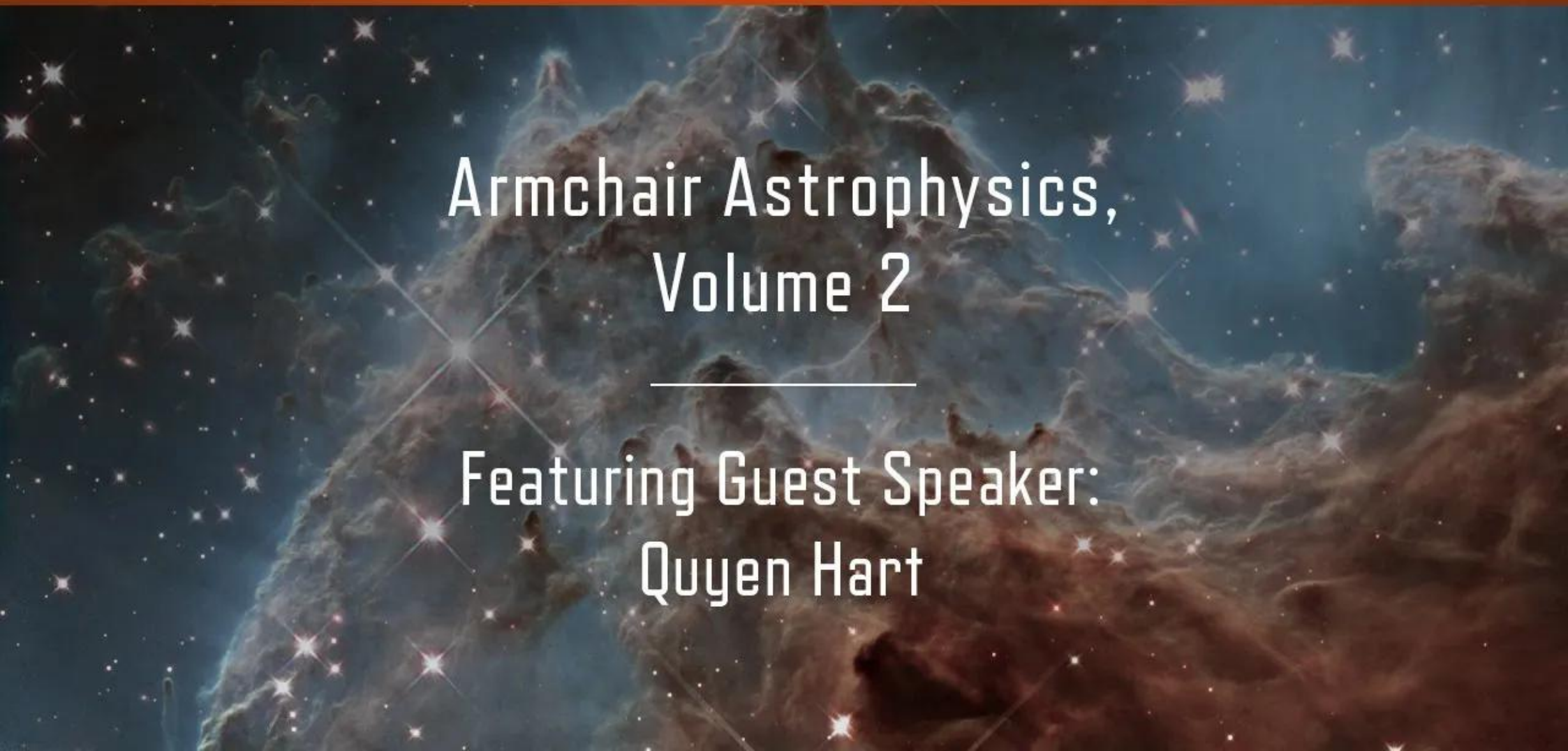
PUBLIC LECTURE SERIES



Armchair Astrophysics, Volume 2

Featuring Guest Speaker: Quyen Hart

1
00:00:05,749 --> 00:00:04,390
welcome to the space telescope public

2
00:00:09,190 --> 00:00:05,759
lecture series

3
00:00:11,749 --> 00:00:09,200
tonight's talk armchair astrophysics

4
00:00:12,549 --> 00:00:11,759
volume 2 by quen hart of the space

5
00:00:16,070 --> 00:00:12,559
telescope

6
00:00:18,310 --> 00:00:16,080
science institute i'm your host

7
00:00:19,189 --> 00:00:18,320
dr frank summers of the office of public

8
00:00:21,029 --> 00:00:19,199
outreach

9
00:00:23,029 --> 00:00:21,039
and i would like to thank our wonderful

10
00:00:25,029 --> 00:00:23,039
tech team thomas marufu

11
00:00:26,710 --> 00:00:25,039
and grant justice who helped bring this

12
00:00:29,349 --> 00:00:26,720
to you every month

13
00:00:30,070 --> 00:00:29,359

i will also note that we will continue

14
00:00:32,870 --> 00:00:30,080
to be online

15
00:00:33,510 --> 00:00:32,880
only until further notice most likely

16
00:00:36,229 --> 00:00:33,520
will be

17
00:00:42,830 --> 00:00:36,239
online only throughout the rest of 2021

18
00:00:48,950 --> 00:00:45,590
whoops our upcoming talks

19
00:00:53,910 --> 00:00:48,960
in august we'll have the importance of

20
00:00:56,950 --> 00:00:53,920
small objects exo comets not exoplanets

21
00:01:00,790 --> 00:00:56,960
but exo comets comets around

22
00:01:03,510 --> 00:01:00,800
other stars by isabel robolido

23
00:01:04,630 --> 00:01:03,520
of the space telescope science institute

24
00:01:07,270 --> 00:01:04,640
on september

25
00:01:08,310 --> 00:01:07,280
7th we will have recipes for planet

26
00:01:11,510 --> 00:01:08,320
formation

27
00:01:12,149 --> 00:01:11,520
by nicole arolanthanum also of the space

28
00:01:15,429 --> 00:01:12,159
telescope

29
00:01:16,550 --> 00:01:15,439
science institute and in october we have

30
00:01:18,310 --> 00:01:16,560
a special guest

31
00:01:20,149 --> 00:01:18,320
todd lauer from the national optical

32
00:01:22,710 --> 00:01:20,159
astronomy observatory

33
00:01:24,469 --> 00:01:22,720
and he will talk about a really

34
00:01:25,429 --> 00:01:24,479
interesting paper they put out earlier

35
00:01:29,109 --> 00:01:25,439
this year

36
00:01:29,910 --> 00:01:29,119
how dark is space what is the true

37
00:01:32,230 --> 00:01:29,920
blackness

38
00:01:33,749 --> 00:01:32,240

of the night and if you would like to

39
00:01:35,510 --> 00:01:33,759
find out about what these upcoming

40
00:01:38,789 --> 00:01:35,520
lectures or more information

41
00:01:41,510 --> 00:01:38,799
you go to our website stsci.edu

42
00:01:42,870 --> 00:01:41,520
public hyphen lectures or you go to your

43
00:01:44,710 --> 00:01:42,880
favorite search engine

44
00:01:46,950 --> 00:01:44,720
and put in hubble public lectures and

45
00:01:49,030 --> 00:01:46,960
you should be able to find this page

46
00:01:50,710 --> 00:01:49,040
on the lower left you can see the links

47
00:01:52,789 --> 00:01:50,720
to our webcasts

48
00:01:53,749 --> 00:01:52,799
both on the youtube playlist and on the

49
00:01:56,789 --> 00:01:53,759
stsci

50
00:01:59,429 --> 00:01:56,799
webcast archive on the lower right

51
00:02:00,310 --> 00:01:59,439
you can see how you can subscribe to our

52
00:02:05,590 --> 00:02:00,320
email list

53
00:02:09,270 --> 00:02:05,600
push that button and you'll be

54
00:02:11,510 --> 00:02:09,280
subscribed to our email list

55
00:02:12,949 --> 00:02:11,520
we also on our website we have the

56
00:02:16,309 --> 00:02:12,959
information about the upcoming

57
00:02:17,190 --> 00:02:16,319
lectures um the uh information the list

58
00:02:21,030 --> 00:02:17,200
of them

59
00:02:23,350 --> 00:02:21,040
they show you the details the

60
00:02:25,830 --> 00:02:23,360
description and after it's been recorded

61
00:02:29,110 --> 00:02:25,840
the links to the stsci webcast as well

62
00:02:31,589 --> 00:02:29,120
as the youtube webcast

63
00:02:33,270 --> 00:02:31,599

for the email announcements i said the

64
00:02:34,630 --> 00:02:33,280
easiest way to do it is just to sign up

65
00:02:36,790 --> 00:02:34,640
at our website

66
00:02:38,710 --> 00:02:36,800
you also may want to subscribe to our

67
00:02:42,070 --> 00:02:38,720
youtube channel

68
00:02:44,229 --> 00:02:42,080
youtube.com hubble space telescope

69
00:02:46,229 --> 00:02:44,239
you will if you subscribe you will get

70
00:02:48,630 --> 00:02:46,239
notices of our new videos as well as

71
00:02:50,309 --> 00:02:48,640
reminders of live events

72
00:02:52,390 --> 00:02:50,319
and finally if you have comments or

73
00:02:53,030 --> 00:02:52,400
questions you can send them to the email

74
00:02:57,430 --> 00:02:53,040
address

75
00:02:59,589 --> 00:02:57,440
public lecture stsci.edu

76
00:03:01,190 --> 00:02:59,599
our social media channels are available

77
00:03:03,509 --> 00:03:01,200
for the hubble space telescope

78
00:03:05,670 --> 00:03:03,519
the james webb space telescope and for

79
00:03:07,190 --> 00:03:05,680
the space telescope science institute

80
00:03:09,350 --> 00:03:07,200
and you can see them listed here for

81
00:03:11,830 --> 00:03:09,360
facebook twitter youtube

82
00:03:13,509 --> 00:03:11,840
and instagram if you would like to see

83
00:03:15,750 --> 00:03:13,519
what i have to say about the universe

84
00:03:17,509 --> 00:03:15,760
well i do a tiny bit of social media

85
00:03:22,070 --> 00:03:17,519
and you can find me on facebook and

86
00:03:25,470 --> 00:03:24,390
and now our news from the universe for

87
00:03:28,789 --> 00:03:25,480
july

88
00:03:31,990 --> 00:03:28,799

2021 our first story

89
00:03:33,589 --> 00:03:32,000
is about hubble and the extended anomaly

90
00:03:35,110 --> 00:03:33,599
that seems that's currently happening

91
00:03:38,789 --> 00:03:35,120
with hubble so

92
00:03:41,190 --> 00:03:38,799
if you didn't know on june 13th 2021

93
00:03:43,190 --> 00:03:41,200
hubble entered what we call safe mode

94
00:03:45,350 --> 00:03:43,200
it's not taking any observations

95
00:03:47,430 --> 00:03:45,360
everything's all in in safe mode while

96
00:03:49,830 --> 00:03:47,440
we diagnose a problem

97
00:03:51,990 --> 00:03:49,840
the problem is involved in the science

98
00:03:52,630 --> 00:03:52,000
instrument command and data handling

99
00:03:55,830 --> 00:03:52,640
unit

100
00:03:58,830 --> 00:03:55,840
the sic and dh and

101
00:04:00,070 --> 00:03:58,840
it turns it is an issue with the payload

102
00:04:03,270 --> 00:04:00,080
computer

103
00:04:05,589 --> 00:04:03,280
stopped

104
00:04:07,990 --> 00:04:05,599
and on june 14th they tried to restart

105
00:04:10,149 --> 00:04:08,000
it and that restart failed

106
00:04:11,750 --> 00:04:10,159
it initially indicated that there was a

107
00:04:13,190 --> 00:04:11,760
degrading memory module

108
00:04:15,589 --> 00:04:13,200
there was problems reading and writing

109
00:04:17,430 --> 00:04:15,599
to memory but there were unsuccessful

110
00:04:19,430 --> 00:04:17,440
attempts to switch up to a backup memory

111
00:04:20,150 --> 00:04:19,440
module there are four memory modules on

112
00:04:24,230 --> 00:04:20,160
hubble

113
00:04:26,070 --> 00:04:24,240

only one is active at a time and so

114
00:04:27,990 --> 00:04:26,080
perhaps the memory errors were only a

115
00:04:30,230 --> 00:04:28,000
symptom so they moved on to

116
00:04:31,110 --> 00:04:30,240
other hardware tests the standard

117
00:04:33,909 --> 00:04:31,120
interface

118
00:04:35,749 --> 00:04:33,919
and the central processing module these

119
00:04:37,110 --> 00:04:35,759
did not uncover the problem with the

120
00:04:40,150 --> 00:04:37,120
computer

121
00:04:42,390 --> 00:04:40,160
so there is redundancy on hubble there

122
00:04:43,990 --> 00:04:42,400
as i said there are four memory modules

123
00:04:45,430 --> 00:04:44,000
only one of them is active but there's

124
00:04:48,070 --> 00:04:45,440
also a full backup

125
00:04:49,909 --> 00:04:48,080
payload computer so they switched to the

126
00:04:51,270 --> 00:04:49,919
backup payload computer they tested out

127
00:04:53,270 --> 00:04:51,280
different memory modules

128
00:04:54,710 --> 00:04:53,280
they did various configurations of the

129
00:04:56,950 --> 00:04:54,720
main computer

130
00:04:58,150 --> 00:04:56,960
and and then the backup computer and the

131
00:04:59,749 --> 00:04:58,160
memory modules

132
00:05:01,270 --> 00:04:59,759
and they still kept getting the same

133
00:05:03,590 --> 00:05:01,280
errors so

134
00:05:05,029 --> 00:05:03,600
after all that testing they've they've

135
00:05:07,749 --> 00:05:05,039
now moved on to looking at

136
00:05:11,909 --> 00:05:07,759
other hardware the command unit science

137
00:05:14,070 --> 00:05:11,919
data formatter wonderful cusdf

138
00:05:15,510 --> 00:05:14,080

gotta have the acronyms for these um as

139
00:05:15,749 --> 00:05:15,520
well as looking at the power regulator

140
00:05:23,270 --> 00:05:15,759
in

141
00:05:26,390 --> 00:05:23,280
that's a little bit more complicated

142
00:05:29,110 --> 00:05:26,400
so at this point we do not have

143
00:05:30,870 --> 00:05:29,120
uh the solution for what is wrong with

144
00:05:32,710 --> 00:05:30,880
hubble we have not isolated the problem

145
00:05:35,749 --> 00:05:32,720
to a specific piece of hardware

146
00:05:36,390 --> 00:05:35,759
but they are still working at it now i

147
00:05:39,189 --> 00:05:36,400
will

148
00:05:41,510 --> 00:05:39,199
note that things like this happen

149
00:05:43,990 --> 00:05:41,520
relatively regularly okay

150
00:05:45,270 --> 00:05:44,000
we have one or two safe mode events

151
00:05:47,029 --> 00:05:45,280
every year

152
00:05:50,390 --> 00:05:47,039
in fact one of the most important ones

153
00:05:51,029 --> 00:05:50,400
happened uh in september 2008 and this

154
00:05:53,189 --> 00:05:51,039
is a

155
00:05:54,469 --> 00:05:53,199
gorgeous picture of the space shuttles

156
00:05:56,710 --> 00:05:54,479
at the launch pads

157
00:05:58,629 --> 00:05:56,720
getting ready for servicing mission 4 in

158
00:06:02,309 --> 00:05:58,639
september 2008

159
00:06:05,430 --> 00:06:02,319
and that was when the cu sdf failed

160
00:06:07,590 --> 00:06:05,440
the cos fds failed at that point and we

161
00:06:10,550 --> 00:06:07,600
had to switch to a backup

162
00:06:12,070 --> 00:06:10,560
well this is this is such an important

163
00:06:14,390 --> 00:06:12,080

piece of equipment

164
00:06:15,590 --> 00:06:14,400
that we actually delayed service engine

165
00:06:18,710 --> 00:06:15,600
4 for another six

166
00:06:20,070 --> 00:06:18,720
months so that they could add the

167
00:06:22,790 --> 00:06:20,080
replacement of the sic

168
00:06:24,150 --> 00:06:22,800
and dh to servicing mission 4. so the

169
00:06:26,070 --> 00:06:24,160
sic and dh was

170
00:06:27,350 --> 00:06:26,080
fully replaced during servicing mission

171
00:06:29,029 --> 00:06:27,360
4 which

172
00:06:31,270 --> 00:06:29,039
kind of looks like a smart thing right

173
00:06:34,710 --> 00:06:31,280
now considering that it is

174
00:06:38,070 --> 00:06:34,720
having problems again here in 2021

175
00:06:40,550 --> 00:06:38,080
so there is a backup for the cusdf

176
00:06:42,790 --> 00:06:40,560
uh which if they hadn't replaced it in

177
00:06:46,390 --> 00:06:42,800
2009 it there wouldn't be

178
00:06:48,230 --> 00:06:46,400
so they we have really amazing people

179
00:06:49,990 --> 00:06:48,240
working on this they have solved all

180
00:06:51,110 --> 00:06:50,000
these problems but they have to work

181
00:06:53,110 --> 00:06:51,120
extremely slowly

182
00:06:54,950 --> 00:06:53,120
they have to work very carefully and

183
00:06:56,870 --> 00:06:54,960
make sure that they isolate it to what

184
00:06:59,189 --> 00:06:56,880
piece of hardware is not working

185
00:07:00,309 --> 00:06:59,199
and make sure they confirm that all the

186
00:07:02,629 --> 00:07:00,319
other pieces of hardware

187
00:07:05,029 --> 00:07:02,639
are working so they're still working the

188
00:07:08,309 --> 00:07:05,039

problem

189
00:07:11,830 --> 00:07:08,319
our second story tonight separated at

190
00:07:13,589 --> 00:07:11,840
birth the lunar edition

191
00:07:15,189 --> 00:07:13,599
now what we're talking about here

192
00:07:18,629 --> 00:07:15,199
involves the juno mission

193
00:07:19,270 --> 00:07:18,639
at jupiter juno is a mission to study

194
00:07:22,309 --> 00:07:19,280
the

195
00:07:24,150 --> 00:07:22,319
jupiter

196
00:07:25,510 --> 00:07:24,160
really trying to understand the internal

197
00:07:28,070 --> 00:07:25,520
structure of jupiter

198
00:07:29,589 --> 00:07:28,080
but one thing that they did is they put

199
00:07:31,270 --> 00:07:29,599
on a

200
00:07:33,029 --> 00:07:31,280
an instrument called junocam which is

201
00:07:33,670 --> 00:07:33,039
not a science instrument it's really an

202
00:07:36,870 --> 00:07:33,680
outreach

203
00:07:37,830 --> 00:07:36,880
uh camera to take gorgeous pictures of

204
00:07:41,350 --> 00:07:37,840
jupiter

205
00:07:42,390 --> 00:07:41,360
and it really has found some gorgeous

206
00:07:44,550 --> 00:07:42,400
pictures like

207
00:07:45,909 --> 00:07:44,560
this getting really close to jupiter's

208
00:07:49,189 --> 00:07:45,919
um atmosphere

209
00:07:52,550 --> 00:07:49,199
got an amazing picture of this storm on

210
00:07:55,589 --> 00:07:52,560
jupiter a couple years ago um

211
00:07:58,070 --> 00:07:55,599
and also it has taken long

212
00:08:00,070 --> 00:07:58,080
long shots and being able to get jupiter

213
00:08:03,029 --> 00:08:00,080

and the four galilean moons of

214
00:08:03,670 --> 00:08:03,039
jupiter in the same shot ganon mead io

215
00:08:06,550 --> 00:08:03,680
callisto

216
00:08:08,150 --> 00:08:06,560
and europa they have since been able to

217
00:08:11,350 --> 00:08:08,160
configure the orbits to fly

218
00:08:14,869 --> 00:08:11,360
past some of these moons and this month

219
00:08:17,350 --> 00:08:14,879
they flew past ganymede and so they got

220
00:08:19,510 --> 00:08:17,360
the closest approach to ganymede since

221
00:08:23,909 --> 00:08:19,520
the voyager missions in the

222
00:08:26,950 --> 00:08:23,919
uh in the late 70s and early 80s so

223
00:08:30,070 --> 00:08:26,960
brand new picture of ganymede

224
00:08:33,909 --> 00:08:30,080
and this is taken from 1 000

225
00:08:35,589 --> 00:08:33,919
kilometers away like 650 miles above the

226
00:08:38,389 --> 00:08:35,599
surface okay

227
00:08:41,029 --> 00:08:38,399
really cool now it's in black and white

228
00:08:43,190 --> 00:08:41,039
because it's just the green filter

229
00:08:44,230 --> 00:08:43,200
they took red green and blue filters but

230
00:08:45,910 --> 00:08:44,240
they wanted to get the

231
00:08:47,990 --> 00:08:45,920
picture out really quickly so they just

232
00:08:50,070 --> 00:08:48,000
released the green filter

233
00:08:51,430 --> 00:08:50,080
and when i looked at i said wow that's

234
00:08:53,350 --> 00:08:51,440
really great because i mean this is just

235
00:08:54,470 --> 00:08:53,360
a tremendously detailed image of

236
00:08:56,550 --> 00:08:54,480
ganymede

237
00:08:58,870 --> 00:08:56,560
but i also said you know i think i've

238
00:09:02,310 --> 00:08:58,880

sort of seen this before

239
00:09:05,350 --> 00:09:02,320
um and doesn't it sort of look like

240
00:09:07,269 --> 00:09:05,360
our moon hmm

241
00:09:09,509 --> 00:09:07,279
yeah it kind of blinked back and forth

242
00:09:13,430 --> 00:09:09,519
well let's see there's ganymede

243
00:09:16,710 --> 00:09:13,440
and there's our moon were they

244
00:09:18,870 --> 00:09:16,720
separated at birth

245
00:09:20,389 --> 00:09:18,880
the answer is of course no they were not

246
00:09:21,990 --> 00:09:20,399
separated at birth okay

247
00:09:23,670 --> 00:09:22,000
ganymede formed in the outer solar

248
00:09:24,550 --> 00:09:23,680
system the moon formed in the inner

249
00:09:27,590 --> 00:09:24,560
solar system

250
00:09:28,150 --> 00:09:27,600
ganymede has this huge icy layers on its

251
00:09:31,829 --> 00:09:28,160
surface

252
00:09:34,790 --> 00:09:31,839
the moon is all just rock okay but

253
00:09:36,949 --> 00:09:34,800
they do look similar because they've

254
00:09:37,990 --> 00:09:36,959
undergone the same processes so for

255
00:09:41,030 --> 00:09:38,000
example

256
00:09:43,590 --> 00:09:41,040
down here you can see this giant crater

257
00:09:44,710 --> 00:09:43,600
with rays extending out on both of the

258
00:09:46,310 --> 00:09:44,720
objects

259
00:09:48,710 --> 00:09:46,320
if you look in the upper right you can

260
00:09:51,190 --> 00:09:48,720
see these smooth patches

261
00:09:52,550 --> 00:09:51,200
on the moon this has happened when

262
00:09:55,990 --> 00:09:52,560
punctures of the moon and

263
00:09:57,269 --> 00:09:56,000

lava weld up and flowed out on ganymede

264
00:09:58,389 --> 00:09:57,279
i would expect that it would be

265
00:10:00,389 --> 00:09:58,399
punctures that flood

266
00:10:02,230 --> 00:10:00,399
water to spread out and create these

267
00:10:03,990 --> 00:10:02,240
smooth clean patches

268
00:10:05,910 --> 00:10:04,000
there are also these rugged patches

269
00:10:09,110 --> 00:10:05,920
where tons and tons of craters

270
00:10:12,710 --> 00:10:09,120
have formed so while the moon surface

271
00:10:15,590 --> 00:10:12,720
is rock and ganymede's surface is ice

272
00:10:16,150 --> 00:10:15,600
they have undergone the same processes

273
00:10:19,750 --> 00:10:16,160
mainly

274
00:10:22,630 --> 00:10:19,760
cratering small medium large cratering

275
00:10:24,550 --> 00:10:22,640
over billions of years and end up

276
00:10:27,670 --> 00:10:24,560
looking the same

277
00:10:29,829 --> 00:10:27,680
so this is just a preliminary image as i

278
00:10:31,269 --> 00:10:29,839
said it's just the green filter

279
00:10:33,509 --> 00:10:31,279
we're looking forward to getting all the

280
00:10:34,069 --> 00:10:33,519
the red and blue filters add to it to

281
00:10:36,550 --> 00:10:34,079
get the

282
00:10:39,030 --> 00:10:36,560
full color image from it but it shows

283
00:10:41,750 --> 00:10:39,040
you what juno can do

284
00:10:42,790 --> 00:10:41,760
because of its location and able to fly

285
00:10:45,509 --> 00:10:42,800
up close

286
00:10:46,550 --> 00:10:45,519
and get personal with these uh with

287
00:10:50,470 --> 00:10:46,560
these moons

288
00:10:58,069 --> 00:10:54,630

all right our speaker tonight

289
00:10:59,670 --> 00:10:58,079
is quen hart um and quen has been with

290
00:10:59,990 --> 00:10:59,680
us at the space telescope science in

291
00:11:02,470 --> 00:11:00,000
suit

292
00:11:04,230 --> 00:11:02,480
