
skype

1
00:00:00,030 --> 00:00:03,350
one

2
00:00:23,830 --> 00:00:20,729
[Music]

3
00:00:26,410 --> 00:00:23,840
hello and welcome to the everything else

4
00:00:28,749 --> 00:00:26,420
show I'm Martin will assure host we have

5
00:00:30,970 --> 00:00:28,759
a great guest I had the chance to meet

6
00:00:35,079 --> 00:00:30,980
dr. Jeffrey Bennett down in North

7
00:00:36,729 --> 00:00:35,089
Carolina several years ago and I'm real

8
00:00:38,560 --> 00:00:36,739
excited to have him on the show we're

9
00:00:40,900 --> 00:00:38,570
gonna be talking about relativity a

10
00:00:45,310 --> 00:00:40,910
little bit about space black holes it

11
00:00:45,760 --> 00:00:45,320
should be a real fun show so dr. Jeffrey

12
00:00:48,970 --> 00:00:45,770
Bennett

13
00:00:51,490 --> 00:00:48,980

he holds a BA in biophysics biophysics

14
00:00:55,869 --> 00:00:51,500
from the University of California at San

15
00:00:58,119 --> 00:00:55,879
Diego and an MS and PhD in astrophysics

16
00:01:00,790 --> 00:00:58,129
from the University of Colorado at

17
00:01:03,849 --> 00:01:00,800
Boulder Boulder he specializes in

18
00:01:06,940 --> 00:01:03,859
mathematics in science education writing

19
00:01:08,889 --> 00:01:06,950
and speaking for audiences actually he

20
00:01:11,050 --> 00:01:08,899
was on a tour we're gonna talk about

21
00:01:14,380 --> 00:01:11,060
that talking about relativity went to

22
00:01:16,480 --> 00:01:14,390
cities all over the country great guy

23
00:01:18,699 --> 00:01:16,490
glad to have him on how are you Jeffrey

24
00:01:21,749 --> 00:01:18,709
welcome to the show great and thank you

25
00:01:24,940 --> 00:01:21,759
very much for having me on today yes and

26
00:01:27,969 --> 00:01:24,950
it's it's always a pleasure I have

27
00:01:30,130 --> 00:01:27,979
listened to your shows talking about

28
00:01:33,339 --> 00:01:30,140
relativity and are one of them I should

29
00:01:35,350 --> 00:01:33,349
say I found it fascinating and so how

30
00:01:36,910 --> 00:01:35,360
did that all begin you were you were

31
00:01:39,430 --> 00:01:36,920
basically they were reaching out and

32
00:01:43,680 --> 00:01:39,440
asking scientists to talk about this to

33
00:01:46,839 --> 00:01:43,690
celebrate one on 100 years well yeah

34
00:01:48,430 --> 00:01:46,849
2015 was the hundredth anniversary of in

35
00:01:52,990 --> 00:01:48,440
Stein's publication of his general

36
00:01:54,719 --> 00:01:53,000
theory of relativity and so for that the

37
00:01:58,150 --> 00:01:54,729
United Nations had declared at the

38
00:01:59,919 --> 00:01:58,160

International Year of light and so they

39
00:02:02,559 --> 00:01:59,929
were looking for people to go out and

40
00:02:04,540 --> 00:02:02,569
help the public understand relativity

41
00:02:06,880 --> 00:02:04,550
I'd already written a book on relativity

42
00:02:08,740 --> 00:02:06,890
so I thought well I'll just email

43
00:02:10,600 --> 00:02:08,750
friends and say if you want to have me

44
00:02:14,140 --> 00:02:10,610
come give a talk at your university or

45
00:02:15,760 --> 00:02:14,150
wherever I'll do it and I ended up in 25

46
00:02:17,800 --> 00:02:15,770
different cities mostly on college

47
00:02:20,619 --> 00:02:17,810
campuses but a few other places science

48
00:02:21,920 --> 00:02:20,629
museums and things like that and and it

49
00:02:26,149 --> 00:02:21,930
was a lot of fun

50
00:02:29,539 --> 00:02:26,159
great great and also I know you are

51
00:02:32,030 --> 00:02:29,549
doing some talks on climate change and I

52
00:02:33,470 --> 00:02:32,040
would actually like to I'll talk to you

53
00:02:35,720 --> 00:02:33,480
about that at a later time I'd love to

54
00:02:37,550 --> 00:02:35,730
have you back on that if you feel up to

55
00:02:40,009 --> 00:02:37,560
doing it sometime we can talk about that

56
00:02:42,110 --> 00:02:40,019
later absolutely and I should say in

57
00:02:44,629 --> 00:02:42,120
fact that the way that happened was

58
00:02:46,129 --> 00:02:44,639
after 2015 ended and it wasn't the

59
00:02:47,690 --> 00:02:46,139
hundredth anniversary of relativity

60
00:02:48,170 --> 00:02:47,700
anymore I thought oh what am I gonna do

61
00:02:50,539 --> 00:02:48,180
now

62
00:02:52,339 --> 00:02:50,549
and I decided I decided I should pick a

63
00:02:54,409 --> 00:02:52,349

different topic and go on tour for that

64
00:02:55,069 --> 00:02:54,419
so that's what I'm doing now with global

65
00:02:59,030 --> 00:02:55,079
warming

66
00:03:02,860 --> 00:02:59,040
I see great so something happened in

67
00:03:08,479 --> 00:03:02,870
astronomy today let's talk about that

68
00:03:10,399 --> 00:03:08,489
they they of two stars colliding yeah so

69
00:03:12,890 --> 00:03:10,409
this is a really pretty big deal

70
00:03:15,770 --> 00:03:12,900
and it is relativity so it's right up

71
00:03:17,899 --> 00:03:15,780
our alley here for what you perfect

72
00:03:19,280 --> 00:03:17,909
timing for having a me on tonight if we

73
00:03:22,190 --> 00:03:19,290
had done in a month ago we wouldn't have

74
00:03:27,020 --> 00:03:22,200
this new thing to talk about so you

75
00:03:30,949 --> 00:03:27,030
probably heard a couple of years ago in

76
00:03:33,349 --> 00:03:30,959
the end of 2015 the LIGO Observatory

77
00:03:36,469 --> 00:03:33,359
stands for laser interferometric

78
00:03:38,569 --> 00:03:36,479
gravitational observatory the LIGO

79
00:03:40,939 --> 00:03:38,579
Observatory came online in its new

80
00:03:43,399 --> 00:03:40,949
advanced way and it had been built

81
00:03:46,089 --> 00:03:43,409
specifically to detect these things

82
00:03:48,050 --> 00:03:46,099
called gravitational waves that are

83
00:03:51,289 --> 00:03:48,060
important prediction of Einstein's

84
00:03:53,119 --> 00:03:51,299
general theory of relativity now I

85
00:03:55,610 --> 00:03:53,129
should mention we we actually knew that

86
00:03:58,129 --> 00:03:55,620
these things existed already not just

87
00:04:00,499 --> 00:03:58,139
because Einstein had predicted them but

88
00:04:02,719 --> 00:04:00,509

because we had very strong indirect

89
00:04:05,839 --> 00:04:02,729
evidence that they exist and the way

90
00:04:07,610 --> 00:04:05,849
that came about is you have places in

91
00:04:10,819 --> 00:04:07,620
the universe where you have two very

92
00:04:13,580 --> 00:04:10,829
very compact massive stellar corpses

93
00:04:15,860 --> 00:04:13,590
like two neutron stars or two black

94
00:04:18,620 --> 00:04:15,870
holes and they're orbiting around each

95
00:04:21,760 --> 00:04:18,630
other and hopefully viewers can see what

96
00:04:24,200 --> 00:04:21,770
I'm showing here and the idea is that

97
00:04:26,629 --> 00:04:24,210
according to general relativity when you

98
00:04:29,300 --> 00:04:26,639
have two fast-moving objects orbiting

99
00:04:31,640 --> 00:04:29,310
like this they should be emitting energy

100
00:04:34,370 --> 00:04:31,650
in the form of gravitational waves out

101
00:04:35,840 --> 00:04:34,380
into the universe and that energy that's

102
00:04:37,550 --> 00:04:35,850
being carried away

103
00:04:40,070 --> 00:04:37,560
since that means the system is losing

104
00:04:42,320 --> 00:04:40,080
energy that orbit is gonna gradually

105
00:04:44,090 --> 00:04:42,330
decay gets smaller and smaller and

106
00:04:47,180 --> 00:04:44,100
eventually you would expect those

107
00:04:49,460 --> 00:04:47,190
objects to merge so back in starting in

108
00:04:53,390 --> 00:04:49,470
the 70s astronomers have detected some

109
00:04:55,190 --> 00:04:53,400
of these uh binary pulsars like this two

110
00:04:58,400 --> 00:04:55,200
neutron stars orbiting each other and

111
00:05:01,070 --> 00:04:58,410
their orbit was indeed decaying exactly

112
00:05:03,260 --> 00:05:01,080
the way it should if it was decaying

113
00:05:05,480 --> 00:05:03,270

because of the emission of gravitational

114
00:05:07,520 --> 00:05:05,490
waves so we knew the gravitational waves

115
00:05:09,890 --> 00:05:07,530
really were being emitted causing this

116
00:05:13,010 --> 00:05:09,900
decay but we couldn't detect them

117
00:05:14,960 --> 00:05:13,020
directly and what LIGO has done is it's

118
00:05:17,360 --> 00:05:14,970
actually detected the gravitational

119
00:05:19,580 --> 00:05:17,370
waves themselves coming from the last

120
00:05:22,070 --> 00:05:19,590
moment when the two objects merge into

121
00:05:25,280 --> 00:05:22,080
each other so the first discovery was in

122
00:05:27,950 --> 00:05:25,290
2015 and there been a total of four of

123
00:05:30,800 --> 00:05:27,960
these and those first four all involved

124
00:05:33,890 --> 00:05:30,810
two black holes crashing into each other

125
00:05:35,330 --> 00:05:33,900
and from Einstein's equations and from

126
00:05:38,420 --> 00:05:35,340
the signal you get you can actually

127
00:05:40,880 --> 00:05:38,430
calculate exactly how massive each of

128
00:05:43,820 --> 00:05:40,890
the two black holes were how far away

129
00:05:45,680 --> 00:05:43,830
they are and so on but because they were

130
00:05:47,510 --> 00:05:45,690
black holes and I know you want to talk

131
00:05:50,810 --> 00:05:47,520
more about black holes but black holes

132
00:05:52,760 --> 00:05:50,820
don't emit any light and therefore when

133
00:05:54,680 --> 00:05:52,770
they crash into each other they still

134
00:05:56,390 --> 00:05:54,690
don't emit any light they emit lots of

135
00:05:58,310 --> 00:05:56,400
these gravitational waves and that's how

136
00:06:00,140 --> 00:05:58,320
we got the signal but you couldn't point

137
00:06:03,170 --> 00:06:00,150
a telescope there and say oh there it is

138
00:06:05,080 --> 00:06:03,180

in visible light for example today's

139
00:06:07,490 --> 00:06:05,090
announcement is about two neutron stars

140
00:06:09,920 --> 00:06:07,500
that collided with each other merged

141
00:06:13,400 --> 00:06:09,930
together and because those are physical

142
00:06:15,710 --> 00:06:13,410
objects right there the remains of what

143
00:06:18,380 --> 00:06:15,720
we're once big massive stars that are

144
00:06:20,780 --> 00:06:18,390
now just balls of neutrons when they

145
00:06:22,730 --> 00:06:20,790
crash into each other it's a real

146
00:06:24,770 --> 00:06:22,740
collision and so there's all kinds of

147
00:06:27,200 --> 00:06:24,780
light emitted in addition to the

148
00:06:29,960 --> 00:06:27,210
gravitational waves so what happened

149
00:06:33,140 --> 00:06:29,970
this time was like oh recorded the

150
00:06:36,410 --> 00:06:33,150
signal within gravitational waves but

151
00:06:38,690 --> 00:06:36,420
astronomers also saw in virtually every

152
00:06:40,580 --> 00:06:38,700
wavelength of light that there is you

153
00:06:42,680 --> 00:06:40,590
can point up in the sky and see there it

154
00:06:45,650 --> 00:06:42,690
is in visible light there it is in

155
00:06:48,080 --> 00:06:45,660
x-rays there it is in radio and we also

156
00:06:49,340 --> 00:06:48,090
have the gravitational wave signal now

157
00:06:52,340 --> 00:06:49,350
how many light year

158
00:06:53,840 --> 00:06:52,350
away did this occur and in other words

159
00:06:56,360 --> 00:06:53,850
how long ago did this happen

160
00:06:57,920 --> 00:06:56,370
I believe this one if I remember don't

161
00:06:59,180 --> 00:06:57,930
quote me on this but I believe they had

162
00:07:00,860 --> 00:06:59,190
said this one was about a hundred and

163
00:07:03,680 --> 00:07:00,870

thirty million light years away so this

164
00:07:04,820 --> 00:07:03,690
is happening in a distant galaxy but a

165
00:07:08,720 --> 00:07:04,830
hundred and thirty million light years

166
00:07:14,050 --> 00:07:08,730
is actually in universe speak not that

167
00:07:17,480 --> 00:07:14,060
far what now the the two neutron stars

168
00:07:21,820 --> 00:07:17,490
were they part of a binary system of a

169
00:07:24,350 --> 00:07:21,830
solar system do you think so presumably

170
00:07:27,110 --> 00:07:24,360
