dying star blowing off its outer

228
00:08:14,070 --> 00:08:12,319
layers

229
00:08:17,189 --> 00:08:14,080
but these were the instruments that were

230
00:08:19,510 --> 00:08:17,199
used back in the late 1990s

231
00:08:21,749 --> 00:08:19,520
since then we've had some quite a few

232
00:08:25,029 --> 00:08:21,759
technical improvements on hubble

233
00:08:28,390 --> 00:08:25,039
so in 2020 we're able to take

234
00:08:32,289 --> 00:08:28,400
this image and transform it

235
00:08:33,829 --> 00:08:32,299
into this image

236
00:08:37,190 --> 00:08:33,839
[Music]

237
00:08:39,750 --> 00:08:37,200
ah this is really cool

238
00:08:40,630 --> 00:08:39,760

right i mean you're seeing so much more

239
00:08:43,509 --> 00:08:40,640
detail

240
00:08:44,870 --> 00:08:43,519
with the improved instruments on hubble

241
00:08:46,790 --> 00:08:44,880
and it's not just that you're seeing

242
00:08:49,430 --> 00:08:46,800
higher resolution which you are

243
00:08:50,870 --> 00:08:49,440
but you're also seeing all the way from

244
00:08:53,670 --> 00:08:50,880
ultraviolet light

245
00:08:55,030 --> 00:08:53,680
to infrared light this is a pan

246
00:08:58,790 --> 00:08:55,040
chromatic image

247
00:09:00,870 --> 00:08:58,800
of ngc 7027 we're able to see

248
00:09:01,829 --> 00:09:00,880
details and actually we're able to see

249
00:09:04,150 --> 00:09:01,839
changes

250
00:09:05,509 --> 00:09:04,160
in the structure because this is a young

251
00:09:07,509 --> 00:09:05,519
planetary nebula

252
00:09:09,190 --> 00:09:07,519
this actually has changes in its

253
00:09:11,990 --> 00:09:09,200
structure over those

254
00:09:14,389 --> 00:09:12,000
over those 20 years well there's another

255
00:09:17,990 --> 00:09:14,399
planetary nebulae studied in this

256
00:09:20,550 --> 00:09:18,000
and this one is ngc 6302

257
00:09:21,590 --> 00:09:20,560
which actually does have a pretty a more

258
00:09:26,870 --> 00:09:21,600
familiar name

259
00:09:29,110 --> 00:09:26,880
nebula however the bug nebula

260
00:09:31,350 --> 00:09:29,120
kind of got thrown by the wayside when

261
00:09:32,310 --> 00:09:31,360
we had the press release back in 2009

262
00:09:33,829 --> 00:09:32,320
for this image

263
00:09:37,030 --> 00:09:33,839

and we called it it said it looked like

264
00:09:38,389 --> 00:09:37,040
a butterfly so now everyone calls it the

265
00:09:40,070 --> 00:09:38,399
butterfly nebula

266
00:09:42,630 --> 00:09:40,080
and this is just one of the gorgeous

267
00:09:45,829 --> 00:09:42,640
images from service ingredient for

268
00:09:48,550 --> 00:09:45,839
early release observations in 2009

269
00:09:50,389 --> 00:09:48,560
this is another planetary nebula but

270
00:09:52,550 --> 00:09:50,399
instead of having that shell structure

271
00:09:54,949 --> 00:09:52,560
it's got this blowout structure that

272
00:09:56,870 --> 00:09:54,959
forms the wings of the butterfly

273
00:09:58,790 --> 00:09:56,880
material flowing off in opposite

274
00:10:00,790 --> 00:09:58,800
directions okay

275
00:10:02,310 --> 00:10:00,800
and so this is actually a full high

276
00:10:05,990 --> 00:10:02,320
resolution image

277
00:10:08,310 --> 00:10:06,000
and instead of getting higher resolution

278
00:10:09,269 --> 00:10:08,320
what does interesting of the 2020

279
00:10:12,470 --> 00:10:09,279
observation

280
00:10:14,470 --> 00:10:12,480
is that extra wavelength so here is the

281
00:10:18,230 --> 00:10:14,480
panchromatic version

282
00:10:21,750 --> 00:10:18,240
of the butterfly nebula yeah

283
00:10:24,389 --> 00:10:21,760
really gets a lot of more in really cool

284
00:10:25,350 --> 00:10:24,399
interesting detail and my favorite

285
00:10:26,790 --> 00:10:25,360
feature in this

286
00:10:28,550 --> 00:10:26,800
is actually something that shows up in

287
00:10:31,509 --> 00:10:28,560
the infrared all right

288
00:10:33,590 --> 00:10:31,519

and these arrows point to these splays

289
00:10:36,710 --> 00:10:33,600
that are coming off and say sort of an

290
00:10:39,990 --> 00:10:36,720
s shape across it and that

291
00:10:42,790 --> 00:10:40,000
is ionized iron seen

292
00:10:44,790 --> 00:10:42,800
in infrared light and it's the fact that

293
00:10:46,470 --> 00:10:44,800
it's just a sort of a jet of this

294
00:10:48,150 --> 00:10:46,480
ionized iron

295
00:10:49,990 --> 00:10:48,160
tells you something about the emission

296
00:10:52,310 --> 00:10:50,000
that's going on in the at the

297
00:10:54,069 --> 00:10:52,320
central star matter of fact that it

298
00:10:54,790 --> 00:10:54,079
tells you there's probably a disk of

299
00:10:57,430 --> 00:10:54,800
material

300
00:10:58,230 --> 00:10:57,440
so that's that's collimating this

301
00:11:01,190 --> 00:10:58,240
outflow

302
00:11:01,590 --> 00:11:01,200
into this jet and perhaps that this this

303
00:11:04,389 --> 00:11:01,600
disk

304
00:11:05,829 --> 00:11:04,399
material is wobbling around indicative

305
00:11:08,069 --> 00:11:05,839
that there may actually be

306
00:11:09,509 --> 00:11:08,079
two stars at the center that this is a

307
00:11:11,030 --> 00:11:09,519
binary star

308
00:11:13,030 --> 00:11:11,040
that's helping to produce this

309
00:11:16,310 --> 00:11:13,040
collimated outflow that's sort of just

310
00:11:17,670 --> 00:11:16,320
wobbling to get that s shape as it spews

311
00:11:20,630 --> 00:11:17,680
out

312
00:11:21,030 --> 00:11:20,640
so doing these panchromatic studies of

313
00:11:25,269 --> 00:11:21,040

these

314
00:11:28,230 --> 00:11:25,279
pretty young planetary nebula

315
00:11:29,269 --> 00:11:28,240
allows us to get more detail across more

316
00:11:30,710 --> 00:11:29,279
wavelengths

317
00:11:32,389 --> 00:11:30,720
as well as to understand some of the

318
00:11:37,670 --> 00:11:32,399
changes over time

319
00:11:45,509 --> 00:11:42,550
now we go to our our featured speaker um

320
00:11:47,190 --> 00:11:45,519
dr quinn hart has been at the space

321
00:11:49,190 --> 00:11:47,200
telescope science institute

322
00:11:50,470 --> 00:11:49,200
as a colleague of mine in the office of

323
00:11:52,949 --> 00:11:50,480
public outreach for

324
00:11:53,670 --> 00:11:52,959
just only one year i mean it's kind of

325
00:11:56,069 --> 00:11:53,680
funky because i

326
00:11:57,269 --> 00:11:56,079
i i really think of her as you know an

327
00:12:00,069 --> 00:11:57,279
old friend now

328
00:12:01,030 --> 00:12:00,079
but she's only been here a year uh

329
00:12:04,310 --> 00:12:01,040
previously

330
00:12:06,870 --> 00:12:04,320
she was at the um regis university

331
00:12:07,750 --> 00:12:06,880
in uh denver uh where she was there for

332
00:12:11,030 --> 00:12:07,760
10 years

333
00:12:14,069 --> 00:12:11,040
she has incredible history in teaching

334
00:12:15,910 --> 00:12:14,079
um she got her ph.d at colorado

335
00:12:17,829 --> 00:12:15,920
university in boulder

336
00:12:19,350 --> 00:12:17,839
and something unique amongst the

337
00:12:22,150 --> 00:12:19,360
astronomers i know

338
00:12:24,069 --> 00:12:22,160

she was an atmospheric scientist at the

339
00:12:27,750 --> 00:12:24,079
scripps institute of oceanography

340
00:12:30,230 --> 00:12:27,760
before that so she's got a unique resume

341
00:12:32,230 --> 00:12:30,240
and one really cool thing about her is

342
00:12:33,910 --> 00:12:32,240
that she likes to crochet

343
00:12:36,870 --> 00:12:33,920
um and she likes the stories of winnie

344
00:12:40,470 --> 00:12:36,880
the pooh so she has crocheted

345
00:12:43,269 --> 00:12:40,480
a complete set of poo characters

346
00:12:43,990 --> 00:12:43,279
now that's kind of fun uh ladies and

347
00:12:47,990 --> 00:12:44,000
gentlemen

348
00:12:52,150 --> 00:12:48,000
dr quinn hart thank you

349
00:12:53,670 --> 00:12:52,160
um can you hear me okay

350
00:12:55,430 --> 00:12:53,680
all right thank you frank for the

351
00:12:57,670 --> 00:12:55,440
introduction um

352
00:13:00,230 --> 00:12:57,680
i'm really really happy to be able to

353
00:13:03,190 --> 00:13:00,240
talk to you all virtually tonight

354
00:13:05,430 --> 00:13:03,200
about astrophysics when i taught

355
00:13:08,389 --> 00:13:05,440
university level physics courses

356
00:13:09,910 --> 00:13:08,399
my students would say physics is so hard

357
00:13:10,389 --> 00:13:09,920
and i would say well you know what my

358
00:13:12,790 --> 00:13:10,399
job

359
00:13:13,590 --> 00:13:12,800
is for you to change your mind about

360
00:13:17,590 --> 00:13:13,600
physics

361
00:13:19,990 --> 00:13:17,600
that when you walk around all you see is

362
00:13:21,509 --> 00:13:20,000
physics and if you come to me saying hey

363
00:13:23,829 --> 00:13:21,519

i just saw this and i thought about

364
00:13:25,509 --> 00:13:23,839
physics then i know that i succeeded so

365
00:13:27,030 --> 00:13:25,519
that was that's kind of the motivation

366
00:13:29,910 --> 00:13:27,040
for my talk tonight is

367
00:13:31,509 --> 00:13:29,920
to have you see the connections of

368
00:13:34,629 --> 00:13:31,519
physics in your everyday life

369
00:13:36,550 --> 00:13:34,639
to start to understand or

370
00:13:39,030 --> 00:13:36,560
understand more deeply the things that

371
00:13:42,790 --> 00:13:39,040
you might already

372
00:13:42,800 --> 00:13:46,710
okay

373
00:13:50,230 --> 00:13:49,509
so what are we gonna do tonight so i

374
00:13:52,069 --> 00:13:50,240
mentioned that

375
00:13:54,310 --> 00:13:52,079
i'm a firm believer that anybody can

376
00:13:56,310 --> 00:13:54,320
talk about science with anybody else

377
00:13:57,350 --> 00:13:56,320
um it's really in how you see the

378
00:13:59,670 --> 00:13:57,360
connections

379
00:14:01,030 --> 00:13:59,680
and what interests you and the people

380
00:14:03,590 --> 00:14:01,040
around you

381
00:14:05,350 --> 00:14:03,600
now you might think that the science of

382
00:14:07,189 --> 00:14:05,360
astrophysics you know in this nutshell

383
00:14:09,509 --> 00:14:07,199
is a really hard nut to crack

384
00:14:11,030 --> 00:14:09,519
even if you're just starting to learn it

385
00:14:12,389 --> 00:14:11,040
so you might wonder how am i going to

386
00:14:13,590 --> 00:14:12,399
talk about astrophysics

387
00:14:15,269 --> 00:14:13,600
if i don't understand it you want to

388
00:14:16,310 --> 00:14:15,279

crack that nut open right so what are we

389
00:14:17,750 --> 00:14:16,320
going to do today

390
00:14:18,949 --> 00:14:17,760
well we're going to try to crack that

391
00:14:19,750 --> 00:14:18,959
nut open and how are you going to do

392
00:14:21,509 --> 00:14:19,760
that

393
00:14:23,750 --> 00:14:21,519
well you're going to need to use

394
00:14:25,189 --> 00:14:23,760
something that you're familiar with and

395
00:14:27,269 --> 00:14:25,199
so what are you familiar with

396
00:14:28,310 --> 00:14:27,279
you're familiar with your everyday

397
00:14:29,509 --> 00:14:28,320
experiences

398
00:14:31,750 --> 00:14:29,519
so we're going to use some of those

399
00:14:33,189 --> 00:14:31,760
everyday experiences and

400
00:14:35,430 --> 00:14:33,199
draw the connections so you can

401
00:14:36,710 --> 00:14:35,440
understand some of the astrophysics so

402
00:14:40,150 --> 00:14:36,720
that you can take

403
00:14:42,470 --> 00:14:40,160
your other um your experiences to crack

404
00:14:44,470 --> 00:14:42,480
open this astrophysics nut here so that

405
00:14:48,069 --> 00:14:44,480
that's kind of the goal here for

406
00:14:49,910 --> 00:14:48,079
for uh everyone and once you do that

407
00:14:51,829 --> 00:14:49,920
then you'll be able to sit down and have

408
00:14:52,790 --> 00:14:51,839
a nice little conversation with the

409
00:14:56,069 --> 00:14:52,800
people around you

410
00:14:57,189 --> 00:14:56,079
and who knows what uh um you know where

411
00:15:01,269 --> 00:14:57,199
that will lead you

412
00:15:04,550 --> 00:15:04,069
so i want you to think about this in a

413
00:15:06,230 --> 00:15:04,560

very

414
00:15:08,150 --> 00:15:06,240
beginning sense let's start with the

415
00:15:10,629 --> 00:15:08,160
beginning what does physics mean to you

416
00:15:11,990 --> 00:15:10,639
okay so can you look you can look at all

417
00:15:15,030 --> 00:15:12,000
these images and say oh yeah

418
00:15:17,829 --> 00:15:15,040
i get that i know what's going on there

419
00:15:18,310 --> 00:15:17,839
i i see a space shuttle going up in the

420
00:15:20,310 --> 00:15:18,320
sky

421
00:15:22,710 --> 00:15:20,320
roller coaster i see a rainbow i see

422
00:15:24,150 --> 00:15:22,720
light so these are different phenomena

423
00:15:25,189 --> 00:15:24,160
that you see and experience in your

424
00:15:28,150 --> 00:15:25,199
everyday world

425
00:15:28,949 --> 00:15:28,160
and physics plays some role in all of

426
00:15:32,710 --> 00:15:28,959
these

427
00:15:35,910 --> 00:15:32,720
so physics is really the study of nature

428
00:15:38,870 --> 00:15:35,920
it's the study of matter motion

429
00:15:40,470 --> 00:15:38,880
and the forces and energy that you see

430
00:15:44,389 --> 00:15:40,480
that allow the

431
00:15:46,550 --> 00:15:44,399
different reactions that you might see

432
00:15:48,470 --> 00:15:46,560
phenomena that you might see so then you

433
00:15:51,990 --> 00:15:48,480
might say well what is astrophysics

434
00:15:52,710 --> 00:15:52,000
it's really simple astrophysics is the

435
00:15:54,790 --> 00:15:52,720
study

436
00:15:56,550 --> 00:15:54,800
of matter motion forces and energy in

437
00:15:59,030 --> 00:15:56,560
space now this is a very simple

438
00:15:59,590 --> 00:15:59,040

definition but it encompasses some of

439
00:16:02,150 --> 00:15:59,600
the really

440
00:16:03,910 --> 00:16:02,160
basic ideas that we have here of what

441
00:16:05,829 --> 00:16:03,920
we're going to be learning today

442
00:16:07,430 --> 00:16:05,839
so we're going to look at those everyday

443
00:16:08,790 --> 00:16:07,440
phenomena not exactly what you saw in

444
00:16:11,749 --> 00:16:08,800
that previous slide there

445
00:16:13,590 --> 00:16:11,759
okay and use them to understand some of

446
00:16:17,030 --> 00:16:13,600
the basic physics principles

447
00:16:19,110 --> 00:16:17,040
to understand the terrestrial analogs

448
00:16:21,430 --> 00:16:19,120
out there in space

449
00:16:23,189 --> 00:16:21,440
the laws of physics are universal so we

450
00:16:26,069 --> 00:16:23,199
can apply our understanding of what we

451
00:16:28,389 --> 00:16:26,079
know here to what we know in space and

452
00:16:30,790 --> 00:16:28,399
the universe is so large of course

453
00:16:31,990 --> 00:16:30,800
we have surprises all the time so this

454
00:16:33,430 --> 00:16:32,000
doesn't mean that we can

455
00:16:37,990 --> 00:16:33,440
figure out everything but we can figure

456
00:16:41,430 --> 00:16:40,310
so let's start with really something

457
00:16:43,430 --> 00:16:41,440
really really simple

458
00:16:44,949 --> 00:16:43,440
okay so frank showed us all these

459
00:16:47,430 --> 00:16:44,959
wonderful images

460
00:16:48,470 --> 00:16:47,440
we're seeing light okay so the question

461
00:16:50,949 --> 00:16:48,480
down the line will be

462
00:16:51,670 --> 00:16:50,959
where's that light coming from how was

463
00:16:53,430 --> 00:16:51,680

it created

464
00:16:54,870 --> 00:16:53,440
but i just want to talk about the really

465
00:16:56,470 --> 00:16:54,880
simple light

466
00:16:58,629 --> 00:16:56,480
and matter and how they can interact

467
00:17:00,790 --> 00:16:58,639
with each other so

468
00:17:02,150 --> 00:17:00,800
a really basic concept here is that

469