for a little over two years or she had

293
00:11:07,910 --> 00:11:04,240
known it's two years in september

294
00:11:08,550 --> 00:11:07,920
almost two years um she comes to us uh

295
00:11:11,190 --> 00:11:08,560
from a

296
00:11:12,870 --> 00:11:11,200
great history of uh doing lots of lots

297
00:11:15,350 --> 00:11:12,880
of astronomy and other things in various

298
00:11:16,550 --> 00:11:15,360
places she did her undergraduate work at

299
00:11:19,110 --> 00:11:16,560
villanova

300
00:11:21,509 --> 00:11:19,120
and her graduate work at the university

301
00:11:23,910 --> 00:11:21,519
of colorado boulder

302
00:11:27,430 --> 00:11:23,920
she spent some time at the scripps

303
00:11:29,590 --> 00:11:27,440
institute studying atmospheric science

304
00:11:31,110 --> 00:11:29,600
and then she went on to be an assist

305
00:11:34,550 --> 00:11:31,120
associate professor

306
00:11:37,670 --> 00:11:34,560
at uh regis university where she um

307
00:11:39,190 --> 00:11:37,680
you know uh trained in in teaching

308
00:11:41,350 --> 00:11:39,200
classes and such

309
00:11:42,790 --> 00:11:41,360
uh she tells me that while she was at

310
00:11:44,790 --> 00:11:42,800
scripps institute what was

311
00:11:47,030 --> 00:11:44,800
a fun thing to do was at the end of the

312
00:11:47,829 --> 00:11:47,040
day uh scripps is right on the ocean you

313
00:11:49,750 --> 00:11:47,839

can outlook

314
00:11:51,990 --> 00:11:49,760
look out over the over the ocean looking

315
00:11:53,590 --> 00:11:52,000
west watching the sunset

316
00:11:55,509 --> 00:11:53,600
and that they would go out in the at in

317
00:11:55,990 --> 00:11:55,519
the in the evenings and look for the

318
00:11:59,030 --> 00:11:56,000
fabled

319
00:12:00,949 --> 00:11:59,040
green flash i will tell you i have never

320
00:12:02,949 --> 00:12:00,959
seen the green flash i haven't

321
00:12:04,550 --> 00:12:02,959
spent the time looking for it but uh

322
00:12:05,829 --> 00:12:04,560
quinn tells us that they were able to

323
00:12:08,069 --> 00:12:05,839
see the green flash

324
00:12:09,190 --> 00:12:08,079
many times so she is an official member

325
00:12:11,590 --> 00:12:09,200
of the green flash

326
00:12:14,870 --> 00:12:11,600
searchers club ladies and gentlemen dr

327
00:12:20,870 --> 00:12:18,389
thank you frank um

328
00:12:21,590 --> 00:12:20,880
welcome everybody to tonight's public

329
00:12:25,269 --> 00:12:21,600
lecture shoot

330
00:12:26,230 --> 00:12:25,279
series where i will continue a talk with

331
00:12:28,790 --> 00:12:26,240
you all

332
00:12:29,750 --> 00:12:28,800
uh with the title armchair astrophysics

333
00:12:31,590 --> 00:12:29,760
volume two so

334
00:12:33,829 --> 00:12:31,600
i hope this will be an annual event that

335
00:12:37,670 --> 00:12:33,839
you all look forward to

336
00:12:42,310 --> 00:12:40,470
so last time we were thinking um i

337
00:12:44,069 --> 00:12:42,320
wanted to talk to everybody about

338
00:12:46,710 --> 00:12:44,079

astrophysics in a nutshell because i

339
00:12:47,350 --> 00:12:46,720
really think and believe that anyone can

340
00:12:51,350 --> 00:12:47,360
talk about

341
00:12:53,990 --> 00:12:51,360
people around you

342
00:12:54,870 --> 00:12:54,000
it's all how you see the connections in

343
00:12:57,829 --> 00:12:54,880
what you're

344
00:12:59,110 --> 00:12:57,839
learning about uh in astronomy what

345
00:13:00,150 --> 00:12:59,120
interests you and what interests the

346
00:13:01,590 --> 00:13:00,160
people around you

347
00:13:03,829 --> 00:13:01,600
and you have all of this background

348
00:13:06,310 --> 00:13:03,839
knowledge so that you can

349
00:13:07,350 --> 00:13:06,320
take that information and really crack

350
00:13:09,910 --> 00:13:07,360
that nutshell

351
00:13:11,990 --> 00:13:09,920
by using that information you use your

352
00:13:14,230 --> 00:13:12,000
everyday experiences that you have

353
00:13:16,230 --> 00:13:14,240
and use it to crack that science

354
00:13:18,550 --> 00:13:16,240
nutshell of astrophysics

355
00:13:19,590 --> 00:13:18,560
so that you can sit down at a comfy

356
00:13:21,990 --> 00:13:19,600
location

357
00:13:23,430 --> 00:13:22,000
and talk to people about what interests

358
00:13:25,030 --> 00:13:23,440
you in a way that

359
00:13:29,670 --> 00:13:25,040
is very understandable to you and to the

360
00:13:33,910 --> 00:13:31,430
so when we think about physics as a

361
00:13:34,790 --> 00:13:33,920
reminder it really is the study of

362
00:13:37,670 --> 00:13:34,800
matter

363
00:13:38,710 --> 00:13:37,680

of motion of forces and energy so these

364
00:13:40,949 --> 00:13:38,720
are words that you

365
00:13:42,629 --> 00:13:40,959
are very familiar with in some way

366
00:13:45,110 --> 00:13:42,639
motion being movement

367
00:13:46,949 --> 00:13:45,120
like on a roller coaster for summer fun

368
00:13:50,310 --> 00:13:46,959
or if you enjoy playing

369
00:13:51,750 --> 00:13:50,320
uh a game of billiards here light you

370
00:13:53,829 --> 00:13:51,760
see rainbows light coming in through

371
00:13:56,069 --> 00:13:53,839
windows campfires electricity light

372
00:13:57,189 --> 00:13:56,079
bulbs colors reflecting emitting

373
00:13:59,990 --> 00:13:57,199
these are all things that you're

374
00:14:03,269 --> 00:14:00,000
familiar with now what is astrophysics

375
00:14:06,550 --> 00:14:03,279
it's all of those things except we focus

376
00:14:09,030 --> 00:14:06,560
uh the study of those pieces in space

377
00:14:09,590 --> 00:14:09,040
so we can look at different objects in

378
00:14:11,910 --> 00:14:09,600
space

379
00:14:13,590 --> 00:14:11,920
study them and and try to understand how

380
00:14:14,870 --> 00:14:13,600
they came to be

381
00:14:16,870 --> 00:14:14,880
so in tonight's talk we're going to look

382
00:14:19,509 --> 00:14:16,880
at some everyday phenomenon

383
00:14:21,750 --> 00:14:19,519
that can help you to understand how we

384
00:14:24,069 --> 00:14:21,760
understand other things in space

385
00:14:25,590 --> 00:14:24,079
at some at the beginning level and then

386
00:14:28,470 --> 00:14:25,600
just building up a little bit more

387
00:14:30,790 --> 00:14:28,480
intuition for that so let's start with

388
00:14:33,350 --> 00:14:30,800

our first one here

389
00:14:34,150 --> 00:14:33,360
how do we gauge distances are things

390
00:14:36,470 --> 00:14:34,160
nearby

391
00:14:38,550 --> 00:14:36,480
or are they far away so for example on

392
00:14:40,949 --> 00:14:38,560
the left side images here we have some

393
00:14:43,670 --> 00:14:40,959
images you know of a field of flowers

394
00:14:45,590 --> 00:14:43,680
some clouds and some distant objects and

395
00:14:46,629 --> 00:14:45,600
you use your everyday experiences to

396
00:14:48,389 --> 00:14:46,639
gauge

397
00:14:49,829 --> 00:14:48,399
you know the flowers are probably close

398
00:14:52,389 --> 00:14:49,839
by the

399
00:14:54,150 --> 00:14:52,399
uh these these distant trees they're

400
00:14:55,350 --> 00:14:54,160
distant they're smaller than i'm used to

401
00:14:56,949 --> 00:14:55,360
seeing if it's right in front of me so

402
00:14:58,710 --> 00:14:56,959
they're further away

403
00:15:00,150 --> 00:14:58,720
and these clouds maybe some of them are

404
00:15:00,629 --> 00:15:00,160
close by but it's really hard to tell

405
00:15:02,230 --> 00:15:00,639
because i

406
00:15:04,069 --> 00:15:02,240
i don't have a good sense of the sizes

407
00:15:05,350 --> 00:15:04,079
of clouds now if you look at this

408
00:15:06,629 --> 00:15:05,360
mountain picture

409
00:15:08,949 --> 00:15:06,639
you're also using some of that same

410
00:15:11,110 --> 00:15:08,959
intuition you know how big you think

411
00:15:12,870 --> 00:15:11,120
that mountains might be

412
00:15:14,550 --> 00:15:12,880
you see trees some of them look bigger

413
00:15:16,470 --> 00:15:14,560

they're probably closer

414
00:15:18,150 --> 00:15:16,480
some of them are further away they look

415
00:15:19,509 --> 00:15:18,160
smaller so that kind of intuition is

416
00:15:21,430 --> 00:15:19,519
there but as soon as you get to

417
00:15:23,509 --> 00:15:21,440
astronomy and look out into space

418
00:15:24,470 --> 00:15:23,519
the intuition kind of might fall through

419
00:15:26,949 --> 00:15:24,480
the cracks a little bit

420
00:15:28,230 --> 00:15:26,959
so for example in this image here in the

421
00:15:31,910 --> 00:15:28,240
upper right hand side

422
00:15:34,310 --> 00:15:31,920
it's a field of stars are they close by

423
00:15:35,590 --> 00:15:34,320
some of them are they farther away are

424
00:15:37,749 --> 00:15:35,600
they all the same distance

425
00:15:39,509 --> 00:15:37,759
it's really hard to tell the image in

426
00:15:42,710 --> 00:15:39,519
the lower right hand side

427
00:15:44,710 --> 00:15:42,720
are those stars or the galaxies

428
00:15:45,829 --> 00:15:44,720
are they nearby are they far away so

429
00:15:47,749 --> 00:15:45,839
it's really hard

430
00:15:50,310 --> 00:15:47,759
to gauge distances just by looking in

431
00:15:51,910 --> 00:15:50,320
astronomy we need some type of method to

432
00:15:52,629 --> 00:15:51,920
figure out distances to the nearby

433
00:15:54,710 --> 00:15:52,639
things

434
00:15:55,910 --> 00:15:54,720
and then based on that we can start to

435
00:15:57,350 --> 00:15:55,920
look at distances at

436
00:15:58,710 --> 00:15:57,360
things a little bit further away and

437
00:16:00,069 --> 00:15:58,720
then a little bit further away a little

438
00:16:01,749 --> 00:16:00,079

bit further away so distances are

439
00:16:03,110 --> 00:16:01,759
actually extremely hard in astronomy and

440
00:16:05,670 --> 00:16:03,120
we have to build on

441
00:16:06,710 --> 00:16:05,680
our our knowledge of nearby things to

442
00:16:09,189 --> 00:16:06,720
get to

443
00:16:10,550 --> 00:16:09,199
objects that are billions of light years

444
00:16:13,590 --> 00:16:10,560
away

445
00:16:15,110 --> 00:16:13,600
so let's start by looking at an example

446
00:16:18,150 --> 00:16:15,120
so if you're in your car driving

447
00:16:20,230 --> 00:16:18,160
traveling around in the summer time

448
00:16:22,230 --> 00:16:20,240
you notice that if you look outside your

449
00:16:22,550 --> 00:16:22,240
window you'll see the the trees moving

450
00:16:25,350 --> 00:16:22,560
like

451
00:16:26,790 --> 00:16:25,360
quickly but the mountains don't look

452
00:16:28,389 --> 00:16:26,800
like they're moving by very much they

453
00:16:30,629 --> 00:16:28,399
but they're moving a little bit

454
00:16:32,629 --> 00:16:30,639
they appear to move and and the distant

455
00:16:33,749 --> 00:16:32,639
say the clouds perhaps you

456
00:16:35,749 --> 00:16:33,759
might have here that's saying oh the

457
00:16:37,030 --> 00:16:35,759
clouds are following me um

458
00:16:38,870 --> 00:16:37,040
but they're really far away sometimes

459
00:16:39,990 --> 00:16:38,880
and you're not sure or if the sun feels

460
00:16:42,629 --> 00:16:40,000
like it's following you

461
00:16:43,350 --> 00:16:42,639
okay so we have this you know this this

462
00:16:47,350 --> 00:16:43,360
idea of

463
00:16:51,670 --> 00:16:47,360

if i'm moving and changing my pers um

464
00:16:53,509 --> 00:16:51,680
perception my angle out the window

465
00:16:56,710 --> 00:16:53,519
where i see things in that field of view

466
00:16:59,030 --> 00:16:56,720
and this window changes with time

467
00:17:02,829 --> 00:16:59,040
and how it changes allows me to gauge

468
00:17:06,870 --> 00:17:04,470
okay

469
00:17:10,949 --> 00:17:06,880
see this is the same video here again go

470
00:17:17,270 --> 00:17:15,590
so i want to do a little um hands-on

471
00:17:18,630 --> 00:17:17,280
activity with you all so this just

472
00:17:21,429 --> 00:17:18,640
happens to be uh

473
00:17:23,110 --> 00:17:21,439
eta karina in different colors of light

474
00:17:25,829 --> 00:17:23,120
but i'm gonna put three stars

475
00:17:27,270 --> 00:17:25,839
artificial ones on the screen they're

476
00:17:30,310 --> 00:17:27,280
just three different sizes

477
00:17:31,590 --> 00:17:30,320
um you get to pick which one you like so

478
00:17:34,470 --> 00:17:31,600
what i want you to do

479
00:17:35,190 --> 00:17:34,480
is i want you to hold your hand out at

480
00:17:37,190 --> 00:17:35,200
arm's length

481
00:17:39,350 --> 00:17:37,200
okay and just hold up your index finger

482
00:17:40,710 --> 00:17:39,360
i'm sorry i can't see my screen here let

483
00:17:42,230 --> 00:17:40,720
me see so i can see what i'm doing

484
00:17:43,830 --> 00:17:42,240
inside a block okay

485
00:17:46,789 --> 00:17:43,840
so you hold your finger out at arm's

486
00:17:48,150 --> 00:17:46,799
length here and i want you to cover up

487
00:17:50,070 --> 00:17:48,160
pick a star where your whole finger

488
00:17:52,710 --> 00:17:50,080

covers up that star okay

489
00:17:53,830 --> 00:17:52,720
and notice i'm covering my one eye so i

490
00:17:55,430 --> 00:17:53,840
want to look out

491
00:17:58,150 --> 00:17:55,440
at it with your right eye so i'm

492
00:17:59,830 --> 00:17:58,160
covering my left eye holding my finger

493
00:18:01,750 --> 00:17:59,840
out at arm's length and i'm covering one

494
00:18:02,310 --> 00:18:01,760
of the stars so right now i'm covering

495
00:18:06,070 --> 00:18:02,320
up

496
00:18:08,630 --> 00:18:06,080
the middle star then i'm gonna

497
00:18:09,590 --> 00:18:08,640
switch my hand and look at it with my

498
00:18:12,710 --> 00:18:09,600
other eye

499
00:18:13,270 --> 00:18:12,720
okay so what you should see is it looks

500
00:18:16,070 --> 00:18:13,280
like

501
00:18:17,510 --> 00:18:16,080
your finger is moving but your finger's

502
00:18:20,070 --> 00:18:17,520
not moving

503
00:18:21,990 --> 00:18:20,080
really what's happening is that your

504
00:18:25,430 --> 00:18:22,000
line of sight to your finger

505
00:18:27,430 --> 00:18:25,440
one eye versus the other eye compared to

506
00:18:27,990 --> 00:18:27,440
the background of etarina is making it

507
00:18:30,310 --> 00:18:28,000
look

508
00:18:31,350 --> 00:18:30,320
like your finger is moving okay so let's

509
00:18:33,510 --> 00:18:31,360
try this again

510
00:18:34,390 --> 00:18:33,520
so you're covering up your your star

511
00:18:36,390 --> 00:18:34,400
that you've chosen

512
00:18:38,470 --> 00:18:36,400
and you're looking at it with different

513
00:18:40,390 --> 00:18:38,480

eyes and you see like it moves

514
00:18:41,990 --> 00:18:40,400
now pull your finger closer to your face

515
00:18:44,230 --> 00:18:42,000
and do the same thing again

516
00:18:45,430 --> 00:18:44,240
okay what do you notice that's different

517
00:18:46,870 --> 00:18:45,440
now that your fingers a little bit

518
00:18:48,710 --> 00:18:46,880
closer to your face

519
00:18:50,150 --> 00:18:48,720
you'll notice that your finger appears

520
00:18:52,950 --> 00:18:50,160
to move more

521
00:18:54,470 --> 00:18:52,960
than it did before the position of your

522
00:18:56,310 --> 00:18:54,480
eyes have not changed

523
00:18:57,590 --> 00:18:56,320
but the position of your finger which is

524
00:18:59,350 --> 00:18:57,600
closer to your face has

525
00:19:01,190 --> 00:18:59,360
and as you look at it from two different

526
00:19:03,029 --> 00:19:01,200
locations it looks like the finger

527
00:19:05,510 --> 00:19:03,039
shifts more

528
00:19:07,029 --> 00:19:05,520
this is called parallax and notice that

529
00:19:08,630 --> 00:19:07,039
it had to do with two different

530
00:19:11,029 --> 00:19:08,640
locations in this case one

531
00:19:12,070 --> 00:19:11,039
eye versus the other and the location of

532
00:19:14,390 --> 00:19:12,080
my finger

533
00:19:16,390 --> 00:19:14,400
relative to ada karina which is a

534
00:19:16,870 --> 00:19:16,400
background object that was stationary

535
00:19:20,070 --> 00:19:16,880
was

536
00:19:21,830 --> 00:19:20,080
stationary for the most part okay so we

537
00:19:25,669 --> 00:19:21,840
can do the same thing

538
00:19:30,070 --> 00:19:25,679

in space so

539
00:19:31,350 --> 00:19:30,080
in space we're sitting on the earth that

540
00:19:33,909 --> 00:19:31,360
orbits the sun

541
00:19:35,029 --> 00:19:33,919
so we have two well we have many unique

542
00:19:37,990 --> 00:19:35,039
vantage points

543
00:19:41,110 --> 00:19:38,000
but we have two very unique vantage

544
00:19:44,150 --> 00:19:41,120
points we have the earth at one location

545
00:19:45,669 --> 00:19:44,160
here six months later it's at another

546
00:19:47,750 --> 00:19:45,679
location over here

547
00:19:49,430 --> 00:19:47,760
so that's like two sides of your eyeball

548
00:19:50,070 --> 00:19:49,440
when you're on either side of earth's

549
00:19:52,390 --> 00:19:50,080
orbit

550
00:19:53,990 --> 00:19:52,400
so if you see a nearby star here which

551
00:19:55,029 --> 00:19:54,000
is like your finger in the previous

552
00:19:57,430 --> 00:19:55,039
example

553
00:19:59,190 --> 00:19:57,440
it will appear to shift in the sky

554
00:20:01,350 --> 00:19:59,200
relative to the background stars

555
00:20:03,350 --> 00:20:01,360
and then the case um in the example

556
00:20:05,830 --> 00:20:03,360
before the background stars was the

557
00:20:07,110 --> 00:20:05,840
image of just random image of eight

558
00:20:08,789 --> 00:20:07,120
o'clock arena

559
00:20:12,789 --> 00:20:08,799
so let me just go back a little bit here

560
00:20:16,470 --> 00:20:15,590
so if i could move my eyes one eye from

561
00:20:18,149 --> 00:20:16,480
left to right

562
00:20:20,630 --> 00:20:18,159
you would see the motion of the star

563
00:20:23,430 --> 00:20:20,640

change over time this is a different

564
00:20:26,070 --> 00:20:23,440
view it's a top down view so in december

565
00:20:28,230 --> 00:20:26,080
i look at some star

566
00:20:29,909 --> 00:20:28,240
in june i see the star again notice the

567
00:20:30,549 --> 00:20:29,919
star hasn't changed the background stars

568
00:20:33,750 --> 00:20:30,559
haven't changed

569
00:20:35,510 --> 00:20:33,760
only i have changed my location and

570
00:20:37,270 --> 00:20:35,520
the movement of the star in the sky is

571
00:20:39,590 --> 00:20:37,280
called the parallax angle

572
00:20:40,950 --> 00:20:39,600
and it's directly related to how far

573
00:20:43,590 --> 00:20:40,960
away the star is

574
00:20:45,270 --> 00:20:43,600
and how far away we are when we are

575
00:20:48,470 --> 00:20:45,280
moving in our orbit around

576
00:20:49,830 --> 00:20:48,480
the sun and that is a geometrical

577
00:20:52,310 --> 00:20:49,840
relationship that we can use

578
00:20:55,110 --> 00:20:52,320
trigonometry very basic trigonometry

579
00:20:56,710 --> 00:20:55,120
to get a direct measurement of the

580
00:20:57,990 --> 00:20:56,720