what happens is to form a neutron star

171
00:07:29,570 --> 00:07:27,120
neutron star forms in a supernova

172
00:07:31,370 --> 00:07:29,580
explosion so these are these giant

173
00:07:34,430 --> 00:07:31,380
explosions that can occur at the end of

174
00:07:36,680 --> 00:07:34,440
a massive star's life so the only kinds

175
00:07:39,290 --> 00:07:36,690
of stars that undergo supernovae are

176
00:07:42,440 --> 00:07:39,300
massive stars at least eight times the

177
00:07:44,930 --> 00:07:42,450
mass of the Sun or more stars like the

178
00:07:46,730 --> 00:07:44,940
Sun they die in a much gentler fashion

179
00:07:50,090 --> 00:07:46,740
and leave behind corpses that we call

180
00:07:52,760 --> 00:07:50,100
white dwarfs so a neutron star would

181
00:07:55,760 --> 00:07:52,770
have formed when a massive star exploded

182
00:07:59,210 --> 00:07:55,770
so presumably what you had here sometime

183
00:08:01,940 --> 00:07:59,220
in the distant past was two massive

184
00:08:03,740 --> 00:08:01,950
stars orbiting each other and one of

185
00:08:05,600 --> 00:08:03,750
them exploded and became a neutron star

186
00:08:07,790 --> 00:08:05,610
and then sometime later the other one

187
00:08:09,940 --> 00:08:07,800
exploded and became a neutron star and

188
00:08:13,490 --> 00:08:09,950

then you have these two neutron stars

189
00:08:15,590 --> 00:08:13,500
orbiting around each other and they can

190
00:08:18,260 --> 00:08:15,600
get very close because what you have

191
00:08:20,750 --> 00:08:18,270
here a neutron stars mass is typically

192
00:08:22,790 --> 00:08:20,760
about one and a half to two times that

193
00:08:24,950 --> 00:08:22,800
of the Sun it's the remains of a much

194
00:08:29,090 --> 00:08:24,960
more massive star that blew out a lot of

195
00:08:30,830 --> 00:08:29,100
its mass into space because it but what

196
00:08:33,020 --> 00:08:30,840
it has the reason it's called a neutron

197
00:08:35,620 --> 00:08:33,030
star is during the supernova and the

198
00:08:39,260 --> 00:08:35,630
collapse in the center that drives that

199
00:08:42,290 --> 00:08:39,270
that mass you know more than the mass of

200
00:08:47,450 --> 00:08:42,300
the entire Sun gets collapsed down to a

201
00:08:50,180 --> 00:08:47,460
size only about ten miles across so it

202
00:08:52,580 --> 00:08:50,190
could fit in a city basically except for

203
00:08:55,490 --> 00:08:52,590
that if you brought one to your city it

204
00:08:59,120 --> 00:08:55,500
would not be good because when you

205
00:09:03,170 --> 00:08:59,130
brought it to your city it has the mass

206
00:09:04,550 --> 00:09:03,180
of the Sun which is 300,000

207
00:09:07,640 --> 00:09:04,560
I'm the mass of the earth so you

208
00:09:09,320 --> 00:09:07,650
wouldn't really have brought the neutron

209
00:09:11,840 --> 00:09:09,330
star to earth it's really like you

210
00:09:14,690 --> 00:09:11,850
brought the earth to the neutron star

211
00:09:16,430 --> 00:09:14,700
because earth is so small and mass even

212
00:09:18,380 --> 00:09:16,440
though in size it's bigger that the

213
00:09:20,780 --> 00:09:18,390

gravity of the neutron star would very

214
00:09:23,060 --> 00:09:20,790
quickly basically cause the entire earth

215
00:09:27,650 --> 00:09:23,070
to disintegrate and form a layer about a

216
00:09:31,100 --> 00:09:27,660
centimeter thick honest no so yeah don't

217
00:09:34,310 --> 00:09:31,110
bring one to town but but because

218
00:09:36,290 --> 00:09:34,320
they're so massive and so compact you

219
00:09:39,410 --> 00:09:36,300
know if you have two stars stars are you

220
00:09:42,080 --> 00:09:39,420
know a million plus miles across they

221
00:09:44,270 --> 00:09:42,090
can't be that close to each other cuz at

222
00:09:46,790 --> 00:09:44,280
minimum they're separated by their sizes

223
00:09:49,190 --> 00:09:46,800
but now you take all that mass and

224
00:09:51,950 --> 00:09:49,200
collapse it down to only something ten

225
00:09:54,380 --> 00:09:51,960
miles across and they can be very very

226
00:09:56,330 --> 00:09:54,390
close together without hitting right and

227
00:09:57,830 --> 00:09:56,340
that's why they're orbiting very very

228
00:09:59,810 --> 00:09:57,840
fast and emitting all these

229
00:10:02,060 --> 00:09:59,820
gravitational waves in the process and

230
00:10:04,490 --> 00:10:02,070
that's what causes the orbit to decay in

231
00:10:07,130 --> 00:10:04,500
that last moment you have the boom which

232
00:10:11,390 --> 00:10:07,140
was detected now when something implodes

233
00:10:14,390 --> 00:10:11,400
and down to a black hole or you know

234
00:10:17,390 --> 00:10:14,400
anything implodes like that does is it

235
00:10:19,910 --> 00:10:17,400
this down to the atomic level of the

236
00:10:23,330 --> 00:10:19,920
space in the atoms like just squeezed

237
00:10:25,610 --> 00:10:23,340
all together so a neutron star is called

238
00:10:28,430 --> 00:10:25,620

a neutron star because it has been

239
00:10:31,010 --> 00:10:28,440
squeezed so much that its atoms can't

240
00:10:33,680 --> 00:10:31,020
exist anymore the electrons all merge

241
00:10:37,870 --> 00:10:33,690
with the protons and it is actually

242
00:10:40,610 --> 00:10:37,880
basically a ball of solid neutrons which

243
00:10:42,440 --> 00:10:40,620
what what most people don't realize is

244
00:10:45,200 --> 00:10:42,450
that you know we when you feel an object

245
00:10:48,410 --> 00:10:45,210
you know a pan anything it feels solid

246
00:10:51,110 --> 00:10:48,420
to you but it's actually mostly made out

247
00:10:54,620 --> 00:10:51,120
of empty space because the nucleus of an

248
00:10:58,040 --> 00:10:54,630
atom is a hundred thousand times smaller

249
00:11:00,500 --> 00:10:58,050
than the whole atom so individual atoms

250
00:11:02,810 --> 00:11:00,510
are made almost entirely of empty space

251
00:11:06,320 --> 00:11:02,820
all their mass is down in this very tiny

252
00:11:10,670 --> 00:11:06,330
nucleus way way down in the middle so

253
00:11:13,220 --> 00:11:10,680
when a neutron star forms all that empty

254
00:11:15,900 --> 00:11:13,230
space is now filled and it's all

255
00:11:19,200 --> 00:11:15,910
neutrons and that's why it's so dense

256
00:11:21,870 --> 00:11:19,210
if you had a teaspoon full of neutron

257
00:11:25,190 --> 00:11:21,880
star matter it would contain as much

258
00:11:30,510 --> 00:11:25,200
mass as like an entire mountain does

259
00:11:33,990 --> 00:11:30,520
amazing now if say a black hole spit out

260
00:11:37,200 --> 00:11:34,000
matter or dissipated out some matter

261
00:11:41,820 --> 00:11:37,210
that was in it would that matter expand

262
00:11:45,300 --> 00:11:41,830
back to normal sized atoms well no it

263
00:11:47,820 --> 00:11:45,310

can't do that because a black hole by

264
00:11:50,850 --> 00:11:47,830
definition is where the matter has

265
00:11:51,540 --> 00:11:50,860
basically been squeezed out of the

266
00:11:54,030 --> 00:11:51,550
universe

267
00:11:56,400 --> 00:11:54,040
so to speak it's got an event horizon a

268
00:12:00,150 --> 00:11:56,410
place beyond which nothing no

269
00:12:02,280 --> 00:12:00,160
information can ever come out again so

270
00:12:06,030 --> 00:12:02,290
so no now in the case of the neutron

271
00:12:08,490 --> 00:12:06,040
star when that explosion happens and

272
00:12:15,210 --> 00:12:08,500
some of the matter gets spewed out into

273
00:12:17,490 --> 00:12:15,220
space neutrons neutrons by themselves

274
00:12:19,680 --> 00:12:17,500
are not stable particles they will fall

275
00:12:21,540 --> 00:12:19,690
apart and become protons and I think

276
00:12:23,490 --> 00:12:21,550
they must release an electron in the

277
00:12:25,710 --> 00:12:23,500
process I'd have to look up the nuclear

278
00:12:28,350 --> 00:12:25,720
reaction there but so they will in a

279
00:12:30,450 --> 00:12:28,360
sense the little bit that gets spewed

280
00:12:34,050 --> 00:12:30,460
out from that explosion will sort of

281
00:12:37,470 --> 00:12:34,060
become ordinary matter again I see I see

282
00:12:43,470 --> 00:12:37,480
now can a black hole just keep growing

283
00:12:46,140 --> 00:12:43,480
and swallow galaxies if not then why yes

284
00:12:49,200 --> 00:12:46,150
a black hole will will grow as long as

285
00:12:51,960 --> 00:12:49,210
more masses falling into it and but

286
00:12:53,610 --> 00:12:51,970
that's the key one of my favorite

287
00:12:56,870 --> 00:12:53,620
expressions that I like to remind people

288
00:13:00,030 --> 00:12:56,880

of is that black holes don't suck

289
00:13:02,760 --> 00:13:00,040
they're not vacuum cleaners they don't

290
00:13:05,820 --> 00:13:02,770
suck stuff in the only way material gets

291
00:13:08,970 --> 00:13:05,830
into a black hole is if it falls in

292
00:13:12,960 --> 00:13:08,980
because it has an orbit that's crossing

293
00:13:15,510 --> 00:13:12,970
into the black hole's event horizon so

294
00:13:18,150 --> 00:13:15,520
you have to have matter around that's

295
00:13:21,270 --> 00:13:18,160
falling into the black hole in order for

296
00:13:23,130 --> 00:13:21,280
it to gain mass so what happens down for

297
00:13:25,020 --> 00:13:23,140
example in the center of a galaxy where

298
00:13:27,720 --> 00:13:25,030
we know there's supermassive black holes

299
00:13:29,700 --> 00:13:27,730
at the Centers of most galaxies made

300
00:13:33,630 --> 00:13:29,710
famous in the movie interstellar

301
00:13:35,700 --> 00:13:33,640
went to visit one and down in the center

302
00:13:38,760 --> 00:13:35,710
of the galaxy there's lots of gas and

303
00:13:41,310 --> 00:13:38,770
lots of stars so the black hole can feed

304
00:13:43,710 --> 00:13:41,320
on that because those things collide

305
00:13:45,630 --> 00:13:43,720
with each other their orbits shift and

306
00:13:47,460 --> 00:13:45,640
many time in orbit shifts it might cause

307
00:13:50,540 --> 00:13:47,470
the material to end up spiraling and

308
00:13:53,100 --> 00:13:50,550
falling into the black hole when

309
00:13:55,500 --> 00:13:53,110
galaxies are young there's a lot of that

310
00:13:57,510 --> 00:13:55,510
material around and so the black holes

311
00:14:01,170 --> 00:13:57,520
are kind of eating a lot and that makes

312
00:14:03,180 --> 00:14:01,180
them generate a lot of light coming from

313
00:14:05,400 --> 00:14:03,190

around them from the material that's on

314
00:14:08,340 --> 00:14:05,410
its way in and you may have heard of

315
00:14:11,160 --> 00:14:08,350
these objects we call quasars and that's

316
00:14:13,440 --> 00:14:11,170
what a quasar is it's basically the

317
00:14:16,860 --> 00:14:13,450
center of a galaxy where a black hole

318
00:14:19,380 --> 00:14:16,870
was eating a lot very rapidly and we

319
00:14:21,780 --> 00:14:19,390
only see the most powerful quasars at

320
00:14:23,700 --> 00:14:21,790
very great distances which means in the

321
00:14:24,270 --> 00:14:23,710
distant past when the universe was much

322
00:14:28,620 --> 00:14:24,280
younger

323
00:14:31,170 --> 00:14:28,630
why not around here because the black

324
00:14:33,450 --> 00:14:31,180
holes must still be in those galaxies

325
00:14:34,890 --> 00:14:33,460
even when they're much older and the

326
00:14:37,170 --> 00:14:34,900
reason is because they've basically

327
00:14:39,030 --> 00:14:37,180
eaten up most of the material down in

328
00:14:40,650 --> 00:14:39,040
the center of the galaxy already so

329
00:14:41,220 --> 00:14:40,660
there's not as much for them to eat

330
00:14:43,380 --> 00:14:41,230
anymore

331
00:14:45,240 --> 00:14:43,390
so they don't shine so brightly like

332
00:14:48,120 --> 00:14:45,250
ways ours anymore but if you keep

333
00:14:51,300 --> 00:14:48,130
feeding them they will keep growing in

334
00:14:54,360 --> 00:14:51,310
mass so if something has to fall in a

335
00:14:57,450 --> 00:14:54,370
black hole which I assume is very small

336