00:17:04,630 --> 00:17:02,160
matter can emit light

470
00:17:06,069 --> 00:17:04,640
like the hot filament of a light bulb um

471
00:17:09,590 --> 00:17:06,079
matter can absorb light

472
00:17:10,309 --> 00:17:09,600
so um you should put some sunscreen on

473
00:17:12,710 --> 00:17:10,319
because you want

474
00:17:14,230 --> 00:17:12,720
the uv light of the sun to absorb by

475
00:17:16,309 --> 00:17:14,240
that material but your sun

476
00:17:18,069 --> 00:17:16,319
your skin can absorb that uv radiation

477
00:17:19,510 --> 00:17:18,079
from sunlight as well

478
00:17:21,110 --> 00:17:19,520
when you look at sunlight through the

479
00:17:24,470 --> 00:17:21,120
window

480
00:17:27,510 --> 00:17:24,480
the glass pane is transmitting light

481
00:17:28,950 --> 00:17:27,520
so matter can let light pass through it

482
00:17:30,630 --> 00:17:28,960
if you woke up and you brushed your

483
00:17:32,150 --> 00:17:30,640
teeth today good

484
00:17:34,390 --> 00:17:32,160
that means you saw yourself in the

485
00:17:36,470 --> 00:17:34,400
mirror and light was reflecting off that

486
00:17:37,590 --> 00:17:36,480
that mirror so matter can also reflect

487
00:17:39,750 --> 00:17:37,600
light

488
00:17:42,630 --> 00:17:39,760

so when you're looking at all this we're

489
00:17:45,750 --> 00:17:42,640
seeing that interaction

490
00:17:46,630 --> 00:17:45,760
now when you look at sunlight on a nice

491
00:17:49,350 --> 00:17:46,640
sunny day

492
00:17:50,470 --> 00:17:49,360
your eyes perceive it as mostly whitish

493
00:17:53,510 --> 00:17:50,480
light right

494
00:17:55,190 --> 00:17:53,520
but we know that on a nice

495
00:17:57,110 --> 00:17:55,200
uh if it's sunny and there's some rain

496
00:17:59,190 --> 00:17:57,120
drops around that we can get

497
00:18:00,950 --> 00:17:59,200
a rainbow so we know that the sunlight

498
00:18:02,630 --> 00:18:00,960
is composed of the colors of the rainbow

499
00:18:03,430 --> 00:18:02,640
but you need something to spread that

500
00:18:05,750 --> 00:18:03,440
light out

501
00:18:07,830 --> 00:18:05,760
so on this diagram here on the left this

502
00:18:09,350 --> 00:18:07,840
this uh ray of white light here

503
00:18:12,549 --> 00:18:09,360
represents sunlight

504
00:18:15,029 --> 00:18:12,559
and if it can pass through

505
00:18:17,190 --> 00:18:15,039
a rain droplet um that there's a little

506
00:18:19,909 --> 00:18:17,200
bit of transmission going on there

507
00:18:21,190 --> 00:18:19,919
but the direction that each color of

508
00:18:23,190 --> 00:18:21,200
light takes is different

509
00:18:24,230 --> 00:18:23,200
depending on if it's red light or the

510
00:18:25,909 --> 00:18:24,240
blue light

511
00:18:27,990 --> 00:18:25,919
uh on the inside of the rain droplet

512
00:18:28,470 --> 00:18:28,000
there's some reflection going on and

513
00:18:30,390 --> 00:18:28,480

then

514
00:18:31,909 --> 00:18:30,400
there's transmission through the other

515
00:18:33,830 --> 00:18:31,919
side of the raindrop and out the other

516
00:18:35,750 --> 00:18:33,840
side you get the rainbow

517
00:18:37,830 --> 00:18:35,760
and so that's something to spread out

518
00:18:39,510 --> 00:18:37,840
the sunlight into rainbow is is a water

519
00:18:41,029 --> 00:18:39,520
droplet here actually many many water

520
00:18:42,549 --> 00:18:41,039
droplets so that you can see

521
00:18:44,150 --> 00:18:42,559
this beautiful rainbow that we saw a

522
00:18:45,430 --> 00:18:44,160
couple weeks ago in maryland

523
00:18:47,430 --> 00:18:45,440
now you can do the same thing if you

524
00:18:50,470 --> 00:18:47,440
take a blu-ray disc

525
00:18:52,789 --> 00:18:50,480
or dvd player i'm sorry dvd disc

526
00:18:55,350 --> 00:18:52,799
and you hold it up to light okay you'll

527
00:18:57,830 --> 00:18:55,360
also get this rainbow effect because

528
00:18:59,430 --> 00:18:57,840
light in this case is reflecting off the

529
00:19:01,750 --> 00:18:59,440
dvd or blu-ray

530
00:19:03,990 --> 00:19:01,760
but there's tiny tiny grooves in there

531
00:19:05,350 --> 00:19:04,000
that allow the light to reflect off in

532
00:19:06,950 --> 00:19:05,360
different directions depending on the

533
00:19:08,950 --> 00:19:06,960
color which is why you see the

534
00:19:10,789 --> 00:19:08,960
beautiful colors here so this is a

535
00:19:13,110 --> 00:19:10,799
something to spread out the

536
00:19:14,150 --> 00:19:13,120
the sunlight colors into the colors of

537
00:19:15,830 --> 00:19:14,160
the rainbow because the

538
00:19:17,350 --> 00:19:15,840

sunlight is composed of those many

539
00:19:19,190 --> 00:19:17,360
different colors we our eyes just can't

540
00:19:22,830 --> 00:19:19,200
detect that

541
00:19:25,590 --> 00:19:22,840
so if you go outside here maybe you have

542
00:19:26,470 --> 00:19:25,600
a pot of zinnias like i do here in my

543
00:19:27,830 --> 00:19:26,480
yard

544
00:19:29,669 --> 00:19:27,840
maybe you have a beautiful bouquet of

545
00:19:32,070 --> 00:19:29,679
flowers or sunflowers here

546
00:19:33,909 --> 00:19:32,080
so you can look at these flowers i'm

547
00:19:37,430 --> 00:19:33,919
going to use this as an example here

548
00:19:39,029 --> 00:19:37,440
and start to think what's going on here

549
00:19:40,710 --> 00:19:39,039
i just talked about light and matter and

550
00:19:43,029 --> 00:19:40,720
how they interact with each other

551
00:19:44,870 --> 00:19:43,039
so what's going on here is it a mission

552
00:19:47,350 --> 00:19:44,880
of light is it the absorption of light

553
00:19:50,789 --> 00:19:47,360
transmission or reflection of light

554
00:19:53,669 --> 00:19:50,799
so you know that your eyes here are

555
00:19:54,390 --> 00:19:53,679
you're seeing green you're seeing yellow

556
00:19:57,590 --> 00:19:54,400
you're seeing

557
00:20:01,029 --> 00:19:57,600
this purple

558
00:20:01,430 --> 00:20:01,039
so some light is getting into your eyes

559
00:20:03,510 --> 00:20:01,440
here

560
00:20:06,630 --> 00:20:03,520
okay and then it's going to the back of

561
00:20:08,310 --> 00:20:06,640
your eye and it's being absorbed by um

562
00:20:09,990 --> 00:20:08,320
photosensitive cells in the back there

563
00:20:10,870 --> 00:20:10,000

that eventually send a chemical signal

564
00:20:12,310 --> 00:20:10,880
to your head and

565
00:20:14,789 --> 00:20:12,320
you sense light okay so that's what's

566
00:20:15,909 --> 00:20:14,799
going on biologically

567
00:20:18,789 --> 00:20:15,919
now you probably have a really good

568
00:20:20,470 --> 00:20:18,799
sense that the flowers are not

569
00:20:22,310 --> 00:20:20,480
emitting their own light because if you

570
00:20:23,830 --> 00:20:22,320
were in complete darkness you know you

571
00:20:24,149 --> 00:20:23,840
can't see these flowers so you know

572
00:20:27,270 --> 00:20:24,159
that's

573
00:20:28,549 --> 00:20:27,280
probably not emitting light

574
00:20:30,470 --> 00:20:28,559
you probably have a sense that they're

575
00:20:31,909 --> 00:20:30,480
not really transmitting light because if

576
00:20:33,830 --> 00:20:31,919
they were transmitting light you would

577
00:20:34,230 --> 00:20:33,840
need something underneath the flowers

578
00:20:36,870 --> 00:20:34,240
like

579
00:20:38,070 --> 00:20:36,880
you know hidden in these leaves here to

580
00:20:39,110 --> 00:20:38,080
shine through it for you to see it

581
00:20:42,149 --> 00:20:39,120
that's not what you see

582
00:20:43,990 --> 00:20:42,159
so that leaves us with either

583
00:20:45,190 --> 00:20:44,000
there's some reflection going on or some

584
00:20:48,149 --> 00:20:45,200
absorption going on

585
00:20:49,990 --> 00:20:48,159
right so whatever is happening here like

586
00:20:52,549 --> 00:20:50,000
in the yellow of the sunflower

587
00:20:54,870 --> 00:20:52,559
uh it's a yellow light is getting to

588
00:20:58,070 --> 00:20:54,880

your eye for you to see the yellow part

589
00:20:59,510 --> 00:20:58,080
okay and the green part of the leaf here

590
00:21:01,590 --> 00:20:59,520
something is happening where the green

591
00:21:02,070 --> 00:21:01,600
light is coming to your eye so really

592
00:21:05,270 --> 00:21:02,080
what is

593
00:21:08,470 --> 00:21:05,280
happening here is that

594
00:21:11,830 --> 00:21:08,480
there's pigmentation in the

595
00:21:13,909 --> 00:21:11,840
flower petals there's pigmentation

596
00:21:15,430 --> 00:21:13,919
in the green leaf now when i say

597
00:21:17,110 --> 00:21:15,440
pigmentation

598
00:21:19,430 --> 00:21:17,120
what i'm really saying is a molecule

599
00:21:22,789 --> 00:21:19,440
there's a molecule that's very specific

600
00:21:24,230 --> 00:21:22,799
to that particular flower petal and it's

601
00:21:26,070 --> 00:21:24,240
specifically

602
00:21:28,310 --> 00:21:26,080
for the case of the yellow sunflower

603
00:21:32,310 --> 00:21:28,320
here that pigmentation

604
00:21:35,110 --> 00:21:32,320
preferentially absorbs every color

605
00:21:35,990 --> 00:21:35,120
except yellow and yellow is reflected

606
00:21:39,029 --> 00:21:36,000
towards our eye

607
00:21:42,230 --> 00:21:39,039
so it absorbs the sunlight

608
00:21:44,789 --> 00:21:42,240
but preferentially reflects the yellow

609
00:21:46,149 --> 00:21:44,799
so when you see green leaves the

610
00:21:48,950 --> 00:21:46,159
pigmentation in the leaf

611
00:21:49,830 --> 00:21:48,960
again it's it's it's a molecule here

612
00:21:51,909 --> 00:21:49,840
absorbs

613
00:21:53,750 --> 00:21:51,919

all the colors of the sunlight except

614
00:21:56,149 --> 00:21:53,760
for the green and it reflects

615
00:21:58,870 --> 00:21:56,159
so this is a case of reflected light and

616
00:22:00,950 --> 00:21:58,880
absorb light at the same time here

617
00:22:02,310 --> 00:22:00,960
and if you take a close-up look of

618
00:22:03,909 --> 00:22:02,320
flower petals

619
00:22:05,750 --> 00:22:03,919
you can start to see that there are

620
00:22:07,510 --> 00:22:05,760
special distributions

621
00:22:09,669 --> 00:22:07,520
of this pigmentation on the flower so

622
00:22:11,350 --> 00:22:09,679
these are cut offs cutaways of flower

623
00:22:12,470 --> 00:22:11,360
petals sometimes that pigmentation is

624
00:22:14,789 --> 00:22:12,480
all throughout

625
00:22:16,870 --> 00:22:14,799
the material sometimes that pigmentation

626
00:22:19,270 --> 00:22:16,880
is just on the outer edges of the

627
00:22:20,310 --> 00:22:19,280
the petal here and sometimes it's only

628
00:22:22,310 --> 00:22:20,320
on the edge

629
00:22:24,310 --> 00:22:22,320
but the fact that we see red or we see

630
00:22:26,630 --> 00:22:24,320
purple is the fact that that petal

631
00:22:27,750 --> 00:22:26,640
did not absorb that particular color and

632
00:22:31,110 --> 00:22:27,760
reflected it out

633
00:22:33,029 --> 00:22:31,120
okay so that's what we perceive as color

634
00:22:34,390 --> 00:22:33,039
so now you get a sense of what color

635
00:22:36,070 --> 00:22:34,400
means okay so

636
00:22:37,430 --> 00:22:36,080
so now we can say oh frank showed us

637
00:22:38,310 --> 00:22:37,440
this picture of saturn what does that

638
00:22:39,669 --> 00:22:38,320

mean

639
00:22:41,190 --> 00:22:39,679
instead of showing saturn i'm going to

640
00:22:42,149 --> 00:22:41,200
share something else i'm going to show

641
00:22:44,630 --> 00:22:42,159
you

642
00:22:46,230 --> 00:22:44,640
some voyer 2 voyager 2 images of a

643
00:22:48,390 --> 00:22:46,240
uranus on the left the neptune on the

644
00:22:52,070 --> 00:22:48,400
right and they both have this beautiful

645
00:22:55,350 --> 00:22:52,080
blue hue to it so what's going on here

646
00:22:56,470 --> 00:22:55,360
is that in the visible light these

647
00:22:58,950 --> 00:22:56,480
planets do not

648
00:23:00,310 --> 00:22:58,960
um create their own light but we see

649
00:23:02,789 --> 00:23:00,320
them in visible light

650
00:23:04,470 --> 00:23:02,799
and that's because sunlight is shining

651
00:23:07,350 --> 00:23:04,480
on their atmospheres

652
00:23:09,270 --> 00:23:07,360
and the upper layer has methane gas that

653
00:23:11,830 --> 00:23:09,280
preferentially absorbs

654
00:23:12,390 --> 00:23:11,840
more of the reddish colored light here

655
00:23:14,549 --> 00:23:12,400
and so

656
00:23:16,470 --> 00:23:14,559
more the blue light makes it down

657
00:23:17,029 --> 00:23:16,480
towards the methane clouds with that

658
00:23:19,669 --> 00:23:17,039
which then

659
00:23:20,950 --> 00:23:19,679
reflected back out into space which was

660
00:23:24,149 --> 00:23:20,960
captured by the

661
00:23:26,870 --> 00:23:24,159
voyager cameras for us to see here and

662
00:23:28,870 --> 00:23:26,880
um so there's a lot of re uh absorption

663
00:23:30,710 --> 00:23:28,880

going on here and reflection to be able

664
00:23:31,750 --> 00:23:30,720
to give you that hue so that hue is very

665
00:23:34,549 --> 00:23:31,760
indicative

666
00:23:35,909 --> 00:23:34,559
of what the atmosphere is made of now

667
00:23:37,350 --> 00:23:35,919
let's take a look at jupiter because

668
00:23:40,549 --> 00:23:37,360
jupiter has some more

669
00:23:42,310 --> 00:23:40,559
interesting uh patterns to it

670
00:23:43,909 --> 00:23:42,320
so there are a lot of zones and belts

671
00:23:46,470 --> 00:23:43,919
here and these

672
00:23:48,070 --> 00:23:46,480
are ammonia clouds the white here are

673
00:23:50,390 --> 00:23:48,080
the ammonia clouds

674
00:23:52,230 --> 00:23:50,400
that are higher level clouds and the

675
00:23:55,510 --> 00:23:52,240
darker areas here

676
00:23:59,830 --> 00:23:55,520
are deeper clouds in the atmosphere

677
00:24:03,669 --> 00:23:59,840
made of you see here another kind of a

678
00:24:05,350 --> 00:24:03,679
ammonium compound now jupiter

679
00:24:06,950 --> 00:24:05,360
rotates very very quickly and that's

680
00:24:08,549 --> 00:24:06,960
partly why it has a very

681
00:24:10,310 --> 00:24:08,559
unique banded structure and we also have

682
00:24:11,350 --> 00:24:10,320
the great red spot here so here's just a

683
00:24:13,830 --> 00:24:11,360
nice video of

684
00:24:15,269 --> 00:24:13,840
what's going on so again in the visible

685
00:24:19,830 --> 00:24:15,279
light

686
00:24:21,190 --> 00:24:19,840
with the chemical composition of these

687
00:24:24,310 --> 00:24:21,200
trace elements

688
00:24:27,350 --> 00:24:24,320

uh ammonia and mojo

689
00:24:29,909 --> 00:24:27,360
that's absorbing preferentially

690
00:24:32,149 --> 00:24:29,919
all the colors except red in the case

691
00:24:32,950 --> 00:24:32,159
for this banded structure here on the

692
00:24:35,430 --> 00:24:32,960
other hand these

693
00:24:36,789 --> 00:24:35,440
white ammonia clouds they look white to

694
00:24:38,710 --> 00:24:36,799
us so a lot of the

695
00:24:40,549 --> 00:24:38,720
almost all the colors in the visible

696
00:24:41,750 --> 00:24:40,559
spectrum the sunlight is reflected off

697
00:24:43,750 --> 00:24:41,760
there

698
00:24:45,510 --> 00:24:43,760
and this red color here is also related

699
00:24:47,029 --> 00:24:45,520
to and the great red spot is related to

700
00:24:47,669 --> 00:24:47,039
the chemical composition of what's going

701
00:24:50,549 --> 00:24:47,679
on there

702
00:24:52,149 --> 00:24:50,559
doing a combination of absorption of all

703
00:24:55,990 --> 00:24:52,159
the different colors in the rainbow

704
00:25:02,710 --> 00:25:01,269
okay see there stop that

705
00:25:04,630 --> 00:25:02,720
so now we can take that and just go out

706
00:25:07,830 --> 00:25:04,640
a little bit further into space here

707
00:25:10,230 --> 00:25:07,840
