

1
00:00:00,000 --> 00:00:12,230
Joe York is from Princeton University is

2
00:00:08,130 --> 00:00:15,859
a colleague from the pair lab and

3
00:00:12,230 --> 00:00:19,260
physicist with wide-ranging interests

4
00:00:15,859 --> 00:00:21,809
and I am looking forward to seeing what

5
00:00:19,260 --> 00:00:33,299
he has to say about advanced propulsion

6
00:00:21,809 --> 00:00:35,759
and conservation laws okay well let me

7
00:00:33,299 --> 00:00:39,058
begin by talking about what this talk is

8
00:00:35,759 --> 00:00:42,839
not I'm not going to be discussing warp

9
00:00:39,058 --> 00:00:44,968
drives or any other technique for moving

10
00:00:42,840 --> 00:00:47,030
faster than light when I use space

11
00:00:44,969 --> 00:00:50,189
propulsion in the title I simply mean

12
00:00:47,030 --> 00:00:53,730
taking an object preferably a spacecraft

13
00:00:50,189 --> 00:00:55,320
and getting it to move through the three

14
00:00:53,729 --> 00:00:57,148
dimensional space that we're all

15
00:00:55,320 --> 00:01:03,270
familiar with that speeds slower than

16
00:00:57,149 --> 00:01:05,879
light so as an outline there are a

17
00:01:03,270 --> 00:01:08,760
number of systems that we know for space

18
00:01:05,879 --> 00:01:11,429
propulsion that are in use and I

19
00:01:08,760 --> 00:01:12,930
describe them as having failings because

20
00:01:11,430 --> 00:01:16,770
generally they do less than we'd like

21
00:01:12,930 --> 00:01:18,868
I'm going to discuss why some of these

22
00:01:16,769 --> 00:01:21,658
failings seem to be mandated by physical

23
00:01:18,868 --> 00:01:23,519
law some theoretical alternatives that

24
00:01:21,659 --> 00:01:25,920
may allow better propulsion systems to

25
00:01:23,519 --> 00:01:29,789
exist going to review some specific

26
00:01:25,920 --> 00:01:31,560
proposals for such systems but I ask the

27
00:01:29,790 --> 00:01:35,850
audience to remember that all of these

28
00:01:31,560 --> 00:01:41,099
specific proposals are speculative so

29

00:01:35,849 --> 00:01:43,679
let's start with the basic rocket you

30
00:01:41,099 --> 00:01:45,868
move something through space by throwing

31
00:01:43,680 --> 00:01:48,030
mass away in one direction to accelerate

32
00:01:45,868 --> 00:01:50,430
in the other direction this is all in

33
00:01:48,030 --> 00:01:54,210
accordance with Newton's third law and

34
00:01:50,430 --> 00:01:56,159
the conservation of momentum now they're

35
00:01:54,209 --> 00:01:58,530
not usually called rockets but I am

36
00:01:56,159 --> 00:02:01,200
classifying ion drives plasma drives

37
00:01:58,530 --> 00:02:03,899
even exotic speculations like an

38
00:02:01,200 --> 00:02:06,570
antimatter neutrino drive as basically

39
00:02:03,899 --> 00:02:09,868
Rockets because they all work this same

40
00:02:06,569 --> 00:02:12,180
way now if conservation of momentum

41
00:02:09,868 --> 00:02:14,459
holds the rocket is in

42
00:02:12,180 --> 00:02:16,950
fact the only possible completely

43
00:02:14,459 --> 00:02:20,759

self-contained space propulsion system

44

00:02:16,949 --> 00:02:24,328

and somewhat annoyingly all rockets

45

00:02:20,759 --> 00:02:29,908

suffer from the rocket paradox here's an

46

00:02:24,329 --> 00:02:31,549

example we've got a exhaust velocity the

47

00:02:29,908 --> 00:02:34,818

speed at which you're rejecting matter

48

00:02:31,549 --> 00:02:37,409

express plotted across the bottom here

49

00:02:34,818 --> 00:02:40,188

maxing out at the speed of light because

50