00:14:59,490 --> 00:14:57,460
how does it fall into it that's correct

337
00:15:01,170 --> 00:14:59,500
a black hole is actually probably the

338
00:15:04,650 --> 00:15:01,180

most difficult thing in the universe to

339
00:15:07,020 --> 00:15:04,660
fall into by accident because it is so

340
00:15:10,140 --> 00:15:07,030
small you're not just gonna go run into

341
00:15:12,600 --> 00:15:10,150
one but what happens is as material gets

342
00:15:14,550 --> 00:15:12,610
close to a black hole for example in the

343
00:15:16,650 --> 00:15:14,560
center of a galaxy when a star comes

344
00:15:20,580 --> 00:15:16,660
fairly close to that supermassive black

345
00:15:23,190 --> 00:15:20,590
hole just like the moon creates tidal

346
00:15:25,650 --> 00:15:23,200
forces on earth that stretcheth out with

347
00:15:27,810 --> 00:15:25,660
a black hole being much more massive it

348
00:15:30,210 --> 00:15:27,820
creates strong tidal forces and it can

349
00:15:32,910 --> 00:15:30,220
actually rip stars apart as they get

350
00:15:36,180 --> 00:15:32,920
close to it and then that gas from the

351
00:15:38,310 --> 00:15:36,190
star is now orbiting and gas because

352
00:15:39,540 --> 00:15:38,320
it's lots of individual molecules and

353
00:15:41,460 --> 00:15:39,550
they're colliding with each other

354
00:15:44,860 --> 00:15:41,470
whenever there's a collision

355
00:15:46,630 --> 00:15:44,870
one object loses energy and one gains

356
00:15:48,460 --> 00:15:46,640
energy so you're gonna have some objects

357
00:15:50,230 --> 00:15:48,470
that are gonna lose energy and move

358
00:15:53,170 --> 00:15:50,240
closer to the black hole and the end

359
00:15:55,150 --> 00:15:53,180
result is all that gas ends up forming a

360
00:15:57,370 --> 00:15:55,160
disk of material around the black hole

361
00:15:59,890 --> 00:15:57,380
we call it an accretion disk and that

362
00:16:01,990 --> 00:15:59,900
matter it's just gonna keep basically

363
00:16:04,420 --> 00:16:02,000

spiraling in because the collisions are

364
00:16:06,970 --> 00:16:04,430
depriving it of energy it's also very

365
00:16:08,590 --> 00:16:06,980
hot so it's radiating energy away that's

366
00:16:11,500 --> 00:16:08,600
why we can see these things with

367
00:16:14,470 --> 00:16:11,510
telescopes as quasars and other similar

368
00:16:16,450 --> 00:16:14,480
objects but yeah all that gas will

369
00:16:19,780 --> 00:16:16,460
spiral into the black hole so you have

370
00:16:21,250 --> 00:16:19,790
this big disk of gas that's falling into

371
00:16:24,850 --> 00:16:21,260
the black hole because of that energy

372
00:16:28,060 --> 00:16:24,860
loss now how far can we see in our

373
00:16:31,450 --> 00:16:28,070
galaxy as far as lightyears how far away

374
00:16:34,390 --> 00:16:31,460
can we see so in principle we can see as

375
00:16:38,430 --> 00:16:34,400
far as we want in the observable

376
00:16:42,010 --> 00:16:38,440
universe of the observable universe is

377
00:16:45,670 --> 00:16:42,020
by definition because the universe is

378
00:16:48,610 --> 00:16:45,680
about 14 billion years old the farthest

379
00:16:53,200 --> 00:16:48,620
we can see in principle is 14 billion

380
00:16:56,080 --> 00:16:53,210
light-years away because anything if if

381
00:16:58,600 --> 00:16:56,090
an object was 14 billion light-years

382
00:17:01,810 --> 00:16:58,610
away by which I mean its light took 14

383
00:17:04,180 --> 00:17:01,820
billion years to reach us and the

384
00:17:05,680 --> 00:17:04,190
universe is 14 billion years old then

385
00:17:06,880 --> 00:17:05,690
when you see something that far our way

386
00:17:09,220 --> 00:17:06,890
you're seeing it at the moment of its

387
00:17:13,390 --> 00:17:09,230
birth right right when the universe was

388
00:17:15,880 --> 00:17:13,400

born there might be an object that's 15

389
00:17:18,880 --> 00:17:15,890
billion light years away but it's light

390
00:17:20,890 --> 00:17:18,890
takes 15 billion years to reach us which

391
00:17:24,520 --> 00:17:20,900
means we would now be seeing it as it

392
00:17:26,290 --> 00:17:24,530
was 15 billion years ago but 15 billion

393
00:17:29,320 --> 00:17:26,300
years ago the universe and it didn't

394
00:17:32,200 --> 00:17:29,330
exist yet so there's nothing to see Wow

395
00:17:34,720 --> 00:17:32,210
so that so that is amazin so far this we

396
00:17:37,750 --> 00:17:34,730
can see is the observable universe so

397
00:17:41,350 --> 00:17:37,760
obviously we can see to a point where

398
00:17:41,830 --> 00:17:41,360
there isn't any black holes yet uh not

399
00:17:45,070 --> 00:17:41,840
quite

400
00:17:47,050 --> 00:17:45,080
we were worse it depends on how you look

401
00:17:49,750 --> 00:17:47,060
at that we can see with our most

402
00:17:51,610 --> 00:17:49,760
powerful telescopes some of the most the

403
00:17:53,860 --> 00:17:51,620
the objects that we see at the greatest

404
00:17:55,130 --> 00:17:53,870
distances are some of these quasars so

405
00:17:56,210 --> 00:17:55,140
these are places where

406
00:17:59,870 --> 00:17:56,220
there's a supermassive black hole

407
00:18:02,630 --> 00:17:59,880
already in the center of a galaxy and we

408
00:18:03,980 --> 00:18:02,640
see them out almost to the you know when

409
00:18:06,320 --> 00:18:03,990
the universe was just a few hundred

410
00:18:07,970 --> 00:18:06,330
million years old now with Hubble and

411
00:18:10,360 --> 00:18:07,980
with the coming James Webb telescope

412
00:18:14,600 --> 00:18:10,370
we're hoping we might be able to see

413
00:18:16,690 --> 00:18:14,610

galaxies if they were already in

414
00:18:19,039 --> 00:18:16,700
existence even before the black holes

415
00:18:20,780 --> 00:18:19,049
existed now there's a bit of a chicken

416
00:18:22,460 --> 00:18:20,790
and egg question there people aren't

417
00:18:24,200 --> 00:18:22,470
really sure whether the black holes came

418
00:18:26,960 --> 00:18:24,210
first and the galaxies formed around

419
00:18:29,180 --> 00:18:26,970
them or the galaxies came first and the

420
00:18:31,930 --> 00:18:29,190
black holes formed in their middles but

421
00:18:34,610 --> 00:18:31,940
we might be able to figure that out but

422
00:18:37,190 --> 00:18:34,620
you if you go back too far enough

423
00:18:40,640 --> 00:18:37,200
distances you reach a time before stars

424
00:18:43,340 --> 00:18:40,650
existed and then you're in a place where

425
00:18:46,960 --> 00:18:43,350
there's really not anything to see with

426
00:18:50,480 --> 00:18:46,970
one exception which is that the Big Bang

427
00:18:54,320 --> 00:18:50,490
itself should have generated an enormous

428
00:18:56,180 --> 00:18:54,330
amount of heat and light and in

429
00:18:59,360 --> 00:18:56,190
principle we should be able to detect

430
00:19:02,180 --> 00:18:59,370
that light left over from the Big Bang

431
00:19:04,850 --> 00:19:02,190
itself coming from that very edge of the

432
00:19:08,060 --> 00:19:04,860
universe and we do that is what's called

433
00:19:11,120 --> 00:19:08,070
the Cosmic Microwave Background it was

434
00:19:14,360 --> 00:19:11,130
first detected in 1960s right now big

435
00:19:16,250 --> 00:19:14,370
horn thing right up right with that Big

436
00:19:17,960 --> 00:19:16,260
Horn telescope and now you see those

437
00:19:19,340 --> 00:19:17,970
beautiful pictures that maps that we

438
00:19:21,799 --> 00:19:19,350

make of the Cosmic Microwave Background

439
00:19:25,940 --> 00:19:21,809
all across the sky so we're actually

440
00:19:27,710 --> 00:19:25,950
looking at the universe as it was when

441
00:19:29,960 --> 00:19:27,720
that light was first released which

442
00:19:31,909 --> 00:19:29,970
turns out for reasons I won't go into

443
00:19:37,039 --> 00:19:31,919
right now to be about 400,000 years

444
00:19:40,669 --> 00:19:37,049
after the Big Bang itself now is there

445
00:19:44,810 --> 00:19:40,679
any way possible that we could be wrong

446
00:19:49,220 --> 00:19:44,820
about the Big Bang um it depends on what

447
00:19:50,659 --> 00:19:49,230
you mean by wrong okay and and this is

448
00:19:54,590 --> 00:19:50,669
kind of an important point you know

449
00:19:57,080 --> 00:19:54,600
people have this this myth that gets

450
00:19:58,970 --> 00:19:57,090
spread that thought you know when you

451
00:20:01,039 --> 00:19:58,980
get a new theory in science it means the

452
00:20:03,919 --> 00:20:01,049
old theory was wrong and and that's not

453
00:20:07,760 --> 00:20:03,929
true and relativity is a great example

454
00:20:08,860 --> 00:20:07,770
here because general relativity

455
00:20:10,780 --> 00:20:08,870
Einstein's

456
00:20:13,090 --> 00:20:10,790
general theory of relativity is a theory

457
00:20:15,340 --> 00:20:13,100
of gravity that's why it explains things

458
00:20:17,620 --> 00:20:15,350
like black holes and so on but we

459
00:20:19,540 --> 00:20:17,630
already had a theory of gravity for a

460
00:20:20,290 --> 00:20:19,550
couple hundred years before Einstein was

461
00:20:22,299 --> 00:20:20,300
even born

462
00:20:24,310 --> 00:20:22,309
that was called Newton's theory of

463
00:20:26,830 --> 00:20:24,320

gravity and Newton's theory of gravity

464
00:20:29,020 --> 00:20:26,840
works really really well you could land

465
00:20:31,360 --> 00:20:29,030
spacecraft on the moon with it

466
00:20:33,430 --> 00:20:31,370
you can send a spacecraft past Pluto

467
00:20:34,930 --> 00:20:33,440
with it you can explain most things in

468
00:20:38,530 --> 00:20:34,940
the universe with Newton's theory of

469
00:20:40,690 --> 00:20:38,540
gravity so what's the difference but it

470
00:20:42,910 --> 00:20:40,700
turns out that there are some places

471
00:20:44,980 --> 00:20:42,920
where Newton's theory of gravity does

472
00:20:46,840 --> 00:20:44,990
not give you the right answer for

473
00:20:48,460 --> 00:20:46,850
example it does not predict your

474
00:20:50,200 --> 00:20:48,470
avocation 'el waves it doesn't give you

475
00:20:53,799 --> 00:20:50,210
the right answers for objects that are

476
00:20:55,750 --> 00:20:53,809
really really strongly super strong

477
00:20:59,140 --> 00:20:55,760
gravity like neutron stars and black

478
00:21:01,900 --> 00:20:59,150
holes but for most of the universe it

479
00:21:05,080 --> 00:21:01,910
works great so what general relativity

480
00:21:08,799 --> 00:21:05,090
did was it gave us a bigger view of

481
00:21:10,600 --> 00:21:08,809
gravity than we had with Newton and it

482
00:21:12,760 --> 00:21:10,610
gives us a different interpretation of

483
00:21:14,680 --> 00:21:12,770
gravity - Newton had this idea of

484
00:21:18,060 --> 00:21:14,690
gravity as being kind of this magical

485
00:21:21,850 --> 00:21:18,070
force acting between two objects whereas

486
00:21:24,010 --> 00:21:21,860
Einstein says no it's got to do with the

487
00:21:25,480 --> 00:21:24,020
curvature of space-time and that's

488
00:21:27,940 --> 00:21:25,490

actually why you have to have

489
00:21:29,890 --> 00:21:27,950
gravitational waves when space-time

490
00:21:32,230 --> 00:21:29,900
changes its shape in order to propagate

491
00:21:34,299 --> 00:21:32,240
that information outward so we have a

492
00:21:36,610 --> 00:21:34,309
different idea about gravity because of

493
00:21:39,130 --> 00:21:36,620
relativity but Newton's theory was

494
00:21:41,830 --> 00:21:39,140
correct because you can't make all its

495
00:21:44,919 --> 00:21:41,840
successes go away so now you come back

496
00:21:47,860 --> 00:21:44,929
to the Big Bang well we see this

497
00:21:51,190 --> 00:21:47,870
leftover radiation from the Big Bang we

498
00:21:54,580 --> 00:21:51,200
have all kinds of other experimental and

499
00:21:58,030 --> 00:21:54,590
observational data that fit with the Big

500
00:22:00,460 --> 00:21:58,040
Bang Theory all of that stuff those are

501
00:22:03,160 --> 00:22:00,470
observed and experimental facts you

502
00:22:05,740 --> 00:22:03,170
can't make them go away it's always