that's just kind of like in our backyard

708
00:25:11,909 --> 00:25:10,240
so now let's take a look at a a really

709
00:25:13,830 --> 00:25:11,919
fun cluster that

710
00:25:15,029 --> 00:25:13,840
you can definitely see with your eyes

711
00:25:16,549 --> 00:25:15,039
called the pleiades

712
00:25:18,470 --> 00:25:16,559
star cluster sometimes it's referred to

713
00:25:21,510 --> 00:25:18,480

as the seven sisters

714
00:25:23,750 --> 00:25:21,520
it's near the orion constellation and so

715
00:25:25,350 --> 00:25:23,760
what you see here are the stars which

716
00:25:27,590 --> 00:25:25,360
are these uh

717
00:25:29,430 --> 00:25:27,600
brightest objects here and you can see

718
00:25:30,950 --> 00:25:29,440
the diffraction gratings these spiky

719
00:25:32,789 --> 00:25:30,960
things part of the

720
00:25:34,549 --> 00:25:32,799
detector here but then you see this

721
00:25:36,630 --> 00:25:34,559
bluish glow everywhere

722
00:25:37,990 --> 00:25:36,640
okay so what's going on here is that

723
00:25:39,669 --> 00:25:38,000
there's a lot of dust

724
00:25:41,590 --> 00:25:39,679
in fact that dust is in the foreground

725
00:25:44,710 --> 00:25:41,600
in between us and those stars

726
00:25:47,669 --> 00:25:44,720
and the dust grains easily scatter

727
00:25:48,230 --> 00:25:47,679
which is a special kind of reflection

728
00:25:50,390 --> 00:25:48,240
scatter

729
00:25:51,909 --> 00:25:50,400
the blue light of those young stars it

730
00:25:53,350 --> 00:25:51,919
preferentially does that

731
00:25:55,029 --> 00:25:53,360
and so we've talked we call this a

732
00:25:57,750 --> 00:25:55,039
reflection nebula because the light is

733
00:25:59,909 --> 00:25:57,760
being reflected or scattered away

734
00:26:01,990 --> 00:25:59,919
in the direction of our eyes for for

735
00:26:05,430 --> 00:26:02,000
this telescope or your eyes to see it

736
00:26:08,549 --> 00:26:05,440
so this is a an example again of light

737
00:26:10,310 --> 00:26:08,559
interacting with matter in a very one of

738
00:26:12,630 --> 00:26:10,320

those four ways in this way it's a

739
00:26:14,310 --> 00:26:12,640
reflection here

740
00:26:16,390 --> 00:26:14,320
so that's that's an example of how we

741
00:26:17,510 --> 00:26:16,400
look at light in a slightly

742
00:26:19,750 --> 00:26:17,520
different way that you might not have

743
00:26:21,510 --> 00:26:19,760
thought about before

744
00:26:23,029 --> 00:26:21,520
and that's think about something else so

745
00:26:26,070 --> 00:26:23,039
you've been listening my voice

746
00:26:29,750 --> 00:26:26,080
so it's sound right so maybe you've been

747
00:26:31,669 --> 00:26:29,760
lucky or unlucky to have a recorder

748
00:26:34,390 --> 00:26:31,679
by a little kid at home if you have that

749
00:26:37,669 --> 00:26:34,400
sound going on in your head

750
00:26:38,070 --> 00:26:37,679
if i was physically at space telescope

751
00:26:41,110 --> 00:26:38,080
right now

752
00:26:42,789 --> 00:26:41,120
you hear my voice um but as we're

753
00:26:45,430 --> 00:26:42,799
doing everything virtually here you're

754
00:26:48,870 --> 00:26:45,440
hearing my voice through a speaker

755
00:26:51,269 --> 00:26:48,880
and so you hear me the sound here

756
00:26:52,070 --> 00:26:51,279
is being carried through the air from

757
00:26:53,110 --> 00:26:52,080
whether it

758
00:26:54,630 --> 00:26:53,120
well for everybody here it's through

759
00:26:55,990 --> 00:26:54,640
your speaker your earphones whatever

760
00:26:58,070 --> 00:26:56,000
you're listening to

761
00:26:59,669 --> 00:26:58,080
and it's traveling through the air and

762
00:27:01,830 --> 00:26:59,679
then it hits your ear

763
00:27:03,669 --> 00:27:01,840

it travels into your ear vibrates and

764
00:27:05,669 --> 00:27:03,679
bones

765
00:27:07,029 --> 00:27:05,679
and eventually you get a chemical signal

766
00:27:08,549 --> 00:27:07,039
that sends an electrical

767
00:27:11,269 --> 00:27:08,559
signal to your head and you hear sound

768
00:27:13,990 --> 00:27:11,279
here so what needs to happen for

769
00:27:14,390 --> 00:27:14,000
sound though is that it really what it

770
00:27:18,230 --> 00:27:14,400
is

771
00:27:21,909 --> 00:27:18,240
through something

772
00:27:23,909 --> 00:27:21,919
so on your speakers there uh if you look

773
00:27:26,870 --> 00:27:23,919
at it if you uncover it you should see

774
00:27:27,350 --> 00:27:26,880
a speaker that vibrates up and down okay

775
00:27:29,669 --> 00:27:27,360
so as

776
00:27:31,830 --> 00:27:29,679
it vibrates up and down here it can

777
00:27:32,549 --> 00:27:31,840
cause the air molecules to compress

778
00:27:35,830 --> 00:27:32,559
together

779
00:27:37,990 --> 00:27:35,840
and rarify or spread out um so if you

780
00:27:40,389 --> 00:27:38,000
look at this image here on the screen

781
00:27:41,029 --> 00:27:40,399
you can see that where it looks like

782
00:27:43,029 --> 00:27:41,039
it's

783
00:27:44,149 --> 00:27:43,039
ring-like that's where the air molecules

784
00:27:45,909 --> 00:27:44,159
are

785
00:27:47,510 --> 00:27:45,919
closer together where it's compressed

786
00:27:48,870 --> 00:27:47,520
and where the air molecules are a little

787
00:27:49,750 --> 00:27:48,880
bit further apart that's where it's

788
00:27:51,669 --> 00:27:49,760

rarefied

789
00:27:53,029 --> 00:27:51,679
and if you look at that the rings are

790
00:27:56,149 --> 00:27:53,039
kind of

791
00:27:57,110 --> 00:27:56,159
separated by the same amount so there is

792
00:28:00,389 --> 00:27:57,120
a unique

793
00:28:02,630 --> 00:28:00,399
uh signature for this particular sound

794
00:28:03,990 --> 00:28:02,640
wave that is being displayed here

795
00:28:06,549 --> 00:28:04,000
and those little dots there represent

796
00:28:08,630 --> 00:28:06,559
the air molecules

797
00:28:09,669 --> 00:28:08,640
so another way to represent this is

798
00:28:11,590 --> 00:28:09,679
imagine if i

799
00:28:12,789 --> 00:28:11,600
were to take a snapshot i'd see

800
00:28:14,549 --> 00:28:12,799
molecules

801
00:28:16,149 --> 00:28:14,559
compressed here which would be an

802
00:28:17,590 --> 00:28:16,159
increased air pressure

803
00:28:19,029 --> 00:28:17,600
but then when it's rarified it'd be

804
00:28:20,630 --> 00:28:19,039
decreased and so you get this

805
00:28:22,870 --> 00:28:20,640
alternating compressed air

806
00:28:23,909 --> 00:28:22,880
rarefied air compressed air rarefied air

807
00:28:26,230 --> 00:28:23,919
compressed air

808
00:28:27,190 --> 00:28:26,240
and that whole wave moves out from the

809
00:28:28,870 --> 00:28:27,200
source okay

810
00:28:31,590 --> 00:28:28,880
and propagates through the air so we can

811
00:28:33,830 --> 00:28:31,600
talk about the characteristics of this

812
00:28:35,350 --> 00:28:33,840
wave this wave has a speed

813
00:28:37,350 --> 00:28:35,360

it has to move through the air at a

814
00:28:39,830 --> 00:28:37,360
certain speed

815
00:28:41,669 --> 00:28:39,840
there's a directional component to it

816
00:28:43,190 --> 00:28:41,679
there's a wavelength as well and if you

817
00:28:44,710 --> 00:28:43,200
know wavelength and you know speed then

818
00:28:45,590 --> 00:28:44,720
you can talk about the frequency so when

819
00:28:48,870 --> 00:28:45,600
you're

820
00:28:50,789 --> 00:28:48,880
singing a song you might sing at a c

821
00:28:53,029 --> 00:28:50,799
note so the c note is a certain

822
00:28:54,789 --> 00:28:53,039
frequency and that corresponds to a very

823
00:28:58,149 --> 00:28:54,799
particular wavelength

824
00:29:01,269 --> 00:28:58,159
of a sound wave through air

825
00:29:05,110 --> 00:29:01,279
now you might say okay i got that

826
00:29:07,750 --> 00:29:05,120
now um if you ever go into a nice

827
00:29:08,149 --> 00:29:07,760
empty room and you talk you'll find that

828
00:29:09,830 --> 00:29:08,159
you'll

829
00:29:12,149 --> 00:29:09,840
get a lot of echoes it's pretty fun to

830
00:29:15,990 --> 00:29:12,159
just sit there and say hello hello hello

831
00:29:18,230 --> 00:29:16,000
right so we've got a person here

832
00:29:19,430 --> 00:29:18,240
making that hello sound and the sound

833
00:29:23,029 --> 00:29:19,440
wave leaves

834
00:29:25,750 --> 00:29:23,039
and then can hit a solid object and

835
00:29:26,470 --> 00:29:25,760
reflect off of that so now we have sound

836
00:29:28,389 --> 00:29:26,480
waves

837
00:29:30,470 --> 00:29:28,399
reflecting off something solid and this

838
00:29:33,269 --> 00:29:30,480

is what we we call an echo

839
00:29:35,110 --> 00:29:33,279
okay now this happens with radio uh

840
00:29:37,590 --> 00:29:35,120
water waves as well so this is a

841
00:29:38,950 --> 00:29:37,600
an image where you can see shadows of

842
00:29:41,750 --> 00:29:38,960
water waves

843
00:29:43,269 --> 00:29:41,760
in a pool but it hits a wall here and

844
00:29:46,870 --> 00:29:43,279
gets reflected

845
00:29:50,950 --> 00:29:49,269
again have a speed if it's moving

846
00:29:53,430 --> 00:29:50,960
through air it has a certain speed

847
00:29:55,350 --> 00:29:53,440
sound wave sound can also travel through

848
00:29:56,470 --> 00:29:55,360
water and can travel through solid

849
00:29:58,789 --> 00:29:56,480
substances but they have

850
00:30:00,310 --> 00:29:58,799
will travel at different speeds um and

851
00:30:02,070 --> 00:30:00,320
uh wavelength and frequency and there's

852
00:30:05,350 --> 00:30:02,080
energy associated with that

853
00:30:07,029 --> 00:30:05,360
okay great so we know that waves

854
00:30:08,149 --> 00:30:07,039
have these characteristics they can move

855
00:30:09,750 --> 00:30:08,159
they have a wavelength and they can

856
00:30:13,190 --> 00:30:09,760
reflect off things

857
00:30:16,149 --> 00:30:13,200
well guess what light

858
00:30:17,909 --> 00:30:16,159
is a wave okay light can be a particle

859
00:30:18,630 --> 00:30:17,919
too i won't get into the duality of

860
00:30:24,630 --> 00:30:18,640
light

861
00:30:27,830 --> 00:30:24,640
a speed of three hundred thousand

862
00:30:28,630 --> 00:30:27,840
uh three hundred thousand kilometers per

863
00:30:32,710 --> 00:30:28,640

second here

864
00:30:34,070 --> 00:30:32,720
which is about 671 million miles per

865
00:30:35,909 --> 00:30:34,080
hour so really really fast

866
00:30:37,990 --> 00:30:35,919
light from the sun takes just about

867
00:30:40,070 --> 00:30:38,000
eight minutes to get from the sun

868
00:30:41,669 --> 00:30:40,080
to us traveling at the speed of light so

869
00:30:43,510 --> 00:30:41,679
that's really really fast

870
00:30:44,789 --> 00:30:43,520
now different colors of light have

871
00:30:45,909 --> 00:30:44,799
different wavelengths

872
00:30:49,110 --> 00:30:45,919
and they have different energies

873
00:30:51,190 --> 00:30:49,120
associated with it but all the colors of

874
00:30:53,029 --> 00:30:51,200
sunlight here travel through space at

875
00:30:54,470 --> 00:30:53,039
the exact same speed so that's different

876
00:30:55,990 --> 00:30:54,480
than sound waves in that in that sense

877
00:30:57,190 --> 00:30:56,000
that they have the same speed there's a

878
00:30:59,110 --> 00:30:57,200
speed limit in the universe

879
00:31:00,950 --> 00:30:59,120
it's three hundred thousand three

880
00:31:03,029 --> 00:31:00,960
hundred thousand kilometers per second

881
00:31:04,310 --> 00:31:03,039
so we know that light can reflect we've

882
00:31:05,750 --> 00:31:04,320
already talked about how light can

883
00:31:08,310 --> 00:31:05,760
reflect off of mirrors

884
00:31:09,830 --> 00:31:08,320
now if you have a laser a laser is a

885
00:31:11,830 --> 00:31:09,840
very specific

886
00:31:13,430 --> 00:31:11,840
color of light in this case that you see

887
00:31:15,269 --> 00:31:13,440
on the screen is a green color

888
00:31:17,269 --> 00:31:15,279

here and you can use multiple mirrors

889
00:31:19,269 --> 00:31:17,279
and an optics labs for

890
00:31:20,470 --> 00:31:19,279
and and bounce it around so we know it

891
00:31:24,630 --> 00:31:20,480
can reflect

892
00:31:26,310 --> 00:31:24,640
um if you are cleaning perhaps and you

893
00:31:28,789 --> 00:31:26,320
stir up a lot of dust you know that the

894
00:31:30,389 --> 00:31:28,799
dust can also reflect off of

895
00:31:32,149 --> 00:31:30,399
the light can also reflect off the dust

896
00:31:33,830 --> 00:31:32,159
so we know light light does this

897
00:31:36,149 --> 00:31:33,840
and we can ask we can describe it

898
00:31:37,830 --> 00:31:36,159
mathematically as a wave

899
00:31:40,389 --> 00:31:37,840
that reflects and interacts with light

900
00:31:43,669 --> 00:31:40,399
and can reflect in this way

901
00:31:45,990 --> 00:31:43,679
so can we see light echoes in space

902
00:31:48,870 --> 00:31:46,000
something like the sound echo but a

903
00:31:51,830 --> 00:31:48,880
light echo and sure enough we do

904
00:31:52,789 --> 00:31:51,840
so if you have a dusty environment

905
00:31:56,070 --> 00:31:52,799
around

906
00:31:57,590 --> 00:31:56,080
something that can give a burst so when

907
00:32:00,549 --> 00:31:57,600
i do like a click

908
00:32:01,190 --> 00:32:00,559
or snap my fingers that's a very sudden

909
00:32:07,830 --> 00:32:01,200
sound

910
00:32:09,430 --> 00:32:07,840
um you can wait for it to hear

911
00:32:11,110 --> 00:32:09,440
and bounce off things and you can start

912
00:32:14,149 --> 00:32:11,120
to figure out the distances to things

913
00:32:16,389 --> 00:32:14,159

okay so animals are are able to do this

914
00:32:17,669 --> 00:32:16,399
now if in space we have something that

915
00:32:21,029 --> 00:32:17,679
does a burst

916
00:32:22,950 --> 00:32:21,039
of light and let it emanate away

917
00:32:26,830 --> 00:32:22,960
it can also reflect so let me start this

918
00:32:29,029 --> 00:32:26,840
video here so this is v838 monocero

919
00:32:31,669 --> 00:32:29,039
monocerotis

920
00:32:32,549 --> 00:32:31,679
it is a star that when underwent an

921
00:32:37,110 --> 00:32:32,559
outburst

922
00:32:40,310 --> 00:32:37,120
in may 2002 so what you see here

923
00:32:41,669 --> 00:32:40,320
is the light reflecting off dust that

924
00:32:46,070 --> 00:32:41,679
was already there

925
00:32:48,549 --> 00:32:46,080
but the light had to travel outwards

926
00:32:49,509 --> 00:32:48,559
to hit those dust particles and then

927
00:32:52,549 --> 00:32:49,519
reach the earth

928
00:32:54,230 --> 00:32:52,559
in the telescope here so the star that

929
00:32:56,789 --> 00:32:54,240
went out first is at the center

930
00:32:57,509 --> 00:32:56,799
it became very red here it went

931
00:33:00,549 --> 00:32:57,519
underwent a

932
00:33:00,950 --> 00:33:00,559
burst of light an outburst and restart

933
00:33:05,669 --> 00:33:00,960
it

934
00:33:07,110 --> 00:33:05,679
dust exists out here

935
00:33:09,190 --> 00:33:07,120
you can't see it yet because the light

936
00:33:10,230 --> 00:33:09,200
hadn't reached it yet but we know what

937
00:33:13,029 --> 00:33:10,240
the speed of light

938
00:33:15,110 --> 00:33:13,039

is and we can watch this unfold with

939
00:33:16,950 --> 00:33:15,120
these hubble space telescope images

940
00:33:18,549 --> 00:33:16,960
and because of that we can get the

941
00:33:22,070 --> 00:33:18,559
distance to

942
00:33:24,070 --> 00:33:22,080
this object and this object is 20 000

943
00:33:25,070 --> 00:33:24,080
light years away from the earth and

944
00:33:28,070 --> 00:33:25,080
that's a

945
00:33:31,350 --> 00:33:28,080
geometrical distance estimate which is

946
00:33:34,630 --> 00:33:31,360
pretty cool using a light echo