distance to that star if i can measure

581
00:21:00,070 --> 00:20:58,000
the parallax angle

582
00:21:03,110 --> 00:21:00,080
and that's really really amazing you

583
00:21:05,110 --> 00:21:03,120
just need extremely sensitive

584
00:21:06,870 --> 00:21:05,120
telescopes to measure the position

585
00:21:08,630 --> 00:21:06,880
accurately enough so that you can see

586
00:21:10,149 --> 00:21:08,640
the shift in the sky

587
00:21:11,909 --> 00:21:10,159
to see the parallax because once you see

588
00:21:12,710 --> 00:21:11,919

the parallax that changes over the

589
00:21:15,830 --> 00:21:12,720
course of

590
00:21:17,990 --> 00:21:15,840
year to year to year then you can get

591
00:21:20,310 --> 00:21:18,000
the distances to nearby stars

592
00:21:22,070 --> 00:21:20,320
so to gauge these distances a current

593
00:21:22,789 --> 00:21:22,080
telescope doing very precise

594
00:21:24,789 --> 00:21:22,799
measurements

595
00:21:26,070 --> 00:21:24,799
of positions as well as brightness and

596
00:21:27,990 --> 00:21:26,080
spectroscopy

597
00:21:29,909 --> 00:21:28,000
is uh gaia it's called the global

598
00:21:31,350 --> 00:21:29,919
astrometric interferometer for

599
00:21:34,390 --> 00:21:31,360
astrophysics it's a

600
00:21:35,430 --> 00:21:34,400
european space agency astronomical

601
00:21:38,149 --> 00:21:35,440
observing mission

602
00:21:38,710 --> 00:21:38,159
it was launched in 2013 and one of its

603
00:21:41,830 --> 00:21:38,720
goals

604
00:21:44,310 --> 00:21:41,840
here is to look at

605
00:21:44,870 --> 00:21:44,320
the positions and brightnesses of stars

606
00:21:48,870 --> 00:21:44,880
in

607
00:21:50,630 --> 00:21:48,880
our galaxy and look for

608
00:21:52,549 --> 00:21:50,640
their calculate their distances by

609
00:21:54,950 --> 00:21:52,559
parallax but also look for their true

610
00:21:56,630 --> 00:21:54,960
motion through space now you can see how

611
00:21:58,870 --> 00:21:56,640
it gets a little complicated because a

612
00:22:01,830 --> 00:21:58,880
star might look like it's moving

613
00:22:03,029 --> 00:22:01,840

because of us moving around the sun as

614
00:22:04,470 --> 00:22:03,039
the earth orbits around the sun

615
00:22:07,110 --> 00:22:04,480
but there's also true motion of the

616
00:22:08,710 --> 00:22:07,120
stars through space so we have to know

617
00:22:10,950 --> 00:22:08,720
one have very accurate measurements for

618
00:22:12,549 --> 00:22:10,960
that so over the course of

619
00:22:14,710 --> 00:22:12,559
this mission's lifetime it'll be able to

620
00:22:16,710 --> 00:22:14,720
measure about a billion stars

621
00:22:18,710 --> 00:22:16,720
to really get a map of the stars in the

622
00:22:21,350 --> 00:22:18,720
milky way and then start to understand

623
00:22:22,230 --> 00:22:21,360
the evolution of the milky way so in the

624
00:22:24,070 --> 00:22:22,240
past

625
00:22:26,310 --> 00:22:24,080
the prior mission that did another

626
00:22:28,950 --> 00:22:26,320
really nice

627
00:22:31,510 --> 00:22:28,960
mission to measure parallax's uh was

628
00:22:34,470 --> 00:22:31,520
called hipparchus also an issa telescope

629
00:22:36,310 --> 00:22:34,480
and that telescope could only measure

630
00:22:38,630 --> 00:22:36,320
distances a little bit

631
00:22:41,750 --> 00:22:38,640
beyond the orbit of the sun not far

632
00:22:45,590 --> 00:22:41,760
about 300 light years or so

633
00:22:46,310 --> 00:22:45,600
now gaia here can measure the accuracy

634
00:22:49,590 --> 00:22:46,320
of

635
00:22:52,549 --> 00:22:49,600
stars to within 10 percent out to

636
00:22:54,710 --> 00:22:52,559
about 30 000 light years okay so this

637
00:22:56,070 --> 00:22:54,720
bigger circle so this is a big leap from

638
00:22:58,390 --> 00:22:56,080

the hipparchus

639
00:22:59,750 --> 00:22:58,400
but it's not quite that large when you

640
00:23:03,029 --> 00:22:59,760
think about the

641
00:23:04,630 --> 00:23:03,039
uh the the diameter of the milky way

642
00:23:06,630 --> 00:23:04,640
the diameter of the milky way is on the

643
00:23:08,310 --> 00:23:06,640
order of about 100 000 light years

644
00:23:10,390 --> 00:23:08,320
so this is getting out to about the

645
00:23:11,669 --> 00:23:10,400
center of the milky way

646
00:23:12,950 --> 00:23:11,679
but some other stars a little bit

647
00:23:13,750 --> 00:23:12,960
further out with a little bit less

648
00:23:15,510 --> 00:23:13,760
brushes and

649
00:23:17,190 --> 00:23:15,520
will be able to they'll be able to also

650
00:23:19,510 --> 00:23:17,200
measure but the point is is that

651
00:23:21,110 --> 00:23:19,520
more stars and their positions are being

652
00:23:24,070 --> 00:23:21,120
able to be measured

653
00:23:27,029 --> 00:23:24,080
as well as their brightnesses so that we

654
00:23:30,230 --> 00:23:27,039
can start to see

655
00:23:31,510 --> 00:23:30,240
okay fast word here

656
00:23:33,750 --> 00:23:31,520
to some of the positions so if you look

657
00:23:36,950 --> 00:23:33,760
at this video here you can see

658
00:23:39,590 --> 00:23:36,960
this is from some of the data from gaia

659
00:23:40,710 --> 00:23:39,600
and you can see the motion of the stars

660
00:23:44,149 --> 00:23:40,720
the apparent motion

661
00:23:46,070 --> 00:23:44,159
due to the earth orbiting around

662
00:23:47,190 --> 00:23:46,080
the sun and so you could see that

663
00:23:49,430 --> 00:23:47,200

cyclical kind of

664
00:23:51,110 --> 00:23:49,440
wobbling back and forth just like your

665
00:23:52,870 --> 00:23:51,120
finger seemed like it was moving back

666
00:23:54,630 --> 00:23:52,880
and forth

667
00:23:56,870 --> 00:23:54,640
so the distances to all these stars can

668
00:23:59,190 --> 00:23:56,880
be measured as a result of that

669
00:24:00,070 --> 00:23:59,200
shifting now once you take out the

670
00:24:01,909 --> 00:24:00,080
shifting

671
00:24:04,070 --> 00:24:01,919
you can start to study the true motion

672
00:24:06,630 --> 00:24:04,080
of the stars through space

673
00:24:09,190 --> 00:24:06,640
and so this is a forward modeling of the

674
00:24:10,710 --> 00:24:09,200
true motion of those stars over time

675
00:24:13,269 --> 00:24:10,720
and what you saw there which i'll just

676
00:24:16,789 --> 00:24:13,279
rewind a little bit here is

677
00:24:19,190 --> 00:24:16,799
that this is

678
00:24:21,269 --> 00:24:19,200
the constellation of versa major and

679
00:24:23,350 --> 00:24:21,279
over time the stars in ursa major which

680
00:24:25,510 --> 00:24:23,360
are very distances from the earth

681
00:24:26,549 --> 00:24:25,520
will move and the constellations as we

682
00:24:31,190 --> 00:24:26,559
know it now will

683
00:24:35,110 --> 00:24:32,870
okay so that was just distances how do

684
00:24:37,029 --> 00:24:35,120
you gauge distances use parallax

685
00:24:38,870 --> 00:24:37,039
so now let's talk about another uh

686
00:24:39,510 --> 00:24:38,880
everyday experience that you might have

687
00:24:41,110 --> 00:24:39,520
which is

688
00:24:42,870 --> 00:24:41,120

going around and around in circles now

689
00:24:46,070 --> 00:24:42,880
you can take that as a literal

690
00:24:49,750 --> 00:24:46,080
alliterative uh a literal uh

691
00:24:50,870 --> 00:24:49,760
saying or figurative one um so

692
00:24:52,870 --> 00:24:50,880
since it's summertime here in the

693
00:24:55,350 --> 00:24:52,880
northern hemisphere you could talk about

694
00:24:56,630 --> 00:24:55,360
going around on the carousel going on a

695
00:24:59,669 --> 00:24:56,640
ferris wheel

696
00:25:00,870 --> 00:24:59,679
that has motion in a circle it's hot you

697
00:25:02,789 --> 00:25:00,880
might have a ceiling fan

698
00:25:04,549 --> 00:25:02,799
on or regular standing fan where the

699
00:25:07,190 --> 00:25:04,559
blades are spinning

700
00:25:10,390 --> 00:25:07,200
many of us are on computers a lot these

701
00:25:12,390 --> 00:25:10,400
days and sometimes you hear that fan

702
00:25:14,310 --> 00:25:12,400
spiraling around in your laptop so

703
00:25:17,750 --> 00:25:14,320
something's spinning in there okay

704
00:25:19,190 --> 00:25:17,760
a few years ago these uh were kid

705
00:25:20,950 --> 00:25:19,200
favorites there were little fidget

706
00:25:22,549 --> 00:25:20,960
spinners and um

707
00:25:24,070 --> 00:25:22,559
they could spin quite fast so they're

708
00:25:27,669 --> 00:25:24,080
spinning motion and then

709
00:25:29,430 --> 00:25:27,679
then of course we have the rotation of

710
00:25:30,710 --> 00:25:29,440
the earth which is also spinning motion

711
00:25:32,230 --> 00:25:30,720
here and this is from the discover

712
00:25:33,830 --> 00:25:32,240
satellite looking down

713
00:25:35,350 --> 00:25:33,840

um we also have objects that orbit

714
00:25:37,190 --> 00:25:35,360
around the earth too so in some ways

715
00:25:37,909 --> 00:25:37,200
that's a spinning motion it's an orb

716
00:25:41,110 --> 00:25:37,919
it's still or

717
00:25:44,950 --> 00:25:41,120
motion in a circle so let's talk about

718
00:25:47,190 --> 00:25:44,960
motion in a circle so for example

719
00:25:48,149 --> 00:25:47,200
let's i'm going to use the ceiling fan

720
00:25:49,909 --> 00:25:48,159
as our

721
00:25:52,950 --> 00:25:49,919
everyday example here so a typical

722
00:25:55,510 --> 00:25:52,960
ceiling fan here is about 42 inches

723
00:25:57,590 --> 00:25:55,520
in diameter about 1.3 meters and it

724
00:26:01,350 --> 00:25:57,600
rotates at about 100

725
00:26:03,909 --> 00:26:01,360
rotations per minute rpms okay

726
00:26:04,630 --> 00:26:03,919
so as the the blades spin round and

727
00:26:07,029 --> 00:26:04,640
round

728
00:26:08,830 --> 00:26:07,039
you might ask well how fast are the tips

729
00:26:12,070 --> 00:26:08,840
of those blades moving

730
00:26:15,190 --> 00:26:12,080
okay well let's first think

731
00:26:16,950 --> 00:26:15,200
well if i have 100 rpms there's 100

732
00:26:19,029 --> 00:26:16,960
rotations per minute

733
00:26:21,510 --> 00:26:19,039
how many rotations do i get per second

734
00:26:22,230 --> 00:26:21,520
and that works out to be 1.7 rotations

735
00:26:24,870 --> 00:26:22,240
per second

736
00:26:26,789 --> 00:26:24,880
okay so if i have a stopwatch i can

737
00:26:28,070 --> 00:26:26,799
count almost two rotations in a second

738
00:26:29,750 --> 00:26:28,080

but not quite

739
00:26:31,909 --> 00:26:29,760
so what i really want to know is how

740
00:26:33,750 --> 00:26:31,919
long does it take the blade to go around

741
00:26:36,070 --> 00:26:33,760
one time so if i were to take one point

742
00:26:38,950 --> 00:26:36,080
on the blade and watch it go around

743
00:26:41,909 --> 00:26:38,960
one time how long would that take so 100

744
00:26:44,870 --> 00:26:41,919
rpms is roughly 0.6 seconds for one

745
00:26:45,430 --> 00:26:44,880
tip of the blade to make one circle

746
00:26:49,510 --> 00:26:45,440
around

747
00:26:52,950 --> 00:26:49,520
here so as an analogy if we talk about

748
00:26:54,789 --> 00:26:52,960
the earth rotating on its axis

749
00:26:56,950 --> 00:26:54,799
it takes 24 hours to complete one

750
00:26:58,470 --> 00:26:56,960
rotation there so that's the period of

751
00:27:00,950 --> 00:26:58,480
the rotation 24 hours

752
00:27:02,710 --> 00:27:00,960
yeah that period of course we call it a

753
00:27:06,470 --> 00:27:02,720
day here

754
00:27:09,750 --> 00:27:06,480
an earth day that is

755
00:27:12,789 --> 00:27:09,760
so again we wanted to know how fast the

756
00:27:14,390 --> 00:27:12,799
blade tip's moving now speed is is a

757
00:27:16,149 --> 00:27:14,400
very simple concept

758
00:27:17,590 --> 00:27:16,159
it's the distance traveled in a given

759
00:27:19,990 --> 00:27:17,600
period of time

760
00:27:21,430 --> 00:27:20,000
in a given time interval so for example

761
00:27:22,149 --> 00:27:21,440
if you look at your speedometer on your

762
00:27:24,789 --> 00:27:22,159
car

763
00:27:27,269 --> 00:27:24,799

you might be going at 65 miles per hour

764
00:27:30,149 --> 00:27:27,279
or 90 kilometers per hour that's how far

765
00:27:32,789 --> 00:27:30,159
you go in one hour it's your speed

766
00:27:34,710 --> 00:27:32,799
now for this circular motion of the fan

767
00:27:37,269 --> 00:27:34,720
if i look at a dot here

768
00:27:39,190 --> 00:27:37,279
the dot would make a path that marks

769
00:27:41,990 --> 00:27:39,200
that's marked by this dotted line here

770
00:27:43,990 --> 00:27:42,000
okay so that distance traveled is really

771
00:27:46,310 --> 00:27:44,000
the circumference of a circle

772
00:27:47,830 --> 00:27:46,320
with a radius that's from the top of the

773
00:27:48,630 --> 00:27:47,840
blade here to the center of where it

774
00:27:52,389 --> 00:27:48,640
rotates

775
00:27:55,990 --> 00:27:52,399
which is two pi r okay so um

776
00:27:59,110 --> 00:27:56,000
a 1.3 meter diameter ceiling fan

777
00:28:01,269 --> 00:27:59,120
half of that is the radius so 0.66

778
00:28:03,430 --> 00:28:01,279
meters so the circumference is 2 pi

779
00:28:04,389 --> 00:28:03,440
times 0.66 meters so multiply that all

780
00:28:07,190 --> 00:28:04,399
together

781
00:28:09,110 --> 00:28:07,200
and i get a distance from this point

782
00:28:11,590 --> 00:28:09,120
going around the circle once of about

783
00:28:13,590 --> 00:28:11,600
4 meters 4.1 meters okay great i know

784
00:28:16,470 --> 00:28:13,600
the distance that it will travel

785
00:28:17,990 --> 00:28:16,480
in that circular motion so now i can

786
00:28:19,830 --> 00:28:18,000
answer the question of how fast are the

787
00:28:21,669 --> 00:28:19,840
blade tips moving because remember speed

788
00:28:23,830 --> 00:28:21,679

is just distance

789
00:28:24,789 --> 00:28:23,840
for a given time interval so we already

790
00:28:28,310 --> 00:28:24,799
know that

791
00:28:31,510 --> 00:28:28,320
it rotates 100 times per minute

792
00:28:32,950 --> 00:28:31,520
which is 0.6 seconds for once to go

793
00:28:34,389 --> 00:28:32,960
around that's the time

794
00:28:36,149 --> 00:28:34,399
and the distance we just calculated

795
00:28:38,870 --> 00:28:36,159
which was the circumference so 4.1

796
00:28:40,950 --> 00:28:38,880
meters divided by 0.6 seconds is 6.8

797
00:28:43,110 --> 00:28:40,960
meters per second that's the speed

798
00:28:44,389 --> 00:28:43,120
which in miles per hour is about 15

799
00:28:46,870 --> 00:28:44,399
miles an hour

800
00:28:47,990 --> 00:28:46,880
so a rough gauge here i'd always tell

801
00:28:49,510 --> 00:28:48,000
people you know

802
00:28:51,269 --> 00:28:49,520
numbers don't mean anything if you don't

803
00:28:52,710 --> 00:28:51,279
have a reference point so this is a

804
00:28:54,630 --> 00:28:52,720
typical biking speed

805
00:28:56,149 --> 00:28:54,640
if you're not you know running um you

806
00:28:57,590 --> 00:28:56,159
know not in a race or anything like that

807
00:28:59,669 --> 00:28:57,600
so 50 miles per hour that's

808
00:29:00,710 --> 00:28:59,679
reasonable i know that i i won't get

809
00:29:02,470 --> 00:29:00,720
hurt if i

810
00:29:04,149 --> 00:29:02,480
um somehow accidentally get in touch

811
00:29:05,510 --> 00:29:04,159
with obviously right here

812
00:29:07,029 --> 00:29:05,520
so 15 miles per hour there's their

813
00:29:10,830 --> 00:29:07,039

limits you know safety limits for

814
00:29:15,590 --> 00:29:12,950
okay

815
00:29:17,110 --> 00:29:15,600
so this idea of speed is distance over

816
00:29:18,710 --> 00:29:17,120
time is going to be really

817
00:29:21,590 --> 00:29:18,720
straightforward for us to use

818
00:29:23,350 --> 00:29:21,600
in other astronomical scenarios so we

819
00:29:25,269 --> 00:29:23,360
needed to know some type of distance

820
00:29:26,789 --> 00:29:25,279
traveled in that circle

821
00:29:28,070 --> 00:29:26,799
but that circle we need to know

822
00:29:29,990 --> 00:29:28,080
something about how far away in this

823
00:29:34,070 --> 00:29:30,000
case i needed to know the radius

824
00:29:35,750 --> 00:29:34,080
of the ceiling fan here i needed

825
00:29:37,669 --> 00:29:35,760
you might want to know the the speed

826
00:29:39,430 --> 00:29:37,679
which is how fast it's moving

827
00:29:41,430 --> 00:29:39,440
and you want to need to know how much

828
00:29:42,149 --> 00:29:41,440
time is involved in order to rotate once

829
00:29:43,590 --> 00:29:42,159
so

830
00:29:45,830 --> 00:29:43,600
the great thing here is that we have

831
00:29:46,230 --> 00:29:45,840
three terms we have speed distance and

832
00:29:47,909 --> 00:29:46,240
time

833
00:29:49,590 --> 00:29:47,919
and if you have two of those you can

834
00:29:51,830 --> 00:29:49,600
always figure out the other one okay

835
00:29:52,870 --> 00:29:51,840
so it's it's a it's a nice nice

836
00:29:55,190 --> 00:29:52,880
mathematical

837
00:29:57,269 --> 00:29:55,200
uh solution here equation with three

838
00:29:59,110 --> 00:29:57,279

numbers if i have two i always can get

839
00:30:00,710 --> 00:29:59,120
the other one

840
00:30:02,549 --> 00:30:00,720
so what we're going to do here is well

841
00:30:05,830 --> 00:30:02,559
let's figure out how

842
00:30:06,870 --> 00:30:05,840
fast or how much let's take the earth as

843
00:30:08,310 --> 00:30:06,880
an example here

844
00:30:10,389 --> 00:30:08,320
so again we have the rotation of the

845
00:30:11,990 --> 00:30:10,399
earth and

846
00:30:13,990 --> 00:30:12,000
let's say that we live at the equator

847
00:30:14,950 --> 00:30:14,000
and you want to know how fast am i

848
00:30:16,950 --> 00:30:14,960
moving

849
00:30:20,070 --> 00:30:16,960
when i'm on the equator just because the

850
00:30:25,269 --> 00:30:23,029
so in order to do that um we can answer

851
00:30:26,230 --> 00:30:25,279
um can we answer how far we are from the

852
00:30:28,310 --> 00:30:26,240
center of the motion

853
00:30:29,510 --> 00:30:28,320
okay we can the distance the center of

854
00:30:32,310 --> 00:30:29,520
the earth here

855
00:30:33,510 --> 00:30:32,320
um how fast does the earth's surface

856
00:30:35,430 --> 00:30:33,520
rotate well that's what we're trying to

857
00:30:37,830 --> 00:30:35,440
find right

858
00:30:39,029 --> 00:30:37,840
and how much time does it take to rotate

859
00:30:40,710 --> 00:30:39,039
once in its orbit

860
00:30:42,630 --> 00:30:40,720
um or and it's on its axis we know that

861
00:30:45,029 --> 00:30:42,640
it takes 24 hours to go

862
00:30:45,750 --> 00:30:45,039
once on its axis so we can fill in these

863
00:30:48,950 --> 00:30:45,760

numbers

864
00:30:50,310 --> 00:30:48,960
um the radius of the earth here has

865
00:30:52,789 --> 00:30:50,320
actually been known for

866
00:30:53,789 --> 00:30:52,799
some time so that wasn't an unknown here

867
00:30:56,950 --> 00:30:53,799
it's 6

868