503
00:22:07,930 --> 00:22:05,750
possible that in the future we'll have

504
00:22:09,610 --> 00:22:07,940
some different theory that will give us

505
00:22:12,310 --> 00:22:09,620
a different interpretation of this

506
00:22:13,750 --> 00:22:12,320
perhaps even so different that we might

507
00:22:15,430 --> 00:22:13,760
not think of it the same way that we

508
00:22:16,840 --> 00:22:15,440
think of the Big Bang today just like we

509
00:22:20,260 --> 00:22:16,850
don't think of gravity the same way

510
00:22:22,659 --> 00:22:20,270
Newton did but but you won't make all

511
00:22:26,379 --> 00:22:22,669
this evidence disappear yeah

512
00:22:29,859 --> 00:22:26,389
is there and it's very very solved right

513
00:22:33,279 --> 00:22:29,869

now do you think along the relativity do

514
00:22:35,200 --> 00:22:33,289
you think that it is possible I mean do

515
00:22:37,450 --> 00:22:35,210
you think it's totally impossible that

516
00:22:40,989 --> 00:22:37,460
something cannot go faster than the

517
00:22:44,220 --> 00:22:40,999
speed of light and if so what regulates

518
00:22:48,849 --> 00:22:44,230
that that is as fast as anything can go

519
00:22:53,320 --> 00:22:48,859
so the idea that things can't go faster

520
00:22:58,210 --> 00:22:53,330
than light that seems to be an

521
00:23:00,940 --> 00:22:58,220
indisputable and ungettable fact but

522
00:23:03,580 --> 00:23:00,950
there's a caveat there right which every

523
00:23:05,590 --> 00:23:03,590
science fiction fan is aware of it says

524
00:23:10,149 --> 00:23:05,600
you can't go faster than the speed of

525
00:23:12,090 --> 00:23:10,159
light through space so if you could

526
00:23:15,580 --> 00:23:12,100
somehow jump out of space into

527
00:23:19,119 --> 00:23:15,590
hyperspace whatever that is or take a

528
00:23:21,849 --> 00:23:19,129
shortcut through a wormhole you know

529
00:23:25,450 --> 00:23:21,859
there might be ways around this but that

530
00:23:29,649 --> 00:23:25,460
basic idea is fundamental and relativity

531
00:23:32,289 --> 00:23:29,659
and it's one of the key thought

532
00:23:34,299 --> 00:23:32,299
experiments that I do in my book and in

533
00:23:37,090 --> 00:23:34,309
the talk that I think you watched which

534
00:23:39,580 --> 00:23:37,100
is that what relativity tells us

535
00:23:41,169 --> 00:23:39,590
basically is that in our everyday

536
00:23:42,820 --> 00:23:41,179
there's lots of ways it's to look at

537
00:23:44,710 --> 00:23:42,830
relativity but one way to look at it is

538
00:23:48,700 --> 00:23:44,720

it tells us that in our everyday lives

539
00:23:51,729 --> 00:23:48,710
we think space is one thing and time is

540
00:23:55,330 --> 00:23:51,739
another thing mm-hmm relativity tells us

541
00:23:57,940 --> 00:23:55,340
that's not right they're actually merged

542
00:24:00,789 --> 00:23:57,950
together as this thing called space-time

543
00:24:03,249 --> 00:24:00,799
and what that means is that because we

544
00:24:05,919 --> 00:24:03,259
think of them differently we think well

545
00:24:08,049 --> 00:24:05,929
you can go as fast as you want by

546
00:24:11,019 --> 00:24:08,059
covering a certain distance in space in

547
00:24:13,659 --> 00:24:11,029
a short amount of time but relativity

548
00:24:16,210 --> 00:24:13,669
says no it's all merged together in

549
00:24:20,739 --> 00:24:16,220
space-time and the thing that's actually

550
00:24:22,690 --> 00:24:20,749
fixed is the speed of light people

551
00:24:25,330 --> 00:24:22,700
different observers will disagree about

552
00:24:27,039 --> 00:24:25,340
the amount of space between two objects

553
00:24:29,889 --> 00:24:27,049
they'll disagree about the amount of

554
00:24:32,440 --> 00:24:29,899
time between two events but everyone

555
00:24:34,060 --> 00:24:32,450
will always agree on the speed of light

556
00:24:36,220 --> 00:24:34,070
that's what relativity is built upon

557
00:24:38,379 --> 00:24:36,230
that's its foundation

558
00:24:41,710 --> 00:24:38,389
and that's an experimentally tested fact

559
00:24:43,750 --> 00:24:41,720
in fact every time you look at a

560
00:24:46,090 --> 00:24:43,760
telescope picture from the Hubble Space

561
00:24:48,399 --> 00:24:46,100
Telescope or so on you're proving that

562
00:24:51,490 --> 00:24:48,409
fact because of the light from all those

563
00:24:53,560 --> 00:24:51,500

distant objects wasn't coming to us all

564
00:24:55,810 --> 00:24:53,570
at the same speed we'd get a big blur

565
00:24:58,330 --> 00:24:55,820
instead of those nice clear images that

566
00:25:00,039 --> 00:24:58,340
we have and so we know that no matter

567
00:25:02,620 --> 00:25:00,049
how fast all those objects out there

568
00:25:04,600 --> 00:25:02,630
removing their light always comes at the

569
00:25:06,370 --> 00:25:04,610
same speed which is a kind of a weird

570
00:25:07,960 --> 00:25:06,380
idea it's not the way we think of

571
00:25:09,850 --> 00:25:07,970
objects in everyday life you know if

572
00:25:11,680 --> 00:25:09,860
you're on - in a car and you have

573
00:25:14,919 --> 00:25:11,690
another car next to you you'll say it's

574
00:25:16,690 --> 00:25:14,929
going some speed relative to you but

575
00:25:17,950 --> 00:25:16,700
somebody on the ground they'll say no

576
00:25:19,120 --> 00:25:17,960
it's going a different speed and

577
00:25:22,090 --> 00:25:19,130
somebody going the opposite direction

578
00:25:24,850 --> 00:25:22,100
I'll see it go by really fast right but

579
00:25:28,180 --> 00:25:24,860
with light we all always see it go the

580
00:25:30,460 --> 00:25:28,190
same speed and that sets up this very

581
00:25:32,560 --> 00:25:30,470
simple thought experiment that drives a

582
00:25:34,720 --> 00:25:32,570
lot of people crazy right but imagine

583
00:25:37,600 --> 00:25:34,730
I'm in a spaceship and I'm going any

584
00:25:39,100 --> 00:25:37,610
speed I want to go I have I'm not going

585
00:25:40,389 --> 00:25:39,110
to put a limit on it I'm not gonna tell

586
00:25:42,220 --> 00:25:40,399
you I'm not going faster than the speed

587
00:25:44,830 --> 00:25:42,230
of light I'm saying go as fast as I want

588
00:25:46,840 --> 00:25:44,840

well there's a light coming from my face

589
00:25:48,519 --> 00:25:46,850
right infrared light that I emit or I

590
00:25:51,610 --> 00:25:48,529
could have headlights on my spaceship

591
00:25:53,350 --> 00:25:51,620
and according to me that light has to be

592
00:25:55,120 --> 00:25:53,360
going out ahead of me at the speed of

593
00:25:58,810 --> 00:25:55,130
light because everyone sees the speed of

594
00:26:01,659 --> 00:25:58,820
light well what do you see if you're

595
00:26:03,399 --> 00:26:01,669
watching me you also see the light going

596
00:26:06,310 --> 00:26:03,409
the speed of light because everyone

597
00:26:08,250 --> 00:26:06,320
always agrees with that but you also see

598
00:26:10,570 --> 00:26:08,260
that light is going out ahead of me

599
00:26:13,960 --> 00:26:10,580
which means I'm going slower than the

600
00:26:16,330 --> 00:26:13,970
speed of light so there's nothing you

601
00:26:19,180 --> 00:26:16,340
can do to get around that any object you

602
00:26:22,330 --> 00:26:19,190
look at it cannot outrace its own light

603
00:26:24,100 --> 00:26:22,340
and therefore it's always going slower

604
00:26:26,860 --> 00:26:24,110
than the speed of light so if you so if

605
00:26:29,409 --> 00:26:26,870
you had a ship going near the speed of

606
00:26:32,399 --> 00:26:29,419
light with a headlight in front of it it

607
00:26:35,500 --> 00:26:32,409
would catch up to its it's light in

608
00:26:37,629 --> 00:26:35,510
front of it no no it would not catch up

609
00:26:39,279 --> 00:26:37,639
to it because it also has to see that's

610
00:26:41,230 --> 00:26:39,289
like going speed of light so you would

611
00:26:44,169 --> 00:26:41,240
always see the light going ahead of it

612
00:26:45,789 --> 00:26:44,179
now you if it was going let's say that

613
00:26:47,710 --> 00:26:45,799

it's going 99 percent of the speed of

614
00:26:49,360 --> 00:26:47,720
light you'd see the light going the full

615
00:26:49,900 --> 00:26:49,370
speed of light and you'd see the ship

616
00:26:52,540 --> 00:26:49,910
going

617
00:26:54,220 --> 00:26:52,550
9% so the light would gradually be

618
00:26:56,680 --> 00:26:54,230
pulling away from it but there's nothing

619
00:26:58,150 --> 00:26:56,690
you can do to actually catch its own

620
00:27:03,640 --> 00:26:58,160
light there's no way that can happen

621
00:27:06,310 --> 00:27:03,650
well now what about how come or do you

622
00:27:08,260 --> 00:27:06,320
think it will ever be figured out a

623
00:27:10,780 --> 00:27:08,270
theory of everything I know I said that

624
00:27:13,330 --> 00:27:10,790
kind of a backwards question but you get

625
00:27:16,870 --> 00:27:13,340
what I'm trying to say right yeah well

626
00:27:20,170 --> 00:27:16,880
so the history of physics has been a

627
00:27:25,050 --> 00:27:20,180
history of of unifications in a sense

628
00:27:30,070 --> 00:27:25,060
you know for example the word universe

629
00:27:32,830 --> 00:27:30,080
actually was I don't know exactly when

630
00:27:34,900 --> 00:27:32,840
it was first used but it's basically

631
00:27:37,210 --> 00:27:34,910
what Newton discovered because before

632
00:27:40,030 --> 00:27:37,220
Newton people thought that there were

633
00:27:41,710 --> 00:27:40,040
laws of nature that existed on earth and

634
00:27:44,770 --> 00:27:41,720
there were separate laws for the heaven

635
00:27:46,870 --> 00:27:44,780
for the heavens and Newton showed nope

636
00:27:48,160 --> 00:27:46,880
the same things that are keeping the

637
00:27:50,110 --> 00:27:48,170
moon in orbit of the earth and the

638
00:27:51,460 --> 00:27:50,120

heavens is the same force that's holding

639
00:27:54,940 --> 00:27:51,470
us down to the ground

640
00:27:57,250 --> 00:27:54,950
he showed that the same forces I operate

641
00:27:59,260 --> 00:27:57,260
on earth and in the heavens and that's

642
00:28:02,740 --> 00:27:59,270
why we call it a universe now because

643
00:28:05,470 --> 00:28:02,750
it's one thing right so that was kind of

644
00:28:09,460 --> 00:28:05,480
the first big unification that we

645
00:28:11,410 --> 00:28:09,470
unified the law of physics across the

646
00:28:13,180 --> 00:28:11,420
universe then later as people did

647
00:28:15,280 --> 00:28:13,190
experiments in electricity and magnetism

648
00:28:17,890 --> 00:28:15,290
people had known about electricity known

649
00:28:19,510 --> 00:28:17,900
about magnetism but in the 1800s they

650
00:28:21,280 --> 00:28:19,520
figured out that electricity and

651
00:28:23,550 --> 00:28:21,290
magnetism were different manifestations

652
00:28:24,790 --> 00:28:23,560
of the same thing that we now call

653
00:28:29,410 --> 00:28:24,800
electromagnetism

654
00:28:31,480 --> 00:28:29,420
so that was a unification Einstein in a

655
00:28:35,100 --> 00:28:31,490
sense unified space and time as

656
00:28:37,390 --> 00:28:35,110
space-time and as time has progressed

657
00:28:39,060 --> 00:28:37,400
we've learned that there's four basic

658
00:28:41,410 --> 00:28:39,070
forces in nature gravity

659
00:28:44,950 --> 00:28:41,420
electromagnetism the strong and weak

660
00:28:48,400 --> 00:28:44,960
nuclear forces as scientists suspect

661
00:28:49,960 --> 00:28:48,410
that under very high-energy conditions

662
00:28:51,490 --> 00:28:49,970
like in the early universe you would

663
00:28:53,950 --> 00:28:51,500

find that these are actually just

664
00:28:57,760 --> 00:28:53,960
different manifestations of a smaller

665
00:29:00,610 --> 00:28:57,770
number of forces so the electromagnetic

666
00:29:03,340 --> 00:29:00,620
and weak forces were actually unified in

667
00:29:05,440 --> 00:29:03,350
a theory back in the 1980s and that's

668
00:29:09,400 --> 00:29:05,450
been tested and verified with particle