947
00:33:37,669 --> 00:33:34,640
off of dust from from a star here

948
00:33:39,669 --> 00:33:37,679
so that's an example of a light echo now

949
00:33:41,350 --> 00:33:39,679
this is nearby this is in our own um

950
00:33:43,909 --> 00:33:41,360
galaxy we'll draw a little bit further

951
00:33:46,950 --> 00:33:43,919
away so we have a

952
00:33:49,110 --> 00:33:46,960
um star bursting galaxy so star bursting

953
00:33:52,230 --> 00:33:49,120
galaxy is a galaxy that's creating

954
00:33:54,149 --> 00:33:52,240
stars way more than the milky way galaxy

955
00:33:56,310 --> 00:33:54,159
is doing and in fact it's so much that's

956
00:33:59,669 --> 00:33:56,320
actually blowing material out of this

957
00:34:02,230 --> 00:33:59,679
spiral galaxy here but what was really

958
00:34:04,310 --> 00:34:02,240
interesting is in 2014

959
00:34:07,750 --> 00:34:04,320
a supernova explosion went off and that

960
00:34:10,710 --> 00:34:07,760
is a

961
00:34:12,230 --> 00:34:10,720
end to a very massive star's life and

962
00:34:14,790 --> 00:34:12,240
supernova explosions are

963
00:34:15,270 --> 00:34:14,800

very energetic and again a burst of

964
00:34:18,069 --> 00:34:15,280
light

965
00:34:19,510 --> 00:34:18,079
that can come out and so what we see

966
00:34:22,629 --> 00:34:19,520
here

967
00:34:25,829 --> 00:34:22,639
is when that supernova went off

968
00:34:28,470 --> 00:34:25,839
this was embedded in a very dusty area

969
00:34:31,030 --> 00:34:28,480
and so we see a light echo here as well

970
00:34:35,430 --> 00:34:31,040
and so this is unfolding over

971
00:34:39,109 --> 00:34:35,440
um and uh

972
00:34:43,750 --> 00:34:39,119
look at it loop again here 2014

973
00:34:45,990 --> 00:34:43,760
all the way to 2017 there

974
00:34:47,669 --> 00:34:46,000
so over the course of several years here

975
00:34:49,510 --> 00:34:47,679
um seeing that light echo

976
00:34:51,430 --> 00:34:49,520
and that light echo is not exactly

977
00:34:54,230 --> 00:34:51,440
symmetric so the fact that

978
00:34:55,030 --> 00:34:54,240
it's um has brightening in certain areas

979
00:34:58,550 --> 00:34:55,040
actually gives us

980
00:35:00,390 --> 00:34:58,560
more of a information about how the dust

981
00:35:03,430 --> 00:35:00,400
is distributed in the region around the

982
00:35:05,190 --> 00:35:03,440
supernova explosion

983
00:35:06,950 --> 00:35:05,200
and then if you look at the reflection

984
00:35:07,829 --> 00:35:06,960
this light echo in more than one

985
00:35:09,510 --> 00:35:07,839
wavelength

986
00:35:11,910 --> 00:35:09,520
it gives you information about the dust

987
00:35:13,510 --> 00:35:11,920
itself because dust interacts with light

988
00:35:15,349 --> 00:35:13,520

differently at different wavelengths and

989
00:35:17,430 --> 00:35:15,359
so if i have i look at it

990
00:35:19,109 --> 00:35:17,440
in one color and then look at another

991
00:35:21,510 --> 00:35:19,119
color and then another color

992
00:35:23,510 --> 00:35:21,520
that gives me best properties which is

993
00:35:25,910 --> 00:35:23,520
pretty cool from a light echo

994
00:35:31,270 --> 00:35:25,920
okay so it's just light bouncing off

995
00:35:32,790 --> 00:35:31,280
something instead of sound waves

996
00:35:34,150 --> 00:35:32,800
all right let's talk about some more

997
00:35:36,230 --> 00:35:34,160
light because it's you know i've got

998
00:35:37,030 --> 00:35:36,240
this fireworky looking background behind

999
00:35:40,390 --> 00:35:37,040
me which is a

1000
00:35:42,150 --> 00:35:40,400
um korean nebula so who doesn't love a

1001
00:35:44,710 --> 00:35:42,160
really good fireworks show right

1002
00:35:46,310 --> 00:35:44,720
so um i know a lot of people's fire uh

1003
00:35:47,670 --> 00:35:46,320
fourth of july celebrations were

1004
00:35:50,950 --> 00:35:47,680
derailed this year

1005
00:35:52,870 --> 00:35:50,960
um my neighbors uh had a really nice

1006
00:35:54,390 --> 00:35:52,880
fireworks show so this is me sitting

1007
00:35:55,910 --> 00:35:54,400
outside of my porch

1008
00:35:58,310 --> 00:35:55,920
watching fireworks so it was quite

1009
00:36:00,069 --> 00:35:58,320
lovely um

1010
00:36:01,430 --> 00:36:00,079
and it looks a little bit yellowy in

1011
00:36:03,829 --> 00:36:01,440
color but when

1012
00:36:06,550 --> 00:36:03,839
um your past experiences you've seen

1013
00:36:09,750 --> 00:36:06,560

fireworks of many different colors

1014
00:36:11,990 --> 00:36:09,760
blues and yellows and reds and greens

1015
00:36:13,910 --> 00:36:12,000
and so what you're seeing here is

1016
00:36:17,190 --> 00:36:13,920
there's an emission

1017
00:36:19,190 --> 00:36:17,200
something is emitting light um and

1018
00:36:20,710 --> 00:36:19,200
it's by some chemicals that are in uh

1019
00:36:22,069 --> 00:36:20,720
the fireworks themselves so there's a

1020
00:36:24,470 --> 00:36:22,079
combustion that

1021
00:36:25,670 --> 00:36:24,480
inserts energy and then you get this

1022
00:36:27,190 --> 00:36:25,680
light so the question is

1023
00:36:29,030 --> 00:36:27,200
why does it have the specific colors

1024
00:36:31,910 --> 00:36:29,040
that that's really what we're at here

1025
00:36:34,150 --> 00:36:31,920
okay so when you're looking at certain

1026
00:36:35,670 --> 00:36:34,160
colors of fireworks it's actually due to

1027
00:36:37,670 --> 00:36:35,680
the chemical composition

1028
00:36:39,750 --> 00:36:37,680
uh of the salts or the powders that are

1029
00:36:40,310 --> 00:36:39,760
composed um that are in the firework

1030
00:36:42,630 --> 00:36:40,320
here

1031
00:36:44,550 --> 00:36:42,640
so for example if you see yellowy

1032
00:36:46,150 --> 00:36:44,560
colored fireworks it's most likely

1033
00:36:49,510 --> 00:36:46,160
sodium

1034
00:36:52,390 --> 00:36:49,520
if you see some pink that's lithium here

1035
00:36:54,710 --> 00:36:52,400
green is barium uh we've got some

1036
00:36:57,589 --> 00:36:54,720
potassium that's a little bit more

1037
00:36:59,670 --> 00:36:57,599
kind of tingy like yellowy pink and

1038
00:37:00,230 --> 00:36:59,680

copper is a little bit more bluish green

1039
00:37:02,150 --> 00:37:00,240
here

1040
00:37:03,589 --> 00:37:02,160
so you might remember when you were in

1041
00:37:05,030 --> 00:37:03,599
chemistry class in high school that you

1042
00:37:06,069 --> 00:37:05,040
used to do a flame test as one of your

1043
00:37:08,710 --> 00:37:06,079
experiments you

1044
00:37:10,630 --> 00:37:08,720
switched you know swish around a metal

1045
00:37:12,630 --> 00:37:10,640
rod and you put in a

1046
00:37:13,910 --> 00:37:12,640
solution and you stick it over the flame

1047
00:37:16,550 --> 00:37:13,920
and the flame

1048
00:37:18,150 --> 00:37:16,560
um that you would see there is is it's

1049
00:37:19,990 --> 00:37:18,160
because it's heated up that solution got

1050
00:37:21,190 --> 00:37:20,000
heated up it only displays certain

1051
00:37:23,430 --> 00:37:21,200
colors

1052
00:37:24,790 --> 00:37:23,440
hence the flame test there so what's

1053
00:37:27,670 --> 00:37:24,800
really going on in order

1054
00:37:29,430 --> 00:37:27,680
for us to see this light okay we have to

1055
00:37:32,310 --> 00:37:29,440
talk about the atoms themselves

1056
00:37:32,870 --> 00:37:32,320
okay so let me take sodium the sodium

1057
00:37:42,870 --> 00:37:32,880
atom

1058
00:37:44,870 --> 00:37:42,880
makes that sodium

1059
00:37:45,990 --> 00:37:44,880
there's also some neutrons in there and

1060
00:37:48,230 --> 00:37:46,000
if you want

1061
00:37:49,990 --> 00:37:48,240
those protons are positively charged so

1062
00:37:51,829 --> 00:37:50,000
if you have a neutral sodium atom then

1063
00:37:53,109 --> 00:37:51,839

you have to balance the positive charges

1064
00:37:54,630 --> 00:37:53,119
with the negative charges which are

1065
00:37:57,270 --> 00:37:54,640
these electrons

1066
00:37:58,390 --> 00:37:57,280
and so this cartoon of an atom here just

1067
00:38:00,950 --> 00:37:58,400
represents

1068
00:38:02,470 --> 00:38:00,960
kind of the energy states that those

1069
00:38:04,310 --> 00:38:02,480
electrons can be at so there's a

1070
00:38:05,829 --> 00:38:04,320
configuration that

1071
00:38:09,109 --> 00:38:05,839
sodium normally wants to be at with

1072
00:38:11,510 --> 00:38:09,119
those electrons now if you add energy

1073
00:38:12,630 --> 00:38:11,520
uh to that atom you can change the

1074
00:38:14,230 --> 00:38:12,640
configuration

1075
00:38:16,470 --> 00:38:14,240
and you can actually get one of these

1076
00:38:19,030 --> 00:38:16,480
electrons to go to a different level to

1077
00:38:19,589 --> 00:38:19,040
a higher level and to go to a higher

1078
00:38:21,670 --> 00:38:19,599
level

1079
00:38:23,349 --> 00:38:21,680
you need to gain energy to do that

1080
00:38:25,990 --> 00:38:23,359
because it takes work to do that

1081
00:38:28,150 --> 00:38:26,000
so if an electron can gain energy it's

1082
00:38:30,390 --> 00:38:28,160
great it's like yay i gained energy

1083
00:38:31,990 --> 00:38:30,400
but it doesn't like to be in this higher

1084
00:38:34,310 --> 00:38:32,000
energy level so it's going to be like

1085
00:38:36,870 --> 00:38:34,320
i'm going to go down and in the process

1086
00:38:37,589 --> 00:38:36,880
of going down back to a lower energy

1087
00:38:40,870 --> 00:38:37,599
state

1088
00:38:42,870 --> 00:38:40,880

it emits light okay to do that

1089
00:38:45,670 --> 00:38:42,880
and it's not just any old light it's a

1090
00:38:47,990 --> 00:38:45,680
very specific color of light

1091
00:38:49,670 --> 00:38:48,000
now you might be thinking okay i've

1092
00:38:51,030 --> 00:38:49,680
learned this before i remember hearing

1093
00:38:52,790 --> 00:38:51,040
about it

1094
00:38:55,190 --> 00:38:52,800
this is really quantum mechanics here

1095
00:38:58,150 --> 00:38:55,200
because the energy

1096
00:39:00,870 --> 00:38:58,160
that the electrons can give off is

1097
00:39:03,030 --> 00:39:00,880
dictated by the state of this atom here

1098
00:39:03,990 --> 00:39:03,040
which is dictated by quantum mechanics

1099
00:39:05,430 --> 00:39:04,000
so really when you're looking at

1100
00:39:06,470 --> 00:39:05,440
fireworks there's quantum mechanics

1101
00:39:08,150 --> 00:39:06,480
going on here so

1102
00:39:11,109 --> 00:39:08,160
that's really deep for your uh for

1103
00:39:13,270 --> 00:39:11,119
today's armchair astrophysics there

1104
00:39:14,710 --> 00:39:13,280
all the atoms are different so if i to

1105
00:39:17,349 --> 00:39:14,720
go back to sodium

1106
00:39:18,710 --> 00:39:17,359
there is for the temperatures of

1107
00:39:21,109 --> 00:39:18,720
combustion

1108
00:39:22,550 --> 00:39:21,119
there's a very unique transition that

1109
00:39:24,710 --> 00:39:22,560
electrons will make that will

1110
00:39:26,230 --> 00:39:24,720
predominantly give off yellow light and

1111
00:39:28,550 --> 00:39:26,240
that's what you see here

1112
00:39:30,470 --> 00:39:28,560
now if you look at street lights some of

1113
00:39:31,750 --> 00:39:30,480

the older street lights around

1114
00:39:33,829 --> 00:39:31,760
some of those street lights that they

1115
00:39:36,470 --> 00:39:33,839
have not switched out to led lights

1116
00:39:38,310 --> 00:39:36,480
are yellow they're yellow because

1117
00:39:41,510 --> 00:39:38,320
there's a sodium gas inside

1118
00:39:43,589 --> 00:39:41,520
and that sodium gas is heated

1119
00:39:45,349 --> 00:39:43,599
by electricity and it gets those

1120
00:39:47,430 --> 00:39:45,359
electrons excited

1121
00:39:49,190 --> 00:39:47,440
but then they uh they give them some

1122
00:39:50,630 --> 00:39:49,200
energy but then it gives back the energy

1123
00:39:52,550 --> 00:39:50,640
in the form of light so

1124
00:39:53,750 --> 00:39:52,560
yellow street lights are sodium it's the

1125
00:39:56,950 --> 00:39:53,760
emission of light by

1126
00:39:59,349 --> 00:39:56,960
atoms when you see neon signs

1127
00:40:01,030 --> 00:39:59,359
the same idea except they're not always

1128
00:40:03,109 --> 00:40:01,040
filled with neon

1129
00:40:04,790 --> 00:40:03,119
if it's really really red then that tube

1130
00:40:07,510 --> 00:40:04,800
is most likely filled with neon

1131
00:40:08,950 --> 00:40:07,520
and to heat the gas up you put

1132
00:40:11,670 --> 00:40:08,960
electrical charge through it

1133
00:40:12,790 --> 00:40:11,680
and that allows the electrons to go to

1134
00:40:14,630 --> 00:40:12,800
higher

1135
00:40:16,710 --> 00:40:14,640
energy states and then when they want to

1136
00:40:18,390 --> 00:40:16,720
go when they always go back down they

1137
00:40:21,750 --> 00:40:18,400
emit that color of light and so

1138
00:40:23,349 --> 00:40:21,760

all these um different colors of

1139
00:40:25,670 --> 00:40:23,359
neon lights actually don't always

1140
00:40:29,109 --> 00:40:25,680
contain neon and it has to do with

1141
00:40:30,150 --> 00:40:29,119
the atom so sodium here produces that

1142
00:40:32,230 --> 00:40:30,160
yellow light

1143
00:40:34,790 --> 00:40:32,240
but because helium is different than

1144
00:40:36,790 --> 00:40:34,800
neon it has a different color

1145
00:40:39,030 --> 00:40:36,800
because argon is different than neon

1146
00:40:41,589 --> 00:40:39,040
from an atomic level it produces

1147
00:40:43,430 --> 00:40:41,599
light that is different than neon and

1148
00:40:46,390 --> 00:40:43,440
it's it has to do with that

1149
00:40:47,430 --> 00:40:46,400
atom that atom itself is is really key

1150
00:40:51,190 --> 00:40:47,440
so now you

1151
00:40:51,510 --> 00:40:51,200
understand firework the chemistry of

1152
00:40:54,309 --> 00:40:51,520
fight

1153
00:40:55,190 --> 00:40:54,319
this is really chemistry um but it is at

1154
00:40:57,829 --> 00:40:55,200
the heart of it

1155
00:40:59,990 --> 00:40:57,839
physics okay so now we we've talked

1156
00:41:03,109 --> 00:41:00,000
about terrestrial fireworks

1157
00:41:04,230 --> 00:41:03,119
let's talk about cosmic fireworks now so

1158
00:41:06,710 --> 00:41:04,240
here's the beautiful

1159
00:41:07,670 --> 00:41:06,720
lagoon nebula and this is an emission

1160
00:41:14,150 --> 00:41:07,680
nebula

1161
00:41:15,349 --> 00:41:14,160
there's a mission of light here so this

1162
00:41:18,390 --> 00:41:15,359
emission nebula

1163
00:41:21,270 --> 00:41:18,400

is a place where many many stars are

1164
00:41:22,790 --> 00:41:21,280
born um an invisible light you can't you

1165
00:41:24,150 --> 00:41:22,800
can see one of the stars at the center

1166
00:41:25,750 --> 00:41:24,160
here but there are many more that are

1167
00:41:28,950 --> 00:41:25,760
hidden behind here

1168
00:41:30,470 --> 00:41:28,960
um this cloud of dark dust so

1169
00:41:33,270 --> 00:41:30,480
let's just look at the colors first the

1170
00:41:34,790 --> 00:41:33,280
red hue here is showing us that the

1171
00:41:38,230 --> 00:41:34,800
nitrogen gas

1172
00:41:39,430 --> 00:41:38,240
has been um the electrons have gained

1173
00:41:41,270 --> 00:41:39,440
some energy

1174
00:41:42,550 --> 00:41:41,280
and when they release that energy we see

1175
00:41:45,109 --> 00:41:42,560
this red light

1176
00:41:45,990 --> 00:41:45,119
that that nitrogen gas is giving off and

1177
00:41:48,550 --> 00:41:46,000
it's getting

1178
00:41:50,150 --> 00:41:48,560
heated by those embedded stars at the

1179
00:41:53,109 --> 00:41:50,160
center of that nebula

1180
00:41:54,950 --> 00:41:53,119
the green hue is from hydrogen gas it's

1181
00:41:56,550 --> 00:41:54,960
really really easy to excite hydrogen