00:30:58,070 --> 00:30:56,960
378 kilometers which is approximately

869
00:31:01,190 --> 00:30:58,080
i'm rounding up here

870
00:31:03,029 --> 00:31:01,200
um about 4 000 miles okay so

871
00:31:05,430 --> 00:31:03,039
the circumference around the equator

872
00:31:07,669 --> 00:31:05,440
here is about 40 000 kilometers

873
00:31:09,430 --> 00:31:07,679
okay and again it takes us 24 hours to

874
00:31:11,909 --> 00:31:09,440
complete that rotation

875
00:31:13,190 --> 00:31:11,919
around once on our axis so that means i

876
00:31:15,669 --> 00:31:13,200
can calculate the

877
00:31:17,110 --> 00:31:15,679
speed so the speed here is the distance

878
00:31:20,230 --> 00:31:17,120
over time so that's the 40

879
00:31:23,909 --> 00:31:20,240
000 kilometers divided by the 24 hours

880
00:31:26,230 --> 00:31:23,919
it comes up to 1 66 kilometers per hour

881
00:31:27,430 --> 00:31:26,240
okay so now you know that compared to

882
00:31:32,630 --> 00:31:27,440
typical car

883
00:31:34,389 --> 00:31:32,640
motion um in miles per hour it's 1038

884
00:31:37,990 --> 00:31:34,399
miles per hour so it's quite quick if

885
00:31:40,230 --> 00:31:38,000
you're just sitting on the equator

886
00:31:41,990 --> 00:31:40,240
and moving with the earth's rotation now

887
00:31:45,110 --> 00:31:42,000
if you're at higher latitudes

888
00:31:46,470 --> 00:31:45,120

your speed on the earth as it rotates is

889
00:31:49,029 --> 00:31:46,480
a little bit smaller

890
00:31:50,310 --> 00:31:49,039
because the circumference at that

891
00:31:53,110 --> 00:31:50,320
latitude is smaller

892
00:31:54,389 --> 00:31:53,120
okay but you still make a rotation in 24

893
00:31:56,070 --> 00:31:54,399
hours

894
00:31:57,509 --> 00:31:56,080
so you're going smaller distance in the

895
00:31:58,149 --> 00:31:57,519
same amount of time so you can you can

896
00:31:59,350 --> 00:31:58,159
go slower

897
00:32:01,350 --> 00:31:59,360
okay so that if you're sitting right at

898
00:32:02,630 --> 00:32:01,360
the north pole here um

899
00:32:03,990 --> 00:32:02,640
you're not rotating at all because

900
00:32:04,630 --> 00:32:04,000
you're standing on the top of the world

901
00:32:06,630 --> 00:32:04,640
okay

902
00:32:08,789 --> 00:32:06,640
so this is using the same concepts as we

903
00:32:09,350 --> 00:32:08,799
did for the ceiling fan to understand

904
00:32:11,269 --> 00:32:09,360
how

905
00:32:13,430 --> 00:32:11,279
quickly the tips of the ceiling fan

906
00:32:15,430 --> 00:32:13,440
blades were moving to get the

907
00:32:17,990 --> 00:32:15,440
rotation at the surface of the earth

908
00:32:21,110 --> 00:32:18,000
here okay let's take it one step further

909
00:32:23,350 --> 00:32:21,120
how about the sun okay so same equation

910
00:32:25,350 --> 00:32:23,360
speed is distance over time i have three

911
00:32:27,110 --> 00:32:25,360
numbers if i only have two i can

912
00:32:28,870 --> 00:32:27,120
calculate the third okay

913
00:32:31,110 --> 00:32:28,880

so we have the question of how far away

914
00:32:32,549 --> 00:32:31,120
how fast and how much time

915
00:32:34,630 --> 00:32:32,559
all right well let's start with how far

916
00:32:37,669 --> 00:32:34,640
away so the sun

917
00:32:40,070 --> 00:32:37,679
is a star in our milky way galaxy that

918
00:32:43,029 --> 00:32:40,080
contains hundreds of billions of stars

919
00:32:44,549 --> 00:32:43,039
and early in astronomy astronomers

920
00:32:46,310 --> 00:32:44,559
thought the sun was at the center of the

921
00:32:48,149 --> 00:32:46,320
galaxy it was really hard to figure that

922
00:32:49,990 --> 00:32:48,159
out but when they started to

923
00:32:52,230 --> 00:32:50,000
astronomers start to tease out different

924
00:32:53,669 --> 00:32:52,240
components of the milky way

925
00:32:56,230 --> 00:32:53,679
they were able to see that there was

926
00:32:59,190 --> 00:32:56,240
some distribution around the center

927
00:33:00,389 --> 00:32:59,200
specifically globular clusters and once

928
00:33:02,230 --> 00:33:00,399
they were able to map

929
00:33:04,549 --> 00:33:02,240
out the distances of those globular

930
00:33:05,269 --> 00:33:04,559
clusters they could map out the distance

931
00:33:06,470 --> 00:33:05,279
of the sun

932
00:33:09,110 --> 00:33:06,480
relative to the center of that

933
00:33:09,509 --> 00:33:09,120
distribution and it's roughly about 26

934
00:33:12,070 --> 00:33:09,519
000

935
00:33:13,350 --> 00:33:12,080
light years away from the center of the

936
00:33:16,389 --> 00:33:13,360
milky way galaxy

937
00:33:17,909 --> 00:33:16,399
so that's roughly um uh

938
00:33:19,909 --> 00:33:17,919

that's the rate the distance away from

939
00:33:21,590 --> 00:33:19,919
the center so if the

940
00:33:23,029 --> 00:33:21,600
galaxy is rotating then the

941
00:33:25,029 --> 00:33:23,039
circumference

942
00:33:26,230 --> 00:33:25,039
which is the path in the dotted uh

943
00:33:29,630 --> 00:33:26,240
orange circle there

944
00:33:32,310 --> 00:33:29,640
would be about 163 thousand um

945
00:33:34,470 --> 00:33:32,320
163 000 light years okay so that would

946
00:33:36,630 --> 00:33:34,480
be the distance traveled

947
00:33:38,310 --> 00:33:36,640
all right what other thing do i know how

948
00:33:40,630 --> 00:33:38,320
fast okay

949
00:33:41,350 --> 00:33:40,640
how fast is the sun moving through space

950
00:33:44,149 --> 00:33:41,360
now

951
00:33:45,990 --> 00:33:44,159
you can make accurate measurements of

952
00:33:48,389 --> 00:33:46,000
the positions of stars nearby

953
00:33:50,870 --> 00:33:48,399
but you can also measure the speeds at

954
00:33:54,549 --> 00:33:50,880
which the stars are moving through space

955
00:33:55,430 --> 00:33:54,559
looking at spectroscopy of those stars

956
00:33:58,789 --> 00:33:55,440
that's when we take

957
00:34:01,430 --> 00:33:58,799
light and we break it up into very very

958
00:34:02,870 --> 00:34:01,440
detailed pieces of the light looking for

959
00:34:04,630 --> 00:34:02,880
signatures

960
00:34:06,549 --> 00:34:04,640
that are like fingerprints of the gases

961
00:34:09,109 --> 00:34:06,559
and that actually can give us

962
00:34:10,149 --> 00:34:09,119
motion it's very similar to the doppler

963
00:34:13,190 --> 00:34:10,159

effect

964
00:34:14,310 --> 00:34:13,200
that you can use on on radars to get a

965
00:34:16,389 --> 00:34:14,320
sense of speed

966
00:34:18,149 --> 00:34:16,399
so astronomers astronomers can do a

967
00:34:20,149 --> 00:34:18,159
similar thing and once you know what the

968
00:34:21,750 --> 00:34:20,159
motion of stars are around the sun you

969
00:34:24,149 --> 00:34:21,760
can start to figure out how fast

970
00:34:25,430 --> 00:34:24,159
the sun is moving um as well and we find

971
00:34:28,790 --> 00:34:25,440
that the sun is moving

972
00:34:31,909 --> 00:34:28,800
about 240 000 kilometers per second uh

973
00:34:32,470 --> 00:34:31,919
which is roughly 86 400 kilometers per

974
00:34:39,990 --> 00:34:32,480
hour

975
00:34:41,990 --> 00:34:40,000
so it's really fast okay so

976
00:34:43,829 --> 00:34:42,000
we have two of the three we've got

977
00:34:46,069 --> 00:34:43,839
distance and we've got speed

978
00:34:48,230 --> 00:34:46,079
so that means now i can figure out how

979
00:34:51,510 --> 00:34:48,240
long it takes the sun to go around the

980
00:34:53,349 --> 00:34:51,520
galaxy once okay so time here if i

981
00:34:56,310 --> 00:34:53,359
rearrange that is just the distance

982
00:34:57,430 --> 00:34:56,320
divided by the speed um so if i take

983
00:35:00,230 --> 00:34:57,440
that distance and

984
00:35:03,109 --> 00:35:00,240
by the speed it takes the sun about 200

985
00:35:04,710 --> 00:35:03,119
million years to go around one time

986
00:35:06,310 --> 00:35:04,720
okay so this these are really rough

987
00:35:08,150 --> 00:35:06,320
approximations given

988
00:35:10,230 --> 00:35:08,160

assumptions like circular orbits um

989
00:35:12,550 --> 00:35:10,240
that's the main assumption here

990
00:35:13,589 --> 00:35:12,560
so it's 200 million years to go around

991
00:35:16,710 --> 00:35:13,599
one time

992
00:35:18,150 --> 00:35:16,720
now if it takes the sun that amount of

993
00:35:19,349 --> 00:35:18,160
time to go around once

994
00:35:21,270 --> 00:35:19,359
how long how many times has it gone

995
00:35:23,750 --> 00:35:21,280
around the milky way well the

996
00:35:24,950 --> 00:35:23,760
the age of the sun is about 4.6 a

997
00:35:27,270 --> 00:35:24,960
billion years

998
00:35:28,390 --> 00:35:27,280
so it's been going around and around the

999
00:35:30,710 --> 00:35:28,400
center of the milky way

1000
00:35:32,310 --> 00:35:30,720
about 20 just a little over 20 times

1001
00:35:34,790 --> 00:35:32,320
here okay so again

1002
00:35:36,790 --> 00:35:34,800
everyday concept of circular motion

1003
00:35:37,349 --> 00:35:36,800
things that you see in your space around

1004
00:35:40,710 --> 00:35:37,359
you

1005
00:35:41,109 --> 00:35:40,720
outside everywhere can be used to do

1006
00:35:43,670 --> 00:35:41,119
very

1007
00:35:46,790 --> 00:35:43,680
simple estimates for other types of

1008
00:35:49,910 --> 00:35:46,800
circular motion in space

1009
00:35:51,430 --> 00:35:49,920
so now let's talk about energy okay so

1010
00:35:53,109 --> 00:35:51,440
i just want you to take a second and

1011
00:35:54,550 --> 00:35:53,119
look all around you

1012
00:35:55,990 --> 00:35:54,560
look in the space where you might be

1013
00:35:56,550 --> 00:35:56,000

might be in a coffee shop you might be

1014
00:35:58,310 --> 00:35:56,560
outside

1015
00:35:59,910 --> 00:35:58,320
enjoying the weather you might be inside

1016
00:36:00,870 --> 00:35:59,920
with your family and look around maybe

1017
00:36:04,230 --> 00:36:00,880
your space is clean

1018
00:36:06,310 --> 00:36:04,240
maybe it's not so clean um it's

1019
00:36:07,670 --> 00:36:06,320
it's perfect for you is there anything

1020
00:36:09,349 --> 00:36:07,680
interesting in that space

1021
00:36:11,109 --> 00:36:09,359
what if you look outside what's

1022
00:36:12,950 --> 00:36:11,119
interesting there um

1023
00:36:15,910 --> 00:36:12,960
so let's see what kind of energy we can

1024
00:36:19,430 --> 00:36:15,920
talk about now energy is a word that

1025
00:36:22,150 --> 00:36:19,440
uh we use in signs one way and

1026
00:36:23,430 --> 00:36:22,160
we use it very informally in everyday

1027
00:36:26,390 --> 00:36:23,440
speak so i wanted to

1028
00:36:28,950 --> 00:36:26,400
kind of draw some some definitions so we

1029
00:36:30,790 --> 00:36:28,960
can use that as a common language here

1030
00:36:32,710 --> 00:36:30,800
so there's all different kinds of energy

1031
00:36:33,349 --> 00:36:32,720
first of all and let's just talk about

1032
00:36:37,030 --> 00:36:33,359
energy

1033
00:36:39,910 --> 00:36:37,040
so anytime there's

1034
00:36:41,430 --> 00:36:39,920
movement anytime there's speed

1035
00:36:41,990 --> 00:36:41,440
physically go from one location to

1036
00:36:44,150 --> 00:36:42,000
another

1037
00:36:46,390 --> 00:36:44,160
be it small or big there's going to be

1038
00:36:47,109 --> 00:36:46,400

kinetic energy associated with that

1039
00:36:48,790 --> 00:36:47,119
motion

1040
00:36:51,030 --> 00:36:48,800
so if you're running down the street

1041
00:36:54,390 --> 00:36:51,040
moving in your car

1042
00:36:56,710 --> 00:36:54,400
on the surface of your rotating around

1043
00:36:58,310 --> 00:36:56,720
or on the earth going around the sun or

1044
00:37:00,710 --> 00:36:58,320
the sun moving through space

1045
00:37:02,069 --> 00:37:00,720
the ceiling fans the air in your in this

1046
00:37:03,349 --> 00:37:02,079
room that i'm sitting in in the room

1047
00:37:04,870 --> 00:37:03,359
that you're sitting in

1048
00:37:06,550 --> 00:37:04,880
it's moving as well so there's kinetic

1049
00:37:11,270 --> 00:37:06,560
energy all associated

1050
00:37:14,870 --> 00:37:13,910
now temperature you might say well it's

1051
00:37:16,310 --> 00:37:14,880
temperature energy

1052
00:37:18,230 --> 00:37:16,320
well she's bringing up temperature for

1053
00:37:19,910 --> 00:37:18,240
some reason okay let's let's see this

1054
00:37:21,349 --> 00:37:19,920
let's step back for a second so

1055
00:37:23,109 --> 00:37:21,359
temperature we talk about things that

1056
00:37:24,470 --> 00:37:23,119
are hot that are cold that are warm and

1057
00:37:27,109 --> 00:37:24,480
astronomers talk about

1058
00:37:28,150 --> 00:37:27,119
the temperature of different objects in

1059
00:37:31,190 --> 00:37:28,160
space and

1060
00:37:32,390 --> 00:37:31,200
and um and that could be very relative

1061
00:37:35,030 --> 00:37:32,400
some someone's hot

1062
00:37:36,230 --> 00:37:35,040
might be someone's cold so we could talk

1063
00:37:38,550 --> 00:37:36,240

about things that are hot like

1064
00:37:40,470 --> 00:37:38,560
lava or hot the hot air on the summer

1065
00:37:41,750 --> 00:37:40,480
day or it could be very cold like the

1066
00:37:44,870 --> 00:37:41,760
ice cubes in your

1067
00:37:45,910 --> 00:37:44,880
freezer or the cold air outside when

1068
00:37:49,270 --> 00:37:45,920
it's snowing

1069
00:37:50,069 --> 00:37:49,280
um what's warm it's relative maybe

1070
00:37:52,550 --> 00:37:50,079
you're really hungry

1071
00:37:54,230 --> 00:37:52,560
and you love warm biscuits uh maybe

1072
00:37:55,349 --> 00:37:54,240
spring is warm because you're trying to

1073
00:37:57,109 --> 00:37:55,359
grow things and you're

1074
00:37:58,390 --> 00:37:57,119
really ready to get out of the cold so

1075
00:38:01,589 --> 00:37:58,400
what's warm right so

1076
00:38:03,670 --> 00:38:01,599
but we talk about these as a description

1077
00:38:07,109 --> 00:38:03,680
and notice that they're all pictures of

1078
00:38:09,030 --> 00:38:07,119
big things macroscopic things

1079
00:38:11,190 --> 00:38:09,040
but what happens if i look at it from a

1080
00:38:13,990 --> 00:38:11,200
microscopic standpoint

1081
00:38:15,670 --> 00:38:14,000
so in this image here on the left i

1082
00:38:17,430 --> 00:38:15,680
talked about how the molecules in the

1083
00:38:19,030 --> 00:38:17,440
room here are moving they're not

1084
00:38:20,550 --> 00:38:19,040
static they don't stay still they're

1085
00:38:22,230 --> 00:38:20,560
moving all around

1086
00:38:25,349 --> 00:38:22,240
they bounce into each other they hit the

1087
00:38:28,310 --> 00:38:25,359
walls they hit your skin

1088
00:38:30,310 --> 00:38:28,320

and what you feel as temperature really

1089
00:38:31,349 --> 00:38:30,320
is a bombardment of those molecules with

1090
00:38:33,670 --> 00:38:31,359
your skin

1091
00:38:34,710 --> 00:38:33,680
transferring some of that kinetic energy

1092
00:38:37,270 --> 00:38:34,720
to your skin

1093
00:38:38,230 --> 00:38:37,280
okay and your skin warms up because you

1094
00:38:40,950 --> 00:38:38,240
get some energy

1095
00:38:42,710 --> 00:38:40,960
that's transferred there so that's

1096
00:38:44,310 --> 00:38:42,720
what's happening with gaseous

1097
00:38:45,750 --> 00:38:44,320
molecules and when we try to say

1098
00:38:45,990 --> 00:38:45,760
something about the temperature when we

1099
00:38:47,589 --> 00:38:46,000
talk

1100
00:38:49,910 --> 00:38:47,599
about liquids we could have a cold

1101
00:38:53,670 --> 00:38:49,920
liquid or a warm liquid like cold water

1102
00:38:57,109 --> 00:38:53,680
warm water so the molecules are still

1103
00:38:59,510 --> 00:38:57,119
um they can affect each other

1104
00:39:01,190 --> 00:38:59,520
but in in cold water they they're

1105
00:39:03,829 --> 00:39:01,200
they're more closely

1106
00:39:04,950 --> 00:39:03,839
um they're more they're closer to each

1107
00:39:06,870 --> 00:39:04,960
other where the warm water they're a

1108
00:39:09,030 --> 00:39:06,880
little bit further apart from each other

1109
00:39:09,990 --> 00:39:09,040
so the temperature has to do with how

1110
00:39:11,910 --> 00:39:10,000
how uh

1111
00:39:14,230 --> 00:39:11,920
for lack of a better word here fluid the

1112
00:39:17,510 --> 00:39:14,240
liquid is being um

1113
00:39:18,630 --> 00:39:17,520

a little bit closer versus less

1114
00:39:20,870 --> 00:39:18,640
separated here

1115
00:39:22,390 --> 00:39:20,880
now a solid we can think of a solid when

1116
00:39:24,069 --> 00:39:22,400
you think of solid you know knock on the

1117
00:39:25,270 --> 00:39:24,079
table or the chair it's

1118
00:39:26,470 --> 00:39:25,280
you know it's solid but that's what we

1119
00:39:27,990 --> 00:39:26,480
say when it's solid right so we're

1120
00:39:30,390 --> 00:39:28,000
talking about something where

1121
00:39:31,750 --> 00:39:30,400
the the the pieces are not uh don't

1122
00:39:34,550 --> 00:39:31,760
can't move around very much

1123
00:39:35,910 --> 00:39:34,560
but they can still vibrate okay um and

1124
00:39:37,750 --> 00:39:35,920
there's usually a

1125
00:39:40,870 --> 00:39:37,760
crystalline structure sometimes with

1126
00:39:43,270 --> 00:39:40,880
with the way the materials laid together

1127
00:39:45,109 --> 00:39:43,280
but they can still move there's still

1128
00:39:47,510 --> 00:39:45,119
kinetic energy associated with

1129
00:39:49,510 --> 00:39:47,520
with a solid because we know things that

1130
00:39:51,510 --> 00:39:49,520
are solid can have a temperature to them

1131
00:39:52,870 --> 00:39:51,520
and um so it's relating to the jiggling

1132
00:39:55,030 --> 00:39:52,880
the jostling of those elect

1133
00:39:57,910 --> 00:39:55,040
those molecules and the the structure of

1134
00:40:01,510 --> 00:40:00,870
so that's kinetic energy and oh let's go

1135
00:40:04,069 --> 00:40:01,520
back one

1136
00:40:07,190 --> 00:40:04,079
so temperature at the heart is really

1137
00:40:10,470 --> 00:40:07,200
kinetic energy it's energy due to motion

1138
00:40:12,390 --> 00:40:10,480

so the hotter a gas is the more quickly

1139
00:40:15,510 --> 00:40:12,400
the particles are moving

1140
00:40:16,870 --> 00:40:15,520
um the same thing with liquid and with a

1141
00:40:20,470 --> 00:40:16,880
solid

1142
00:40:23,510 --> 00:40:20,480
the hotter it is the more jostling it is

1143
00:40:26,550 --> 00:40:23,520
the colder it is

1144
00:40:28,630 --> 00:40:26,560
less jostling less movement so there's a

1145
00:40:30,230 --> 00:40:28,640
an absolute zero on the temperature

1146
00:40:33,109 --> 00:40:30,240
scale where

1147
00:40:35,030 --> 00:40:33,119
um you can say that motion ceases

1148
00:40:38,309 --> 00:40:35,040
because there's be no kinetic energy

1149
00:40:39,349 --> 00:40:38,319
zero temperature okay now that's just

1150
00:40:41,510 --> 00:40:39,359
one kind of energy

1151
00:40:43,190 --> 00:40:41,520
there is also uh different kinds of

1152