00:02:37,408 --> 00:02:43,798

you can't throw anything away any faster

51

00:02:40,188 --> 00:02:47,039

mass consumption goes down energy

52

00:02:43,799 --> 00:02:49,530

consumption goes up the more efficient

53

00:02:47,039 --> 00:02:52,108

your rocket is in terms of its use of

54

00:02:49,530 --> 00:02:58,468

mass the less efficient it is in terms

55

00:02:52,109 --> 00:03:04,379

of the use of energy in addition there

56

00:02:58,468 --> 00:03:06,358

is the rocket equation on the velocity

57

00:03:04,378 --> 00:03:10,979

at which you throw away your reaction

58
00:03:06,359 --> 00:03:13,019
mass um is pretty much a constraint on

59
00:03:10,979 --> 00:03:16,518
how much you can maneuver on what total

60
00:03:13,019 --> 00:03:19,799
change of velocity you can accomplish on

61
00:03:16,519 --> 00:03:22,799
specifically the total mass of fuel you

62
00:03:19,799 --> 00:03:24,989
need or whether you're the ratio of your

63
00:03:22,799 --> 00:03:28,469
fuels mass to the payload mass you're

64
00:03:24,989 --> 00:03:32,609
trying to move grows exponentially with

65
00:03:28,469 --> 00:03:36,530
the ratio of the Delta V the velocity

66
00:03:32,609 --> 00:03:40,069
change you want to accomplish to the

67
00:03:36,530 --> 00:03:44,598
speed at which you're rejecting the fuel

68
00:03:40,068 --> 00:03:48,839
the blue curve here is a plot of the

69
00:03:44,598 --> 00:03:52,168
rocket equation in dimensionless units

70
00:03:48,840 --> 00:03:55,579
of just the ratio of your desired

71
00:03:52,169 --> 00:04:02,340
velocity change to your exhaust speed

72
00:03:55,579 --> 00:04:03,989
these other straight lines are based on

73
00:04:02,340 --> 00:04:09,509
the chemical rockets we're building

74
00:04:03,989 --> 00:04:11,878
these days the Green Line is the minimum

75
00:04:09,508 --> 00:04:13,649
requirements for velocity change for

76
00:04:11,878 --> 00:04:19,949
planetary missions such as NASA is

77
00:04:13,650 --> 00:04:23,600
conducting right now um and the red

78
00:04:19,949 --> 00:04:25,970
horizontal line is the

79
00:04:23,600 --> 00:04:28,220
our maximum engineering capability in

80
00:04:25,970 --> 00:04:30,710
terms of how much fuel we can cram onto

81
00:04:28,220 --> 00:04:33,130
the thing in terms relative to the mass

82
00:04:30,709 --> 00:04:36,829
of the structure required to hold it on

83
00:04:33,129 --> 00:04:38,360
the fact that this intersection is below

84
00:04:36,829 --> 00:04:41,000
this intersection is what makes

85
00:04:38,360 --> 00:04:42,590
planetary missions possible and the fact

86

00:04:41,000 --> 00:04:47,959
that they're so close to each other is

87
00:04:42,589 --> 00:04:51,019
what makes them so slow and expensive so

88
00:04:47,959 --> 00:04:53,359
if conservation of energy and momentum

89
00:04:51,019 --> 00:04:55,939
forces the rocket paradox onto any

90
00:04:53,360 --> 00:04:58,009
self-contained drive what about systems

91
00:04:55,939 --> 00:05:00,079
that aren't self-contained we've seen

92
00:04:58,009 --> 00:05:02,599
allusions to some of these in previous

93
00:05:00,079 --> 00:05:04,939
talks light sales get thrust by

94
00:05:02,600 --> 00:05:08,660
reflecting radiation from an outside

95
00:05:04,939 --> 00:05:10,879
source the Bussard ramjet we sort of

96
00:05:08,660 --> 00:05:12,470
discussed as a fusion ramjet I like to

97
00:05:10,879 --> 00:05:14,449
credit the guy who seems to come up with

98
00:05:12,470 --> 00:05:17,390
the original idea you scoop up the

99
00:05:14,449 --> 00:05:19,189