1182
00:41:57,109 --> 00:41:56,560
when you look at normal everyday stars

1183
00:41:59,349 --> 00:41:57,119
like this

1184
00:42:00,230 --> 00:41:59,359
the purpley hue here is a combination of

1185
00:42:02,230 --> 00:42:00,240
hydrogen gas

1186
00:42:03,750 --> 00:42:02,240
oxygen and nitrogen so the fact that we

1187
00:42:04,309 --> 00:42:03,760
see this light emitted by different

1188
00:42:07,349 --> 00:42:04,319

elements

1189
00:42:10,069 --> 00:42:07,359
there

1190
00:42:11,510 --> 00:42:10,079
now you can't see color everywhere in

1191
00:42:14,069 --> 00:42:11,520
fact some of the gas

1192
00:42:16,309 --> 00:42:14,079
and dust here so dense that it doesn't

1193
00:42:18,309 --> 00:42:16,319
even let the light from behind it

1194
00:42:20,790 --> 00:42:18,319
to go through it okay so there's no

1195
00:42:22,470 --> 00:42:20,800
transmission if the density here is is

1196
00:42:23,430 --> 00:42:22,480
very high and so these dark clouds that

1197
00:42:25,510 --> 00:42:23,440
you see here

1198
00:42:26,790 --> 00:42:25,520
are just really really really really

1199
00:42:33,829 --> 00:42:26,800
dense

1200
00:42:36,390 --> 00:42:33,839
for space

1201
00:42:38,630 --> 00:42:36,400
for sure that's an example of cosmic

1202
00:42:41,430 --> 00:42:38,640
fireworks in the lagoon nebula

1203
00:42:42,390 --> 00:42:41,440
this year hubble celebrated the 30th

1204
00:42:45,430 --> 00:42:42,400
anniversary

1205
00:42:47,510 --> 00:42:45,440
and we had this beautiful

1206
00:42:48,630 --> 00:42:47,520
image that we also called the cosmic

1207
00:42:52,030 --> 00:42:48,640
reef and there's actually

1208
00:42:55,270 --> 00:42:52,040
two ngc catalog objects here ngc

1209
00:42:56,230 --> 00:42:55,280
2020 which is actually one very massive

1210
00:42:58,710 --> 00:42:56,240
star

1211
00:42:59,430 --> 00:42:58,720
that's puffed off its outer atmosphere

1212
00:43:02,470 --> 00:42:59,440
um

1213
00:43:03,589 --> 00:43:02,480

and the hot light i'm sorry that the

1214
00:43:07,030 --> 00:43:03,599
energetic light

1215
00:43:09,910 --> 00:43:07,040
of that star is heating up the gas

1216
00:43:11,510 --> 00:43:09,920
uh that it's been puffing off and that

1217
00:43:12,309 --> 00:43:11,520
is mostly oxygen that's showing up in

1218
00:43:14,390 --> 00:43:12,319
the blue here

1219
00:43:15,910 --> 00:43:14,400
there's a whole bunch of young stars

1220
00:43:17,829 --> 00:43:15,920
that are being formed in here

1221
00:43:18,950 --> 00:43:17,839
as well some of them are 10 times the

1222
00:43:21,829 --> 00:43:18,960
mass of the sun

1223
00:43:24,630 --> 00:43:21,839
they've recently formed and they're the

1224
00:43:29,030 --> 00:43:24,640
sources of energy that provide

1225
00:43:31,270 --> 00:43:29,040
the atoms with with energy to

1226
00:43:32,790 --> 00:43:31,280
to gain some energy in the electrons so

1227
00:43:35,270 --> 00:43:32,800
that when they fall back down

1228
00:43:36,790 --> 00:43:35,280
it gives off this signature and the hue

1229
00:43:38,069 --> 00:43:36,800
here the red is from hydrogen and

1230
00:43:41,030 --> 00:43:38,079
nitrogen again

1231
00:43:41,829 --> 00:43:41,040
and blue is oxygen so some more cosmic

1232
00:43:43,910 --> 00:43:41,839
fireworks

1233
00:43:45,030 --> 00:43:43,920
and it's a glowing star formation region

1234
00:43:48,870 --> 00:43:45,040
and we see lots of this

1235
00:43:51,030 --> 00:43:48,880
out in space lots of different regions

1236
00:43:53,349 --> 00:43:51,040
that are emitting light from very

1237
00:43:57,430 --> 00:43:53,359
specific atoms not too dissimilar

1238
00:44:00,309 --> 00:43:57,440

from how the light from fireworks work

1239
00:44:01,990 --> 00:44:00,319
okay so so we got we got light we've got

1240
00:44:05,349 --> 00:44:02,000
sound we've got fireworks

1241
00:44:08,710 --> 00:44:05,359
so let's move to air let's move to wind

1242
00:44:09,190 --> 00:44:08,720
okay so on earth like today in maryland

1243
00:44:14,230 --> 00:44:09,200
it was

1244
00:44:15,990 --> 00:44:14,240
is wind wind is just simply moving air

1245
00:44:17,349 --> 00:44:16,000
that's all it is so if you want to go

1246
00:44:20,630 --> 00:44:17,359
fly tight

1247
00:44:21,030 --> 00:44:20,640
the best uh wind uh values to get you

1248
00:44:23,109 --> 00:44:21,040
know

1249
00:44:25,030 --> 00:44:23,119
the best uh breeze here is five to ten

1250
00:44:26,950 --> 00:44:25,040
miles per hour fly kite

1251
00:44:28,230 --> 00:44:26,960
uh the other day it's just a nice breezy

1252
00:44:32,390 --> 00:44:28,240
day my backyard

1253
00:44:34,550 --> 00:44:32,400
and uh breezy winds are about 15 to 25

1254
00:44:36,309 --> 00:44:34,560
and then we know that we can get quite

1255
00:44:39,430 --> 00:44:36,319
extreme gust of wind

1256
00:44:41,589 --> 00:44:39,440
for very um hurricane-like

1257
00:44:42,950 --> 00:44:41,599
uh weather here so category one

1258
00:44:46,550 --> 00:44:42,960
hurricanes have

1259
00:44:47,430 --> 00:44:46,560
sustained winds of 94 to 95 miles per

1260
00:44:50,390 --> 00:44:47,440
hour

1261
00:44:51,030 --> 00:44:50,400
so wind is just moving air that's you

1262
00:44:54,069 --> 00:44:51,040
got

1263
00:44:57,670 --> 00:44:54,079

wind is air particles moving but

1264
00:44:59,510 --> 00:44:57,680
they have to move somehow right so

1265
00:45:01,030 --> 00:44:59,520
how do you move something how do you

1266
00:45:04,069 --> 00:45:01,040
move matter how does

1267
00:45:05,510 --> 00:45:04,079
uh how do you accelerate matter well

1268
00:45:07,030 --> 00:45:05,520
newton this is the only equation i

1269
00:45:08,150 --> 00:45:07,040
promise you that i'll show today f

1270
00:45:11,589 --> 00:45:08,160
equals m a

1271
00:45:14,710 --> 00:45:11,599
so to cause something to move from rest

1272
00:45:15,670 --> 00:45:14,720
to some some velocity you have to apply

1273
00:45:18,069 --> 00:45:15,680
a force

1274
00:45:19,589 --> 00:45:18,079
so if wind is moving it wasn't breezy

1275
00:45:21,190 --> 00:45:19,599
and all of a sudden it was breezy

1276
00:45:23,510 --> 00:45:21,200
there must have been a force to move

1277
00:45:25,750 --> 00:45:23,520
that air

1278
00:45:27,430 --> 00:45:25,760
along so we need a force that's very

1279
00:45:29,750 --> 00:45:27,440
important

1280
00:45:30,710 --> 00:45:29,760
now if take a very ideal situation where

1281
00:45:33,349 --> 00:45:30,720
there's no

1282
00:45:34,390 --> 00:45:33,359
wind at all it's a very still day okay

1283
00:45:36,230 --> 00:45:34,400
so maybe

1284
00:45:37,430 --> 00:45:36,240
if we think about this column of air

1285
00:45:40,150 --> 00:45:37,440
here

1286
00:45:41,670 --> 00:45:40,160
just due to the gravity of the the mass

1287
00:45:43,030 --> 00:45:41,680
of the earth here

1288
00:45:45,030 --> 00:45:43,040

if you're standing right here at the

1289
00:45:47,109 --> 00:45:45,040
bottom of this column of air

1290
00:45:48,870 --> 00:45:47,119
you feel air pressure because it's just

1291
00:45:49,589 --> 00:45:48,880
the weight of all the air molecules on

1292
00:45:51,910 --> 00:45:49,599
top of you

1293
00:45:53,910 --> 00:45:51,920
and you know that if you go to higher

1294
00:45:55,349 --> 00:45:53,920
elevations like denver for example

1295
00:45:57,430 --> 00:45:55,359
the air pressure is a little bit lower

1296
00:45:58,870 --> 00:45:57,440
because you're now standing uh one mile

1297
00:46:00,550 --> 00:45:58,880
above sea level so the air pressure's a

1298
00:46:04,069 --> 00:46:00,560
little bit lower because not the same

1299
00:46:06,470 --> 00:46:04,079
number of atoms are pushing down on you

1300
00:46:07,349 --> 00:46:06,480
now this is where nothing you know

1301
00:46:10,230 --> 00:46:07,359
nothing is moving

1302
00:46:11,270 --> 00:46:10,240
there's no um it's still there's no

1303
00:46:14,069 --> 00:46:11,280
there's no force

1304
00:46:16,550 --> 00:46:14,079
yet to cause air to move around but we

1305
00:46:19,430 --> 00:46:16,560
know air moves around

1306
00:46:20,470 --> 00:46:19,440
why okay well air needs to move around

1307
00:46:21,910 --> 00:46:20,480
on earth

1308
00:46:23,190 --> 00:46:21,920
when it moves from an area of high

1309
00:46:23,750 --> 00:46:23,200
pressure to low pressure so you might

1310
00:46:25,030 --> 00:46:23,760
say well

1311
00:46:26,790 --> 00:46:25,040
what's that what's high pressure low

1312
00:46:29,349 --> 00:46:26,800
pressure it's very very simple

1313
00:46:30,710 --> 00:46:29,359

so here we take sunlight and sunlight

1314
00:46:32,870 --> 00:46:30,720
hits the surface of the earth

1315
00:46:34,309 --> 00:46:32,880
and it warms the air near the surface

1316
00:46:37,349 --> 00:46:34,319
okay so

1317
00:46:39,270 --> 00:46:37,359
um hot air temperature is really just

1318
00:46:40,630 --> 00:46:39,280
the motion of particles so if you heat

1319
00:46:42,150 --> 00:46:40,640
air up

1320
00:46:43,670 --> 00:46:42,160
the particle partisan particles are

1321
00:46:45,109 --> 00:46:43,680
going to move around faster and it'll

1322
00:46:46,950 --> 00:46:45,119
become lower density

1323
00:46:48,309 --> 00:46:46,960
whereas colder air won't move around as

1324
00:46:50,790 --> 00:46:48,319
much and it's just

1325
00:46:52,950 --> 00:46:50,800
it's a denser air so if you heat the air

1326
00:46:53,589 --> 00:46:52,960
up it becomes less dense and what does

1327
00:46:56,790 --> 00:46:53,599
less dense

1328
00:46:57,829 --> 00:46:56,800
air want to do it rises and so the warm

1329
00:46:59,270 --> 00:46:57,839
air rises

1330
00:47:01,190 --> 00:46:59,280
and what happens is that it leaves

1331
00:47:03,670 --> 00:47:01,200
behind a low pressure

1332
00:47:04,790 --> 00:47:03,680
from where it just was so what happens

1333
00:47:07,910 --> 00:47:04,800
is that

1334
00:47:09,990 --> 00:47:07,920
high pressure over here will

1335
00:47:12,069 --> 00:47:10,000
flow towards the low pressure where the

1336
00:47:14,150 --> 00:47:12,079
warm air just was and that's wind

1337
00:47:16,790 --> 00:47:14,160
and the bigger the difference between

1338
00:47:18,710 --> 00:47:16,800

the pressure at the ground

1339
00:47:20,630 --> 00:47:18,720
and the pressure nearby the stronger the

1340
00:47:22,549 --> 00:47:20,640
wind so you can have very gentle breezes

1341
00:47:23,270 --> 00:47:22,559
or you can have a really gusty breeze

1342
00:47:27,109 --> 00:47:23,280
where there's

1343
00:47:29,270 --> 00:47:27,119
major differences in pressure

1344
00:47:31,750 --> 00:47:29,280
so that pressure change is what is the

1345
00:47:33,910 --> 00:47:31,760
force that allows the air to move

1346
00:47:34,870 --> 00:47:33,920
okay now we know that wind can push you

1347
00:47:37,510 --> 00:47:34,880
around

1348
00:47:38,870 --> 00:47:37,520
okay it can push we can have this wind

1349
00:47:39,750 --> 00:47:38,880
sock and we know the direction of the

1350
00:47:42,150 --> 00:47:39,760
wind

1351
00:47:43,910 --> 00:47:42,160
it can sculpt trees it can sculpt the

1352
00:47:45,910 --> 00:47:43,920
earth it can actually push particles

1353
00:47:46,309 --> 00:47:45,920
away there's erosion so wind erosion is

1354
00:47:50,069 --> 00:47:46,319
a

1355
00:47:52,790 --> 00:47:50,079
is wind erosion now this is

1356
00:47:54,549 --> 00:47:52,800
air physically moving around but what if

1357
00:47:57,670 --> 00:47:54,559
you're physically moving around

1358
00:47:59,030 --> 00:47:57,680
you can feel a wind right so if you're

1359
00:48:00,790 --> 00:47:59,040
moving through the air

1360
00:48:02,470 --> 00:48:00,800
it can feel windy to you even though

1361
00:48:03,750 --> 00:48:02,480
it's not actually windy because you're

1362
00:48:05,190 --> 00:48:03,760
moving through the material so if you

1363
00:48:06,790 --> 00:48:05,200

put your hand outside your car

1364
00:48:09,589 --> 00:48:06,800
you know that your hand moves backwards

1365
00:48:11,670 --> 00:48:09,599
because of the force of the wind

1366
00:48:13,750 --> 00:48:11,680
as your hand moves through it so there

1367
00:48:15,589 --> 00:48:13,760
are many windy scenarios

1368
00:48:16,870 --> 00:48:15,599
in the in the universe and let's start

1369
00:48:18,829 --> 00:48:16,880
with some really basic one maybe

1370
00:48:20,549 --> 00:48:18,839
something that you've already seen

1371
00:48:23,829 --> 00:48:20,559
before

1372
00:48:26,470 --> 00:48:23,839
now the sun gives off a wind okay so

1373
00:48:26,950 --> 00:48:26,480
there are two let's talk about the solar

1374
00:48:31,990 --> 00:48:26,960
wind

1375
00:48:33,910 --> 00:48:32,000
of fast-moving particles now not

1376
00:48:34,470 --> 00:48:33,920
particles like the air molecules on

1377
00:48:37,589 --> 00:48:34,480
earth

1378
00:48:37,990 --> 00:48:37,599
but very energetic charged particles but

1379
00:48:41,430 --> 00:48:38,000
it's

1380
00:48:43,670 --> 00:48:41,440
too

1381
00:48:45,349 --> 00:48:43,680
this solar wind can move at about a

1382
00:48:46,790 --> 00:48:45,359
million miles per hour

1383
00:48:49,030 --> 00:48:46,800
and that wind is going off in all

1384
00:48:51,990 --> 00:48:49,040
directions in space from the sun

1385
00:48:54,230 --> 00:48:52,000
now a comet here gets its very beautiful

1386
00:48:57,750 --> 00:48:54,240
appearance when it approaches the sun

1387
00:49:00,069 --> 00:48:57,760
now comet really is just a ball of ice

1388
00:49:02,549 --> 00:49:00,079

with a lot of dust and rocks in it so

1389
00:49:04,150 --> 00:49:02,559
it's a dirty snowball it's cold when

1390
00:49:05,990 --> 00:49:04,160
it's out far away from the sun but when

1391
00:49:08,150 --> 00:49:06,000
it gets closer to the sun

1392
00:49:09,670 --> 00:49:08,160
the sun's radiation can start to heat it

1393
00:49:13,190 --> 00:49:09,680
up and then

1394
00:49:16,549 --> 00:49:13,200
the solar wind can affect the material

1395
00:49:16,790 --> 00:49:16,559
that is um uh that that's getting heated

1396
00:49:20,390 --> 00:49:16,800
up

1397
00:49:22,150 --> 00:49:20,400
in the comment itself so this is an

1398
00:49:24,470 --> 00:49:22,160
image of comet mealwise

1399
00:49:26,710 --> 00:49:24,480
that uh you might have heard about being

1400
00:49:29,510 --> 00:49:26,720
visible earlier this month

1401
00:49:31,430 --> 00:49:29,520
comments usually have two tails and the

1402
00:49:33,670 --> 00:49:31,440
comet itself is quite small it's only on

1403
00:49:35,589 --> 00:49:33,680
the order of a few miles or so

1404
00:49:37,349 --> 00:49:35,599
but it's usually i see like i said so if

1405
00:49:38,549 --> 00:49:37,359
it gets too close to the sun the sun's

1406
00:49:41,349 --> 00:49:38,559
radiation

1407
00:49:42,829 --> 00:49:41,359
will start to melt it and it actually

1408
00:49:45,270 --> 00:49:42,839
can also

1409
00:49:47,430 --> 00:49:45,280
excite and heat up

1410
00:49:48,710 --> 00:49:47,440
some of the molecules so that their

1411
00:49:51,670 --> 00:49:48,720
electrons

1412
00:49:52,470 --> 00:49:51,680
can go to higher energy levels where

1413
00:49:54,549 --> 00:49:52,480

they don't want to stay

1414
00:49:55,670 --> 00:49:54,559
they'll de-excite and they'll emit light

1415
00:49:58,870 --> 00:49:55,680
so what you see here

1416
00:50:02,309 --> 00:49:58,880
is called an ion tail

1417
00:50:06,069 --> 00:50:02,319
which is a gaseous tail from heated

1418
00:50:08,470 --> 00:50:06,079
molecular gap gas specifically co2

1419
00:50:09,510 --> 00:50:08,480
and n2 molecular compounds that you're

1420
00:50:11,670 --> 00:50:09,520
familiar with here

1421
00:50:13,349 --> 00:50:11,680
so it's carbon monoxide carbon dioxide