00:40:44,870 --> 00:40:43,200
energy so there's potential energy and

1153
00:40:47,270 --> 00:40:44,880
potential energy is stored energy that

1154
00:40:49,990 --> 00:40:47,280
can be converted to all other types

1155
00:40:51,109 --> 00:40:50,000
so for example the fruit hanging on this

1156
00:40:53,829 --> 00:40:51,119
apple tree

1157
00:40:55,030 --> 00:40:53,839
they all have kinetic energy so just

1158
00:40:57,030 --> 00:40:55,040
like this

1159
00:40:58,069 --> 00:40:57,040
little i can't you can't see it little

1160
00:40:59,910 --> 00:40:58,079
apple i have here

1161
00:41:01,270 --> 00:40:59,920
so right now it's it's hanging out oh

1162
00:41:02,950 --> 00:41:01,280
this is not the best here um

1163
00:41:05,190 --> 00:41:02,960

because of the green screen that's good

1164
00:41:08,309 --> 00:41:05,200
um

1165
00:41:09,750 --> 00:41:08,319
so this apple here has

1166
00:41:11,109 --> 00:41:09,760
is that a certain height above the

1167
00:41:12,630 --> 00:41:11,119
surface of the earth but you know that

1168
00:41:14,870 --> 00:41:12,640
if i let go of this

1169
00:41:16,230 --> 00:41:14,880
it's going to start moving right so i

1170
00:41:17,910 --> 00:41:16,240
dropped it and it moved

1171
00:41:20,069 --> 00:41:17,920
as soon as it moved it had kinetic

1172
00:41:21,750 --> 00:41:20,079
energy so there's they can be converted

1173
00:41:23,670 --> 00:41:21,760
so that gravitational potential energy

1174
00:41:26,150 --> 00:41:23,680
was converted in that case

1175
00:41:27,109 --> 00:41:26,160
now the fruit has complex minerals

1176
00:41:28,630 --> 00:41:27,119
molecules too

1177
00:41:31,589 --> 00:41:28,640
they have chemical potential energy in

1178
00:41:34,150 --> 00:41:31,599
the bonds there's one

1179
00:41:36,790 --> 00:41:34,160
molecule called lutein here which has 40

1180
00:41:38,150 --> 00:41:36,800
carbon atoms 56 hydrogen atoms and two

1181
00:41:41,270 --> 00:41:38,160
oxygen atoms

1182
00:41:44,470 --> 00:41:41,280
and this

1183
00:41:47,510 --> 00:41:44,480
is one of many molecules and minerals in

1184
00:41:49,109 --> 00:41:47,520
the atom and those

1185
00:41:50,630 --> 00:41:49,119
elements are bound together in that

1186
00:41:52,390 --> 00:41:50,640
molecule molecule

1187
00:41:55,270 --> 00:41:52,400
with chemical bonds so if you break them

1188
00:41:56,790 --> 00:41:55,280

apart it requires energy but it can also

1189
00:41:59,030 --> 00:41:56,800
release energy too

1190
00:42:00,870 --> 00:41:59,040
and then when we look at the actual

1191
00:42:02,069 --> 00:42:00,880
elements themselves we have a nucleus

1192
00:42:04,150 --> 00:42:02,079
and electrons

1193
00:42:05,349 --> 00:42:04,160
and those have blinding energy that's

1194
00:42:10,870 --> 00:42:05,359
also

1195
00:42:14,309 --> 00:42:12,950
so in your room here where you're

1196
00:42:16,309 --> 00:42:14,319
looking around so now look around

1197
00:42:17,670 --> 00:42:16,319
now i can start to spot different types

1198
00:42:19,270 --> 00:42:17,680
of energy so maybe you have

1199
00:42:21,030 --> 00:42:19,280
something on a shelf that's high up that

1200
00:42:22,710 --> 00:42:21,040
has gravitational potential energy

1201
00:42:24,069 --> 00:42:22,720
has the ability to fall off and change

1202
00:42:27,190 --> 00:42:24,079
into motion right

1203
00:42:28,630 --> 00:42:27,200
you have food around your house

1204
00:42:31,990 --> 00:42:28,640
there's lots of chemical potential

1205
00:42:34,470 --> 00:42:32,000
energy stored there anything with mass

1206
00:42:36,069 --> 00:42:34,480
has energy too so you might be familiar

1207
00:42:37,190 --> 00:42:36,079
with equals m c squared anything that

1208
00:42:38,630 --> 00:42:37,200
has mass has energy

1209
00:42:40,630 --> 00:42:38,640
it's called mass energy but it's really

1210
00:42:42,230 --> 00:42:40,640
hard to get to but it's there and has

1211
00:42:44,870 --> 00:42:42,240
the potential to be converted

1212
00:42:46,309 --> 00:42:44,880
and this is how stars make energy by

1213
00:42:49,109 --> 00:42:46,319

nuclear fusion

1214
00:42:51,349 --> 00:42:49,119
um because you can turn four hydrogen

1215
00:42:52,950 --> 00:42:51,359
atoms into one helium atom

1216
00:42:54,710 --> 00:42:52,960
and there's a mass difference between

1217
00:42:55,829 --> 00:42:54,720
that and that mass got converted into

1218
00:42:57,430 --> 00:42:55,839
energy

1219
00:42:59,190 --> 00:42:57,440
so that's one way of transformation of

1220
00:43:00,710 --> 00:42:59,200
one type to another

1221
00:43:02,230 --> 00:43:00,720
there's other types of potential energy

1222
00:43:03,109 --> 00:43:02,240
too there's electrical potential energy

1223
00:43:05,670 --> 00:43:03,119
your body

1224
00:43:06,710 --> 00:43:05,680
is one basically big electrical circuit

1225
00:43:08,069 --> 00:43:06,720
um sending

1226
00:43:09,910 --> 00:43:08,079
chemical signals i mean i'm sorry

1227
00:43:11,829 --> 00:43:09,920
electrical signals from your brain

1228
00:43:13,349 --> 00:43:11,839
to your different parts of your body to

1229
00:43:16,790 --> 00:43:13,359
make your hands move

1230
00:43:18,630 --> 00:43:16,800
um if you're walking you have uh

1231
00:43:20,710 --> 00:43:18,640
elastic potential energy in your muscles

1232
00:43:23,750 --> 00:43:20,720
as they contract and release

1233
00:43:25,109 --> 00:43:23,760
springs in your cars help to

1234
00:43:26,950 --> 00:43:25,119
absorb some of the jostling so there's

1235
00:43:28,550 --> 00:43:26,960
lots of potential energy around so

1236
00:43:30,069 --> 00:43:28,560
each of you has loads of potential

1237
00:43:31,589 --> 00:43:30,079
energy of all different kinds

1238
00:43:33,270 --> 00:43:31,599

even the astronauts up in the

1239
00:43:36,710 --> 00:43:33,280
international space station

1240
00:43:37,109 --> 00:43:36,720
have different kinds of energy as part

1241
00:43:39,910 --> 00:43:37,119
of

1242
00:43:41,750 --> 00:43:39,920
their everyday life here okay now

1243
00:43:43,510 --> 00:43:41,760
another type of energy is radiative

1244
00:43:44,069 --> 00:43:43,520
energy and this is the energy carried by

1245
00:43:53,589 --> 00:43:44,079
light

1246
00:43:56,710 --> 00:43:53,599
one type uh form of radiative energy in

1247
00:44:03,270 --> 00:44:00,069
now you and animals have a

1248
00:44:04,230 --> 00:44:03,280
body temperature that emits light in the

1249
00:44:07,589 --> 00:44:04,240
infrared

1250
00:44:08,630 --> 00:44:07,599
here so in the visible these animals are

1251
00:44:12,230 --> 00:44:08,640
reflecting

1252
00:44:14,150 --> 00:44:12,240
sunlight off of their surfaces

1253
00:44:15,349 --> 00:44:14,160
but if you have an infrared camera on

1254
00:44:16,630 --> 00:44:15,359
the animals

1255
00:44:18,150 --> 00:44:16,640
you can see the difference between the

1256
00:44:19,270 --> 00:44:18,160
warm blooded animals and the cold

1257
00:44:22,550 --> 00:44:19,280
blooded animals

1258
00:44:24,390 --> 00:44:22,560
or if a camera is on your face you glow

1259
00:44:25,589 --> 00:44:24,400
in the infrared you're emitting

1260
00:44:31,589 --> 00:44:25,599
radiative energy

1261
00:44:35,990 --> 00:44:34,470
now i'm sure you have your phone next to

1262
00:44:38,790 --> 00:44:36,000
you like i do

1263
00:44:39,670 --> 00:44:38,800

i have my laptop i have my wi-fi on i

1264
00:44:42,790 --> 00:44:39,680
just heated up some

1265
00:44:44,710 --> 00:44:42,800
food we have radio

1266
00:44:46,390 --> 00:44:44,720
light which is a type of radio energy

1267
00:44:48,309 --> 00:44:46,400
all around us because of the

1268
00:44:49,670 --> 00:44:48,319
electronics that we use all the time so

1269
00:44:51,910 --> 00:44:49,680
they carry energy

1270
00:44:53,510 --> 00:44:51,920
with you so if you wanted to know well

1271
00:44:55,750 --> 00:44:53,520
how does a cell phone

1272
00:44:56,710 --> 00:44:55,760
create radio waves well you know it only

1273
00:45:00,230 --> 00:44:56,720
works with battery

1274
00:45:04,069 --> 00:45:00,240
so electrical potential energy can

1275
00:45:07,030 --> 00:45:04,079
be supplied to electrons that

1276
00:45:08,870 --> 00:45:07,040
move them change it into kinetic energy

1277
00:45:10,790 --> 00:45:08,880
and when the electrons move

1278
00:45:12,870 --> 00:45:10,800
they produce radio signals and that

1279
00:45:14,870 --> 00:45:12,880
radio signal gets transferred

1280
00:45:16,630 --> 00:45:14,880
to a cell tower and then the cell tower

1281
00:45:17,430 --> 00:45:16,640
can read it and send you signals back to

1282
00:45:20,069 --> 00:45:17,440
so there's

1283
00:45:21,030 --> 00:45:20,079
lots of radio signals all around us lots

1284
00:45:22,069 --> 00:45:21,040
of radio of light

1285
00:45:24,069 --> 00:45:22,079
okay so these are different kinds of

1286
00:45:25,030 --> 00:45:24,079
energy we'll come back to this different

1287
00:45:26,550 --> 00:45:25,040
kind of energy

1288
00:45:28,069 --> 00:45:26,560

so the now the question is how can

1289
00:45:30,710 --> 00:45:28,079
energy be transferred okay

1290
00:45:31,670 --> 00:45:30,720
well we use the word heat a lot and

1291
00:45:33,109 --> 00:45:31,680
temperature sometimes

1292
00:45:35,190 --> 00:45:33,119
interchangeably so i wanted to make

1293
00:45:38,309 --> 00:45:35,200
another distinction about

1294
00:45:39,109 --> 00:45:38,319
um heat so heat is the transfer of

1295
00:45:43,510 --> 00:45:39,119
energy

1296
00:45:45,349 --> 00:45:43,520
a hotter object to a cooler object okay

1297
00:45:48,069 --> 00:45:45,359
so we've introduced temperature here

1298
00:45:50,390 --> 00:45:48,079
and we talked about energy so here are

1299
00:45:52,630 --> 00:45:50,400
just some three examples that i'll do

1300
00:45:54,230 --> 00:45:52,640
talk about with every day and how that

1301
00:45:57,829 --> 00:45:54,240
can

1302
00:46:01,510 --> 00:45:57,839
relate to something in astronomy

1303
00:46:02,870 --> 00:46:01,520
so heat here again is the transfer of

1304
00:46:04,950 --> 00:46:02,880
energy but there's different ways that

1305
00:46:06,870 --> 00:46:04,960
the heat can be transported and these

1306
00:46:09,510 --> 00:46:06,880
mechanisms are

1307
00:46:11,270 --> 00:46:09,520
conduction convection and radiation here

1308
00:46:13,430 --> 00:46:11,280
so i'm going to start with conduction

1309
00:46:15,030 --> 00:46:13,440
first here so let's talk about that warm

1310
00:46:18,150 --> 00:46:15,040
coffee or warm tea

1311
00:46:19,670 --> 00:46:18,160
warm beverage that you've had you know

1312
00:46:20,790 --> 00:46:19,680
that over time it'll cool off so

1313
00:46:23,270 --> 00:46:20,800

something's happening

1314
00:46:24,069 --> 00:46:23,280
to allow the temperature of that liquid

1315
00:46:27,190 --> 00:46:24,079
in your cup

1316
00:46:29,270 --> 00:46:27,200
to go down over time so remember

1317
00:46:30,870 --> 00:46:29,280
um temperature is really kinetic energy

1318
00:46:31,990 --> 00:46:30,880
so if the temperature goes down the

1319
00:46:34,630 --> 00:46:32,000
motion of those

1320
00:46:35,750 --> 00:46:34,640
molecules are going down but it it had

1321
00:46:36,550 --> 00:46:35,760
the energy had to go somewhere so where

1322
00:46:38,230 --> 00:46:36,560
did the energy go

1323
00:46:39,589 --> 00:46:38,240
okay so it had to be transferred out

1324
00:46:42,870 --> 00:46:39,599
some kind of the heat here

1325
00:46:44,630 --> 00:46:42,880
the transfer energy so if we do take a

1326
00:46:45,910 --> 00:46:44,640
microscopic look here so what's really

1327
00:46:48,950 --> 00:46:45,920
conduction conduction

1328
00:46:50,390 --> 00:46:48,960
is when the molecules vibrate okay

1329
00:46:53,750 --> 00:46:50,400
and they can transfer some of their

1330
00:46:55,510 --> 00:46:53,760
kinetic energy to a nearby molecule

1331
00:46:56,950 --> 00:46:55,520
so in the case for the coffee mug we

1332
00:46:59,510 --> 00:46:56,960
have the liquid inside

1333
00:47:00,470 --> 00:46:59,520
and it's touching the inside walls of

1334
00:47:02,630 --> 00:47:00,480
the ceramic mug

1335
00:47:04,870 --> 00:47:02,640
okay and those particles bombard the

1336
00:47:08,230 --> 00:47:04,880
ceramic mug

1337
00:47:09,349 --> 00:47:08,240
allowing some of the energy to transfer

1338
00:47:12,309 --> 00:47:09,359

to the edge of the mug

1339
00:47:13,670 --> 00:47:12,319
and then mug molecules vibrate okay get

1340
00:47:14,309 --> 00:47:13,680
warmer you know that if you touch the

1341
00:47:19,349 --> 00:47:14,319
outside

1342
00:47:21,190 --> 00:47:19,359
the air molecules can hit that mug

1343
00:47:23,349 --> 00:47:21,200
and some of the energy is transferred so

1344
00:47:24,069 --> 00:47:23,359
this is conduction of energy away from

1345
00:47:26,870 --> 00:47:24,079
the inside

1346
00:47:28,870 --> 00:47:26,880
of the coffee mug outwards okay now the

1347
00:47:30,230 --> 00:47:28,880
molecules themselves in the coffee mug

1348
00:47:31,589 --> 00:47:30,240
don't actually move away

1349
00:47:33,349 --> 00:47:31,599
unless we're talking about evaporation

1350
00:47:34,069 --> 00:47:33,359
and that's something else conduction

1351
00:47:35,750 --> 00:47:34,079
here is also

1352
00:47:37,430 --> 00:47:35,760
what's happening with the cast iron pot

1353
00:47:38,790 --> 00:47:37,440
the heat sources at the bottom but you

1354
00:47:42,470 --> 00:47:38,800
know that

1355
00:47:45,670 --> 00:47:42,480
there's some material that conducts heat

1356
00:47:49,270 --> 00:47:45,680
conducts gets hotter quicker right

1357
00:47:50,870 --> 00:47:49,280
and sometimes it doesn't so so there's

1358
00:47:52,390 --> 00:47:50,880
the heating of the metal

1359
00:47:54,230 --> 00:47:52,400
which can then conduct through the whole

1360
00:47:57,349 --> 00:47:54,240
metal so the sides of the

1361
00:47:59,109 --> 00:47:57,359
pot or the pan here can get hot okay the

1362
00:48:01,270 --> 00:47:59,119
molecules don't actually move though in

1363
00:48:03,990 --> 00:48:01,280

that cast iron pot

1364
00:48:04,950 --> 00:48:04,000
so what is an example of conduction of

1365
00:48:07,750 --> 00:48:04,960
energy out

1366
00:48:07,990 --> 00:48:07,760
by this idea of conduction so if we look

1367
00:48:10,470 --> 00:48:08,000
at

1368
00:48:11,430 --> 00:48:10,480
sirius um the brightest nighttime star

1369
00:48:13,510 --> 00:48:11,440
in the sky

1370
00:48:15,270 --> 00:48:13,520
it actually has a lo so sirius is this

1371
00:48:18,470 --> 00:48:15,280
is the one that you would see with your

1372
00:48:20,390 --> 00:48:18,480
actual eyes there's a very faint

1373
00:48:20,870 --> 00:48:20,400
companion next to it it's called sirius

1374
00:48:23,109 --> 00:48:20,880
b

1375
00:48:24,390 --> 00:48:23,119
it's a white dwarf star which is a

1376
00:48:27,510 --> 00:48:24,400
collapsed core

1377
00:48:29,829 --> 00:48:27,520
of a dead star so it's made out of

1378
00:48:31,589 --> 00:48:29,839
really weird material that doesn't exist

1379
00:48:33,190 --> 00:48:31,599
in that abundance on earth called

1380
00:48:34,390 --> 00:48:33,200
degenerate gas and we won't go into

1381
00:48:36,470 --> 00:48:34,400
there but

1382
00:48:37,630 --> 00:48:36,480
what i want you to know about this is

1383
00:48:40,950 --> 00:48:37,640
that it's

1384
00:48:43,910 --> 00:48:40,960
extremely dense inside the white dwarf

1385
00:48:44,950 --> 00:48:43,920
and it's mostly made out of densely

1386
00:48:48,390 --> 00:48:44,960
packed oxygen

1387
00:48:50,870 --> 00:48:48,400
and carbon and electrons

1388
00:48:52,230 --> 00:48:50,880

the electrons are not attached to the

1389
00:48:54,309 --> 00:48:52,240
carbon and the oxygen

1390
00:48:57,190 --> 00:48:54,319
but it's so dense that it acts like a

1391
00:49:01,349 --> 00:48:57,200
crystalline structure so very solid like

1392
00:49:03,510 --> 00:49:01,359
and so the energy the the the the

1393
00:49:04,870 --> 00:49:03,520
energy of those atoms in the interior of

1394
00:49:07,750 --> 00:49:04,880
the white dwarf

1395
00:49:09,510 --> 00:49:07,760
jostle around and conduct so that it can

1396
00:49:10,549 --> 00:49:09,520
cool off now eventually that hits an

1397
00:49:13,910 --> 00:49:10,559
outer layer

1398
00:49:14,950 --> 00:49:13,920
um that won't act like a solid axe more

1399
00:49:18,150 --> 00:49:14,960
like a fluid and

1400
00:49:19,829 --> 00:49:18,160
and then eventually at the surface

1401
00:49:21,910 --> 00:49:19,839
it emits light and i'll talk about how

1402
00:49:22,950 --> 00:49:21,920
radiative energy is another way to take

1403
00:49:24,790 --> 00:49:22,960
energy away

1404
00:49:26,870 --> 00:49:24,800
and cool it off so at the surface of the

1405
00:49:28,710 --> 00:49:26,880
star it's not conducting it's all on the

1406
00:49:31,030 --> 00:49:28,720
interior here

1407
00:49:32,470 --> 00:49:31,040
so the analogy here is like passing a

1408
00:49:34,150 --> 00:49:32,480
note from person to person

1409
00:49:36,069 --> 00:49:34,160
to get it to the other side of the room

1410
00:49:37,589 --> 00:49:36,079
okay so the note is the energy

1411
00:49:39,030 --> 00:49:37,599
and you're passing it to one person and

1412
00:49:40,069 --> 00:49:39,040
the person passes to the next person to

1413
00:49:42,150 --> 00:49:40,079

the next person

1414
00:49:43,589 --> 00:49:42,160
and that's conduction um because the

1415
00:49:45,030 --> 00:49:43,599
energy is getting out but the people are

1416
00:49:47,030 --> 00:49:45,040
not moving

1417
00:49:48,390 --> 00:49:47,040
now let's talk about convection here so

1418
00:49:50,630 --> 00:49:48,400
convection

1419
00:49:52,549 --> 00:49:50,640
is when the particles physically can

1420
00:49:55,430 --> 00:49:52,559
carry away the energy themselves

1421
00:49:56,950 --> 00:49:55,440
okay so in that note passing analogy so

1422
00:49:57,589 --> 00:49:56,960
instead of passing the note from person

1423
00:49:59,510 --> 00:49:57,599
to person

1424
00:50:00,950 --> 00:49:59,520
you physically carry it to the other

1425
00:50:02,309 --> 00:50:00,960
side of the room because you're the

1426
00:50:04,309 --> 00:50:02,319
particle and if you're moving

1427
00:50:05,990 --> 00:50:04,319
it and carrying the note the energy

1428
00:50:08,950 --> 00:50:06,000
you're the the transporter of that

1429
00:50:09,510 --> 00:50:08,960
that that uh energy here so an example

1430
00:50:13,430 --> 00:50:09,520
of this

1431
00:50:15,109 --> 00:50:13,440
is um when you're boiling water so

1432
00:50:16,950 --> 00:50:15,119
first there's conduction going on with

1433
00:50:17,829 --> 00:50:16,960
that hue source at the bottom of the gas

1434
00:50:20,870 --> 00:50:17,839
and the glass

1435
00:50:22,549 --> 00:50:20,880
is absorbing that energy and heating up

1436
00:50:24,630 --> 00:50:22,559