ambient medium as fuel current carrying

100
00:05:17,389 --> 00:05:22,909

tethers get thrust from exploiting

101

00:05:19,189 --> 00:05:24,860

ambient magnetic fields magnetic sales

102

00:05:22,910 --> 00:05:30,280

get thrust from deflecting ambient

103

00:05:24,860 --> 00:05:32,689

plasma the ramjet may be impossible on

104

00:05:30,279 --> 00:05:35,019

collecting interstellar hydrogen is a

105

00:05:32,689 --> 00:05:37,939

hard problem in itself and getting it to

106

00:05:35,019 --> 00:05:40,490

undergo fusion on the fly is even harder

107

00:05:37,939 --> 00:05:42,410

all the other systems are dependent on

108

00:05:40,490 --> 00:05:47,420

special environments or support from

109

00:05:42,410 --> 00:05:50,439

home the core problem that makes all of

110

00:05:47,420 --> 00:05:52,610

these drives unsatisfactory

111

00:05:50,439 --> 00:05:54,829

unfortunately happens to be two basic

112

00:05:52,610 --> 00:05:58,759

laws of physics conservation of energy

113

00:05:54,829 --> 00:06:01,009

and conservation of momentum now in

114

00:05:58,759 --> 00:06:03,829

relativity these are the same wall

115
00:06:01,009 --> 00:06:05,449
energy and momentum form a relativistic

116
00:06:03,829 --> 00:06:09,199
four vector and all of its components

117
00:06:05,449 --> 00:06:11,360
are conserved unfortunately you can't

118
00:06:09,199 --> 00:06:14,029
escape the problem just by rejecting

119
00:06:11,360 --> 00:06:16,699
relativity there's something called

120
00:06:14,029 --> 00:06:19,399
nethers theorem in mathematical physics

121
00:06:16,699 --> 00:06:22,370
a very long-standing result it's a

122
00:06:19,399 --> 00:06:25,250
mathematical proof that any continuous

123
00:06:22,370 --> 00:06:28,610
symmetry in a physical law leads to the

124
00:06:25,250 --> 00:06:30,319
existence of a conserved quantity the

125
00:06:28,610 --> 00:06:32,600
result of having physical laws that

126
00:06:30,319 --> 00:06:34,560
don't change over time is the total

127
00:06:32,600 --> 00:06:37,360
energy has to be conserved

128
00:06:34,560 --> 00:06:39,459
similarly momentum conservation follows

129
00:06:37,360 --> 00:06:41,230
from the fact that physical laws don't

130
00:06:39,459 --> 00:06:43,989
change when you move from one place to

131
00:06:41,230 --> 00:06:45,340
another I step from here to here the

132
00:06:43,990 --> 00:06:47,519
laws of physics are the same in both

133
00:06:45,339 --> 00:06:52,060
places therefore momentum is conserved

134
00:06:47,519 --> 00:06:56,019
according to nethers theorem but there

135
00:06:52,060 --> 00:06:59,019
is a loophole the tensor calculus used

136
00:06:56,019 --> 00:07:00,519
in general relativity satisfies the

137
00:06:59,019 --> 00:07:03,159
defining symmetries of general

138
00:07:00,519 --> 00:07:06,159
relativity automatically as a matter of

139
00:07:03,160 --> 00:07:08,680
notation the never construction becomes

140
00:07:06,160 --> 00:07:13,150
trivial it doesn't allow you to compute

141
00:07:08,680 --> 00:07:15,129
a conserved quantity um in fact energy

142
00:07:13,149 --> 00:07:18,039
and momentum conservation in general

143

00:07:15,129 --> 00:07:20,920
relativity have only been proven for

144
00:07:18,040 --> 00:07:24,730
simple special cases there is no general

145
00:07:20,920 --> 00:07:27,460
proof so the conservation laws may not

146
00:07:24,730 --> 00:07:29,290
hold for the full theory in fact when

147
00:07:27,459 --> 00:07:32,409
you're dealing with an arbitrarily