1422
00:50:14,790 --> 00:50:13,359
and molecular nitrogen which is

1423
00:50:16,470 --> 00:50:14,800
most of the composition of the earth's

1424
00:50:19,109 --> 00:50:16,480
atmosphere in fact

1425
00:50:19,589 --> 00:50:19,119
and it gives off this bluish hue and it

1426
00:50:22,630 --> 00:50:19,599
points

1427
00:50:26,069 --> 00:50:22,640
roughly in a direction away from

1428
00:50:30,390 --> 00:50:26,079
the sun now this tail is created by

1429
00:50:33,910 --> 00:50:30,400
the sunlight interacting with the

1430
00:50:37,270 --> 00:50:33,920
molecules this whitish tail now you can

1431
00:50:39,430 --> 00:50:37,280
imagine oh it's really white it must be

1432
00:50:40,710 --> 00:50:39,440
doing either emitting all the colors or

1433
00:50:43,990 --> 00:50:40,720
reflecting all the colors

1434
00:50:46,630 --> 00:50:44,000
that's the dust tail and sunlight

1435
00:50:47,910 --> 00:50:46,640
is reflecting off of that dust tail and

1436
00:50:49,990 --> 00:50:47,920
the solar wind

1437
00:50:51,510 --> 00:50:50,000
the particles from the sun that solar

1438
00:50:53,829 --> 00:50:51,520

wind are pushing

1439
00:50:55,510 --> 00:50:53,839
the dust particles away into this

1440
00:50:57,670 --> 00:50:55,520
beautiful tail

1441
00:50:59,190 --> 00:50:57,680
and that so that tail also always points

1442
00:51:01,349 --> 00:50:59,200
away from the sun

1443
00:51:03,109 --> 00:51:01,359
because it's a a result of the

1444
00:51:06,150 --> 00:51:03,119
interaction of the wind with the dust

1445
00:51:10,069 --> 00:51:08,470
so really what is a comet comets are

1446
00:51:13,270 --> 00:51:10,079
nature's wood socks

1447
00:51:15,190 --> 00:51:13,280
it gives you a directional component and

1448
00:51:17,109 --> 00:51:15,200
can give you something about the energy

1449
00:51:19,750 --> 00:51:17,119
associated with the solar wind

1450
00:51:20,950 --> 00:51:19,760
when you look at a comet now there are

1451
00:51:22,950 --> 00:51:20,960
other features

1452
00:51:24,390 --> 00:51:22,960
that are very large in the universe so

1453
00:51:26,630 --> 00:51:24,400
for example if you take an elliptical

1454
00:51:29,109 --> 00:51:26,640
galaxy elliptical galaxy is a collection

1455
00:51:32,230 --> 00:51:29,119
of older stars stars older than the

1456
00:51:34,630 --> 00:51:32,240
the sun is and this could be hundreds of

1457
00:51:36,309 --> 00:51:34,640
billions of stars and in the optical it

1458
00:51:37,829 --> 00:51:36,319
would be this yellow light here

1459
00:51:39,910 --> 00:51:37,839
now if there's a supermassive black hole

1460
00:51:40,710 --> 00:51:39,920
at the center that happens to be very

1461
00:51:43,990 --> 00:51:40,720
active

1462
00:51:45,030 --> 00:51:44,000
it can shoot off these jets um that we

1463
00:51:48,230 --> 00:51:45,040

can see

1464
00:51:51,109 --> 00:51:48,240
with emission in radio light um

1465
00:51:51,510 --> 00:51:51,119
and so these this this false color red

1466
00:52:00,230 --> 00:51:51,520
is

1467
00:52:02,710 --> 00:52:00,240
really big it's a big feature it's one

1468
00:52:05,750 --> 00:52:02,720
and a half million light years wide here

1469
00:52:08,549 --> 00:52:05,760
so the question is what will happen

1470
00:52:08,950 --> 00:52:08,559
if this is moving through space let's

1471
00:52:12,470 --> 00:52:08,960
say

1472
00:52:13,190 --> 00:52:12,480
in that direction okay and what if it

1473
00:52:15,270 --> 00:52:13,200
was moving

1474
00:52:17,430 --> 00:52:15,280
through some dense material what do you

1475
00:52:20,549 --> 00:52:17,440
think might happen

1476
00:52:21,109 --> 00:52:20,559
could that happen where you you feel a

1477
00:52:24,309 --> 00:52:21,119
wind

1478
00:52:28,630 --> 00:52:24,319
because you're moving

1479
00:52:31,430 --> 00:52:28,640
so galaxies uh sometimes um

1480
00:52:32,710 --> 00:52:31,440
collect in clusters of galaxies so in

1481
00:52:35,109 --> 00:52:32,720
this image here

1482
00:52:36,790 --> 00:52:35,119
each little yellow blob is an elliptical

1483
00:52:40,870 --> 00:52:36,800
galaxy

1484
00:52:43,750 --> 00:52:40,880
immersed in all this is

1485
00:52:44,470 --> 00:52:43,760
in a very dense gas that happens to be

1486
00:52:47,109 --> 00:52:44,480
really really

1487
00:52:48,710 --> 00:52:47,119
hot so hot that he emits x-rays you

1488
00:52:50,950 --> 00:52:48,720

can't see an invisible but if i switch

1489
00:52:53,349 --> 00:52:50,960
to an x-ray telescope

1490
00:52:54,390 --> 00:52:53,359
it's really really hot there this gas is

1491
00:52:57,430 --> 00:52:54,400
emitting

1492
00:53:00,069 --> 00:52:57,440
this gas is 10 out 10 million

1493
00:53:02,069 --> 00:53:00,079
degrees kelvin and it's really dense so

1494
00:53:04,790 --> 00:53:02,079
imagine i take that galaxy

1495
00:53:05,829 --> 00:53:04,800
and let's say it's in that cluster embed

1496
00:53:08,790 --> 00:53:05,839
it in this gas

1497
00:53:11,430 --> 00:53:08,800
and it's moving okay something's going

1498
00:53:14,870 --> 00:53:11,440
to happen to those jets and those lobes

1499
00:53:16,710 --> 00:53:14,880
in that radio source something like that

1500
00:53:18,870 --> 00:53:16,720
and we see evidence of that they're

1501
00:53:20,470 --> 00:53:18,880
actually called bent radio galaxies

1502
00:53:23,510 --> 00:53:20,480
it's kind of like having your hair swept

1503
00:53:25,109 --> 00:53:23,520
bad back if it's a really windy day here

1504
00:53:27,190 --> 00:53:25,119
or you can think about it as a wake up

1505
00:53:30,309 --> 00:53:27,200
the jets as the galaxy moves so that

1506
00:53:32,230 --> 00:53:30,319
hot cluster gas um and so

1507
00:53:33,910 --> 00:53:32,240
the the galaxy is actually at the center

1508
00:53:36,150 --> 00:53:33,920
here and this is one of those uh

1509
00:53:37,990 --> 00:53:36,160
the jets here and the lobes are a little

1510
00:53:40,309 --> 00:53:38,000
bit uh shredded

1511
00:53:41,990 --> 00:53:40,319
but it's bent back hence the bent jet

1512
00:53:43,990 --> 00:53:42,000
name here

1513
00:53:45,670 --> 00:53:44,000

if you take a survey of lots of

1514
00:53:47,190 --> 00:53:45,680
different radio galaxies you can start

1515
00:53:49,030 --> 00:53:47,200
to see that they're not all straight

1516
00:53:50,790 --> 00:53:49,040
like that hercules a image some of them

1517
00:53:53,829 --> 00:53:50,800
are bent back like this

1518
00:53:54,790 --> 00:53:53,839
so we so astronomers look for bent radio

1519
00:53:57,349 --> 00:53:54,800
galaxies

1520
00:53:59,349 --> 00:53:57,359
because it's an indication that it's

1521
00:54:01,270 --> 00:53:59,359
moving through something dense

1522
00:54:03,510 --> 00:54:01,280
and most likely it's in a dense

1523
00:54:05,109 --> 00:54:03,520
environment

1524
00:54:06,470 --> 00:54:05,119
which means we can find clusters that

1525
00:54:08,309 --> 00:54:06,480
way sometimes it's easier to find a

1526
00:54:10,630 --> 00:54:08,319
cluster by finding one object

1527
00:54:13,349 --> 00:54:10,640
and looking for them in the vicinity

1528
00:54:17,030 --> 00:54:15,349
so that's one way that astronomers do

1529
00:54:19,030 --> 00:54:17,040
that so that's another windy scenario

1530
00:54:21,670 --> 00:54:19,040
that we can see out in space

1531
00:54:23,030 --> 00:54:21,680
another windy scenario is very similar

1532
00:54:26,230 --> 00:54:23,040
to the erosion of

1533
00:54:30,470 --> 00:54:26,240
rocks by a wind here on earth

1534
00:54:32,950 --> 00:54:30,480
this is the young star cluster ngc 602

1535
00:54:34,069 --> 00:54:32,960
there's a bunch of young stars here that

1536
00:54:36,470 --> 00:54:34,079
are

1537
00:54:37,589 --> 00:54:36,480
very very massive pumping out a lot of

1538
00:54:42,230 --> 00:54:37,599

radiation

1539
00:54:48,390 --> 00:54:42,240
wind

1540
00:54:49,670 --> 00:54:48,400
and you can see these beautiful ridges

1541
00:54:52,390 --> 00:54:49,680
here

1542
00:54:52,789 --> 00:54:52,400
you can see that it's lit up because

1543
00:54:55,670 --> 00:54:52,799
that

1544
00:54:57,430 --> 00:54:55,680
young star cluster has heated the gas to

1545
00:55:01,829 --> 00:54:57,440
create the light we see but it's also

1546
00:55:05,349 --> 00:55:02,950
all right so those are some windy

1547
00:55:06,950 --> 00:55:05,359
scenarios here that we see out in space

1548
00:55:10,150 --> 00:55:06,960
that kind of analogs to the windy

1549
00:55:12,470 --> 00:55:10,160
scenarios we see here on earth

1550
00:55:14,710 --> 00:55:12,480
now let's talk about spiral galaxies

1551
00:55:15,750 --> 00:55:14,720
when i first started my phd someone had

1552
00:55:17,589 --> 00:55:15,760
asked me why do you want to work with

1553
00:55:19,109 --> 00:55:17,599
spiral galaxies and the first thing that

1554
00:55:22,230 --> 00:55:19,119
i blurted out of my mouth was

1555
00:55:24,549 --> 00:55:22,240
they're beautiful because they are

1556
00:55:25,990 --> 00:55:24,559
so i could stare at these all day long

1557
00:55:26,710 --> 00:55:26,000
and one of the things about spiral

1558
00:55:28,950 --> 00:55:26,720
galaxies

1559
00:55:30,069 --> 00:55:28,960
is that spiral nature and we see

1560
00:55:31,910 --> 00:55:30,079
something very uh

1561
00:55:33,349 --> 00:55:31,920
similar across all these galaxies they

1562
00:55:36,789 --> 00:55:33,359
have these arms

1563
00:55:39,510 --> 00:55:36,799

that are easy to see okay they also look

1564
00:55:41,910 --> 00:55:39,520
bluish in color

1565
00:55:43,109 --> 00:55:41,920
they also appear there's these dark dust

1566
00:55:45,349 --> 00:55:43,119
lanes

1567
00:55:46,630 --> 00:55:45,359
the middle of these galaxies are more

1568
00:55:48,549 --> 00:55:46,640
yellowy in color

1569
00:55:49,990 --> 00:55:48,559
so all that gives us clues to the

1570
00:55:52,710 --> 00:55:50,000
formation history but i really want to

1571
00:55:54,470 --> 00:55:52,720
concentrate on the spiral arms here

1572
00:55:56,230 --> 00:55:54,480
now galaxies are collections of hundreds

1573
00:55:58,549 --> 00:55:56,240
of billions of stars

1574
00:56:00,150 --> 00:55:58,559
and they're all moving and we can watch

1575
00:56:02,230 --> 00:56:00,160
these stars move and we know that the

1576
00:56:03,990 --> 00:56:02,240
stars closer to the center move around

1577
00:56:05,430 --> 00:56:04,000
faster than the stars further out that's

1578
00:56:07,190 --> 00:56:05,440
something that we've known when we even

1579
00:56:09,349 --> 00:56:07,200
look our own galaxy here

1580
00:56:10,950 --> 00:56:09,359
so the question is these galaxies have

1581
00:56:14,470 --> 00:56:10,960
been around a long time

1582
00:56:18,390 --> 00:56:14,480
and we see these spiral arms how do they

1583
00:56:20,309 --> 00:56:18,400
persist okay so here's an example

1584
00:56:22,230 --> 00:56:20,319
of a the pinwheel galaxy the question

1585
00:56:23,349 --> 00:56:22,240
might be maybe it's just because it's

1586
00:56:25,910 --> 00:56:23,359
rotating that's

1587
00:56:27,349 --> 00:56:25,920
why i see spiral arms now there's

1588
00:56:32,789 --> 00:56:27,359

there's a problem there

1589
00:56:36,150 --> 00:56:34,630
and say that the spiral arms here so

1590
00:56:37,990 --> 00:56:36,160
this is a simulation that the

1591
00:56:39,510 --> 00:56:38,000
stars that are in the spiral arms are

1592
00:56:40,069 --> 00:56:39,520
always in the spiral arms that's my

1593
00:56:42,549 --> 00:56:40,079
assumption

1594
00:56:44,549 --> 00:56:42,559
are the same stars always in the arms

1595
00:56:46,150 --> 00:56:44,559
and they let them move so remember the

1596
00:56:47,270 --> 00:56:46,160
inner stars here go around faster than

1597
00:56:50,230 --> 00:56:47,280
the average star so what's going to

1598
00:56:52,630 --> 00:56:50,240
happen is that over time

1599
00:56:53,829 --> 00:56:52,640
what the the spiral arms are going to

1600
00:56:56,630 --> 00:56:53,839
wind themselves

1601
00:56:58,630 --> 00:56:56,640
up so that they eventually disappear so

1602
00:56:59,510 --> 00:56:58,640
this can't be what's happening because

1603
00:57:02,150 --> 00:56:59,520
we see

1604
00:57:03,670 --> 00:57:02,160
a lot of spiral arms in spiral galaxies

1605
00:57:05,510 --> 00:57:03,680
we don't see them

1606
00:57:07,670 --> 00:57:05,520
in this scenario so this is not what's

1607
00:57:09,910 --> 00:57:07,680
going on it's um

1608
00:57:11,910 --> 00:57:09,920
this this is a wine big problem if we

1609
00:57:13,510 --> 00:57:11,920
assume that the stars are always the

1610
00:57:15,190 --> 00:57:13,520
same stars in the firearms

1611
00:57:16,789 --> 00:57:15,200
so there must be a different reason for

1612
00:57:19,190 --> 00:57:16,799
why that's happening

1613
00:57:20,309 --> 00:57:19,200

so let's switch and think about traffic

1614
00:57:22,309 --> 00:57:20,319
jams

1615
00:57:24,549 --> 00:57:22,319
i'm sure we've all been in a traffic jam

1616
00:57:26,150 --> 00:57:24,559
one time in our life

1617
00:57:27,670 --> 00:57:26,160
one thing that's common with chopstick

1618
00:57:29,109 --> 00:57:27,680
jams is that there's always a high

1619
00:57:30,390 --> 00:57:29,119
density of moving cars

1620
00:57:31,990 --> 00:57:30,400
now you eventually get out of the

1621
00:57:33,109 --> 00:57:32,000
traffic jam sometimes you don't know

1622
00:57:36,230 --> 00:57:33,119
what's happening

1623
00:57:37,430 --> 00:57:36,240
to cause the jam but your assumption is

1624
00:57:39,430 --> 00:57:37,440
that it was going fine

1625
00:57:41,670 --> 00:57:39,440
until somebody did something like that

1626
00:57:44,470 --> 00:57:41,680
red car and everyone slowed down

1627
00:57:45,750 --> 00:57:44,480
and as a result of that slow down a wave

1628
00:57:47,750 --> 00:57:45,760
of slowness

1629
00:57:50,069 --> 00:57:47,760
starts to move back down the highway

1630
00:57:51,270 --> 00:57:50,079
okay

1631
00:57:52,710 --> 00:57:51,280
so i'll play it one more time so

1632
00:57:54,390 --> 00:57:52,720
everything's going fine then a

1633
00:57:57,750 --> 00:57:54,400
disturbance happens

1634
00:57:59,510 --> 00:57:57,760
that car and it causes cars to slow down

1635
00:58:02,309 --> 00:57:59,520
and as a result everyone needs to react

1636
00:58:04,950 --> 00:58:02,319
to that and so this is a density wave

1637
00:58:05,589 --> 00:58:04,960
of a of a traffic jam that can move

1638
00:58:07,430 --> 00:58:05,599

along

1639
00:58:08,710 --> 00:58:07,440
at a different velocity than the cars

1640
00:58:10,630 --> 00:58:08,720
that are there and

1641
00:58:12,069 --> 00:58:10,640
cars can move through that area of

1642
00:58:13,910 --> 00:58:12,079
higher density

1643
00:58:17,190 --> 00:58:13,920
but that density might stay there and it

1644
00:58:19,190 --> 00:58:17,200
could persist there for a long time

1645
00:58:23,589 --> 00:58:19,200
now imagine i take this roadway and turn

1646
00:58:26,230 --> 00:58:23,599
it into a circle

1647
00:58:28,069 --> 00:58:26,240
and have traffic go so if you take a

1648
00:58:30,230 --> 00:58:28,079
look at the circle here you can see that

1649
00:58:33,510 --> 00:58:30,240
the cars are moving around in a

1650
00:58:35,589 --> 00:58:33,520
orbit and the area of density

1651
00:58:37,670 --> 00:58:35,599
also moves but it moves at a different

1652
00:58:40,390 --> 00:58:37,680
pace than the cars that are in there

1653
00:58:41,910 --> 00:58:40,400
so we can talk about the density wave

1654
00:58:43,670 --> 00:58:41,920
that moves around

1655
00:58:46,230 --> 00:58:43,680
in the galaxy at a different pace than

1656
00:58:47,430 --> 00:58:46,240
the stars so this concept of a density