so it's a solid but it's heating up

1437
00:50:25,589 --> 00:50:24,640
via conduction but then the water sits

1438
00:50:27,829 --> 00:50:25,599

on top of that

1439
00:50:30,390 --> 00:50:27,839
and there's some conduction here at the

1440
00:50:33,349 --> 00:50:30,400
bottom as the water heats up but then

1441
00:50:34,230 --> 00:50:33,359
the water heats up it gets a little bit

1442
00:50:36,069 --> 00:50:34,240
less dense

1443
00:50:37,270 --> 00:50:36,079
and it starts to rise and so those

1444
00:50:41,270 --> 00:50:37,280
bubbles you see there

1445
00:50:49,190 --> 00:50:45,109
warmer water rising okay and physically

1446
00:50:52,230 --> 00:50:51,109
now where do we see this we see this on

1447
00:50:56,309 --> 00:50:52,240
the sun

1448
00:50:57,270 --> 00:50:56,319
so this is um a image of the surface of

1449
00:50:59,910 --> 00:50:57,280
the sun

1450
00:51:00,710 --> 00:50:59,920
it's roughly one eleven thousand eight

1451
00:51:03,910 --> 00:51:00,720
hundred by

1452
00:51:05,349 --> 00:51:03,920
six thousand seven hundred miles view of

1453
00:51:07,430 --> 00:51:05,359
the sun's surface

1454
00:51:09,430 --> 00:51:07,440
so this is a just looking at that the

1455
00:51:11,190 --> 00:51:09,440
outermost layer of the star

1456
00:51:12,470 --> 00:51:11,200
of the sun so what you see here in

1457
00:51:15,589 --> 00:51:12,480
yellow is

1458
00:51:18,790 --> 00:51:15,599
hotter gas and what you see in black

1459
00:51:20,630 --> 00:51:18,800
is the cooler gas that's sinking so

1460
00:51:22,710 --> 00:51:20,640
in the previous image you saw the little

1461
00:51:25,750 --> 00:51:22,720
bubbles of water going upwards

1462
00:51:28,870 --> 00:51:25,760
so imagine instead of water a big

1463
00:51:29,910 --> 00:51:28,880

bubble of hot gas going up to the

1464
00:51:31,750 --> 00:51:29,920
surface

1465
00:51:33,349 --> 00:51:31,760
and you see this light which is

1466
00:51:35,109 --> 00:51:33,359
radiating away so that's

1467
00:51:37,349 --> 00:51:35,119
actually how it's cooling on the surface

1468
00:51:37,829 --> 00:51:37,359
but the in the heat and the inside of

1469
00:51:39,829 --> 00:51:37,839
the sun

1470
00:51:41,670 --> 00:51:39,839
is is coming up by these convective

1471
00:51:43,589 --> 00:51:41,680
cells now these cells are pretty large

1472
00:51:45,510 --> 00:51:43,599
they're about the size of texas okay and

1473
00:51:47,150 --> 00:51:45,520
this is a time lapse image you can see

1474
00:51:52,549 --> 00:51:47,160
here this was taken in

1475
00:51:57,430 --> 00:51:54,230
about 15 minutes or so so you can see

1476
00:51:59,030 --> 00:51:57,440
that there's motion here

1477
00:52:01,270 --> 00:51:59,040
and you'd see that there's also light

1478
00:52:02,870 --> 00:52:01,280
being emitted here so convection cells

1479
00:52:06,230 --> 00:52:02,880
again are bringing the hot plasma from

1480
00:52:11,109 --> 00:52:08,710
now the interior of some really massive

1481
00:52:12,630 --> 00:52:11,119
stars also has this type of convection

1482
00:52:15,270 --> 00:52:12,640
going on to bring the energy from

1483
00:52:18,549 --> 00:52:15,280
nuclear fusion out from the core

1484
00:52:20,150 --> 00:52:18,559
upwards and and that's one way that

1485
00:52:22,790 --> 00:52:20,160
energy is transported out from the

1486
00:52:24,950 --> 00:52:22,800
interior of really massive stars

1487
00:52:26,309 --> 00:52:24,960
now the last we have is radiation so

1488
00:52:28,950 --> 00:52:26,319

radiation

1489
00:52:30,150 --> 00:52:28,960
is a heat transport mechanism that

1490
00:52:32,870 --> 00:52:30,160
transports the energy

1491
00:52:34,069 --> 00:52:32,880
by the light particles themselves by the

1492
00:52:35,990 --> 00:52:34,079
light waves so

1493
00:52:37,430 --> 00:52:36,000
like we can talk about as a particle and

1494
00:52:37,910 --> 00:52:37,440
we call that a photon or we can talk

1495
00:52:40,549 --> 00:52:37,920
about the

1496
00:52:41,190 --> 00:52:40,559
electromagnetic wave that carries energy

1497
00:52:43,750 --> 00:52:41,200
which is

1498
00:52:45,349 --> 00:52:43,760
electric fields and magnetic fields but

1499
00:52:48,069 --> 00:52:45,359
carries energy

1500
00:52:48,790 --> 00:52:48,079
now in this campfire you see visible

1501
00:52:53,990 --> 00:52:48,800
light

1502
00:52:55,990 --> 00:52:54,000
photons coming out of that combustion

1503
00:52:57,829 --> 00:52:56,000
mechanism there is going into your eyes

1504
00:53:00,870 --> 00:52:57,839
it's being absorbed you see the light

1505
00:53:03,030 --> 00:53:00,880
okay now it's also really warm

1506
00:53:04,710 --> 00:53:03,040
okay and we know the infrared light is

1507
00:53:06,790 --> 00:53:04,720
emitted because you

1508
00:53:08,549 --> 00:53:06,800
quote unquote feel it when your skin

1509
00:53:10,870 --> 00:53:08,559
absorbs that infrared energy that's why

1510
00:53:11,990 --> 00:53:10,880
it feels warm to you that's one reason

1511
00:53:14,069 --> 00:53:12,000
one reason why it feels really warm

1512
00:53:16,390 --> 00:53:14,079
because the infrared light

1513
00:53:17,349 --> 00:53:16,400

is being absorbed same thing is

1514
00:53:19,510 --> 00:53:17,359
happening with a

1515
00:53:21,190 --> 00:53:19,520
hot coffee mug it's also a radiant you

1516
00:53:22,710 --> 00:53:21,200
can't see it invisible but if you turn

1517
00:53:24,470 --> 00:53:22,720
on infrared camera

1518
00:53:25,990 --> 00:53:24,480
it does radiate and you can see that the

1519
00:53:28,390 --> 00:53:26,000
inner pieces here

1520
00:53:29,670 --> 00:53:28,400
yellow is hotter the ceramic mug is not

1521
00:53:31,270 --> 00:53:29,680
as hot as the liquid

1522
00:53:33,109 --> 00:53:31,280
but it's definitely not as warm as the

1523
00:53:35,030 --> 00:53:33,119
surrounding air here

1524
00:53:37,109 --> 00:53:35,040
so you can still feel that infrared

1525
00:53:40,069 --> 00:53:37,119
radiation because it's being absorbed

1526
00:53:41,270 --> 00:53:40,079
by your skin so the analogy of radiation

1527
00:53:42,790 --> 00:53:41,280
here is instead of

1528
00:53:44,870 --> 00:53:42,800
passing the note or carrying the note

1529
00:53:46,549 --> 00:53:44,880
yourself you just throw the note

1530
00:53:48,150 --> 00:53:46,559
and the note is representing the photon

1531
00:53:49,190 --> 00:53:48,160
moving through whatever substance it

1532
00:53:52,150 --> 00:53:49,200
might be moving through

1533
00:53:53,990 --> 00:53:52,160
in this case it's moving through visible

1534
00:53:56,470 --> 00:53:54,000
the visible and infrared light is moving

1535
00:53:59,510 --> 00:53:56,480
through air

1536
00:54:01,270 --> 00:53:59,520
so we have lots of radiation examples in

1537
00:54:04,390 --> 00:54:01,280
astronomy without

1538
00:54:05,990 --> 00:54:04,400

radiation moving through space

1539
00:54:08,150 --> 00:54:06,000
we would not be able to capture the

1540
00:54:10,069 --> 00:54:08,160
images that we do in astronomy so again

1541
00:54:13,349 --> 00:54:10,079
the sun surface is visible

1542
00:54:18,230 --> 00:54:13,359
here in that image we also

1543
00:54:21,510 --> 00:54:18,240
see the cells and the convection zones

1544
00:54:24,549 --> 00:54:21,520
bubbling upwards the yellow is hotter

1545
00:54:25,670 --> 00:54:24,559
than the dark cells of gas going down

1546
00:54:28,470 --> 00:54:25,680
so there's something with the

1547
00:54:31,750 --> 00:54:28,480
temperature of the gas that makes the

1548
00:54:33,750 --> 00:54:31,760
intensity of the light change okay the

1549
00:54:35,430 --> 00:54:33,760
temperature of stars also changes the

1550
00:54:37,510 --> 00:54:35,440
visible color that you might see so

1551
00:54:38,549 --> 00:54:37,520
hotter stars look actually very blue

1552
00:54:40,710 --> 00:54:38,559
white

1553
00:54:42,069 --> 00:54:40,720
because of the the radiation that it's

1554
00:54:43,510 --> 00:54:42,079
emitting because of the temperature of

1555
00:54:47,349 --> 00:54:43,520
the star as a whole

1556
00:54:49,430 --> 00:54:47,359
cooler stars um like m dwarf stars

1557
00:54:51,510 --> 00:54:49,440
are are quite cooler than the sun and

1558
00:54:52,069 --> 00:54:51,520
emit a lot of light in the red part of

1559
00:54:53,670 --> 00:54:52,079
the spectrum

1560
00:54:56,069 --> 00:54:53,680
so they overall look red so that's the

1561
00:54:58,309 --> 00:54:56,079
one thing in astronomy that you can say

1562
00:54:59,510 --> 00:54:58,319
when you look up at the space is the

1563
00:55:00,470 --> 00:54:59,520

color of the star will tell you the

1564
00:55:02,710 --> 00:55:00,480
temperature of the star

1565
00:55:04,549 --> 00:55:02,720
the bluer redder i'm sorry the blue or

1566
00:55:07,109 --> 00:55:04,559
whiter the star

1567
00:55:08,470 --> 00:55:07,119
it's a hotter star and the redder the

1568
00:55:11,990 --> 00:55:08,480
star it's much warmer

1569
00:55:15,190 --> 00:55:12,000
um as well it's a way that you can

1570
00:55:17,670 --> 00:55:15,200
cool the surface of the sun of of stars

1571
00:55:19,990 --> 00:55:17,680
this way the energy is carried away

1572
00:55:21,430 --> 00:55:20,000
now energy is being produced inside a

1573
00:55:24,150 --> 00:55:21,440
normal star like the sun so that that

1574
00:55:27,030 --> 00:55:24,160
energy is being replenished

1575
00:55:27,750 --> 00:55:27,040
in a planetary nebula the gas here is

1576
00:55:29,589 --> 00:55:27,760
being

1577
00:55:31,109 --> 00:55:29,599
heated up by the ultraviolet radiation

1578
00:55:32,549 --> 00:55:31,119
of a white dwarf that's at the center of

1579
00:55:35,270 --> 00:55:32,559
that planetary nebula

1580
00:55:37,349 --> 00:55:35,280
and over time that nebula has to cool

1581
00:55:38,710 --> 00:55:37,359
off and has a very hard time of cooling

1582
00:55:40,710 --> 00:55:38,720
off and so

1583
00:55:42,470 --> 00:55:40,720
eventually it does and emits light and

1584
00:55:43,270 --> 00:55:42,480
these particular molecules give off the

1585
00:55:46,309 --> 00:55:43,280
light

1586
00:55:50,230 --> 00:55:46,319
and in the orion nebula the same is true

1587
00:55:52,390 --> 00:55:50,240
there are very complex um uh

1588
00:55:53,430 --> 00:55:52,400

molecules here that are emitting in the

1589
00:55:55,270 --> 00:55:53,440
infrared

1590
00:55:57,349 --> 00:55:55,280
uh some of the stars that you see in

1591
00:55:59,349 --> 00:55:57,359
here this is the surface of the star

1592
00:56:01,030 --> 00:55:59,359
um which is cooler and you can see it in

1593
00:56:03,510 --> 00:56:01,040
the infrared and you can also see the

1594
00:56:05,589 --> 00:56:03,520
gas that's really hot and glowing in

1595
00:56:07,589 --> 00:56:05,599
this multi-wavelength image of the orion

1596
00:56:10,150 --> 00:56:07,599
nebula

1597
00:56:11,990 --> 00:56:10,160
so there are different ways for energy

1598
00:56:16,069 --> 00:56:12,000
to get transported

1599
00:56:18,309 --> 00:56:16,079
away from objects in space by radiation

1600
00:56:20,150 --> 00:56:18,319
by conduction or convection and there's

1601
00:56:23,990 --> 00:56:20,160
different kinds of energy as well

1602
00:56:27,510 --> 00:56:24,000
so let's see here

1603
00:56:29,750 --> 00:56:27,520
and so

1604
00:56:31,349 --> 00:56:29,760
the conclusion here of my talk the world

1605
00:56:31,829 --> 00:56:31,359
around you is beautiful the world that

1606
00:56:33,910 --> 00:56:31,839
you are

1607
00:56:36,069 --> 00:56:33,920
in every day is beautiful there are a

1608
00:56:38,789 --> 00:56:36,079
lot of things in your everyday life

1609
00:56:39,670 --> 00:56:38,799
that you understand and you can think

1610
00:56:41,510 --> 00:56:39,680
about

1611
00:56:42,950 --> 00:56:41,520
in different ways and so now you can

1612
00:56:45,270 --> 00:56:42,960
start thinking about the connections to

1613
00:56:48,150 --> 00:56:45,280

astronomy

1614
00:56:50,150 --> 00:56:48,160
the telescope is our virtual starship

1615
00:56:52,710 --> 00:56:50,160
the light comes to us

1616
00:56:53,349 --> 00:56:52,720
our telescopes can detect it we can take

1617
00:56:55,270 --> 00:56:53,359
images

1618
00:56:56,470 --> 00:56:55,280
we can take the light apart and

1619
00:56:59,910 --> 00:56:56,480
understand

1620
00:57:02,309 --> 00:56:59,920
the different types of

1621
00:57:03,349 --> 00:57:02,319
energy related to atoms and how we can

1622
00:57:05,109 --> 00:57:03,359
see specific

1623
00:57:06,789 --> 00:57:05,119
wavelengths of light and what energy

1624
00:57:08,230 --> 00:57:06,799
conditions and temperature conditions

1625
00:57:09,190 --> 00:57:08,240
and density conditions are needed for

1626
00:57:11,510 --> 00:57:09,200
that to happen

1627
00:57:13,109 --> 00:57:11,520
we can see things moving through space

1628
00:57:13,510 --> 00:57:13,119
how quickly it moves through space if

1629
00:57:15,430 --> 00:57:13,520
it's

1630
00:57:17,750 --> 00:57:15,440
hitting and shocking other material it

1631
00:57:20,390 --> 00:57:17,760
tells us so much about what's going on

1632
00:57:22,150 --> 00:57:20,400
and then once you figure that all out

1633
00:57:23,910 --> 00:57:22,160
using your arsenal of

1634
00:57:26,309 --> 00:57:23,920
information from your everyday

1635
00:57:28,309 --> 00:57:26,319
experiences you can sit down

1636
00:57:31,349 --> 00:57:28,319
with your friends and family and talk

1637
00:57:33,829 --> 00:57:31,359
about everything astronomy

1638
00:57:37,510 --> 00:57:33,839

for as long as you want so thank you so

1639
00:57:43,750 --> 00:57:41,109
thank you quinn i think that um

1640
00:57:44,870 --> 00:57:43,760
this sort of expresses kind of the the

1641
00:57:47,109 --> 00:57:44,880
the

1642
00:57:48,950 --> 00:57:47,119
fascination with astronomy that's that

1643
00:57:51,190 --> 00:57:48,960
i've i've sort of had all my life

1644
00:57:52,710 --> 00:57:51,200
is that you learn physics and you learn

1645
00:57:54,390 --> 00:57:52,720
about all these these cool things

1646
00:57:55,750 --> 00:57:54,400
but the reason to go into astrophysics

1647
00:57:56,950 --> 00:57:55,760
is because then you get to apply all

1648
00:58:00,230 --> 00:57:56,960
these physical principles

1649
00:58:02,950 --> 00:58:00,240
to that cool stuff out there you know um

1650
00:58:05,670 --> 00:58:02,960
and to me it's like it's problem solving

1651
00:58:07,670 --> 00:58:05,680
on the grandest scale right

1652
00:58:09,750 --> 00:58:07,680
you get all these ideas and then you can

1653
00:58:12,710 --> 00:58:09,760
say all right well that thing is

1654
00:58:13,349 --> 00:58:12,720
20 million light years away but using

1655
00:58:15,190 --> 00:58:13,359
what i know

1656
00:58:16,470 --> 00:58:15,200
here i can figure out what's going on

1657
00:58:17,750 --> 00:58:16,480
out there

1658
00:58:20,630 --> 00:58:17,760
i've always thought that just really

1659
00:58:24,150 --> 00:58:20,640
cool it is and i think in some ways

1660
00:58:27,349 --> 00:58:24,160
it sometimes our job is a little bit

1661
00:58:29,670 --> 00:58:27,359
more simple in in some ways because

1662
00:58:30,950 --> 00:58:29,680
um we have to use the tools that of the

1663
00:58:32,950 --> 00:58:30,960

things that we know here

1664
00:58:34,309 --> 00:58:32,960
to be able to interpret what's going on

1665
00:58:36,789 --> 00:58:34,319
out there because we can never go there

1666
00:58:40,150 --> 00:58:36,799
and get that sample there's very limited

1667
00:58:42,230 --> 00:58:40,160
limited examples of um return

1668
00:58:43,750 --> 00:58:42,240
samples in astronomy more in planetary

1669
00:58:46,789 --> 00:58:43,760
science of course but um

1670
00:58:49,190 --> 00:58:46,799
so that puzzle piece is absolutely uh

1671
00:58:51,030 --> 00:58:49,200
very true for many astronomers and and

1672
00:58:54,069 --> 00:58:51,040
that our tools

1673
00:58:57,910 --> 00:58:54,079
are physics forces

1674
00:58:59,750 --> 00:58:57,920
and energy yes an interaction of light

1675
00:59:01,190 --> 00:58:59,760
with particles

1676
00:59:03,270 --> 00:59:01,200
and you know i sort of i sort of think

1677
00:59:05,190 --> 00:59:03,280
of it is it's a

1678
00:59:07,270 --> 00:59:05,200
detective novel type thing where you

1679
00:59:08,549 --> 00:59:07,280
just get this you get the clues

1680
00:59:10,950 --> 00:59:08,559
from the light that you receive from

1681
00:59:13,670 --> 00:59:10,960
these other these uh distant objects

1682
00:59:15,270 --> 00:59:13,680
and then you get to try and puzzle out

1683
00:59:17,829 --> 00:59:15,280
what's going on

1684
00:59:18,870 --> 00:59:17,839
yeah one of my most um i like to tell

1685
00:59:20,789 --> 00:59:18,880
people when i'm at the

1686
00:59:23,270 --> 00:59:20,799
this is improved handling these um

1687
00:59:24,549 --> 00:59:23,280
having people at the telescope and just

1688
00:59:26,390 --> 00:59:24,559

you know when they see pictures and they

1689
00:59:28,309 --> 00:59:26,400
say that that can't be real

1690
00:59:29,910 --> 00:59:28,319
that can't be saturn that can't be

1691
00:59:31,589 --> 00:59:29,920
jupiter that's a picture you put at the

1692
00:59:33,829 --> 00:59:31,599
end like no it's really

1693
00:59:34,789 --> 00:59:33,839
it's really what you're seeing or those

1694
00:59:37,030 --> 00:59:34,799
stars and

1695
00:59:38,309 --> 00:59:37,040
so the piece of wonder that i always

1696
00:59:41,109 --> 00:59:38,319
like people to walk away with

1697
00:59:41,670 --> 00:59:41,119
is when you're looking out in space that

1698
00:59:44,789 --> 00:59:41,680
light

1699
00:59:46,150 --> 00:59:44,799
came from something in space okay

1700
00:59:47,829 --> 00:59:46,160
whether it's reflected or actually

1701
00:59:50,069 --> 00:59:47,839
emitted and that light

1702
00:59:51,510 --> 00:59:50,079
went through the earth's atmosphere went

1703
00:59:53,030 --> 00:59:51,520
through the telescope

1704
00:59:55,109 --> 00:59:53,040
got focused by the telescope but then it

1705
00:59:56,630 --> 00:59:55,119
went into your eye and then it has to

1706
00:59:57,270 --> 00:59:56,640
interact with your eye to actually see

1707
00:59:59,349 --> 00:59:57,280
it

1708
01:00:01,190 --> 00:59:59,359
and so that's one way of you interacting

1709
01:00:04,309 --> 01:00:01,200
with the universe because

1710
01:00:07,430 --> 01:00:04,319
um uh that that's that that's

1711
01:00:08,789 --> 01:00:07,440
uh uh light that you're receiving

1712
01:00:10,230 --> 01:00:08,799
now if it's infrared light there's

1713
01:00:11,190 --> 01:00:10,240

another way you can think about it uh

1714
01:00:12,870 --> 01:00:11,200
you know if there that

1715
01:00:14,870 --> 01:00:12,880
you can think about infrared light could

1716
01:00:16,870 --> 01:00:14,880
warm things up so there could be also

1717
01:00:18,549 --> 01:00:16,880
an example where we have an infrared