148
00:07:29,290 --> 00:07:34,840
curved space-time such as is allowed for

149
00:07:32,410 --> 00:07:36,370
the theory it becomes a little bit

150
00:07:34,839 --> 00:07:39,039
difficult to figure out what something

151
00:07:36,370 --> 00:07:43,840
like an energy density even is let alone

152
00:07:39,040 --> 00:07:46,210
whether it's conserved digressing for a

153
00:07:43,839 --> 00:07:47,949
moment for most of this talk I'm

154
00:07:46,209 --> 00:07:51,879
assuming that's both special and general

155
00:07:47,949 --> 00:07:53,680
relativity are true now there's a lot of

156
00:07:51,879 --> 00:07:57,240
evidence for this and any alternative

157
00:07:53,680 --> 00:08:00,189

theory if it is to be taken seriously

158

00:07:57,240 --> 00:08:02,079

has to match a tremendous body of

159

00:08:00,189 --> 00:08:05,639

observational evidence that confirms

160

00:08:02,079 --> 00:08:08,169

both special and general relativity

161

00:08:05,639 --> 00:08:11,129

however since there are some anti

162

00:08:08,170 --> 00:08:13,360

relativists around especially in the sse

163

00:08:11,129 --> 00:08:17,350

it seems important to consider

164

00:08:13,360 --> 00:08:19,900

alternatives at least briefly now

165

00:08:17,350 --> 00:08:24,370

general relativity is mathematically

166

00:08:19,899 --> 00:08:27,060

unique it's the only theory that that

167

00:08:24,370 --> 00:08:30,340

that satisfies the appropriate

168

00:08:27,060 --> 00:08:31,689

symmetries except for little bells and

169

00:08:30,339 --> 00:08:35,168

whistles like whether or not there's a

170

00:08:31,689 --> 00:08:37,960

cosmological constant if gr is wrong

171

00:08:35,168 --> 00:08:40,210

there's no way I should qualify that

172
00:08:37,960 --> 00:08:42,580
there's no way that I know of to avoid

173
00:08:40,210 --> 00:08:44,610
the nether construction and we're stuck

174
00:08:42,580 --> 00:08:46,970
with conservation laws that are

175
00:08:44,610 --> 00:08:50,600
technologically inconvenient

176
00:08:46,970 --> 00:08:52,819
however a non relativistic theory by

177
00:08:50,600 --> 00:08:56,180
definition admits the possibility of

178
00:08:52,818 --> 00:08:58,729
non-local interactions that propagate

179
00:08:56,179 --> 00:09:00,919
faster than light which can create the

180
00:08:58,730 --> 00:09:03,500
local appearance of not momentum non

181
00:09:00,919 --> 00:09:08,059
conservation by having reaction forces

182
00:09:03,500 --> 00:09:10,399
apply to remote objects in the most

183
00:09:08,059 --> 00:09:12,768
extreme case a non relativistic theory

184
00:09:10,399 --> 00:09:15,980
might allow instantaneous reaction with

185
00:09:12,769 --> 00:09:17,629
the entire background universe the local

186

00:09:15,980 --> 00:09:21,649
acceleration of the drive might be

187

00:09:17,629 --> 00:09:23,720
obvious but the reaction of all other

188

00:09:21,649 --> 00:09:27,139
matter everywhere would be impossible to

189

00:09:23,720 --> 00:09:31,329
measure in fact if machs principle is

190

00:09:27,139 --> 00:09:33,560
valid it doesn't really have any meaning

191

00:09:31,328 --> 00:09:36,078
machs principle which has been mentioned

192

00:09:33,559 --> 00:09:37,909
several times for people who haven't

193

00:09:36,078 --> 00:09:40,578
heard of it is simply the idea that it's

194

00:09:37,909 --> 00:09:43,399
the behavior of the matter in the

195

00:09:40,578 --> 00:09:45,948
universe as a whole that defines what is

196

00:09:43,399 --> 00:09:50,870