1657
00:58:49,910 --> 00:58:47,440
wave which is basically

1658
00:58:51,829 --> 00:58:49,920
like a traffic jam here has been

1659
00:58:56,230 --> 00:58:51,839
explored to try to understand

1660
00:58:59,589 --> 00:58:56,240
spiral arms and indeed

1661
00:59:01,670 --> 00:58:59,599
allows us to understand the

1662
00:59:03,270 --> 00:59:01,680
nature of spiral arms that it's really a

1663
00:59:05,349 --> 00:59:03,280

wave of density

1664
00:59:06,630 --> 00:59:05,359
that when a star enters that area of

1665
00:59:10,710 --> 00:59:06,640
higher density

1666
00:59:12,390 --> 00:59:10,720
it it gravitationally is attracted to

1667
00:59:13,349 --> 00:59:12,400
that spiral arm and then it exits out

1668
00:59:16,549 --> 00:59:13,359
the other side

1669
00:59:18,710 --> 00:59:16,559
now if you're a cloud of gas

1670
00:59:19,910 --> 00:59:18,720
when you enter the spiral arms you get

1671
00:59:22,950 --> 00:59:19,920
compressed

1672
00:59:25,190 --> 00:59:22,960
and if cloud compresses it heats up

1673
00:59:26,470 --> 00:59:25,200
if it heats up it can form stars and

1674
00:59:28,470 --> 00:59:26,480
this is why there's a lot of star

1675
00:59:29,910 --> 00:59:28,480
formation going on in the spiral arms

1676
00:59:30,549 --> 00:59:29,920
because there are areas of higher

1677
00:59:32,549 --> 00:59:30,559
density

1678
00:59:34,309 --> 00:59:32,559
like the traffic jam and when you get a

1679
00:59:35,670 --> 00:59:34,319
lot of dust and gas you can get star

1680
00:59:37,190 --> 00:59:35,680
formation and that's also why they're

1681
00:59:40,549 --> 00:59:37,200
very blue

1682
00:59:42,150 --> 00:59:40,559
because the youngest stars are blue

1683
00:59:43,589 --> 00:59:42,160
and they don't live for very long so

1684
00:59:45,670 --> 00:59:43,599
they're pretty much where they were born

1685
00:59:47,030 --> 00:59:45,680
and that's why we can see the spar arm

1686
00:59:49,030 --> 00:59:47,040
so well

1687
00:59:50,950 --> 00:59:49,040
because of that so spiral arms are just

1688
00:59:51,829 --> 00:59:50,960

really cosmic traffic jams for stars and

1689
00:59:53,750 --> 00:59:51,839
gas

1690
00:59:56,470 --> 00:59:53,760
and we can use some of the same physics

1691
00:59:59,190 --> 00:59:56,480
to try to understand that

1692
00:59:59,990 --> 00:59:59,200
all right the last thing here are

1693
01:00:03,829 --> 01:00:00,000
bubbles

1694
01:00:05,829 --> 01:00:03,839
pastime of mine to sit down and try to

1695
01:00:08,069 --> 01:00:05,839
get little bubbles big bubbles

1696
01:00:09,430 --> 01:00:08,079
bubbles that have a very pretty

1697
01:00:11,270 --> 01:00:09,440
iridescent color

1698
01:00:13,270 --> 01:00:11,280
i won't get into the color but the idea

1699
01:00:15,030 --> 01:00:13,280
here is that when you're blowing bubbles

1700
01:00:17,270 --> 01:00:15,040
you need to have something inflate the

1701
01:00:19,750 --> 01:00:17,280
bubble and in this case it's the

1702
01:00:20,789 --> 01:00:19,760
the air out of your lungs and the

1703
01:00:24,069 --> 01:00:20,799
material here

1704
01:00:25,910 --> 01:00:24,079
is the soapy mixture and there's a lot

1705
01:00:27,990 --> 01:00:25,920
there's some amazing physics that's

1706
01:00:29,510 --> 01:00:28,000
going on here but the key takeaway

1707
01:00:31,349 --> 01:00:29,520
here is that you need something to

1708
01:00:33,190 --> 01:00:31,359
inflate it soap bubbles need to be

1709
01:00:36,069 --> 01:00:33,200
inflated so let's look at some soap

1710
01:00:37,190 --> 01:00:36,079
some bubbles in space that are inflated

1711
01:00:39,589 --> 01:00:37,200
not by

1712
01:00:41,030 --> 01:00:39,599
wind coming from your mouth but by

1713
01:00:43,030 --> 01:00:41,040

radiation

1714
01:00:44,789 --> 01:00:43,040
so we have these blowing bubbles in

1715
01:00:45,990 --> 01:00:44,799
space so on the left here is the bubble

1716
01:00:51,109 --> 01:00:46,000
nebula

1717
01:00:53,270 --> 01:00:51,119
it's about 7 000 light years away

1718
01:00:55,190 --> 01:00:53,280
it's about seven light years across and

1719
01:00:57,510 --> 01:00:55,200
there's a very hot

1720
01:00:59,589 --> 01:00:57,520
star at the center here that's giving

1721
01:01:02,470 --> 01:00:59,599
off a very strong stellar wind not

1722
01:01:03,109 --> 01:01:02,480
um different from the sun but much more

1723
01:01:05,190 --> 01:01:03,119
powerful

1724
01:01:06,390 --> 01:01:05,200
so instead of a million miles per hour

1725
01:01:09,510 --> 01:01:06,400
this wind's going out

1726
01:01:10,390 --> 01:01:09,520
four million miles per hour so really

1727
01:01:13,109 --> 01:01:10,400
really fast

1728
01:01:13,990 --> 01:01:13,119
and that wind slams into the surrounding

1729
01:01:16,549 --> 01:01:14,000
material

1730
01:01:17,109 --> 01:01:16,559
and it's kind of like a snow plow and it

1731
01:01:19,430 --> 01:01:17,119
um

1732
01:01:21,829 --> 01:01:19,440
piles up some of the gas there creating

1733
01:01:24,950 --> 01:01:21,839
this uh structure this rim here

1734
01:01:25,990 --> 01:01:24,960
and that hot star is pumping out a lot

1735
01:01:28,230 --> 01:01:26,000
of high energy

1736
01:01:29,430 --> 01:01:28,240
light like ultraviolet light and it

1737
01:01:31,270 --> 01:01:29,440
heats up the gas

1738
01:01:33,030 --> 01:01:31,280

and that's the source of energy to light

1739
01:01:35,109 --> 01:01:33,040
it up as the emission nebula

1740
01:01:36,870 --> 01:01:35,119
so the green here is hydrogen the blue

1741
01:01:39,190 --> 01:01:36,880
is oxygen atoms

1742
01:01:40,789 --> 01:01:39,200
that where the electrons have been

1743
01:01:41,910 --> 01:01:40,799
gained some energy to go to some higher

1744
01:01:43,510 --> 01:01:41,920
energies but then they

1745
01:01:45,190 --> 01:01:43,520
go back to lower energies emitting the

1746
01:01:47,430 --> 01:01:45,200
light that we see here

1747
01:01:49,510 --> 01:01:47,440
uh on the right here we see a supernova

1748
01:01:52,470 --> 01:01:49,520
remnant so this is a quick

1749
01:01:54,549 --> 01:01:52,480
um very powerful explosion and in that

1750
01:01:57,349 --> 01:01:54,559
powerful explosion

1751
01:01:58,630 --> 01:01:57,359
uh a lot of radiation um and mechanical

1752
01:02:01,029 --> 01:01:58,640
energy is um

1753
01:02:02,789 --> 01:02:01,039
imparted in into the surrounding region

1754
01:02:04,710 --> 01:02:02,799
and this is most likely some of that

1755
01:02:07,829 --> 01:02:04,720
material that the star

1756
01:02:08,470 --> 01:02:07,839
which is no longer there left behind but

1757
01:02:12,069 --> 01:02:08,480
the

1758
01:02:13,990 --> 01:02:12,079
can

1759
01:02:18,230 --> 01:02:14,000
create this emission of light here that

1760
01:02:21,349 --> 01:02:20,309
we also have stars that are quite

1761
01:02:24,230 --> 01:02:21,359
massive and

1762
01:02:25,270 --> 01:02:24,240
undergo outburst and that outbursts here

1763
01:02:27,910 --> 01:02:25,280

create these

1764
01:02:29,990 --> 01:02:27,920
double lobe structures um there's

1765
01:02:31,430 --> 01:02:30,000
probably two stars here in the image on

1766
01:02:35,029 --> 01:02:31,440
the left ada carina

1767
01:02:36,950 --> 01:02:35,039
um and it's embedded in uh nitrogen gas

1768
01:02:39,510 --> 01:02:36,960
that's glowing here in red

1769
01:02:41,750 --> 01:02:39,520
in the ultraviolet there's magnesium and

1770
01:02:43,029 --> 01:02:41,760
these two lobes here are dusty loops

1771
01:02:45,190 --> 01:02:43,039
they're quite thin

1772
01:02:46,150 --> 01:02:45,200
um but they've been puffed up by the

1773
01:02:48,630 --> 01:02:46,160
outburst

1774
01:02:50,710 --> 01:02:48,640
uh and because uh there's a disc of

1775
01:02:51,910 --> 01:02:50,720
material there's a kind of a bottleneck

1776
01:02:53,829 --> 01:02:51,920
at the center here

1777
01:02:55,670 --> 01:02:53,839
and the really cool thing of this image

1778
01:02:56,630 --> 01:02:55,680
is that there are holes in the dust of

1779
01:02:58,230 --> 01:02:56,640
those lobes

1780
01:03:01,190 --> 01:02:58,240
and so you can see streaks of light

1781
01:03:03,910 --> 01:03:01,200
coming out through those holes here

1782
01:03:04,549 --> 01:03:03,920
but this is another example of blowing

1783
01:03:07,829 --> 01:03:04,559
bubbles

1784
01:03:10,470 --> 01:03:07,839
in space now these are all quite small

1785
01:03:11,589 --> 01:03:10,480
small being solar system size or a

1786
01:03:14,630 --> 01:03:11,599
little bit bigger at least for

1787
01:03:17,670 --> 01:03:14,640
eta carina on a very large scale

1788
01:03:19,190 --> 01:03:17,680

we have the milky way galaxy so imagine

1789
01:03:21,029 --> 01:03:19,200
i could stretch it out this is the milky

1790
01:03:22,309 --> 01:03:21,039
way galaxy you see an edge on from edge

1791
01:03:25,670 --> 01:03:22,319
to edge it's about 100

1792
01:03:27,589 --> 01:03:25,680
000 light years in diameter

1793
01:03:29,430 --> 01:03:27,599
we have a supermassive black hole it's

1794
01:03:31,109 --> 01:03:29,440
not active right now

1795
01:03:34,069 --> 01:03:31,119
but we think that it was active in the

1796
01:03:37,349 --> 01:03:34,079
past because we see these two lobes

1797
01:03:39,589 --> 01:03:37,359
of extremely energetic light

1798
01:03:40,549 --> 01:03:39,599
from gamma rays even more energetic than

1799
01:03:42,710 --> 01:03:40,559
x-ray light

1800
01:03:44,950 --> 01:03:42,720
and we see these lobes these bubbles

1801
01:03:47,430 --> 01:03:44,960
being blown above and below

1802
01:03:48,470 --> 01:03:47,440
the disc of the milky way and we think

1803
01:03:51,670 --> 01:03:48,480
that

1804
01:03:52,870 --> 01:03:51,680
in the past the supernova was i'm sorry

1805
01:03:54,710 --> 01:03:52,880
the supernova the supermassive black

1806
01:03:56,630 --> 01:03:54,720
hole at the center of the milky way

1807
01:03:58,150 --> 01:03:56,640
had a lot of material dump on it and

1808
01:04:00,950 --> 01:03:58,160
this is kind of like a cosmic

1809
01:04:02,309 --> 01:04:00,960
burp where the material comes out but it

1810
01:04:05,109 --> 01:04:02,319
was

1811
01:04:05,589 --> 01:04:05,119
very energetic to emit these gamma rays

1812
01:04:07,829 --> 01:04:05,599
here

1813
01:04:09,029 --> 01:04:07,839

but again blowing bubbles in our own

1814
01:04:11,349 --> 01:04:09,039
milky way

1815
01:04:12,309 --> 01:04:11,359
so these are just all different examples

1816
01:04:14,630 --> 01:04:12,319
of

1817
01:04:15,430 --> 01:04:14,640
common everyday things that you see

1818
01:04:17,510 --> 01:04:15,440
around you

1819
01:04:18,470 --> 01:04:17,520
with some basic physics and we can use

1820
01:04:21,589 --> 01:04:18,480
that to

1821
01:04:23,510 --> 01:04:21,599
understand what we see in the universe

1822
01:04:24,950 --> 01:04:23,520
and as we go through this there's i

1823
01:04:26,950 --> 01:04:24,960
could redo this whole talk and talk

1824
01:04:28,470 --> 01:04:26,960
about different physics and all that

1825
01:04:31,990 --> 01:04:28,480
so this is a starting point for our

1826
01:04:35,190 --> 01:04:32,000
journey on for armchair astrophysics

1827
01:04:36,789 --> 01:04:35,200
the world around you is beautiful

1828
01:04:39,029 --> 01:04:36,799
and and frank just showed that at the

1829
01:04:41,190 --> 01:04:39,039
beginning here the butterfly nebula

1830
01:04:42,309 --> 01:04:41,200
and beauty is in the eye of the beholder

1831
01:04:44,390 --> 01:04:42,319
so for you

1832
01:04:46,470 --> 01:04:44,400
maybe it's in these images that we see

1833
01:04:47,589 --> 01:04:46,480
these beautiful emission nebula and

1834
01:04:50,069 --> 01:04:47,599
spiral nebula

1835
01:04:50,630 --> 01:04:50,079
uh spiral galaxies or supernova remnants

1836
01:04:52,710 --> 01:04:50,640
um

1837
01:04:54,549 --> 01:04:52,720
or planets it's it could be many

1838
01:04:57,990 --> 01:04:54,559

different things

1839
01:05:00,390 --> 01:04:58,000
maybe the beauty is knowing that

1840
01:05:01,510 --> 01:05:00,400
we're here on the earth we can't go

1841
01:05:03,430 --> 01:05:01,520
anywhere

1842
01:05:05,349 --> 01:05:03,440
yet we know so much because we let the

1843
01:05:06,630 --> 01:05:05,359
ah the light from the universe come to

1844
01:05:08,390 --> 01:05:06,640
us

1845
01:05:10,630 --> 01:05:08,400
and it hits our detectors on our

1846
01:05:11,190 --> 01:05:10,640
telescope it allows us to be in a

1847
01:05:13,029 --> 01:05:11,200
virtual

1848
01:05:15,029 --> 01:05:13,039
starship where the light comes to us or

1849
01:05:17,910 --> 01:05:15,039
to your eyes and that light

1850
01:05:19,430 --> 01:05:17,920
came from a star came from the gas

1851
01:05:20,630 --> 01:05:19,440
around the star and traveled all through

1852
01:05:23,190 --> 01:05:20,640
space

1853
01:05:23,750 --> 01:05:23,200
entered your eye and disappeared so i

1854
01:05:28,309 --> 01:05:23,760
think that

1855
01:05:29,589 --> 01:05:28,319
universe that then that's one way it's

1856
01:05:31,109 --> 01:05:29,599
through the light because light is a

1857
01:05:33,109 --> 01:05:31,119
cosmic messenger

1858
01:05:34,950 --> 01:05:33,119
maybe you think that the beauty in the

1859
01:05:36,789 --> 01:05:34,960
universe lies in the fact that there is

1860
01:05:38,710 --> 01:05:36,799
all this underlying physics

1861
01:05:40,150 --> 01:05:38,720
and you can use mathematics to

1862
01:05:43,270 --> 01:05:40,160
understand that

1863
01:05:46,230 --> 01:05:43,280

um all of these here

1864
01:05:48,230 --> 01:05:46,240
lets you think about what the universe

1865
01:05:50,470 --> 01:05:48,240
the world means to you

1866
01:05:52,150 --> 01:05:50,480
sit down with a friend have a

1867
01:05:54,950 --> 01:05:52,160
conversation

1868
01:05:56,150 --> 01:05:54,960
about what is stirring your curiosity

1869
01:05:58,150 --> 01:05:56,160
okay so make sure you have that

1870
01:06:00,309 --> 01:05:58,160
really comfortable arm chair because you

1871
01:06:03,430 --> 01:06:00,319
might have a really long conversation

1872
01:06:04,069 --> 01:06:03,440
and even better take it outside and look

1873
01:06:08,069 --> 01:06:04,079
up

1874
01:06:13,430 --> 01:06:11,109
thank you quinn that was wonderful

1875
01:06:14,630 --> 01:06:13,440
um i was waiting for you to when you

1876
01:06:16,829 --> 01:06:14,640
were talking about supernova

1877
01:06:20,950 --> 01:06:16,839
to get into the snow pile phase of the

1878
01:06:24,870 --> 01:06:22,789
i thought that would be a funny way to

1879
01:06:26,870 --> 01:06:24,880
pull things in yeah

1880
01:06:28,150 --> 01:06:26,880
but i've been watching the conversation

1881
01:06:31,910 --> 01:06:28,160
on youtube we've got

1882
01:06:32,390 --> 01:06:31,920
a lively conversation in uh behind here

1883
01:06:35,190 --> 01:06:32,400
and

1884
01:06:36,710 --> 01:06:35,200
um i only was able to glance at it but

1885
01:06:38,549 --> 01:06:36,720
grant has been following it better so

1886
01:06:41,349 --> 01:06:38,559
let me bring in grant justice

1887
01:06:43,430 --> 01:06:41,359
um who is our uh behind the scenes tech

1888
01:06:45,589 --> 01:06:43,440

guy who's been following the chat

1889
01:06:47,430 --> 01:06:45,599
uh and grant do we have some questions

1890
01:06:50,710 --> 01:06:47,440
for our speaker

1891
01:06:52,069 --> 01:06:50,720
we do we do and the first one you've

1892
01:06:53,510 --> 01:06:52,079
answered one of these but i'm going to

1893
01:06:54,770 --> 01:06:53,520
bring it up again because i want to see

1894
01:06:58,390 --> 01:06:54,780
how quinn answers it

1895
01:07:00,710 --> 01:06:58,400
[Laughter]