1718
01:00:19,430 --> 01:00:18,559
telescope or even sub-millimeter

1719
01:00:21,589 --> 01:00:19,440
telescope where th

1720
01:00:22,549 --> 01:00:21,599
that the heat is actually what is being

1721
01:00:23,829 --> 01:00:22,559
detected so

1722
01:00:26,069 --> 01:00:23,839
it's another way that you can think

1723
01:00:28,630 --> 01:00:26,079
about interacting with the universe

1724
01:00:29,349 --> 01:00:28,640
okay well we've had a uh a good

1725
01:00:32,309 --> 01:00:29,359
discussion

1726
01:00:33,270 --> 01:00:32,319
on the uh youtube chat and grant is

1727
01:00:35,190 --> 01:00:33,280
going to come join us

1728
01:00:37,270 --> 01:00:35,200
and uh pick he i'm sure he's found

1729
01:00:39,430 --> 01:00:37,280
several questions from there

1730
01:00:40,630 --> 01:00:39,440
and if he hasn't i i noted a couple to

1731
01:00:43,270 --> 01:00:40,640
myself

1732
01:00:44,950 --> 01:00:43,280
yeah i grabbed a few um first off before

1733
01:00:45,510 --> 01:00:44,960
we begin the question and answer section

1734
01:00:47,270 --> 01:00:45,520
frank

1735
01:00:50,549 --> 01:00:47,280
um we need you to turn yourself up a

1736
01:00:55,109 --> 01:00:50,559
little bit or move the mic mike michaels

1737
01:00:57,349 --> 01:00:55,119
yes it's it sounds really good in my

1738
01:00:59,430 --> 01:00:57,359

my and my feedback i believe you but on

1739
01:01:02,230 --> 01:00:59,440
youtube it's a little different

1740
01:01:03,990 --> 01:01:02,240
all right um so first off i want to

1741
01:01:06,950 --> 01:01:04,000
throw this in there because you both

1742
01:01:09,510 --> 01:01:06,960
already knew this was coming where do

1743
01:01:10,630 --> 01:01:09,520
gravitational waves fit into your energy

1744
01:01:14,150 --> 01:01:10,640
theory

1745
01:01:14,160 --> 01:01:19,430
let me think about that one for a second

1746
01:01:23,190 --> 01:01:21,349
i have to say that i'm not an expert on

1747
01:01:24,710 --> 01:01:23,200
gravitational waves

1748
01:01:26,309 --> 01:01:24,720
and i might have to come back to that

1749
01:01:28,309 --> 01:01:26,319
question okay

1750
01:01:29,349 --> 01:01:28,319
yeah that's fair i'll i'll i'll bat it

1751
01:01:32,309 --> 01:01:29,359
over to frank's

1752
01:01:33,750 --> 01:01:32,319
uh uh arena all right so i think of

1753
01:01:36,870 --> 01:01:33,760
gravitational waves as

1754
01:01:37,990 --> 01:01:36,880
as motion of space time itself right so

1755
01:01:39,990 --> 01:01:38,000
i would think it was more of a

1756
01:01:42,390 --> 01:01:40,000
conduction of of the ripples

1757
01:01:44,309 --> 01:01:42,400
passing through space-time right because

1758
01:01:45,510 --> 01:01:44,319
when we detect a gravitational wave what

1759
01:01:48,309 --> 01:01:45,520
we're actually detecting

1760
01:01:50,150 --> 01:01:48,319
is a stretching of space right we've got

1761
01:01:50,789 --> 01:01:50,160
these two laser interferometers that are

1762
01:01:52,549 --> 01:01:50,799
looking off

1763
01:01:54,549 --> 01:01:52,559

in parallel directions and they're

1764
01:01:55,510 --> 01:01:54,559
measuring the distance here versus the

1765
01:01:57,990 --> 01:01:55,520
distance here

1766
01:01:59,270 --> 01:01:58,000
and we're actually seeing a tiny tiny

1767
01:02:02,630 --> 01:01:59,280
tiny tiny

1768
01:02:04,870 --> 01:02:02,640
tiny stretch of uh space-time

1769
01:02:06,309 --> 01:02:04,880
so to me that sort of makes it into

1770
01:02:08,950 --> 01:02:06,319
conduction

1771
01:02:09,510 --> 01:02:08,960
but of space time itself which is really

1772
01:02:13,349 --> 01:02:09,520
kind of

1773
01:02:16,710 --> 01:02:13,359
crazy why um what i'll throw in there

1774
01:02:19,029 --> 01:02:16,720
is thinking about um

1775
01:02:19,990 --> 01:02:19,039
distance and speed right so that

1776
01:02:22,069 --> 01:02:20,000
stretching of

1777
01:02:24,069 --> 01:02:22,079
space means that the length that has to

1778
01:02:27,910 --> 01:02:24,079
be traveled is slightly different

1779
01:02:31,589 --> 01:02:27,920
and so these mirrors on on ligo are

1780
01:02:35,270 --> 01:02:31,599
quite sensitive that it could really

1781
01:02:37,589 --> 01:02:35,280
measure the time delay or

1782
01:02:39,190 --> 01:02:37,599
it actually is these waves meeting up

1783
01:02:40,390 --> 01:02:39,200
and if they meet up right at the same

1784
01:02:42,710 --> 01:02:40,400
time

1785
01:02:45,270 --> 01:02:42,720
you don't get these shadows but if they

1786
01:02:47,029 --> 01:02:45,280
meet up just slightly off because the

1787
01:02:49,510 --> 01:02:47,039
space has been distorted you're going to

1788
01:02:50,870 --> 01:02:49,520

see what are called interference fringes

1789
01:02:53,270 --> 01:02:50,880
it's it's a way that the light waves

1790
01:02:54,549 --> 01:02:53,280
don't match up and so in some ways you

1791
01:02:57,029 --> 01:02:54,559
can think about it as a you know

1792
01:03:00,309 --> 01:02:57,039
distance and time

1793
01:03:03,510 --> 01:03:00,319
measurement with those um those arms

1794
01:03:07,190 --> 01:03:03,520
that frank was just talking about

1795
01:03:09,430 --> 01:03:07,200
what do we get next so next one

1796
01:03:11,430 --> 01:03:09,440
um is the point of rotation for the

1797
01:03:14,309 --> 01:03:11,440
milky way equivalent to its

1798
01:03:16,150 --> 01:03:14,319
center of mass if it's not would you

1799
01:03:20,630 --> 01:03:16,160
expand a little more on

1800
01:03:25,349 --> 01:03:20,640
how we actually move within our galaxy

1801
01:03:28,710 --> 01:03:25,359
okay so one thing that um

1802
01:03:30,870 --> 01:03:28,720
i didn't go into is is how the stars in

1803
01:03:33,029 --> 01:03:30,880
the milky way actually move around

1804
01:03:35,029 --> 01:03:33,039
the center of the milky way a lot of

1805
01:03:35,510 --> 01:03:35,039
mass exists at the center of the milky

1806
01:03:37,829 --> 01:03:35,520
way

1807
01:03:38,789 --> 01:03:37,839
in the supermassive black hole that's at

1808
01:03:40,870 --> 01:03:38,799
the center

1809
01:03:42,549 --> 01:03:40,880
which is about four million times the

1810
01:03:43,829 --> 01:03:42,559
mass of the sun

1811
01:03:45,990 --> 01:03:43,839
but it's not the bulk of the mass

1812
01:03:49,190 --> 01:03:46,000
there's over 100 billion stars

1813
01:03:51,670 --> 01:03:49,200

um plus dust and gas in the milky way

1814
01:03:52,230 --> 01:03:51,680
so for the most part objects do orbit

1815
01:03:55,190 --> 01:03:52,240
around

1816
01:03:56,309 --> 01:03:55,200
this the center of the galaxy but not

1817
01:03:57,829 --> 01:03:56,319
like a solid

1818
01:03:59,510 --> 01:03:57,839
merry-go-round that you were seeing in

1819
01:04:00,710 --> 01:03:59,520
the images before so in a merry ground

1820
01:04:02,470 --> 01:04:00,720
if you're on the inside of the merry

1821
01:04:03,910 --> 01:04:02,480
ground you still go around

1822
01:04:05,029 --> 01:04:03,920
the center in the same amount of time if

1823
01:04:05,670 --> 01:04:05,039
you're on the outside of the merry

1824
01:04:08,789 --> 01:04:05,680
ground

1825
01:04:09,829 --> 01:04:08,799
and that's not true for the milky way we

1826
01:04:12,309 --> 01:04:09,839
call that

1827
01:04:13,670 --> 01:04:12,319
the the carrier cell a solid body

1828
01:04:16,230 --> 01:04:13,680
rotation

1829
01:04:16,710 --> 01:04:16,240
around the center of the carousel and

1830
01:04:18,870 --> 01:04:16,720
then the

1831
01:04:20,630 --> 01:04:18,880
in the milky way that's not true and

1832
01:04:22,549 --> 01:04:20,640
this is actually how dark matter was

1833
01:04:25,670 --> 01:04:22,559
discovered was that

1834
01:04:27,829 --> 01:04:25,680
it turns out that there's as much mass

1835
01:04:29,430 --> 01:04:27,839
inside the orbit of the sun from all the

1836
01:04:31,829 --> 01:04:29,440
stars combined as there is

1837
01:04:32,870 --> 01:04:31,839
outside and because of that the motion

1838
01:04:34,789 --> 01:04:32,880

of stars

1839
01:04:36,069 --> 01:04:34,799
in circular orbits if we make that rough

1840
01:04:39,349 --> 01:04:36,079
approximation

1841
01:04:41,349 --> 01:04:39,359
would not be the same as

1842
01:04:42,710 --> 01:04:41,359
the type of physics that dictates how

1843
01:04:45,029 --> 01:04:42,720
planets go around the sun

1844
01:04:46,390 --> 01:04:45,039
so there's a law called kepler's laws

1845
01:04:49,990 --> 01:04:46,400
for planetary motion

1846
01:04:53,349 --> 01:04:50,000
that can very well very accurately

1847
01:04:55,190 --> 01:04:53,359
um tell you the orbit of a planet going

1848
01:04:57,109 --> 01:04:55,200
around the sun where the sun has the

1849
01:04:57,990 --> 01:04:57,119
majority of mass in the in the solar

1850
01:05:00,710 --> 01:04:58,000
system

1851
01:05:02,390 --> 01:05:00,720
um and kepler lived in the 1700s and was

1852
01:05:06,230 --> 01:05:02,400
able to figure this out this is how

1853
01:05:08,630 --> 01:05:06,240
astronomers today look at how planets

1854
01:05:09,829 --> 01:05:08,640
go around other stars and looking at

1855
01:05:11,430 --> 01:05:09,839
those extra pilots

1856
01:05:13,109 --> 01:05:11,440
but the physics there that's different

1857
01:05:14,230 --> 01:05:13,119
that's the concentration of mass at the

1858
01:05:16,390 --> 01:05:14,240
center in those star

1859
01:05:18,069 --> 01:05:16,400
systems with planets whereas the stars

1860
01:05:19,109 --> 01:05:18,079
in a milky way are not concentrated in

1861
01:05:21,829 --> 01:05:19,119
that way

1862
01:05:23,430 --> 01:05:21,839
and so um so we can talk about the earth

1863
01:05:25,670 --> 01:05:23,440

the sun's rotation

1864
01:05:27,750 --> 01:05:25,680
at its particular point in its

1865
01:05:29,670 --> 01:05:27,760
particular location or

1866
01:05:31,349 --> 01:05:29,680
around the milky way and we can also do

1867
01:05:32,950 --> 01:05:31,359
that for other stars and knowing the

1868
01:05:35,109 --> 01:05:32,960
motions of the stars

1869
01:05:36,789 --> 01:05:35,119
um everywhere in the galaxy lets us

1870
01:05:40,309 --> 01:05:36,799
understand how

1871
01:05:42,230 --> 01:05:40,319
the galaxy was um put together

1872
01:05:44,309 --> 01:05:42,240
uh so you can see if there was there

1873
01:05:46,309 --> 01:05:44,319
interactions in the past so looking at

1874
01:05:47,510 --> 01:05:46,319
the positions of stars you might see oh

1875
01:05:49,910 --> 01:05:47,520
there's a a

1876
01:05:50,710 --> 01:05:49,920
title tale of stars that looks really

1877
01:05:52,470 --> 01:05:50,720
weird

1878
01:05:54,630 --> 01:05:52,480
could that have been a gravitational

1879
01:05:55,270 --> 01:05:54,640
interaction with a satellite galaxy

1880
01:05:58,549 --> 01:05:55,280
that's

1881
01:06:00,789 --> 01:05:58,559
off over here and so just those motions

1882
01:06:01,349 --> 01:06:00,799
alone tells us a lot but we always start

1883
01:06:02,950 --> 01:06:01,359
in one

1884
01:06:04,710 --> 01:06:02,960
assumption until the assumptions break

1885
01:06:07,750 --> 01:06:04,720
down and then we start to bring in

1886
01:06:08,150 --> 01:06:07,760
more complicated motions to explain it

1887
01:06:10,150 --> 01:06:08,160
with

1888
01:06:15,109 --> 01:06:10,160

gravitational forces being the main

1889
01:06:18,549 --> 01:06:17,510
all right great that's all right um

1890
01:06:20,710 --> 01:06:18,559
frank if you've got one

1891
01:06:21,670 --> 01:06:20,720
i'm reading through a couple more okay

1892
01:06:23,829 --> 01:06:21,680
um i

1893
01:06:25,750 --> 01:06:23,839
noted one that came up immediately and

1894
01:06:29,109 --> 01:06:25,760
you were talking about parallax

1895
01:06:31,349 --> 01:06:29,119
they wanted to know uh the sun is also

1896
01:06:35,190 --> 01:06:31,359
moving so doesn't that change the

1897
01:06:38,789 --> 01:06:36,789
over the course of six months let me

1898
01:06:45,670 --> 01:06:38,799
think about that um does it change the

1899
01:06:49,109 --> 01:06:48,309
if it does it's quite minor in

1900
01:06:51,829 --> 01:06:49,119
comparison

1901
01:06:52,950 --> 01:06:51,839
to the emotion that you see to the earth

1902
01:06:55,750 --> 01:06:52,960
going around the sun

1903
01:06:57,910 --> 01:06:55,760
over the course of six months here right

1904
01:06:59,510 --> 01:06:57,920
the positions of some of the

1905
01:07:01,510 --> 01:06:59,520
go ahead oh i was just gonna say a

1906
01:07:02,710 --> 01:07:01,520
related question when you showed that

1907
01:07:04,950 --> 01:07:02,720
gaia movie

1908
01:07:05,829 --> 01:07:04,960
and there were the constellations

1909
01:07:08,069 --> 01:07:05,839
changing

1910
01:07:09,829 --> 01:07:08,079
what was the time scale is that 10 000

1911
01:07:10,710 --> 01:07:09,839
years that a hundred thousand a million

1912
01:07:13,270 --> 01:07:10,720
years

1913
01:07:14,309 --> 01:07:13,280

i do not know but i will drop the i

1914
01:07:16,630 --> 01:07:14,319
don't know i guess i can

1915
01:07:18,390 --> 01:07:16,640
pass the link to grant and uh to to

1916
01:07:20,069 --> 01:07:18,400
connect people to the information

1917
01:07:21,589 --> 01:07:20,079
i'm sorry i can throw it up in the chat

1918
01:07:23,589 --> 01:07:21,599
okay thanks yeah well

1919
01:07:24,950 --> 01:07:23,599
i know it can't be like a thousand years

1920
01:07:26,470 --> 01:07:24,960
right because you know

1921
01:07:27,589 --> 01:07:26,480
we've we've tracked the constellations

1922
01:07:28,710 --> 01:07:27,599
for a thousand years and they move a

1923
01:07:31,829 --> 01:07:28,720
little bit but they don't move

1924
01:07:33,190 --> 01:07:31,839
that much um so i was guessing it had to

1925
01:07:34,789 --> 01:07:33,200
be at least a hundred thousand years

1926
01:07:36,390 --> 01:07:34,799
maybe a million years

1927
01:07:39,990 --> 01:07:36,400
for the constellations to move as much

1928
01:07:46,630 --> 01:07:43,029
gotcha i actually have a really good one

1929
01:07:48,950 --> 01:07:46,640
i like this i like this a lot so

1930
01:07:49,910 --> 01:07:48,960
what are some of the best introductory

1931
01:07:52,789 --> 01:07:49,920
materials

1932
01:07:54,069 --> 01:07:52,799
or like books or research on the topic

1933
01:07:54,710 --> 01:07:54,079
that you would recommend to somebody

1934
01:07:58,470 --> 01:07:54,720
who's

1935
01:07:59,589 --> 01:07:58,480
just starting off these are my personal

1936
01:08:02,230 --> 01:07:59,599
recommendations

1937
01:08:04,950 --> 01:08:02,240
yes no no endorsement from from space

1938
01:08:08,309 --> 01:08:04,960

telescope at all

1939
01:08:12,069 --> 01:08:08,319
yes i i really enjoy

1940
01:08:15,190 --> 01:08:12,079
um the crash course

1941
01:08:16,550 --> 01:08:15,200
astronomy by um by phil

1942
01:08:18,470 --> 01:08:16,560
plate i think that's how you say his

1943
01:08:21,030 --> 01:08:18,480
last name um they're

1944
01:08:21,590 --> 01:08:21,040
really they're nice and short they do a

1945
01:08:24,789 --> 01:08:21,600
lot of

1946
01:08:26,709 --> 01:08:24,799
um really

1947
01:08:28,070 --> 01:08:26,719
uh great analogies to help you

1948
01:08:31,110 --> 01:08:28,080
understand astronomy

1949
01:08:34,709 --> 01:08:33,110
the let's see what else let me think

1950
01:08:38,070 --> 01:08:34,719
some more

1951
01:08:40,630 --> 01:08:38,080
frank do you have some uh suggestions

1952
01:08:42,149 --> 01:08:40,640
no i don't have um uh off the top of my

1953
01:08:44,550 --> 01:08:42,159
head suggestions i've uh there are

1954
01:08:45,910 --> 01:08:44,560
tremendous number of materials that i

1955
01:08:47,749 --> 01:08:45,920
might have on my bookshelf or other

1956
01:08:49,189 --> 01:08:47,759
places but i don't uh

1957
01:08:51,030 --> 01:08:49,199
i haven't i haven't kept that sort of

1958
01:08:53,349 --> 01:08:51,040
thing off top of my head um

1959
01:08:54,950 --> 01:08:53,359
i've got one that i can remember it's an

1960
01:08:58,229 --> 01:08:54,960
author not a book but um

1961
01:09:01,510 --> 01:08:58,239
micho kaku is very good at

1962
01:09:03,669 --> 01:09:01,520
explaining very dense physics theory in

1963
01:09:05,510 --> 01:09:03,679

a way that makes sense

1964
01:09:06,789 --> 01:09:05,520
because i am not an astronomer as you

1965
01:09:09,110 --> 01:09:06,799
guys are so

1966
01:09:10,630 --> 01:09:09,120
if i can get it it's a decent resource

1967
01:09:13,510 --> 01:09:10,640
for the

1968
01:09:14,309 --> 01:09:13,520
the chat well one of the things i will

1969
01:09:16,709 --> 01:09:14,319
supply

1970
01:09:17,510 --> 01:09:16,719
well this is also um disclaimer i work

1971
01:09:20,070 --> 01:09:17,520
on a lot of

1972
01:09:20,950 --> 01:09:20,080
nasa's universal learning materials and

1973
01:09:23,749 --> 01:09:20,960
so we do

1974
01:09:25,110 --> 01:09:23,759
create a whole bunch of products for

1975
01:09:29,430 --> 01:09:25,120
view space

1976
01:09:31,189 --> 01:09:29,440
which people might not be familiar with

1977
01:09:33,189 --> 01:09:31,199
a lot of museums use it so sometimes

1978
01:09:35,030 --> 01:09:33,199
when you are at a planetarium you might

1979
01:09:37,910 --> 01:09:35,040
see videos outside while you're

1980
01:09:40,390 --> 01:09:37,920
waiting most likely that's new space but

1981
01:09:44,070 --> 01:09:40,400
we also create these great interactives

1982
01:09:45,990 --> 01:09:44,080
where where you can look at the universe

1983
01:09:47,749 --> 01:09:46,000
in different wavelengths for example

1984
01:09:49,269 --> 01:09:47,759
like the eagle nebula and you could

1985
01:09:52,470 --> 01:09:49,279
slide the bar around to

1986
01:09:53,590 --> 01:09:52,480
see the universe in um in x-rays and

1987
01:09:56,229 --> 01:09:53,600
radio

1988
01:09:57,669 --> 01:09:56,239

and there's a description of um of the

1989
01:09:59,910 --> 01:09:57,679
science below that as well

1990
01:10:01,669 --> 01:09:59,920
as additional resources so for someone

1991
01:10:01,990 --> 01:10:01,679
who's just starting and trying to get a

1992
01:10:05,510 --> 01:10:02,000
little

1993
01:10:07,350 --> 01:10:05,520
idea that is it's really um you know a

1994
01:10:07,669 --> 01:10:07,360
novice i guess that that's one way to

1995
01:10:09,510 --> 01:10:07,679
say

1996
01:10:11,110 --> 01:10:09,520
that's a great place to start and we

1997
01:10:15,270 --> 01:10:11,120
have a lot of material

1998
01:10:17,270 --> 01:10:15,280
from exoplanets star-forming regions

1999
01:10:18,709 --> 01:10:17,280
star formation different kinds of star

2000
01:10:20,390 --> 01:10:18,719
stellar death there

2001
01:10:21,830 --> 01:10:20,400
so that's also a really great place to

2002
01:10:23,990 --> 01:10:21,840
start and i

2003
01:10:26,550 --> 01:10:24,000
i personally love to read articles

2004
01:10:29,750 --> 01:10:26,560