an accelerating or non accelerating

197

00:09:45,948 --> 00:09:53,838
frame of reference so getting back to

198

00:09:50,870 --> 00:09:55,639
relativity if general relativity is

199

00:09:53,839 --> 00:09:58,040
correct the door may be open to

200

00:09:55,639 --> 00:10:00,740
violating momentum conservation this

201
00:09:58,039 --> 00:10:03,399
would allow non rocket drives that don't

202
00:10:00,740 --> 00:10:05,720
need to thrill NASA way to accelerate

203
00:10:03,399 --> 00:10:08,149
candidates worth examining in detail

204
00:10:05,720 --> 00:10:10,939
manipulation of inertia manipulation of

205
00:10:08,149 --> 00:10:13,220
gravity and then getting someone farther

206
00:10:10,938 --> 00:10:14,688
out manipulating tachyons or violating

207
00:10:13,220 --> 00:10:16,610
the weak energy condition which is a

208
00:10:14,688 --> 00:10:21,708
rather enigmatic statement that I'll

209
00:10:16,610 --> 00:10:25,850
discuss in more detail later so one

210
00:10:21,708 --> 00:10:28,188
thing that um even a lot of physicists

211
00:10:25,850 --> 00:10:30,589
don't notice unless they've researched

212
00:10:28,188 --> 00:10:33,490
the topic there are actually three kinds

213
00:10:30,589 --> 00:10:37,009
three fundamental definitions of mass

214
00:10:33,490 --> 00:10:39,740

inertial mass that's the N in mutants

215

00:10:37,009 --> 00:10:42,139

famous F equals MA equation it's the

216

00:10:39,740 --> 00:10:44,480

resistance of an object to acceleration

217

00:10:42,139 --> 00:10:48,558

it's the original quantity that got

218

00:10:44,480 --> 00:10:50,980

called mass gravitational mass also due

219

00:10:48,558 --> 00:10:54,078

to Newton about twenty years later is

220

00:10:50,980 --> 00:10:56,569

the the both of the m's that appear in

221

00:10:54,078 --> 00:10:58,338

Newton's gravity formula it's how

222

00:10:56,568 --> 00:10:59,610

strongly an object attracts everything

223

00:10:58,339 --> 00:11:03,290

else

224

00:10:59,610 --> 00:11:06,778

energy content mass is the M in

225

00:11:03,289 --> 00:11:09,208

Einstein's e equals MC squared it's the

226

00:11:06,778 --> 00:11:11,700

total energy content of a system divided

227

00:11:09,208 --> 00:11:16,139

by the speed of light squared okay sorry

228

00:11:11,700 --> 00:11:19,709

about the typo now all three of these

229
00:11:16,139 --> 00:11:22,199
masses are exactly equivalent but nobody

230
00:11:19,708 --> 00:11:24,268
really knows why unless you simply take

231
00:11:22,200 --> 00:11:25,950
it as an assumption and we certainly

232
00:11:24,269 --> 00:11:33,690
don't have any demonstration that this

233
00:11:25,950 --> 00:11:36,390
is always true now for inertia inertial

234
00:11:33,690 --> 00:11:38,310
reaction force is the force that resists

235
00:11:36,389 --> 00:11:40,500
any attempt to accelerate an object the

236
00:11:38,309 --> 00:11:45,208
equal and opposite reaction in Newton's

237
00:11:40,500 --> 00:11:47,909
third law most physicists assume that

238
00:11:45,208 --> 00:11:49,588
inertia and inertial reaction forces are

239
00:11:47,909 --> 00:11:52,049
in 82 bass they're just part of what

240
00:11:49,589 --> 00:11:54,390
mass is it's what it means to say that

241
00:11:52,049 --> 00:11:56,429
some things I massive object however

242
00:11:54,389 --> 00:11:59,069
some physicists wonder of why these

243
00:11:56,429 --> 00:12:01,828
reaction forces exist and speculate that

244
00:11:59,070 --> 00:12:04,440
it might be somehow extrinsic rather