669
00:29:10,990 --> 00:29:09,410
accelerators the strong force we a lot

670
00:29:13,240 --> 00:29:11,000
of scientists think they have a handle

671
00:29:15,250 --> 00:29:13,250
on how the strong forces unifies with

672
00:29:17,289 --> 00:29:15,260
those other two so if that's correct

673
00:29:20,260 --> 00:29:17,299
then we're down to two forces in the

674
00:29:21,970 --> 00:29:20,270
universe that grand unified forces they

675
00:29:24,880 --> 00:29:21,980
call it or gut force which kind of a

676
00:29:26,980 --> 00:29:24,890
weird name and gravity so the idea

677
00:29:28,930 --> 00:29:26,990
behind a theory of everything is that we

678
00:29:31,210 --> 00:29:28,940
would find a way to unify gravity with

679
00:29:34,570 --> 00:29:31,220
those other three also and then we would

680
00:29:38,140 --> 00:29:34,580
have one theory that explains all forces

681
00:29:40,600 --> 00:29:38,150
and actions in the universe so theory of

682
00:29:42,190 --> 00:29:40,610
everything is a theory of the everything

683
00:29:43,480 --> 00:29:42,200
of physics it doesn't mean you're gonna

684
00:29:45,039 --> 00:29:43,490
be able to predict everything that

685
00:29:47,409 --> 00:29:45,049
happens in the universe just means

686
00:29:48,310 --> 00:29:47,419
you'll understand the underlying science

687
00:29:50,980 --> 00:29:48,320
behind it

688
00:29:55,029 --> 00:29:50,990

I see now there's someone sent me a link

689
00:29:58,149 --> 00:29:55,039
today of Jonathan Volkl unified force

690
00:29:59,710 --> 00:29:58,159
have you ever heard of that it sounds

691
00:30:02,560 --> 00:29:59,720
vaguely familiar but I can't say I know

692
00:30:04,149 --> 00:30:02,570
what it does you know okay I didn't

693
00:30:07,899 --> 00:30:04,159
really I'm fortunate I didn't get a

694
00:30:10,870 --> 00:30:07,909
chance to look at it so I remember being

695
00:30:12,700 --> 00:30:10,880
like I think I was in I don't know high

696
00:30:16,120 --> 00:30:12,710
school at some point and the science

697
00:30:19,090 --> 00:30:16,130
teacher had us try to explain what time

698
00:30:21,970 --> 00:30:19,100
is and I think we all failed and this

699
00:30:25,720 --> 00:30:21,980
may be kind of a layman question here

700
00:30:30,970 --> 00:30:25,730
but how do the thoughts of linear time

701
00:30:33,250 --> 00:30:30,980
work with relativity um it's still there

702
00:30:35,649 --> 00:30:33,260
um and let me just back up one sec if

703
00:30:37,270 --> 00:30:35,659
your viewers listeners there haven't

704
00:30:39,130 --> 00:30:37,280
seen the movie theory of everything

705
00:30:42,220 --> 00:30:39,140
about Stephen Hawking they should

706
00:30:44,169 --> 00:30:42,230
because you know it's a very cool movie

707
00:30:45,730 --> 00:30:44,179
about him but it's also talks about what

708
00:30:47,350 --> 00:30:45,740
we mean by a theory of everything much

709
00:30:49,960 --> 00:30:47,360
like I was trying to say very briefly

710
00:30:53,830 --> 00:30:49,970
there a time so what is time well

711
00:30:56,590 --> 00:30:53,840
scientifically it is very difficult to

712
00:30:59,289 --> 00:30:56,600
define time but the simplest sort of

713
00:31:04,000 --> 00:30:59,299

normal definition we have from time is

714
00:31:07,390 --> 00:31:04,010
it's the direction in which entropy

715
00:31:09,460 --> 00:31:07,400
increases disorder increases so it's the

716
00:31:10,990 --> 00:31:09,470
ideas you know if you're familiar with

717
00:31:13,240 --> 00:31:11,000
this that's what's called the second law

718
00:31:14,799 --> 00:31:13,250
of thermodynamics the idea that disorder

719
00:31:16,960 --> 00:31:14,809
always increases what they're talking

720
00:31:19,299 --> 00:31:16,970
about is let's say you have a jaw

721
00:31:21,759 --> 00:31:19,309
and you got some smelly substance in the

722
00:31:22,469 --> 00:31:21,769
jar and it's got a lid on if you take

723
00:31:25,299 --> 00:31:22,479
the lid off

724
00:31:26,919 --> 00:31:25,309
well those molecules why were they in

725
00:31:28,269 --> 00:31:26,929
the jar they were in the jar cuz that

726
00:31:29,649 --> 00:31:28,279
was as far as they had to move around

727
00:31:32,080 --> 00:31:29,659
but they're always bouncing around

728
00:31:33,729 --> 00:31:32,090
randomly if you take the lid off

729
00:31:36,249 --> 00:31:33,739
you've now given them a lot more space

730
00:31:40,779 --> 00:31:36,259
to bounce around randomly in so they

731
00:31:43,680 --> 00:31:40,789
will now in principle they could all at

732
00:31:46,389 --> 00:31:43,690
one moment decide to be back in the jar

733
00:31:48,729 --> 00:31:46,399
but the probability if you calculate

734
00:31:52,210 --> 00:31:48,739
that out of it happening is it would

735
00:31:54,639 --> 00:31:52,220
never ever happen so the idea that the

736
00:31:57,419 --> 00:31:54,649
molecules will escape from the jar but

737
00:32:00,960 --> 00:31:57,429
won't spontaneously go back into it

738
00:32:03,789 --> 00:32:00,970

that's the direction of time oh wow

739
00:32:05,440 --> 00:32:03,799
that's so that's the the basic idea of

740
00:32:08,560 --> 00:32:05,450
times the direction that things will

741
00:32:10,599 --> 00:32:08,570
flow on their own now in relativity it

742
00:32:12,249 --> 00:32:10,609
doesn't change that what relativity

743
00:32:13,810 --> 00:32:12,259
tells us is that different people will

744
00:32:15,969 --> 00:32:13,820
amount different different observers

745
00:32:19,450 --> 00:32:15,979
will measure the amount of time between

746
00:32:21,609 --> 00:32:19,460
two events differently really well but

747
00:32:24,519 --> 00:32:21,619
it's still it's still a linear time

748
00:32:25,989 --> 00:32:24,529
uh-huh well you know like if you slip

749
00:32:27,339 --> 00:32:25,999
and fall on the ice or something like

750
00:32:29,049 --> 00:32:27,349
that you can never go back that

751
00:32:31,899 --> 00:32:29,059
billionth of a second to take that step

752
00:32:34,060 --> 00:32:31,909
back you know that's right it's forward

753
00:32:36,419 --> 00:32:34,070
moving but that that brings me to a

754
00:32:39,729 --> 00:32:36,429
question kind of out there a little bit

755
00:32:43,229 --> 00:32:39,739
do you think time travel could ever be a

756
00:32:45,310 --> 00:32:43,239
possibility and if so is it only one way

757
00:32:45,669 --> 00:32:45,320
well that's that's a really good

758
00:32:47,739 --> 00:32:45,679
question

759
00:32:49,989 --> 00:32:47,749
time travel is certainly possible into

760
00:32:54,430 --> 00:32:49,999
the future because we're doing it right

761
00:32:56,769 --> 00:32:54,440
now as we speak but the quite and you

762
00:32:58,779 --> 00:32:56,779
can to some extent you have some control

763
00:33:00,669 --> 00:32:58,789

over that in relativity if you travel

764
00:33:02,349 --> 00:33:00,679
fast enough your time will move at a

765
00:33:05,049 --> 00:33:02,359
different rate than the rate of people

766
00:33:08,229 --> 00:33:05,059
staying back on earth whether you could

767
00:33:10,289 --> 00:33:08,239
actually travel backwards in time is is

768
00:33:12,999 --> 00:33:10,299
a very difficult question because

769
00:33:15,219 --> 00:33:13,009
relativity doesn't say anything about

770
00:33:17,950 --> 00:33:15,229
that in fact because it tells you that

771
00:33:20,710 --> 00:33:17,960
space and time are all intertwined and

772
00:33:22,749 --> 00:33:20,720
we can move back and forth in space it

773
00:33:25,989 --> 00:33:22,759
makes you wonder why can't you do the

774
00:33:28,869 --> 00:33:25,999
same thing in time and so people have

775
00:33:30,820 --> 00:33:28,879
been investigating that question no one

776
00:33:33,190 --> 00:33:30,830
knows the answer to it

777
00:33:35,289 --> 00:33:33,200
Stephen Hawking has a favor famous

778
00:33:37,779 --> 00:33:35,299
saying that he doesn't believe that time

779
00:33:41,860 --> 00:33:37,789
travel is possible because he wants to

780
00:33:46,210 --> 00:33:44,019
I remember saying a joke as a kid

781
00:33:47,889 --> 00:33:46,220
something along the lines like time

782
00:33:53,470 --> 00:33:47,899
travel will never happen because we

783
00:33:56,560 --> 00:33:53,480
don't see anyone from the future so just

784
00:33:58,690 --> 00:33:56,570
I want to skip back to black hole just

785
00:34:00,820 --> 00:33:58,700
for once black holes just for one second

786
00:34:02,519 --> 00:34:00,830
and then we'll go back into more of

787
00:34:06,240 --> 00:34:02,529
relativity

788
00:34:08,589 --> 00:34:06,250

first of all do all galaxies all

789
00:34:13,270 --> 00:34:08,599
galaxies that we know of have a black

790
00:34:16,089 --> 00:34:13,280
hole in the center we think yes although

791
00:34:18,460 --> 00:34:16,099
it's not a hundred percent sure but it

792
00:34:20,409 --> 00:34:18,470
most all the galaxies that we've looked

793
00:34:23,440 --> 00:34:20,419
at and been able to check they do seem

794
00:34:24,550 --> 00:34:23,450
to have supermassive black holes in

795
00:34:27,490 --> 00:34:24,560
their centers now there's a little

796
00:34:28,869 --> 00:34:27,500
caveat on that which is there are a lot

797
00:34:30,940 --> 00:34:28,879
of things out there that are kind of

798
00:34:33,460 --> 00:34:30,950
like really tiny galaxies and it's not

799
00:34:35,859 --> 00:34:33,470
clear whether they have black holes in

800
00:34:37,869 --> 00:34:35,869
their centers or not but for big

801
00:34:39,579 --> 00:34:37,879
ordinary galaxy the Milky Way type

802
00:34:41,649 --> 00:34:39,589
galaxies they all seem to have a

803
00:34:43,990 --> 00:34:41,659
supermassive black hole down in their

804
00:34:46,320 --> 00:34:44,000
centers and it's thought that these

805
00:34:49,030 --> 00:34:46,330
actually play an important role in

806
00:34:51,040 --> 00:34:49,040
regulating the rate at which galaxies

807
00:34:53,260 --> 00:34:51,050
can form stars because as they're eating

808
00:34:57,400 --> 00:34:53,270
this material and generating all this

809
00:35:01,240 --> 00:34:57,410
energy and spewing out this radiation it

810
00:35:02,680 --> 00:35:01,250
has effects on the entire galaxy and so

811
00:35:05,980 --> 00:35:02,690
there are some correlations that have

812
00:35:07,810 --> 00:35:05,990
been seen that's pretty strongly

813
00:35:10,120 --> 00:35:07,820

indicate that somehow we don't

814
00:35:12,040 --> 00:35:10,130
understand exactly how but what's going

815
00:35:15,490 --> 00:35:12,050
on down in the middle by that black hole

816
00:35:17,650 --> 00:35:15,500
is affecting things out of great

817
00:35:19,570 --> 00:35:17,660
distances within the galaxy in terms of

818
00:35:25,480 --> 00:35:19,580
how many stars are being born

819
00:35:28,630 --> 00:35:25,490
for example now could there ever be a

820
00:35:34,560 --> 00:35:28,640
possibility of like a rogue black hole

821
00:35:39,940 --> 00:35:34,570
wandering in space between galaxies I'm

822
00:35:42,400 --> 00:35:39,950
sure there there's you know there

823
00:35:43,270 --> 00:35:42,410
there's a lot of we don't know a lot

824
00:35:45,850 --> 00:35:43,280
about

825
00:35:49,110 --> 00:35:45,860
how many black holes there are and and

826
00:35:51,400 --> 00:35:49,120
so on there have been some people who

827
00:35:53,110 --> 00:35:51,410
imagined that during the Big Bang there

828
00:35:56,020 --> 00:35:53,120
might have been lots of mini black holes

829
00:35:59,730 --> 00:35:56,030
that formed that would be out there just

830
00:36:02,140 --> 00:35:59,740
floating around in in space today and

831
00:36:04,060 --> 00:36:02,150
whether could there be one that's a

832
00:36:06,850 --> 00:36:04,070
supermassive black hole that didn't ever

833
00:36:09,340 --> 00:36:06,860
get a galaxy around it that's unlikely

834
00:36:13,140 --> 00:36:09,350
because its gravity would have attracted

835
00:36:15,100 --> 00:36:13,150
gas that was nearby and so over time it

836
00:36:17,620 --> 00:36:15,110