1896
01:07:01,870 --> 01:07:00,720
so if light is a particle and all

1897
01:07:04,069 --> 01:07:01,880
particles have

1898
01:07:06,069 --> 01:07:04,079
anti-particles does light have

1899
01:07:08,470 --> 01:07:06,079
corresponding anti-particles is one of

1900
01:07:11,750 --> 01:07:08,480
the first ones i saw

1901
01:07:13,029 --> 01:07:11,760
um i'm gonna have to pass because i

1902
01:07:15,910 --> 01:07:13,039
don't

1903
01:07:16,230 --> 01:07:15,920
tongue frank do you have an answer for

1904
01:07:20,549 --> 01:07:16,240
that

1905
01:07:23,589 --> 01:07:20,559
the photon is its own anti-particle

1906
01:07:24,309 --> 01:07:23,599
okay the um photon has no mass and no

1907
01:07:27,430 --> 01:07:24,319
charge

1908
01:07:29,190 --> 01:07:27,440
so if you try and make the opposite of

1909
01:07:31,190 --> 01:07:29,200
that it's the same thing

1910
01:07:34,870 --> 01:07:31,200
so the photon is considered to be its

1911
01:07:40,470 --> 01:07:38,230
okay yeah

1912
01:07:43,430 --> 01:07:40,480
all right and when referring to the

1913
01:07:46,150 --> 01:07:43,440

differences in energy of particles

1914
01:07:48,309 --> 01:07:46,160
what is an analogy for us to use to

1915
01:07:49,990 --> 01:07:48,319
understand what energy is what's your go

1916
01:07:51,270 --> 01:07:50,000
to or what's one that you think would be

1917
01:07:53,270 --> 01:07:51,280
useful for the audience if they're

1918
01:07:55,910 --> 01:07:53,280
trying to explain to someone

1919
01:07:56,950 --> 01:07:55,920
okay well that's a great question um

1920
01:07:59,990 --> 01:07:56,960
well energy

1921
01:08:03,029 --> 01:08:00,000
that word is all encompassing we have

1922
01:08:06,390 --> 01:08:03,039
tons of with different kinds of energy

1923
01:08:09,109 --> 01:08:06,400
so in today's talk um light

1924
01:08:09,990 --> 01:08:09,119
is one of those forms of energy so i can

1925
01:08:12,549 --> 01:08:10,000
talk about red

1926
01:08:13,270 --> 01:08:12,559
light it carries energy specifically we

1927
01:08:15,990 --> 01:08:13,280
i'll

1928
01:08:17,269 --> 01:08:16,000
categorize it as radiative energy energy

1929
01:08:20,870 --> 01:08:17,279
carry by light

1930
01:08:23,430 --> 01:08:20,880
um now there's there's um

1931
01:08:24,070 --> 01:08:23,440
there's energy that's bound up in atoms

1932
01:08:27,990 --> 01:08:24,080
for example

1933
01:08:28,950 --> 01:08:28,000
molecules in order to break their bonds

1934
01:08:31,269 --> 01:08:28,960
you need to

1935
01:08:32,070 --> 01:08:31,279
to to give it energy in order to break

1936
01:08:34,229 --> 01:08:32,080
those bonds

1937
01:08:35,669 --> 01:08:34,239
so we can talk about the bonds that hold

1938
01:08:38,070 --> 01:08:35,679

atoms together we can talk about the

1939
01:08:39,669 --> 01:08:38,080
energy that holds molecules together

1940
01:08:42,149 --> 01:08:39,679
there's gravitational energy potential

1941
01:08:45,349 --> 01:08:42,159
energy so energy to me

1942
01:08:48,950 --> 01:08:45,359
is something that can

1943
01:08:52,309 --> 01:08:48,960
um either it could be part of

1944
01:08:54,229 --> 01:08:52,319
the characteristic of the particle

1945
01:08:55,349 --> 01:08:54,239
if it's moving it has kinetic energy so

1946
01:08:58,630 --> 01:08:55,359
that's a characteristic

1947
01:09:00,550 --> 01:08:58,640
of what it's doing so that's matter

1948
01:09:01,829 --> 01:09:00,560
motion and energy combined together

1949
01:09:03,189 --> 01:09:01,839
that's what i was talking about with

1950
01:09:06,950 --> 01:09:03,199
physics there

1951
01:09:08,789 --> 01:09:06,960
if we're talking about just um uh

1952
01:09:10,470 --> 01:09:08,799
a particle sitting like you sitting on

1953
01:09:12,309 --> 01:09:10,480
your chair i could talk about all the

1954
01:09:13,510 --> 01:09:12,319
energy associated with you just sitting

1955
01:09:16,550 --> 01:09:13,520
on your chair

1956
01:09:16,870 --> 01:09:16,560
um so it's bound to the situation um is

1957
01:09:21,590 --> 01:09:16,880
one

1958
01:09:24,229 --> 01:09:21,600
another way to think about it with atoms

1959
01:09:26,149 --> 01:09:24,239
there's energy to keep those electrons

1960
01:09:27,510 --> 01:09:26,159
bound to those atoms so if you want to

1961
01:09:29,590 --> 01:09:27,520
change that

1962
01:09:31,349 --> 01:09:29,600
you have to give it energy and if it

1963
01:09:32,550 --> 01:09:31,359

wants to change back it has to give off

1964
01:09:36,229 --> 01:09:32,560
energy

1965
01:09:37,910 --> 01:09:36,239
also be through a collision

1966
01:09:39,829 --> 01:09:37,920
because collisions also have energy

1967
01:09:41,430 --> 01:09:39,839
associated with as well so there's in in

1968
01:09:43,189 --> 01:09:41,440
astrophysics we have

1969
01:09:45,110 --> 01:09:43,199
emission of light that can be due to

1970
01:09:47,749 --> 01:09:45,120
collisions when it's really really low

1971
01:09:52,070 --> 01:09:50,789
but it has in physics energy has a unit

1972
01:09:54,229 --> 01:09:52,080
associated with it

1973
01:09:55,510 --> 01:09:54,239
so you know quinn i always find that

1974
01:09:56,550 --> 01:09:55,520
people have trouble with potential

1975
01:10:02,709 --> 01:09:56,560
energy

1976
01:10:03,350 --> 01:10:02,719
but what somebody said to me all right

1977
01:10:05,669 --> 01:10:03,360
well

1978
01:10:06,470 --> 01:10:05,679
think of agoraphobia your fear of

1979
01:10:08,790 --> 01:10:06,480
heights

1980
01:10:10,070 --> 01:10:08,800
okay you're standing on a high building

1981
01:10:12,229 --> 01:10:10,080
you're looking down

1982
01:10:14,070 --> 01:10:12,239
and you have that fear of heights not

1983
01:10:15,990 --> 01:10:14,080
because you're falling or anything but

1984
01:10:18,149 --> 01:10:16,000
there's the potential for following

1985
01:10:20,310 --> 01:10:18,159
right and that's the potential energy

1986
01:10:22,070 --> 01:10:20,320
you have that you could be falling

1987
01:10:24,790 --> 01:10:22,080
so your fear of heights is really sort

1988
01:10:26,470 --> 01:10:24,800

of a an emotional expression of

1989
01:10:29,030 --> 01:10:26,480
potential energy i i like that

1990
01:10:31,590 --> 01:10:29,040
description

1991
01:10:33,430 --> 01:10:31,600
yeah potential energy is is it it's it

1992
01:10:35,510 --> 01:10:33,440
it's it's energy that's there

1993
01:10:36,550 --> 01:10:35,520
you just can't get to it really easily

1994
01:10:38,149 --> 01:10:36,560
you have to

1995
01:10:39,270 --> 01:10:38,159
it has to change to do something you

1996
01:10:41,750 --> 01:10:39,280
have to do something to it that's the

1997
01:10:44,790 --> 01:10:41,760
way i think about potential energy

1998
01:10:46,149 --> 01:10:44,800
okay what else grant okay

1999
01:10:48,790 --> 01:10:46,159
when you're trying to make sense of

2000
01:10:51,910 --> 01:10:48,800
something you observe like say we come

2001
01:10:53,750 --> 01:10:51,920
across a new phenomena or

2002
01:10:55,270 --> 01:10:53,760
something that you're trying to

2003
01:10:59,030 --> 01:10:55,280
understand

2004
01:11:00,950 --> 01:10:59,040
do you begin to see from a data

2005
01:11:02,790 --> 01:11:00,960
perspective like do you look at the

2006
01:11:05,110 --> 01:11:02,800
observations that we have

2007
01:11:06,310 --> 01:11:05,120
or do you try to relate it to something

2008
01:11:08,229 --> 01:11:06,320
physical

2009
01:11:11,430 --> 01:11:08,239
do you try to look at it and relate it

2010
01:11:14,070 --> 01:11:11,440
to an object or something like

2011
01:11:16,630 --> 01:11:14,080
well that's that good question um the

2012
01:11:19,669 --> 01:11:16,640
chat's been really good today

2013
01:11:21,110 --> 01:11:19,679

that's a really great question um i i

2014
01:11:23,110 --> 01:11:21,120
would say that if i

2015
01:11:24,550 --> 01:11:23,120
you know to get it for me if i gotta i

2016
01:11:26,390 --> 01:11:24,560
haven't done any um

2017
01:11:28,390 --> 01:11:26,400
observing in a long time but i'm

2018
01:11:28,870 --> 01:11:28,400
thinking back to my youth when i used to

2019
01:11:31,189 --> 01:11:28,880
do that

2020
01:11:33,510 --> 01:11:31,199
um when i would get some data i would

2021
01:11:36,709 --> 01:11:33,520
make sure first that what i'm seeing

2022
01:11:39,990 --> 01:11:36,719
is is is got

2023
01:11:41,510 --> 01:11:40,000
all of the the systematic

2024
01:11:42,550 --> 01:11:41,520
things that are related to detector

2025
01:11:44,070 --> 01:11:42,560
things that are related to the

2026
01:11:45,990 --> 01:11:44,080
instrument or the weather like all of

2027
01:11:47,510 --> 01:11:46,000
that i've already been able to take out

2028
01:11:50,950 --> 01:11:47,520
so when i look at the data

2029
01:11:52,310 --> 01:11:50,960
i try to say okay i expect that i should

2030
01:11:54,950 --> 01:11:52,320
see this

2031
01:11:55,510 --> 01:11:54,960
did i see that so sometimes people

2032
01:11:57,750 --> 01:11:55,520
expect

2033
01:11:58,709 --> 01:11:57,760
to get some certain type of information

2034
01:12:01,590 --> 01:11:58,719
because um

2035
01:12:03,350 --> 01:12:01,600
astronomers plan especially if they use

2036
01:12:04,229 --> 01:12:03,360
space telescopes they have to have a

2037
01:12:06,870 --> 01:12:04,239
really

2038
01:12:08,470 --> 01:12:06,880

strong justification for why they want

2039
01:12:10,550 --> 01:12:08,480
to use the hubble space telescope

2040
01:12:12,709 --> 01:12:10,560
or the future james webb space telescope

2041
01:12:14,229 --> 01:12:12,719
so they have an expectation of what they

2042
01:12:15,990 --> 01:12:14,239
might get

2043
01:12:17,110 --> 01:12:16,000
and so they're going to look to see if

2044
01:12:17,669 --> 01:12:17,120
they got what they thought they were

2045
01:12:20,070 --> 01:12:17,679
going to get

2046
01:12:22,149 --> 01:12:20,080
so that's definitely one thing but the

2047
01:12:24,149 --> 01:12:22,159
beauty of the science is that

2048
01:12:25,910 --> 01:12:24,159
most of the there's many times when

2049
01:12:27,750 --> 01:12:25,920
you're looking this way

2050
01:12:29,189 --> 01:12:27,760
and something this way catches your eye

2051
01:12:32,310 --> 01:12:29,199
that's unexpected

2052
01:12:34,550 --> 01:12:32,320
and so uh scientists have to be

2053
01:12:35,750 --> 01:12:34,560
kind of looking in both directions

2054
01:12:37,830 --> 01:12:35,760
looking for what they're

2055
01:12:38,870 --> 01:12:37,840
they're trying to study but also look

2056
01:12:42,550 --> 01:12:38,880
for the you know

2057
01:12:44,229 --> 01:12:42,560
the the unexpected um so

2058
01:12:46,390 --> 01:12:44,239
if i'm taking a picture of light in the

2059
01:12:48,630 --> 01:12:46,400
visible it might be that i expect this

2060
01:12:50,390 --> 01:12:48,640
but did i see any other features that i

2061
01:12:55,830 --> 01:12:50,400
wasn't expecting and that could tell me

2062
01:12:59,430 --> 01:12:58,149
if i'm using a model to explain the

2063
01:13:01,350 --> 01:12:59,440

observations

2064
01:13:02,630 --> 01:13:01,360
and they're not meshing together then i

2065
01:13:04,870 --> 01:13:02,640
have to sit down and say

2066
01:13:06,790 --> 01:13:04,880
hey what's what's what's why is this not

2067
01:13:08,870 --> 01:13:06,800
meshing is it my observations

2068
01:13:10,630 --> 01:13:08,880
or it's at the model and so then you can

2069
01:13:12,630 --> 01:13:10,640
tweak the model or say that it

2070
01:13:14,229 --> 01:13:12,640
you know the observations weren't

2071
01:13:14,630 --> 01:13:14,239
weren't as good as they should be and

2072
01:13:17,270 --> 01:13:14,640
you

2073
01:13:19,990 --> 01:13:17,280
need to take more data so so i would say

2074
01:13:23,910 --> 01:13:20,000
there's there's both

2075
01:13:27,590 --> 01:13:23,920
okay and frank answered it a little bit

2076
01:13:29,430 --> 01:13:27,600
online um but frank do you want to

2077
01:13:31,110 --> 01:13:29,440
give your opinion on that just because

2078
01:13:32,149 --> 01:13:31,120
both of you are experts in your fields

2079
01:13:34,310 --> 01:13:32,159
here

2080
01:13:36,550 --> 01:13:34,320
okay well my answer online was that you

2081
01:13:36,950 --> 01:13:36,560
know if you're looking at an observation

2082
01:13:39,030 --> 01:13:36,960
right

2083
01:13:40,630 --> 01:13:39,040
the first thing you want to do is try to

2084
01:13:41,350 --> 01:13:40,640
figure out the physics that's going on

2085
01:13:43,030 --> 01:13:41,360
there

2086
01:13:44,390 --> 01:13:43,040
right because if you're just doing

2087
01:13:46,310 --> 01:13:44,400
something question which was phrased in

2088
01:13:47,669 --> 01:13:46,320

terms of numbers and equations and

2089
01:13:49,590 --> 01:13:47,679
the only equations you can use are the

2090
01:13:51,189 --> 01:13:49,600
ones that relate to the physics that you

2091
01:13:53,990 --> 01:13:51,199
think is going on there

2092
01:13:54,470 --> 01:13:54,000
um you know i think uh there's a great

2093
01:13:56,149 --> 01:13:54,480
time

2094
01:13:57,510 --> 01:13:56,159
it's a wonderful thing to look at

2095
01:13:58,870 --> 01:13:57,520
something and realize

2096
01:14:00,790 --> 01:13:58,880
hey i don't really understand what's

2097
01:14:02,229 --> 01:14:00,800
going on here because then there's

2098
01:14:04,070 --> 01:14:02,239
there's more physics than you thought

2099
01:14:07,110 --> 01:14:04,080
was involved um

2100
01:14:09,830 --> 01:14:07,120
like uh the the zamon splitting of lines

2101
01:14:10,550 --> 01:14:09,840
in the from the sun which it just means

2102
01:14:14,229 --> 01:14:10,560
that there

2103
01:14:16,310 --> 01:14:14,239
magnetic field on the surface of the sun

2104
01:14:18,070 --> 01:14:16,320
right and you wouldn't expect expect to

2105
01:14:20,390 --> 01:14:18,080
see these dual lines

2106
01:14:21,270 --> 01:14:20,400
um if you were just thinking in the

2107
01:14:23,430 --> 01:14:21,280
normal

2108
01:14:25,350 --> 01:14:23,440
plasma physics but once you invoke these

2109
01:14:29,189 --> 01:14:25,360
really strong magnetic fields you go

2110
01:14:31,669 --> 01:14:29,199
ah that's how you get this um and so

2111
01:14:33,270 --> 01:14:31,679
it's you know it's good for her

2112
01:14:34,550 --> 01:14:33,280
scientists to not know what he's talking

2113
01:14:36,310 --> 01:14:34,560

about because

2114
01:14:39,189 --> 01:14:36,320
then that indicates there's something

2115
01:14:43,350 --> 01:14:41,830
always the context you can understand

2116
01:14:45,350 --> 01:14:43,360
anything if you have the understanding

2117
01:14:46,950 --> 01:14:45,360
of the basic underlying principles or

2118
01:14:48,630 --> 01:14:46,960
the context i would approach it the same

2119
01:14:50,070 --> 01:14:48,640
way frank would

2120
01:14:51,910 --> 01:14:50,080
understand what's happening there and

2121
01:14:53,350 --> 01:14:51,920
then from there you can build on what we

2122
01:14:56,950 --> 01:14:53,360
have

2123
01:14:58,790 --> 01:14:56,960
um okay so let's see

2124
01:15:01,030 --> 01:14:58,800
i asked online to see if we could get

2125
01:15:05,030 --> 01:15:01,040
another good question

2126
01:15:08,229 --> 01:15:05,040
uh there's one about um

2127
01:15:09,430 --> 01:15:08,239
oh there was something about the fermi

2128
01:15:10,950 --> 01:15:09,440
bubbles yes um

2129
01:15:13,110 --> 01:15:10,960
oh yeah how did they measure the size of

2130
01:15:17,669 --> 01:15:13,120
the fermi bubbles of our galaxy

2131
01:15:19,669 --> 01:15:17,679
good catch frank um

2132
01:15:21,110 --> 01:15:19,679
this is not my area so let me think

2133
01:15:25,750 --> 01:15:21,120
about what they would

2134
01:15:28,070 --> 01:15:25,760
have done um

2135
01:15:29,590 --> 01:15:28,080
wasn't it uh quasar absorption's flying

2136
01:15:31,189 --> 01:15:29,600
features and i say it would have to be

2137
01:15:34,630 --> 01:15:31,199
something intervening

2138
01:15:37,750 --> 01:15:34,640

um for for that uh i i know that

2139
01:15:39,189 --> 01:15:37,760
that feature uh these bubbles that are

2140
01:15:42,390 --> 01:15:39,199
blowing out of the

2141
01:15:46,550 --> 01:15:42,400
um the the galaxy were not

2142
01:15:49,430 --> 01:15:46,560
noticeable in the first several um

2143
01:15:50,630 --> 01:15:49,440
surveys um uh at those gamma-ray

2144
01:15:52,950 --> 01:15:50,640
wavelengths it was just

2145
01:15:53,669 --> 01:15:52,960
recently within the last couple of years

2146
01:15:55,030 --> 01:15:53,679
or so that

2147
01:15:57,110 --> 01:15:55,040
they were able to look at the data and

2148
01:15:58,390 --> 01:15:57,120
they had hints that these bubbles were

2149
01:15:59,750 --> 01:15:58,400
there because you can see them in the

2150
01:16:01,910 --> 01:15:59,760
x-rays a little bit

2151
01:16:03,430 --> 01:16:01,920
and so i there was an indication that

2152
01:16:05,590 --> 01:16:03,440
something interesting was there and

2153
01:16:07,110 --> 01:16:05,600
another wavelength in the x-rays and so

2154
01:16:08,790 --> 01:16:07,120
they looked at in the gamma rays to see

2155
01:16:12,630 --> 01:16:08,800
is there something coordinating there

2156
01:16:12,950 --> 01:16:12,640
and so with um really this is going back

2157
01:16:14,630 --> 01:16:12,960
to

2158
01:16:17,510 --> 01:16:14,640
what i was saying what do i know about

2159
01:16:20,870 --> 01:16:17,520
the instrumentation and the observations

2160
01:16:22,229 --> 01:16:20,880
so that it can really push my data to

2161
01:16:25,110 --> 01:16:22,239
its limits to know

2162
01:16:26,950 --> 01:16:25,120
what's real and what's not real and this

2163
01:16:28,870 --> 01:16:26,960

feature is actually quite

2164
01:16:30,630 --> 01:16:28,880
dim it doesn't come out of the data

2165
01:16:31,990 --> 01:16:30,640
easily it's not like boom pops in your

2166
01:16:32,870 --> 01:16:32,000
eye like the emission nebulas that we

2167
01:16:34,709 --> 01:16:32,880
were talking about

2168
01:16:36,070 --> 01:16:34,719
that'd be way too easy that would be way

2169
01:16:38,550 --> 01:16:36,080
too easy

2170
01:16:39,350 --> 01:16:38,560
so so um i think you're right about the

2171
01:16:41,590 --> 01:16:39,360
quasars that

2172
01:16:43,990 --> 01:16:41,600
we need to see some intervening material

2173
01:16:46,709 --> 01:16:44,000
because that gamma ray radiation is not

2174
01:16:47,510 --> 01:16:46,719
um it's there but it's not high

2175
01:16:48,790 --> 01:16:47,520
intensity

2176
01:16:51,110 --> 01:16:48,800
there's not a lot of it there i should

2177
01:16:57,270 --> 01:16:54,950
okay and i have one last one that is

2178
01:16:58,709 --> 01:16:57,280
uh quick but it's the one we'll end on

2179
01:17:00,830 --> 01:16:58,719
here which is

2180
01:17:02,630 --> 01:17:00,840
what is meant by a black hole being

2181
01:17:04,950 --> 01:17:02,640
active oh

2182
01:17:05,910 --> 01:17:04,960
okay i have a good analogy for this one

2183
01:17:09,030 --> 01:17:05,920
this is bring it on

2184
01:17:12,550 --> 01:17:09,040
this is my go-to analogy ready all right

2185
01:17:14,790 --> 01:17:12,560
um so i i have a i have a

2186
01:17:17,030 --> 01:17:14,800
a daughter she's three and a half so

2187
01:17:18,630 --> 01:17:17,040
usually she's really calm

2188
01:17:21,510 --> 01:17:18,640

but sometimes if you give her too much

2189
01:17:23,189 --> 01:17:21,520
candy she might kind of get active

2190
01:17:25,510 --> 01:17:23,199
if you give her too much candy she gets

2191
01:17:26,390 --> 01:17:25,520
really active and she might even throw

2192
01:17:29,510 --> 01:17:26,400
things

2193
01:17:32,310 --> 01:17:29,520
um she's very sweet though but i have

2194
01:17:34,310 --> 01:17:32,320
used this analogy in toxins so so super

2195
01:17:36,229 --> 01:17:34,320
massive black holes exist

2196
01:17:37,350 --> 01:17:36,239
they need to become active and usually

2197
01:17:40,709 --> 01:17:37,360
they become active

2198
01:17:41,590 --> 01:17:40,719
if they're fueled by by um in falling

2199
01:17:44,470 --> 01:17:41,600
material

2200
01:17:46,310 --> 01:17:44,480
uh it could be debris that's around the

2201
01:17:48,550 --> 01:17:46,320
supermassive black hole it could be

2202
01:17:50,229 --> 01:17:48,560
stars that orbits are decaying and

2203
01:17:51,030 --> 01:17:50,239
falling into the super max black hole so

2204
01:17:53,830 --> 01:17:51,040
think of that as the

2205
01:17:55,030 --> 01:17:53,840
candy uh the the sweets that get them

2206
01:17:58,229 --> 01:17:55,040
fired up right

2207
01:18:00,550 --> 01:17:58,239
and so um so if you can make it

2208
01:18:01,350 --> 01:18:00,560
if you can fuel super massive black hole

2209
01:18:03,910 --> 01:18:01,360
you can make it

2210
01:18:05,669 --> 01:18:03,920
active and how you find activity in a

2211
01:18:07,350 --> 01:18:05,679
super massive black hole depends on your

2212
01:18:08,950 --> 01:18:07,360
wavelength of choice so

2213
01:18:10,470 --> 01:18:08,960

you could find them in the radio with

2214
01:18:12,149 --> 01:18:10,480
those really beautiful

2215
01:18:14,070 --> 01:18:12,159
giant jets that i showed you earlier

2216
01:18:16,310 --> 01:18:14,080
that's one way really close to the

2217
01:18:19,350 --> 01:18:16,320
supermassive black hole you can get

2218
01:18:21,750 --> 01:18:19,360
some x-ray emission really really close

2219
01:18:23,910 --> 01:18:21,760
and that's also indication of a

2220
01:18:25,910 --> 01:18:23,920
supermassive black hole

2221
01:18:27,510 --> 01:18:25,920
you can also see there's some some winds

2222
01:18:28,870 --> 01:18:27,520
that come off of the disc and so if you

2223
01:18:29,669 --> 01:18:28,880
look in the uv you can also get

2224
01:18:31,910 --> 01:18:29,679
indications

2225
01:18:33,189 --> 01:18:31,920
of um some of that activity as well now

2226
01:18:36,950 --> 01:18:33,199
our milky way

2227
01:18:40,229 --> 01:18:36,960
is is in palm state right now

2228
01:18:42,790 --> 01:18:40,239
fingers crossed by the way yeah

2229
01:18:44,470 --> 01:18:42,800
so there's my analogy for active

2230
01:18:46,070 --> 01:18:44,480
supermassive black holes

2231
01:18:48,790 --> 01:18:46,080
i'm sure your daughter appreciates being

2232
01:18:50,790 --> 01:18:48,800
used as an analogy

2233
01:18:52,310 --> 01:18:50,800
for black holes no less later on when

2234
01:18:55,430 --> 01:18:52,320
she grows up she'll find this video and

2235
01:18:57,510 --> 01:18:55,440
you'll have something to do

2236
01:18:59,590 --> 01:18:57,520
all right so thank you quinn that was a

2237
01:19:01,990 --> 01:18:59,600
wonderful talk thank you grant for

2238
01:19:02,790 --> 01:19:02,000

taking care of the messages and such uh

2239
01:19:05,430 --> 01:19:02,800
next month

2240
01:19:07,750 --> 01:19:05,440
september 1st we will have sailing

2241
01:19:10,470 --> 01:19:07,760
across the local universe with ulysses

2242
01:19:11,270 --> 01:19:10,480
a hubble program to observe ultraviolet

2243
01:19:13,750 --> 01:19:11,280
light from

2244
01:19:15,189 --> 01:19:13,760
young stars the huge ulysses program

2245
01:19:17,830 --> 01:19:15,199
will be next september

2246
01:19:19,669 --> 01:19:17,840
um if you were live you would give a

2247
01:19:20,229 --> 01:19:19,679
huge round of applause for quinn so i'll

2248
01:19:22,630 --> 01:19:20,239
give my