245
00:12:01,828 --> 00:12:06,899
than intrinsic in which case it might be

246
00:12:04,440 --> 00:12:11,610
possible to manipulate whatever external

247
00:12:06,899 --> 00:12:14,009
factors caused it ah now manipulating an

248
00:12:11,610 --> 00:12:16,680
issue in ursa automatically violates

249
00:12:14,009 --> 00:12:19,588
momentum conservation the definition of

250
00:12:16,679 --> 00:12:22,250
momentum uses the inertial mass so if

251
00:12:19,589 --> 00:12:25,649
inertial mass changes momentum changes

252
00:12:22,250 --> 00:12:27,419
however manipulating inertia can do more

253
00:12:25,649 --> 00:12:29,429
than just mess up the bookkeeping it

254
00:12:27,419 --> 00:12:37,198
allows you to construct the ultimate

255
00:12:29,429 --> 00:12:39,088
space propulsion device okay now that

256
00:12:37,198 --> 00:12:41,250
everybody's had their giggle why am i

257

00:12:39,089 --> 00:12:46,170
calling a wagon wheel the ultimate space

258
00:12:41,250 --> 00:12:48,899
propulsion device um inertial

259
00:12:46,169 --> 00:12:52,078
manipulation lets you turn a rotating

260
00:12:48,899 --> 00:12:54,448
wheel into a space Drive now every spot

261
00:12:52,078 --> 00:12:57,539
on the rim of a rotating wheel is being

262
00:12:54,448 --> 00:13:00,509
accelerated inward and exerts an outward

263
00:12:57,539 --> 00:13:03,028
reaction force normally all of these

264
00:13:00,509 --> 00:13:06,049
forces are in equilibrium even an

265
00:13:03,028 --> 00:13:09,328
unbalanced wheel just shakes as it spins

266
00:13:06,049 --> 00:13:11,409
over a full cycle there's no net average

267
00:13:09,328 --> 00:13:15,578
force it just rattles around

268
00:13:11,409 --> 00:13:18,458
fourth now suppose you can manipulate

269
00:13:15,578 --> 00:13:21,609
inertia specifically suppose you can

270
00:13:18,458 --> 00:13:23,799
manipulate inertia in one part of the

271
00:13:21,610 --> 00:13:26,139

wheel either by affecting a volume of

272

00:13:23,799 --> 00:13:28,419

space or by doing something to the

273

00:13:26,139 --> 00:13:31,318

wheels components themselves on the fly

274

00:13:28,419 --> 00:13:34,509

as they pass through the target area

275

00:13:31,318 --> 00:13:37,078

well for this example we're increasing

276

00:13:34,509 --> 00:13:40,028

inertia in this zone the ratio of

277

00:13:37,078 --> 00:13:43,059

acceleration to reaction force changes

278

00:13:40,028 --> 00:13:45,730

we have a bigger reaction force these

279

00:13:43,059 --> 00:13:49,119

are no longer in equilibrium the whole

280

00:13:45,730 --> 00:13:51,009

wheel is going to accelerate that way it

281

00:13:49,120 --> 00:13:53,470

will be pulled toward a zone where

282

00:13:51,009 --> 00:13:56,409

inertia is increased and away from the

283

00:13:53,470 --> 00:14:00,120

zone where inertia is decreased and this

284

00:13:56,409 --> 00:14:00,120

is without expelling mass without

285

00:14:00,688 --> 00:14:06,250

without any other involvement simply the

286
00:14:04,120 --> 00:14:10,269
change in inertia if you can do it this

287
00:14:06,250 --> 00:14:12,688
way we'll have this consequence now one

288
00:14:10,269 --> 00:14:15,639
candidate for inertial manipulation in

289
00:14:12,688 --> 00:14:18,338
1994 Bernie hi shoe I believe is in the

290
00:14:15,639 --> 00:14:20,289
audience Alfonso rey de and Hal put off

291
00:14:18,339 --> 00:14:23,130
published a theory that inertial

292
00:14:20,289 --> 00:14:25,719
reaction forces are a result of

293
00:14:23,129 --> 00:14:28,448