written for the general republic

2005
01:10:30,950 --> 01:10:29,760
so scaring the different new york times

2006
01:10:34,390 --> 01:10:30,960
has great articles that are

2007
01:10:35,669 --> 01:10:34,400
in um forbes has one by ethan siegel

2008
01:10:39,110 --> 01:10:35,679
which i really enjoy

2009
01:10:40,470 --> 01:10:39,120
um and it's important not to forget

2010
01:10:43,910 --> 01:10:40,480
about our websites too

2011
01:10:46,149 --> 01:10:43,920
like hubble site james webb and stsci

2012
01:10:48,229 --> 01:10:46,159
like all of at least information about

2013
01:10:49,990 --> 01:10:48,239

the telescopes and their function

2014
01:10:51,270 --> 01:10:50,000
there's a lot on there and it is

2015
01:10:53,270 --> 01:10:51,280
presented in a way

2016
01:10:54,870 --> 01:10:53,280
that you can understand if you are not a

2017
01:10:58,550 --> 01:10:54,880
fellow astronomer

2018
01:11:00,149 --> 01:10:58,560
definitely okay so we had an interesting

2019
01:11:01,990 --> 01:11:00,159
question that was uh directly relevant

2020
01:11:04,390 --> 01:11:02,000
to your talk

2021
01:11:05,030 --> 01:11:04,400
you mentioned absolute zero as a limit

2022
01:11:07,750 --> 01:11:05,040
on how

2023
01:11:08,149 --> 01:11:07,760
cold things could be is there a limit on

2024
01:11:11,669 --> 01:11:08,159
how

2025
01:11:13,110 --> 01:11:11,679
hot things can be oh is there a limit

2026
01:11:16,790 --> 01:11:13,120
that can i guess

2027
01:11:16,800 --> 01:11:21,590
i never taught that in my class

2028
01:11:27,510 --> 01:11:25,189
from a star standpoint

2029
01:11:28,790 --> 01:11:27,520
there there is a limit to how mass of a

2030
01:11:31,430 --> 01:11:28,800
star can be

2031
01:11:32,790 --> 01:11:31,440
because it would generate so much energy

2032
01:11:33,189 --> 01:11:32,800
it would just blow itself apart so

2033
01:11:36,630 --> 01:11:33,199
there's

2034
01:11:39,189 --> 01:11:36,640
about stars

2035
01:11:40,709 --> 01:11:39,199
being stable and not blowing not

2036
01:11:42,229 --> 01:11:40,719
creating so much radiation because

2037
01:11:44,709 --> 01:11:42,239
there's a point where if there's so

2038
01:11:46,229 --> 01:11:44,719

much light being produced it actually

2039
01:11:49,350 --> 01:11:46,239
can create a force

2040
01:11:51,990 --> 01:11:49,360
like a pressure and push the star

2041
01:11:54,470 --> 01:11:52,000
outwards and actually destroy it so so i

2042
01:11:56,310 --> 01:11:54,480
will say that

2043
01:11:58,070 --> 01:11:56,320
there's there's definitely a limit

2044
01:12:00,149 --> 01:11:58,080
related to how much radiation can be

2045
01:12:02,550 --> 01:12:00,159
produced in really massive stars which

2046
01:12:04,149 --> 01:12:02,560
is connected to how hot the interior is

2047
01:12:06,070 --> 01:12:04,159
that number i do not know off the top of

2048
01:12:08,550 --> 01:12:06,080
my head

2049
01:12:10,390 --> 01:12:08,560
now if we talk about the early early

2050
01:12:10,790 --> 01:12:10,400
early universe right after big the big

2051
01:12:13,510 --> 01:12:10,800
bang

2052
01:12:14,709 --> 01:12:13,520
we i i believe there are temperatures

2053
01:12:19,510 --> 01:12:14,719
associated

2054
01:12:22,790 --> 01:12:19,520
with with the very early universe

2055
01:12:24,790 --> 01:12:22,800
as particles are created now remember

2056
01:12:28,470 --> 01:12:24,800
equals mc squared right so

2057
01:12:30,070 --> 01:12:28,480
mass has energy so in the early universe

2058
01:12:33,350 --> 01:12:30,080
it was all energy

2059
01:12:34,630 --> 01:12:33,360
but as the universe cooled off so that's

2060
01:12:35,750 --> 01:12:34,640
another way you can think of an infinite

2061
01:12:37,590 --> 01:12:35,760
temperature but the universe is

2062
01:12:40,709 --> 01:12:37,600
expanding in all directions

2063
01:12:43,750 --> 01:12:40,719

or expanding and cooling off over time

2064
01:12:45,510 --> 01:12:43,760
and as it cools off then that energy can

2065
01:12:48,229 --> 01:12:45,520
be converted into mass

2066
01:12:48,870 --> 01:12:48,239
of these particles and as the universe

2067
01:12:50,790 --> 01:12:48,880
cooled off

2068
01:12:53,669 --> 01:12:50,800
it can cool off in a certain amount of

2069
01:12:54,630 --> 01:12:53,679
time and it creates particles in certain

2070
01:12:56,950 --> 01:12:54,640
abundances

2071
01:12:58,709 --> 01:12:56,960
so there's a reason why the hydrogen and

2072
01:13:00,790 --> 01:12:58,719
helium abundance in the universe

2073
01:13:03,189 --> 01:13:00,800
is the way it is because the universe

2074
01:13:04,950 --> 01:13:03,199
cooled off in a very specific way

2075
01:13:07,750 --> 01:13:04,960
so going back to the original question

2076
01:13:09,990 --> 01:13:07,760
of is there a temperature limit

2077
01:13:12,390 --> 01:13:10,000
the high end then if we go back to the

2078
01:13:14,740 --> 01:13:12,400
early early early times in the universe

2079
01:13:16,709 --> 01:13:14,750
then it's very very high

2080
01:13:17,910 --> 01:13:16,719
[Laughter]

2081
01:13:20,149 --> 01:13:17,920
yeah i don't know what the temperature

2082
01:13:22,149 --> 01:13:20,159
was at planck time um

2083
01:13:24,149 --> 01:13:22,159
but you know i mean in astronomy we

2084
01:13:26,390 --> 01:13:24,159
study temperatures of

2085
01:13:27,510 --> 01:13:26,400
you know thousands of degrees for stars

2086
01:13:29,189 --> 01:13:27,520
and you know um

2087
01:13:31,910 --> 01:13:29,199
hundred thousand and millions of degrees

2088
01:13:33,669 --> 01:13:31,920

for x-ray and the cores of stars are

2089
01:13:35,669 --> 01:13:33,679
millions of degrees or the cores of red

2090
01:13:37,350 --> 01:13:35,679
giant stars and

2091
01:13:39,590 --> 01:13:37,360
stuff that are not hundreds of millions

2092
01:13:40,950 --> 01:13:39,600
of degrees etc

2093
01:13:42,950 --> 01:13:40,960
you have to go to particle physics

2094
01:13:44,630 --> 01:13:42,960
really to get the the super high

2095
01:13:45,990 --> 01:13:44,640
temperatures and i'm not an expert in

2096
01:13:49,189 --> 01:13:46,000
particle physics so

2097
01:13:50,630 --> 01:13:49,199
i'm not going to go there but no that's

2098
01:13:52,550 --> 01:13:50,640
one of the difficult things about these

2099
01:13:56,390 --> 01:13:52,560
talks is we have such

2100
01:13:57,270 --> 01:13:56,400
incredibly specific areas of expertise

2101
01:13:59,030 --> 01:13:57,280
each talk

2102
01:14:00,630 --> 01:13:59,040
yeah it's nice to have general

2103
01:14:02,310 --> 01:14:00,640
information like this for everybody to

2104
01:14:03,350 --> 01:14:02,320
get the basis to understand some of the

2105
01:14:05,990 --> 01:14:03,360
more

2106
01:14:07,590 --> 01:14:06,000
higher level yeah i have to start making

2107
01:14:09,669 --> 01:14:07,600
my list of uh

2108
01:14:11,030 --> 01:14:09,679
of questions with the answers after this

2109
01:14:14,950 --> 01:14:11,040
talk and have it be like let me look at

2110
01:14:18,310 --> 01:14:14,960
my sheet everyone

2111
01:14:20,310 --> 01:14:18,320
all right so um

2112
01:14:23,470 --> 01:14:20,320
we're looking pretty good oh this is a

2113
01:14:26,149 --> 01:14:23,480

term that i've never heard before

2114
01:14:28,350 --> 01:14:26,159
paleoastronomy ooh paleo

2115
01:14:29,990 --> 01:14:28,360
um are they it might be is it similar to

2116
01:14:31,189 --> 01:14:30,000
archaeoastronomy

2117
01:14:32,470 --> 01:14:31,199
that's a great question i've just never

2118
01:14:33,189 --> 01:14:32,480
seen the term before well that's a

2119
01:14:36,149 --> 01:14:33,199
different one

2120
01:14:39,030 --> 01:14:36,159
so so i'm gonna take a stab at this so

2121
01:14:42,310 --> 01:14:39,040
when we think of paleontology and

2122
01:14:44,470 --> 01:14:42,320
studying things on earth and looking at

2123
01:14:45,590 --> 01:14:44,480
things in the past to reconstruct the

2124
01:14:48,630 --> 01:14:45,600
history of the

2125
01:14:49,750 --> 01:14:48,640
the earth at different eras okay we're

2126
01:14:52,229 --> 01:14:49,760
trying to use that

2127
01:14:53,910 --> 01:14:52,239
information to to say how it got built

2128
01:14:56,310 --> 01:14:53,920
up to what we see today

2129
01:14:57,350 --> 01:14:56,320
so if you think about that in astronomy

2130
01:14:59,830 --> 01:14:57,360
what we see

2131
01:15:01,270 --> 01:14:59,840
is the leftovers of any event that might

2132
01:15:04,070 --> 01:15:01,280
have happened in the past so

2133
01:15:05,430 --> 01:15:04,080
hydrogen and helium is a signature of

2134
01:15:07,350 --> 01:15:05,440
the big bang

2135
01:15:09,270 --> 01:15:07,360
and the universe cooling so we can use

2136
01:15:12,149 --> 01:15:09,280
that to figure out what happened

2137
01:15:13,030 --> 01:15:12,159
in the past to and leading up to today

2138
01:15:15,590 --> 01:15:13,040

because we know

2139
01:15:16,390 --> 01:15:15,600
most of the elements that are more

2140
01:15:19,189 --> 01:15:16,400
massive than

2141
01:15:20,229 --> 01:15:19,199
helium were all created in the inside of

2142
01:15:21,510 --> 01:15:20,239
stars okay

2143
01:15:23,350 --> 01:15:21,520
because of the way we we know the

2144
01:15:25,030 --> 01:15:23,360
abundances so that's just taking going

2145
01:15:26,950 --> 01:15:25,040
back to the detective language that

2146
01:15:28,790 --> 01:15:26,960
frank was talking about we have the this

2147
01:15:30,310 --> 01:15:28,800
the information and we have to try to

2148
01:15:33,350 --> 01:15:30,320
build up the scenario to

2149
01:15:36,470 --> 01:15:33,360
to get it to where we see it today okay

2150
01:15:39,750 --> 01:15:36,480
so for for um

2151
01:15:42,550 --> 01:15:39,760
for looking at the milky way galaxy

2152
01:15:43,430 --> 01:15:42,560
we see distributions of stars that are

2153
01:15:45,510 --> 01:15:43,440
uh

2154
01:15:46,870 --> 01:15:45,520
um there's older stars that are in the

2155
01:15:49,270 --> 01:15:46,880
center regions

2156
01:15:50,310 --> 01:15:49,280
there are younger stars in the arms and

2157
01:15:52,550 --> 01:15:50,320
there are these

2158
01:15:54,310 --> 01:15:52,560
halo stars and globular clusters that

2159
01:15:57,030 --> 01:15:54,320
are kind of spread out above

2160
01:15:58,310 --> 01:15:57,040
and below the disk that are really old

2161
01:16:00,870 --> 01:15:58,320
so if you just took

2162
01:16:02,550 --> 01:16:00,880
a a look at the ages of stars in our

2163
01:16:03,750 --> 01:16:02,560

galaxy and they were in different places

2164
01:16:05,510 --> 01:16:03,760
that gives you an idea of when they

2165
01:16:08,310 --> 01:16:05,520
might have formed first

2166
01:16:09,990 --> 01:16:08,320
so uh the halo stars and the globular

2167
01:16:11,750 --> 01:16:10,000
cluster stars turn out to be

2168
01:16:13,430 --> 01:16:11,760
some of the oldest stars in the universe

2169
01:16:15,110 --> 01:16:13,440
in our galaxy

2170
01:16:16,630 --> 01:16:15,120
and so they must have formed first

2171
01:16:17,350 --> 01:16:16,640
whereas the stars in the discs form

2172
01:16:19,990 --> 01:16:17,360
later

2173
01:16:21,189 --> 01:16:20,000
so the the gap the evolution of the of

2174
01:16:23,590 --> 01:16:21,199
the milky way

2175
01:16:24,550 --> 01:16:23,600
can really we can start to understand it

2176
01:16:27,669 --> 01:16:24,560
by seeing

2177
01:16:29,590 --> 01:16:27,679
what stars are there how old they are

2178
01:16:32,470 --> 01:16:29,600
where they are and how they're moving

2179
01:16:34,709 --> 01:16:32,480
okay so um and so that's kind of that

2180
01:16:36,790 --> 01:16:34,719
um i'm guessing that's where that

2181
01:16:38,709 --> 01:16:36,800
person's paleo astronomy might

2182
01:16:39,910 --> 01:16:38,719
have come from i think that's the um

2183
01:16:41,270 --> 01:16:39,920
frank do you have it have you heard that

2184
01:16:41,990 --> 01:16:41,280
term before but that's my guess my

2185
01:16:44,870 --> 01:16:42,000
interpretation

2186
01:16:46,550 --> 01:16:44,880
looked it up on wiktionary and it says

2187
01:16:47,990 --> 01:16:46,560
the relationship of information about

2188
01:16:50,790 --> 01:16:48,000

the sky to historical

2189
01:16:51,830 --> 01:16:50,800
records a fusion discipline between

2190
01:16:55,189 --> 01:16:51,840
paleontology

2191
01:16:56,870 --> 01:16:55,199
and astronomy so i usually

2192
01:16:58,390 --> 01:16:56,880
so i usually interpret what that

2193
01:17:00,709 --> 01:16:58,400
definition that you just said

2194
01:17:01,990 --> 01:17:00,719
uh frank was is archaeoastronomy so

2195
01:17:05,189 --> 01:17:02,000
there's a lot of

2196
01:17:06,229 --> 01:17:05,199
oculus that interp google takes it and

2197
01:17:07,910 --> 01:17:06,239
immediately turns it into

2198
01:17:08,470 --> 01:17:07,920
archaeoastronomy when you if you search

2199
01:17:11,590 --> 01:17:08,480
for

2200
01:17:14,550 --> 01:17:11,600
astronomy but that makes sense

2201
01:17:15,590 --> 01:17:14,560
well what i just described my version of

2202
01:17:19,030 --> 01:17:15,600
paleo astronomy

2203
01:17:22,070 --> 01:17:19,040
is is uh is looking at the

2204
01:17:22,709 --> 01:17:22,080
the history on billions of years time

2205
01:17:24,229 --> 01:17:22,719
scale

2206
01:17:26,630 --> 01:17:24,239
to get to where we see today archie

2207
01:17:27,189 --> 01:17:26,640
astronomy is is quite interesting as

2208
01:17:29,030 --> 01:17:27,199
well and

2209
01:17:31,110 --> 01:17:29,040
by the way on vspace there's some

2210
01:17:32,870 --> 01:17:31,120
there's two new videos that talk about

2211
01:17:34,149 --> 01:17:32,880
archaeoastronomy and looking at the

2212
01:17:37,189 --> 01:17:34,159
night sky

2213
01:17:39,350 --> 01:17:37,199

um that the mayas all and as well as

2214
01:17:40,550 --> 01:17:39,360
over time how many supernova explosions

2215
01:17:43,350 --> 01:17:40,560
have you seen

2216
01:17:47,270 --> 01:17:43,360
with just your eyes make a guess and

2217
01:17:50,470 --> 01:17:49,189
all right so do we have one one more

2218
01:17:52,630 --> 01:17:50,480
question for her

2219
01:17:53,910 --> 01:17:52,640
yeah i'll um i'll finish it out with

2220
01:17:57,510 --> 01:17:53,920
this last question

2221
01:18:00,709 --> 01:17:57,520
um kind of related to the previous

2222
01:18:01,669 --> 01:18:00,719
uh about the maximum temperature and

2223
01:18:04,790 --> 01:18:01,679
what have you

2224
01:18:05,110 --> 01:18:04,800
so by logical deduction would the center

2225
01:18:08,070 --> 01:18:05,120
of

2226
01:18:11,189 --> 01:18:08,080
galaxies then be the hottest places in

2227
01:18:13,270 --> 01:18:11,199
the observable universe as we know it

2228
01:18:14,709 --> 01:18:13,280
no it would not that's that's a great i

2229
01:18:18,310 --> 01:18:14,719
could see the analogy

2230
01:18:21,350 --> 01:18:18,320
thinking of collections of

2231
01:18:24,390 --> 01:18:21,360
uh the galaxy is definitely a collection

2232
01:18:27,910 --> 01:18:24,400
of billions of stars but

2233
01:18:31,669 --> 01:18:27,920
in reality the space between the stars

2234
01:18:32,630 --> 01:18:31,679
is quite large um there's a lot of dust

2235
01:18:34,390 --> 01:18:32,640
and gas

2236
01:18:35,669 --> 01:18:34,400
but but the chances of another star

2237
01:18:37,750 --> 01:18:35,679
hitting us

2238
01:18:39,189 --> 01:18:37,760

the sun and the solar system is very

2239
01:18:40,149 --> 01:18:39,199
very very low not something you should

2240
01:18:43,270 --> 01:18:40,159
worry about

2241
01:18:45,669 --> 01:18:43,280
um but it's not a solid object like

2242
01:18:48,790 --> 01:18:45,679
this like a star is a star is really

2243
01:18:49,270 --> 01:18:48,800
dense and because of the gravity of the

2244
01:18:51,270 --> 01:18:49,280
gas

2245
01:18:53,350 --> 01:18:51,280
pushing down on the core that's actually

2246
01:18:56,630 --> 01:18:53,360
why the core of a star is so hot

2247
01:18:58,229 --> 01:18:56,640
is because it's the molecules are moving

2248
01:18:59,910 --> 01:18:58,239
around so fast as it's being

2249
01:19:01,510 --> 01:18:59,920
pushed down by the weight of all the

2250
01:19:03,510 --> 01:19:01,520
overlaying materials

2251
01:19:05,510 --> 01:19:03,520
so for those of you are interested look

2252
01:19:06,550 --> 01:19:05,520
at something called gravitational

2253
01:19:08,310 --> 01:19:06,560
equilibrium

2254
01:19:09,830 --> 01:19:08,320
it's it's it's the way the inside of a

2255
01:19:12,630 --> 01:19:09,840
star has

2256
01:19:12,950 --> 01:19:12,640
its temperature and pressure and density

2257
01:19:15,350 --> 01:19:12,960
um

2258
01:19:16,149 --> 01:19:15,360
at a very specific way that's outlined

2259
01:19:19,350 --> 01:19:16,159
by

2260
01:19:19,750 --> 01:19:19,360
um some really simple physics actually

2261
01:19:23,350 --> 01:19:19,760
six

2262
01:19:25,510 --> 01:19:23,360
seven um

2263
01:19:27,510 --> 01:19:25,520

but the inside of a star is hot because

2264
01:19:29,910 --> 01:19:27,520
of that that's not the same scenario in

2265
01:19:31,669 --> 01:19:29,920
a galaxy because the stars are not all

2266
01:19:34,830 --> 01:19:31,679
pushing on each other like the density

2267
01:19:37,830 --> 01:19:34,840
of a star so it's not quite the same

2268
01:19:40,149 --> 01:19:37,840
um the uh

2269
01:19:41,430 --> 01:19:40,159
the centers of let's see let me think of

2270
01:19:42,229 --> 01:19:41,440
some some other centers that might be

2271
01:19:45,910 --> 01:19:42,239
really hot

2272
01:19:51,110 --> 01:19:45,920
um star centers very very much so

2273
01:19:52,790 --> 01:19:51,120
um even the cores of um

2274
01:19:54,149 --> 01:19:52,800
of white dwarfs and neutron stars would

2275
01:19:55,910 --> 01:19:54,159
be hot as a result of that

2276
01:19:57,910 --> 01:19:55,920
gravity the weight of material on top of

2277
01:20:00,550 --> 01:19:57,920
it as well

2278
01:20:01,669 --> 01:20:00,560
okay okay well thank you very much quinn

2279
01:20:04,229 --> 01:20:01,679
i think we have

2280
01:20:05,110 --> 01:20:04,239
taxed your brain and going many

2281
01:20:09,270 --> 01:20:05,120
different

2282
01:20:11,030 --> 01:20:09,280
for that taxing my brain is great

2283
01:20:13,350 --> 01:20:11,040
as you would tax their brains into

2284
01:20:16,390 --> 01:20:13,360
thinking about what they see around them

2285
01:20:16,950 --> 01:20:16,400
and how it applies to the universe next

2286
01:20:20,149 --> 01:20:16,960
month

2287
01:20:23,590 --> 01:20:20,159
on august 3rd the importance of

2288
01:20:26,470 --> 01:20:23,600

small objects exo comets

2289
01:20:27,030 --> 01:20:26,480
that's a really cool idea we will see

2290
01:20:29,110 --> 01:20:27,040
you then

2291
01:20:30,830 --> 01:20:29,120
thank you all for coming and have a

2292
01:20:33,830 --> 01:20:30,840
great day have a great