presumably would have some grown a

837
00:36:20,770 --> 00:36:17,630
galaxy around it from collecting this

838
00:36:23,140 --> 00:36:20,780

gas but there could be black holes

839
00:36:24,670 --> 00:36:23,150
wandering around but again it's not

840
00:36:26,710 --> 00:36:24,680
something that anybody has to ever worry

841
00:36:28,630 --> 00:36:26,720
about because just like they're the

842
00:36:30,640 --> 00:36:28,640
hardest thing to fall into by accident

843
00:36:33,190 --> 00:36:30,650
they're also the hardest thing to have

844
00:36:36,910 --> 00:36:33,200
come wandering by you by accident and we

845
00:36:38,770 --> 00:36:36,920
know there's not anywhere close to us or

846
00:36:40,840 --> 00:36:38,780
any big one close to the Milky Way

847
00:36:43,960 --> 00:36:40,850
because you would feel its gravitational

848
00:36:47,200 --> 00:36:43,970
effects from great distance well and

849
00:36:50,550 --> 00:36:47,210
speaking of gravitational effects from

850
00:36:55,420 --> 00:36:50,560
great distance I also heard you say that

851
00:36:57,310 --> 00:36:55,430
like when someone feels weightless like

852
00:36:58,180 --> 00:36:57,320
in the International Space Station or

853
00:37:00,190 --> 00:36:58,190
something like that

854
00:37:01,290 --> 00:37:00,200
they're on a freefall can you explain

855
00:37:04,390 --> 00:37:01,300
what that's about

856
00:37:06,850 --> 00:37:04,400
yeah you know the Space Station is

857
00:37:08,620 --> 00:37:06,860
orbiting Earth because of gravity so

858
00:37:10,450 --> 00:37:08,630
there's plenty of gravity where the

859
00:37:12,370 --> 00:37:10,460
space station is right the moon is

860
00:37:13,690 --> 00:37:12,380
orbiting Earth because of gravity

861
00:37:15,100 --> 00:37:13,700
there's plenty of gravity out at the

862
00:37:18,310 --> 00:37:15,110
moon's distance there's gravity

863
00:37:21,280 --> 00:37:18,320

everywhere so being weightless has

864
00:37:24,310 --> 00:37:21,290
nothing to do with gravity per se it has

865
00:37:25,750 --> 00:37:24,320
to do with falling so you're falling

866
00:37:27,550 --> 00:37:25,760
whenever you're falling you're

867
00:37:29,950 --> 00:37:27,560
weightless and that the simple way to

868
00:37:32,440 --> 00:37:29,960
understand it is if you're standing on a

869
00:37:34,810 --> 00:37:32,450
scale well if you're on the ground it'll

870
00:37:39,640 --> 00:37:34,820
show a weight right now take the scale

871
00:37:41,350 --> 00:37:39,650
up onto a diving board and jump off and

872
00:37:43,180 --> 00:37:41,360
have somebody push the scale off with

873
00:37:45,310 --> 00:37:43,190
you at the same time well you'll both be

874
00:37:47,260 --> 00:37:45,320
falling at the same rate Galileo showed

875
00:37:49,470 --> 00:37:47,270
us that hundreds of years ago that all

876
00:37:52,060 --> 00:37:49,480
objects fall at the same rate right and

877
00:37:54,250 --> 00:37:52,070
since the scale and you are falling it

878
00:37:55,930 --> 00:37:54,260
the same way it's not gonna read

879
00:37:58,660 --> 00:37:55,940
anything anymore

880
00:38:02,349 --> 00:37:58,670
so it'll read zero so you're weightless

881
00:38:04,660 --> 00:38:02,359
okay so you're basically saying that the

882
00:38:07,690 --> 00:38:04,670
space station is falling toward Earth

883
00:38:10,000 --> 00:38:07,700
yep that's correct Wow

884
00:38:11,920 --> 00:38:10,010
yeah so here's the earth here's the

885
00:38:13,930 --> 00:38:11,930
space station yeah the space station is

886
00:38:17,410 --> 00:38:13,940
falling it should come straight down and

887
00:38:20,650 --> 00:38:17,420
hit it why doesn't it the rotation does

888
00:38:23,170 --> 00:38:20,660

because it's also going 17,000 miles an

889
00:38:25,660 --> 00:38:23,180
hour how yeah okay so that by the time

890
00:38:28,210 --> 00:38:25,670
it falls this far look where it is yeah

891
00:38:31,500 --> 00:38:28,220
it missed if you remember the old

892
00:38:35,349 --> 00:38:31,510
Hitchhiker's Guide to the galaxy books

893
00:38:37,329 --> 00:38:35,359
by Douglas Adams he said flying is easy

894
00:38:40,630 --> 00:38:37,339
all you have to do is throw yourself at

895
00:38:42,730 --> 00:38:40,640
the ground and miss well that's what the

896
00:38:44,200 --> 00:38:42,740
space station is doing it's going fast

897
00:38:46,240 --> 00:38:44,210
enough so it even though it's always

898
00:38:48,640 --> 00:38:46,250
falling towards the ground it always

899
00:38:52,809 --> 00:38:48,650
misses because it's so going so fast and

900
00:38:54,760 --> 00:38:52,819
that's why it has to go fast to be in

901
00:38:56,529 --> 00:38:54,770
orbit if you don't go that fast

902
00:38:59,049 --> 00:38:56,539
you do fall back down and hit the ground

903
00:39:01,390 --> 00:38:59,059
so there's a certain miles per hour or

904
00:39:03,339 --> 00:39:01,400
kilometers per hour that an object has

905
00:39:05,680 --> 00:39:03,349
to go so it doesn't fall the does that

906
00:39:08,859 --> 00:39:05,690
change on the different heights of orbit

907
00:39:12,039 --> 00:39:08,869
yes the orbital velocity is dependent on

908
00:39:14,799 --> 00:39:12,049
how high you are yes so in low orbit

909
00:39:17,440 --> 00:39:14,809
like the space station it's 17,000 miles

910
00:39:22,529 --> 00:39:17,450
an hour as you go higher up it gets

911
00:39:25,599 --> 00:39:22,539
slower I see I see now I know the moon

912
00:39:27,730 --> 00:39:25,609
you know basically moves a very little

913
00:39:29,349 --> 00:39:27,740

bit doesn't it or I know that the moves

914
00:39:34,120 --> 00:39:29,359
actually going around earth at about

915
00:39:36,099 --> 00:39:34,130
3000 km/h a lot slower than the space

916
00:39:38,289 --> 00:39:36,109
station but it that's the orbital

917
00:39:40,000 --> 00:39:38,299
velocity out where the moon is and in

918
00:39:42,910 --> 00:39:40,010
fact if you got to see the solar eclipse

919
00:39:44,650 --> 00:39:42,920
this summer or heard about the solar

920
00:39:47,109 --> 00:39:44,660
eclipse this summer you know the shadow

921
00:39:50,650 --> 00:39:47,119
goes racing across the United States

922
00:39:52,539 --> 00:39:50,660
why that's the moon's orbital motion Wow

923
00:39:55,029 --> 00:39:52,549
and by the way you built an app for that

924
00:39:57,039 --> 00:39:55,039
and I had that app on my iPhone the

925
00:39:59,950 --> 00:39:57,049
totality app and it is still works

926
00:40:02,260 --> 00:39:59,960
because we have the next five total

927
00:40:04,930 --> 00:40:02,270
solar eclipses built into it as well so

928
00:40:08,019 --> 00:40:04,940
just download the totality app it's free

929
00:40:08,270 --> 00:40:08,029
and you can plan your Eclipse trip for

930
00:40:11,930 --> 00:40:08,280
one

931
00:40:15,260 --> 00:40:11,940
2024 that's also in the United States

932
00:40:17,840 --> 00:40:15,270
alright great so I have a question in

933
00:40:20,810 --> 00:40:17,850
the chat room and someone wants to know

934
00:40:24,740 --> 00:40:20,820
if you believe information can propagate

935
00:40:26,600 --> 00:40:24,750
faster than the speed of light what we

936
00:40:30,380 --> 00:40:26,610
understand about information is that it

937
00:40:33,710 --> 00:40:30,390
cannot information is also got to be

938
00:40:36,560 --> 00:40:33,720

encoded in some form either as light or

939
00:40:38,090 --> 00:40:36,570
as particles so if it's particles it's

940
00:40:40,220 --> 00:40:38,100
gonna go slower than light and if it's

941
00:40:42,920 --> 00:40:40,230
light then it's gonna go at the speed of

942
00:40:45,890 --> 00:40:42,930
light Wow interesting Wow

943
00:40:48,530 --> 00:40:45,900
you know what about you know I know

944
00:40:52,640 --> 00:40:48,540
we're getting way off topic here but

945
00:40:55,190 --> 00:40:52,650
what about on quantum physics when a

946
00:40:59,270 --> 00:40:55,200
reaction can be it doesn't matter the

947
00:41:02,420 --> 00:40:59,280
distance of the two is it is a two atoms

948
00:41:04,850 --> 00:41:02,430
or two right two subatomic particles can

949
00:41:06,980 --> 00:41:04,860
become entangled in pain and then when

950
00:41:09,190 --> 00:41:06,990
one changes the other one undergoes the

951
00:41:15,020 --> 00:41:09,200
same change no matter how far away it is

952
00:41:17,930 --> 00:41:15,030
instantly so that kind of sounds like

953
00:41:19,610 --> 00:41:17,940
it's violating relativity but it's not

954
00:41:23,060 --> 00:41:19,620
and and it kind of goes back to your

955
00:41:25,970 --> 00:41:23,070
previous question relativity doesn't

956
00:41:28,160 --> 00:41:25,980
really say that nothing can happen

957
00:41:30,530 --> 00:41:28,170
faster than the speed of light and what

958
00:41:33,530 --> 00:41:30,540
it really says is no information can be

959
00:41:36,320 --> 00:41:33,540
propagated faster than the speed of

960
00:41:38,810 --> 00:41:36,330
light so if you have a particle here and

961
00:41:40,940 --> 00:41:38,820
a particle on the moon and you this one

962
00:41:43,340 --> 00:41:40,950
undergoes a change on earth and this one

963
00:41:45,560 --> 00:41:43,350

goes undergoes the same exact change on

964
00:41:48,080 --> 00:41:45,570
the moon at the same exact time

965
00:41:51,770 --> 00:41:48,090
you would think didn't that violate

966
00:41:53,810 --> 00:41:51,780
relativity but no information was

967
00:41:56,980 --> 00:41:53,820
transferred between them because the

968
00:42:00,530 --> 00:41:56,990
only way you'll know that they both

969
00:42:01,190 --> 00:42:00,540
changed at the same time is by somebody

970
00:42:04,040 --> 00:42:01,200
on the moon

971
00:42:06,530 --> 00:42:04,050
saying hey mine just changed - mm-hmm

972
00:42:10,190 --> 00:42:06,540
that informations gonna propagate at the

973
00:42:13,100 --> 00:42:10,200
speed of light so you cannot use this to

974
00:42:15,200 --> 00:42:13,110
actually transmit any information at a

975
00:42:17,380 --> 00:42:15,210
speed faster than the speed of light and

976
00:42:20,600 --> 00:42:17,390
therefore it doesn't violate relativity

977
00:42:21,319 --> 00:42:20,610
Wow and that is such a mystery how that

978
00:42:23,660 --> 00:42:21,329
how

979
00:42:25,609 --> 00:42:23,670
works and I know there's people

980
00:42:29,359 --> 00:42:25,619
speculating

981
00:42:31,459 --> 00:42:29,369
you know multiverses and all that and

982
00:42:33,380 --> 00:42:31,469
what's your what's your thoughts on all

983
00:42:35,509 --> 00:42:33,390
that well I'm not a fan of the

984
00:42:37,339 --> 00:42:35,519
multiverse I'll say that that doesn't

985
00:42:39,910 --> 00:42:37,349
mean I don't think it might exist it

986
00:42:45,859 --> 00:42:39,920
means I'm not a fan of it if it does

987
00:42:47,749 --> 00:42:45,869
okay because the multiverse is well we

988
00:42:50,449 --> 00:42:47,759

just talked about how the universe got

989
00:42:52,339 --> 00:42:50,459
its name one thing right one ring to

990
00:42:54,140 --> 00:42:52,349
rule them all or whatever one set of

991
00:42:55,729 --> 00:42:54,150
laws for everything the multi-verse

992
00:42:58,219 --> 00:42:55,739
basically says everything that could

993
00:43:02,150 --> 00:42:58,229
ever happen and every possibility exists

994
00:43:06,559 --> 00:43:02,160
in some sense and that's just weird to

995
00:43:08,930 --> 00:43:06,569
me I like a universe I like a plot right

996
00:43:10,219 --> 00:43:08,940
I like my wife always makes fun of me

997
00:43:11,959 --> 00:43:10,229
because when we go to movies I like

998
00:43:14,209 --> 00:43:11,969
movies that have a plot with a beginning

999
00:43:16,479 --> 00:43:14,219
middle and end I'm not big on these ones

1000
00:43:21,079 --> 00:43:16,489
that you know just seem to go nowhere

1001
00:43:24,650 --> 00:43:21,089
and I like a universe the same way so

1002
00:43:27,410 --> 00:43:24,660
our universe makes sense right it's got

1003
00:43:30,439 --> 00:43:27,420
laws it has a beginning in the Big Bang

1004
00:43:31,910 --> 00:43:30,449
we can kind of predict somewhat into the

1005
00:43:33,739 --> 00:43:31,920
future although we don't know all the

1006
00:43:36,559 --> 00:43:33,749
laws of physics so we can't predict too

1007
00:43:38,120 --> 00:43:36,569
far into the future but we can get some

1008
00:43:40,390 --> 00:43:38,130
ideas about what's gonna happen in the

1009
00:43:43,069 --> 00:43:40,400
future if you open it up to a multiverse

1010
00:43:46,400 --> 00:43:43,079
you know you just opened a huge can of

1011
00:43:50,049 --> 00:43:46,410
worms it might be that that's the way it

1012
00:43:52,549 --> 00:43:50,059
is but I'm since nobody knows yet I'm

1013
00:43:53,299 --> 00:43:52,559

rooting for the theories that don't have

1014
00:43:58,400 --> 00:43:53,309
a multiverse

1015
00:44:03,349 --> 00:43:58,410
uh-huh okay now I would I would consider

1016
00:44:05,150 --> 00:44:03,359
that gravity must be the mmm the

1017
00:44:07,279 --> 00:44:05,160
foundation of everything I mean

1018
00:44:09,199 --> 00:44:07,289
everything is all about gravity how

1019
00:44:12,170 --> 00:44:09,209
everything you know the dust particles

1020
00:44:16,130 --> 00:44:12,180
of the the planets and the stars all

1021
00:44:18,109 --> 00:44:16,140
gathered together I know that without

1022
00:44:20,359 --> 00:44:18,119
any of the forces we wouldn't be here

1023
00:44:25,910 --> 00:44:20,369
but would you consider like gravity the

1024
00:44:29,059 --> 00:44:25,920
first force you know you can't really do

1025
00:44:31,370 --> 00:44:29,069
it that way basically gravity gravity

1026
00:44:33,559 --> 00:44:31,380
governs of the four forces gravity

1027
00:44:34,830 --> 00:44:33,569
governs everything that happens on large

1028
00:44:37,410 --> 00:44:34,840
scales

1029
00:44:39,930 --> 00:44:37,420
the reason is cuz the two atomic

1030
00:44:42,000 --> 00:44:39,940
subatomic force is strong and weak they

1031
00:44:44,130 --> 00:44:42,010
only act over distances the size of

1032
00:44:47,310 --> 00:44:44,140
atomic nuclei so we don't notice them in

1033
00:44:49,530 --> 00:44:47,320
our daily lives but everything that you

1034
00:44:51,120 --> 00:44:49,540
know the reason where we have bodies and

1035
00:44:53,580 --> 00:44:51,130
the reason we can breathe everything

1036
00:44:54,210 --> 00:44:53,590
that the reason the you know earth is

1037
00:44:56,610 --> 00:44:54,220
solid

1038
00:44:58,530 --> 00:44:56,620

that's all electromagnetism it's the

1039
00:45:01,080 --> 00:44:58,540
interactions between atoms that which

1040
00:45:04,350 --> 00:45:01,090
are based on charged particles electrons

1041
00:45:06,270 --> 00:45:04,360
and protons that make up the atoms but

1042
00:45:08,340 --> 00:45:06,280
there's the key there is there's

1043
00:45:11,670 --> 00:45:08,350
electrons which are negative and protons

1044
00:45:13,230 --> 00:45:11,680
which are positive so two atoms can have

1045
00:45:15,450 --> 00:45:13,240
very strong effects on each other

1046
00:45:18,510 --> 00:45:15,460
electromagnetically but if you put an

1047
00:45:20,490 --> 00:45:18,520
earth amount of atoms together overall

1048
00:45:22,140 --> 00:45:20,500
it's electrically neutral so the

1049
00:45:24,510 --> 00:45:22,150
electromagnetic force just cancels

1050
00:45:26,370 --> 00:45:24,520
itself out on very big scales so I'm

1051
00:45:27,810 --> 00:45:26,380
very big scales you're left with gravity

1052
00:45:29,910 --> 00:45:27,820
that's all there is and that's why it

1053
00:45:31,680 --> 00:45:29,920
dominates on large scales but we

1054
00:45:35,130 --> 00:45:31,690
wouldn't exist without those other

1055
00:45:37,280 --> 00:45:35,140
forces right right so in the chatroom

1056
00:45:41,390 --> 00:45:37,290
someone wants to know your thoughts or

1057
00:45:44,790 --> 00:45:41,400
possibly the solution to Fermi's paradox

1058
00:45:47,820 --> 00:45:44,800
well Fermi's paradox is is a question

1059
00:45:51,390 --> 00:45:47,830
about why we don't have clear evidence

1060
00:45:55,830 --> 00:45:51,400
of extraterrestrial civilizations yet

1061
00:45:58,200 --> 00:45:55,840
and if you watch my beyond UFOs video

1062
00:46:00,480 --> 00:45:58,210
online or read my beyond UFOs book

1063
00:46:03,890 --> 00:46:00,490

you'll know that my personal favorite

1064
00:46:06,930 --> 00:46:03,900
answer to Fermi's paradox is that

1065
00:46:09,480 --> 00:46:06,940
basically the prime directive of Star

1066
00:46:13,200 --> 00:46:09,490
Trek there's a galactic civilization out

1067
00:46:15,330 --> 00:46:13,210
there already and they just haven't told

1068
00:46:16,970 --> 00:46:15,340
us about themselves yet because they

1069
00:46:20,640 --> 00:46:16,980
don't think we're ready

1070
00:46:24,810 --> 00:46:20,650
hmm yeah yeah I could I could I could

1071
00:46:27,780 --> 00:46:24,820
agree with that actually so one more

1072
00:46:30,840 --> 00:46:27,790
thing about gravity is do you think

1073
00:46:33,540 --> 00:46:30,850
gravity is a standard throughout the

1074
00:46:38,730 --> 00:46:33,550
universe the forces of gravity are

1075
00:46:41,130 --> 00:46:38,740
standard uh we have that's that's a very

1076
00:46:42,930 --> 00:46:41,140
good question so one of them goes along

1077
00:46:45,780 --> 00:46:42,940
with that how do we know that the same

1078
00:46:46,910 --> 00:46:45,790
laws of physics are operating out in the

1079
00:46:50,089 --> 00:46:46,920
distant universe

1080
00:46:52,849 --> 00:46:50,099
as they are here and the way we know is

1081
00:46:55,670 --> 00:46:52,859
by observing so we can look at for

1082
00:46:58,250 --> 00:46:55,680
example galaxies interacting a great

1083
00:47:01,309 --> 00:46:58,260
great distance in the universe and those

1084
00:47:03,049 --> 00:47:01,319
interactions are perfectly explained by

1085
00:47:05,950 --> 00:47:03,059
the same theory of gravity that we use

1086
00:47:08,780 --> 00:47:05,960
to explain why we're here on the ground

1087
00:47:11,599 --> 00:47:08,790
so we it's not just a think we have

1088
00:47:13,910 --> 00:47:11,609

actual evidence that gravity AK operates

1089
00:47:15,230 --> 00:47:13,920
the same way throughout the universe you

1090
00:47:17,870 --> 00:47:15,240
know in a similar way when we look at

1091
00:47:19,250 --> 00:47:17,880
the light from distant objects we can

1092
00:47:20,839 --> 00:47:19,260
look at a spectrum and see these

1093
00:47:23,450 --> 00:47:20,849
spectral lines and they tell us what

1094
00:47:25,670 --> 00:47:23,460
objects are made of we see the exact

1095
00:47:28,010 --> 00:47:25,680
same chemical elements in the spectra of

1096
00:47:30,559 --> 00:47:28,020
distant objects that we see here on

1097
00:47:32,660 --> 00:47:30,569
earth that's how we know that the same

1098
00:47:37,520 --> 00:47:32,670
chemistry applies throughout the

1099
00:47:41,030 --> 00:47:37,530
universe well in this recent this recent

1100
00:47:44,319 --> 00:47:41,040
collision of stars I remember I read

1101
00:47:49,579 --> 00:47:44,329
that briefly but there was elements of

1102
00:47:51,740 --> 00:47:49,589
platinum gold etc and huh right how is

1103
00:47:54,200 --> 00:47:51,750
that detected is that through waves

1104
00:47:56,180 --> 00:47:54,210
somehow respective that's detected

1105
00:47:58,579 --> 00:47:56,190
through those spectral lines in the

1106
00:48:01,099 --> 00:47:58,589
light so every chemical element has a

1107
00:48:03,079 --> 00:48:01,109
unique set of spectral lines kind of

1108
00:48:05,240 --> 00:48:03,089
like fingerprints so when you study a

1109
00:48:07,490 --> 00:48:05,250
spectrum you can determine what the

1110
00:48:10,099 --> 00:48:07,500
object that produced that spectrum is

1111
00:48:11,750 --> 00:48:10,109
made of and one of the big mysteries and

1112
00:48:15,260 --> 00:48:11,760
another reason this discovery announced

1113
00:48:17,000 --> 00:48:15,270

today is so important where did all the

1114
00:48:19,460 --> 00:48:17,010
elements come from well the universe

1115
00:48:21,799 --> 00:48:19,470
began with hydrogen and helium and

1116
00:48:24,920 --> 00:48:21,809
that's it in terms of the elements but

1117
00:48:27,680 --> 00:48:24,930
then we know that in stars through

1118
00:48:29,839 --> 00:48:27,690
fusion hydrogen fuses into helium but

1119
00:48:32,240 --> 00:48:29,849
toward the end of a star's life helium

1120
00:48:35,450 --> 00:48:32,250
confused into carbon and oxygen and so

1121
00:48:39,349 --> 00:48:35,460
on most of the other elements that we

1122
00:48:43,660 --> 00:48:39,359
see were produced inside stars by fusion

1123
00:48:45,829 --> 00:48:43,670
now there's some heavier elements iron

1124
00:48:48,260 --> 00:48:45,839
fusion can only take you up to iron

1125
00:48:49,900 --> 00:48:48,270
beyond iron some of those heavier

1126
00:48:52,970 --> 00:48:49,910
elements we know are produced during

1127
00:48:54,770 --> 00:48:52,980
supernova explosions themselves but

1128
00:48:57,950 --> 00:48:54,780
there were a set of elements including

1129
00:49:00,060 --> 00:48:57,960
silver gold platinum that no one really

1130
00:49:03,030 --> 00:49:00,070
had a really good idea of the origin

1131
00:49:05,250 --> 00:49:03,040
of except that some people had done the

1132
00:49:06,960 --> 00:49:05,260
calculations and built models that said

1133
00:49:09,300 --> 00:49:06,970
they should come from neutron star

1134
00:49:11,700 --> 00:49:09,310
mergers so what we've gotten today is

1135
00:49:14,610 --> 00:49:11,710
confirmation of that these neutron star

1136
00:49:17,820 --> 00:49:14,620
mergers produce these elements that

1137
00:49:19,410 --> 00:49:17,830
previously we weren't really sure where

1138
00:49:22,320 --> 00:49:19,420

they came from so you know if you have a

1139
00:49:24,210 --> 00:49:22,330
gold wedding ring like I do here that

1140
00:49:25,680 --> 00:49:24,220
was produced by a neutron star merger

1141
00:49:29,180 --> 00:49:25,690
it's kind of an amazing thought

1142
00:49:33,060 --> 00:49:29,190
Wow amazing it is and so how does that

1143
00:49:36,090 --> 00:49:33,070
gather in while it's floating out in

1144
00:49:38,400 --> 00:49:36,100
space is it I get it again does it form

1145
00:49:41,340 --> 00:49:38,410
you know a planet in a star and stuff

1146
00:49:44,640 --> 00:49:41,350
like that and then just get embedded yep

1147
00:49:46,650 --> 00:49:44,650
so galaxies I like to think of galaxies

1148
00:49:49,890 --> 00:49:46,660
like our Milky Way galaxy is cosmic

1149
00:49:51,930 --> 00:49:49,900
recycling plants so when stars die they

1150
00:49:54,360 --> 00:49:51,940
explode and they spew out all this

1151
00:49:56,250 --> 00:49:54,370
material if they were just out floating

1152
00:49:58,260 --> 00:49:56,260
around and space by themselves that

1153
00:49:58,830 --> 00:49:58,270
material would just fly out never to be

1154
00:50:02,040 --> 00:49:58,840
seen again

1155
00:50:04,110 --> 00:50:02,050
right but because they're in a galaxy in

1156
00:50:06,480 --> 00:50:04,120
the galaxy as a whole has very strong

1157
00:50:10,110 --> 00:50:06,490
gravity that material flies out for a

1158
00:50:12,030 --> 00:50:10,120
while but then it gets collected back

1159
00:50:13,920 --> 00:50:12,040
and mixes in with the rest of the

1160
00:50:15,960 --> 00:50:13,930
material that's still floating around in

1161
00:50:18,060 --> 00:50:15,970
that galaxy so the same thing with this

1162
00:50:20,220 --> 00:50:18,070
neutron star merger it blows out this

1163
00:50:22,920 --> 00:50:20,230

gold but it doesn't escape to the

1164
00:50:25,500 --> 00:50:22,930
distant universe it's contained within

1165
00:50:28,470 --> 00:50:25,510
the galaxies by the galaxies gravity and

1166
00:50:30,600 --> 00:50:28,480
over time gravity and we're localized

1167
00:50:32,820 --> 00:50:30,610
regions will form new stars that will

1168
00:50:35,490 --> 00:50:32,830
collect the gas together form new stars

1169
00:50:38,010 --> 00:50:35,500
and planets and so these later

1170
00:50:39,930 --> 00:50:38,020
generations of stars and planets will

1171
00:50:42,960 --> 00:50:39,940
have all the material that was spewed

1172
00:50:45,230 --> 00:50:42,970
out from stars that died before they

1173
00:50:47,310 --> 00:50:45,240
formed so our solar system for example

1174
00:50:49,320 --> 00:50:47,320
formed about four-and-a-half billion

1175
00:50:51,990 --> 00:50:49,330
years ago the universe is about 14

1176
00:50:54,060 --> 00:50:52,000
billion years old so that means stars

1177
00:50:55,530 --> 00:50:54,070
were living and dying and spewing out

1178
00:50:58,200 --> 00:50:55,540
all these elements for almost ten

1179
00:51:00,030 --> 00:50:58,210
billion years before our solar system

1180
00:51:02,310 --> 00:51:00,040
was even born and that's how those

1181
00:51:04,080 --> 00:51:02,320
elements got here Wow amazing

1182
00:51:07,530 --> 00:51:04,090
so now I'd like to just a couple

1183
00:51:09,090 --> 00:51:07,540
questions about Einstein if he was never

1184
00:51:11,160 --> 00:51:09,100
born

1185
00:51:13,770 --> 00:51:11,170
do you think we would eventually stumble

1186
00:51:18,420 --> 00:51:13,780
on relativity

1187
00:51:20,160 --> 00:51:18,430
or or not yes you know when when you ask

1188
00:51:22,050 --> 00:51:20,170

this question of historians what they'll

1189
00:51:23,580 --> 00:51:22,060
usually tell you remember relativity he

1190
00:51:27,120 --> 00:51:23,590
published in two parts special

1191
00:51:30,000 --> 00:51:27,130
relativity in 1905 general relativity in

1192
00:51:32,040 --> 00:51:30,010
1915 the difference being that special

1193
00:51:36,570 --> 00:51:32,050
relativity does not deal with gravity

1194
00:51:39,270 --> 00:51:36,580
and general relativity does and special

1195
00:51:41,820 --> 00:51:39,280
relativity it turns out even though

1196
00:51:45,210 --> 00:51:41,830
Einstein discovered it and published it

1197
00:51:47,040 --> 00:51:45,220
in 1905 if you even look at the name of

1198
00:51:48,540 --> 00:51:47,050
his the paper that he wrote on it what

1199
00:51:52,020 --> 00:51:48,550
he one of the things he realized is

1200
00:51:53,820 --> 00:51:52,030
actually was already embedded in the

1201
00:51:55,890 --> 00:51:53,830
equations of electromagnetism that

1202
00:51:59,070 --> 00:51:55,900
Maxwell had discovered forty years

1203
00:52:01,140 --> 00:51:59,080
earlier so in a way we already had

1204
00:52:03,120 --> 00:52:01,150
relativity special relativity before

1205
00:52:05,760 --> 00:52:03,130
Einstein it's just nobody realized it

1206
00:52:07,410 --> 00:52:05,770
until Einstein did and when you talk to

1207
00:52:09,540 --> 00:52:07,420
historians of science they'll say

1208
00:52:11,580 --> 00:52:09,550
Einstein wasn't the only person who was

1209
00:52:13,920 --> 00:52:11,590
on that track of going oh there's

1210
00:52:15,420 --> 00:52:13,930
something here and a lot of people think

1211
00:52:18,450 --> 00:52:15,430
in particular a guy named Poincare a

1212
00:52:21,120 --> 00:52:18,460
might well have published the very same

1213
00:52:23,820 --> 00:52:21,130

theory within six months really about

1214
00:52:26,070 --> 00:52:23,830
Stein if Einstein hadn't gotten there

1215
00:52:27,650 --> 00:52:26,080
first how about that now general

1216
00:52:30,360 --> 00:52:27,660
relativity is a little different in

1217
00:52:32,910 --> 00:52:30,370
general relativity Einstein kind of went

1218
00:52:36,060 --> 00:52:32,920
out on a limb thinking you know about

1219
00:52:38,190 --> 00:52:36,070
how the universe might work and so most

1220
00:52:41,250 --> 00:52:38,200
historians of scientists think he was

1221
00:52:42,810 --> 00:52:41,260
way ahead of everybody else that said

1222
00:52:45,450 --> 00:52:42,820
there were things that we were learning

1223
00:52:47,760 --> 00:52:45,460
that had hints of it already so I would

1224
00:52:52,200 --> 00:52:47,770
say certainly within probably twenty or

1225
00:52:53,640 --> 00:52:52,210
thirty years after 1915 someone would

1226
00:52:55,620 --> 00:52:53,650
have probably figured out general

1227
00:52:58,920 --> 00:52:55,630
relativity but he probably gave us a 20

1228
00:53:02,490 --> 00:52:58,930
to 30 year quicker head start than we

1229
00:53:04,140 --> 00:53:02,500
would have had otherwise now what what

1230
00:53:08,250 --> 00:53:04,150
would you think if Einstein was born

1231
00:53:10,740 --> 00:53:08,260
today with technology at his fingertips

1232
00:53:15,060 --> 00:53:10,750
do you think he could have advanced even

1233
00:53:16,650 --> 00:53:15,070
more into what he was discovering you

1234
00:53:18,480 --> 00:53:16,660
know that's a really tough question I

1235
00:53:20,190 --> 00:53:18,490
think if you talk to a lot of people

1236
00:53:21,900 --> 00:53:20,200
though they might think that it would

1237
00:53:23,100 --> 00:53:21,910
have prevented him from ever realizing

1238
00:53:25,800 --> 00:53:23,110

his genius because he would have been

1239
00:53:27,420 --> 00:53:25,810
too busy playing video games or or

1240
00:53:29,400 --> 00:53:27,430
something so our phone

1241
00:53:31,829 --> 00:53:29,410
it's right it's not clear whether this

1242
00:53:34,710 --> 00:53:31,839
technology is actually helping us at

1243
00:53:37,950 --> 00:53:34,720
this point on many different levels

1244
00:53:42,170 --> 00:53:37,960
right it certainly puts more information

1245
00:53:45,569 --> 00:53:42,180
at our fingertips but that information

1246
00:53:47,400 --> 00:53:45,579
had to have been first found by someone

1247
00:53:49,319 --> 00:53:47,410
else and as and of course one of the big

1248
00:53:50,940 --> 00:53:49,329
problems with all that information

1249
00:53:55,620 --> 00:53:50,950
there's a lot of fake information out

1250
00:53:57,809 --> 00:53:55,630
there too and so but there's a question

1251
00:54:00,870 --> 00:53:57,819
as to whether it's hindering our ability

1252
00:54:02,760 --> 00:54:00,880
to to progress and student's ability to

1253
00:54:04,769 --> 00:54:02,770
really realize their their full

1254
00:54:09,000 --> 00:54:04,779
potential we don't know yet maybe it'll

1255
00:54:11,849 --> 00:54:09,010
prove to be helpful maybe not so it's a

1256
00:54:15,990 --> 00:54:11,859
really tough question to to think about

1257
00:54:18,359 --> 00:54:16,000
right right and do you think there'll be

1258
00:54:23,220 --> 00:54:18,369
another Einstein

1259
00:54:25,680 --> 00:54:23,230
you know another superhuman you know

1260
00:54:28,589 --> 00:54:25,690
figure that comes along and disguise

1261
00:54:31,650 --> 00:54:28,599
it's all about discovery isn't it when

1262
00:54:34,349 --> 00:54:31,660
it comes to physics and things yeah you

1263
00:54:35,700 --> 00:54:34,359

know I think a lot of scientists and

1264
00:54:38,130 --> 00:54:35,710
historians of science would probably

1265
00:54:40,230 --> 00:54:38,140
argue that there have already been many

1266
00:54:41,579 --> 00:54:40,240
other people like Einstein you know

1267
00:54:43,430 --> 00:54:41,589
there there's geniuses throughout

1268
00:54:45,690 --> 00:54:43,440
history

1269
00:54:48,750 --> 00:54:45,700
Einstein wasn't you know like I said

1270
00:54:51,630 --> 00:54:48,760
others were on the trail of what he was

1271
00:54:54,690 --> 00:54:51,640
doing he wasn't a different type of

1272
00:54:55,859 --> 00:54:54,700
person he just had really good ways of

1273
00:54:58,769 --> 00:54:55,869
thinking about things

1274
00:55:00,690 --> 00:54:58,779
and made these discoveries but other

1275
00:55:03,089 --> 00:55:00,700
people have made great discoveries since

1276
00:55:05,880 --> 00:55:03,099
that time too I think the reason he's so

1277
00:55:08,910 --> 00:55:05,890
famous well there's two parts to it one

1278
00:55:11,220 --> 00:55:08,920
is because he was dealing with space and

1279
00:55:14,400 --> 00:55:11,230
time and you can't get away from space

1280
00:55:16,620 --> 00:55:14,410
and time right I mean that's it just

1281
00:55:18,720 --> 00:55:16,630
that's always gonna seem bigger than the

1282
00:55:20,730 --> 00:55:18,730
latest discovery in atomic physics

1283
00:55:22,799 --> 00:55:20,740
doesn't mean that the discoveries

1284
00:55:24,870 --> 00:55:22,809
weren't equal in their overall magnitude

1285
00:55:26,880 --> 00:55:24,880
in terms of their importance to our

1286
00:55:28,799 --> 00:55:26,890
understanding of nature but the space

1287
00:55:32,250 --> 00:55:28,809
and time that Einstein gots gonna seem

1288
00:55:34,650 --> 00:55:32,260

bigger right and and the other was there

1289
00:55:39,180 --> 00:55:34,660
was actually some luck involved in terms

1290
00:55:41,339 --> 00:55:39,190
of the way the media handled it they

1291
00:55:46,079 --> 00:55:41,349
were you know nobody heard of Ines

1292
00:55:49,170 --> 00:55:46,089
until after the solar eclipse of 1919

1293
00:55:51,060 --> 00:55:49,180
when one of his key predictions was was

1294
00:55:53,579 --> 00:55:51,070
verified and it became front-page news

1295
00:55:56,130 --> 00:55:53,589
and that was when all of a sudden

1296
00:55:57,839 --> 00:55:56,140
everyone heard of Einstein so he was at

1297
00:56:02,070 --> 00:55:57,849
the right time in the right place for a

1298
00:56:04,230 --> 00:56:02,080
media moment that was the curvature yes

1299
00:56:05,790 --> 00:56:04,240
a bending of starlight during the total

1300
00:56:08,820 --> 00:56:05,800
solar eclipse which was measured again

1301
00:56:11,370 --> 00:56:08,830
during this recent one oh and did you by

1302
00:56:12,570 --> 00:56:11,380
the way did you go somewhere where you

1303
00:56:14,339 --> 00:56:12,580
must have gone somewhere where you could

1304
00:56:17,040 --> 00:56:14,349
see the total eclipse yeah I was up in

1305
00:56:17,940 --> 00:56:17,050
Idaho Falls on the path of totality yep

1306
00:56:20,609 --> 00:56:17,950
Wow

1307
00:56:22,740 --> 00:56:20,619
yeah yeah you up in Maine here we didn't

1308
00:56:24,870 --> 00:56:22,750
have too much of a know you got to

1309
00:56:27,359 --> 00:56:24,880
travel for the next one that's right

1310
00:56:29,460 --> 00:56:27,369
that's right well this has been a real

1311
00:56:31,650 --> 00:56:29,470
pleasure as always Jeffrey I've always

1312
00:56:33,540 --> 00:56:31,660
enjoyed talking to you thank you very

1313
00:56:35,640 --> 00:56:33,550

much it's been a lot of fun and as I

1314
00:56:37,920 --> 00:56:35,650
said we'll have to have you back on to

1315
00:56:39,960 --> 00:56:37,930
talk about climate change that should be

1316
00:56:42,210 --> 00:56:39,970
sounds great thank you sounds great

1317
00:56:43,230 --> 00:56:42,220
thank you all right you take care you

1318
00:56:46,290 --> 00:56:43,240
too

1319
00:56:48,240 --> 00:56:46,300
all right okay everyone so that's it for

1320
00:56:52,410 --> 00:56:48,250
the show this evening I thank you so

1321
00:56:55,589 --> 00:56:52,420
much for tuning in and we'll be back I

1322
00:57:00,180 --> 00:56:55,599
think it's next week yes I believe it's

1323
00:57:04,950 --> 00:57:00,190
next week and our guest is the noted

1324
00:57:07,079 --> 00:57:04,960
author and I'm just brad Steiger and he

1325
00:57:11,040 --> 00:57:07,089
has just published four I think he's in

1326
00:57:13,020 --> 00:57:11,050
his 80s now so a real cool guy I don't

1327
00:57:14,730 --> 00:57:13,030
know how many books he's published but

1328
00:57:17,099 --> 00:57:14,740
I've been trying to get him on the show

1329
00:57:20,220 --> 00:57:17,109
for quite a while and I lucked out he

1330
00:57:23,060 --> 00:57:20,230
finally said yes so Brad Steiger will be

1331
00:57:26,849 --> 00:57:23,070
on next week so thanks everyone and

1332
00:57:29,910 --> 00:57:26,859
we'll be back next week and on some

1333
00:57:31,290 --> 00:57:29,920
Monday's not every single Monday but

1334
00:57:34,750 --> 00:57:31,300
when we do have a show it will be on