electromagnetic zero-point fluctuations

294
00:14:25,720 --> 00:14:31,000
interacting with matter now in the

295
00:14:28,448 --> 00:14:32,979
spirit of full disclosure I co-wrote a

296
00:14:31,000 --> 00:14:35,139
couple of papers with some of them a few

297
00:14:32,980 --> 00:14:38,709
years later on this theory so I'm not

298
00:14:35,139 --> 00:14:41,560
entirely unbiased but z PF can be

299
00:14:38,708 --> 00:14:43,448
manipulated and in principle this could

300
00:14:41,559 --> 00:14:45,338
change the inertia of objects within the

301
00:14:43,448 --> 00:14:50,409
manipulated volume if this theory is

302
00:14:45,339 --> 00:14:54,639
true ah now the one way we know to

303
00:14:50,409 --> 00:14:55,958
manipulate z PF reliably and it's been

304
00:14:54,639 --> 00:14:58,318
referenced before and is going to be

305
00:14:55,958 --> 00:15:01,388
referenced again is the Casimir effect

306
00:14:58,318 --> 00:15:03,338
parallel conducting plates exclude some

307
00:15:01,389 --> 00:15:05,558
of the z PF modes from the space between

308
00:15:03,339 --> 00:15:08,649
them specifically the modes that are too

309
00:15:05,558 --> 00:15:11,139
big to fit there is a reduced z PF

310
00:15:08,649 --> 00:15:15,129
inside pushes out with less force than

311
00:15:11,139 --> 00:15:16,688
the normal z p f outside pushes in so it

312
00:15:15,129 --> 00:15:18,250
looks like there's an attractive force

313
00:15:16,688 --> 00:15:20,828
pulling the plates together that gets

314

00:15:18,250 --> 00:15:21,328
stronger the closer they are because

315
00:15:20,828 --> 00:15:24,359
you're

316
00:15:21,328 --> 00:15:29,428
excluding more modes this has been

317
00:15:24,360 --> 00:15:32,220
confirmed empirically so that leads us

318
00:15:29,428 --> 00:15:35,970
to what I've labeled the high Shraddha

319
00:15:32,220 --> 00:15:38,040
put off Casimir inertial wheel if the

320
00:15:35,970 --> 00:15:40,350
cpf is the source of inertial reaction

321
00:15:38,039 --> 00:15:42,928
the reduced cpf between Casimir plates

322
00:15:40,350 --> 00:15:45,569
should reduce the inertia so you put

323
00:15:42,928 --> 00:15:48,208
plates on one side of the wheel you get

324
00:15:45,568 --> 00:15:50,368
a reduced inertial reaction force the

325
00:15:48,208 --> 00:15:53,539
wheel accelerates in the direction away

326
00:15:50,369 --> 00:15:56,610
from the side with the plates

327
00:15:53,539 --> 00:15:58,498
unfortunately the cpf change made by

328
00:15:56,610 --> 00:16:00,269

Casimir plates is in the wrong part of

329

00:15:58,499 --> 00:16:04,189

the spectrum to effect inertia very

330

00:16:00,269 --> 00:16:06,209

strongly I'm making wildly optimistic

331

00:16:04,188 --> 00:16:09,568

estimates about our precision

332

00:16:06,208 --> 00:16:11,428

engineering capabilities the best HR PC

333

00:16:09,568 --> 00:16:13,618

wheel with current technology would

334

00:16:11,428 --> 00:16:15,720

accelerate at two times ten to the minus

335

00:16:13,619 --> 00:16:20,790

twenty seventh power meters per second

336

00:16:15,720 --> 00:16:22,619

squared um that would need to operate

337

00:16:20,789 --> 00:16:24,178

for a thousand years to travel a

338

00:16:22,619 --> 00:16:26,730

distance equal to one wavelength of

339

00:16:24,178 --> 00:16:30,568

visible light this is not exactly a

340

00:16:26,730 --> 00:16:34,259

practical drive another candidate for

341

00:16:30,568 --> 00:16:35,668

inertial manipulation for brevity I will

342

00:16:34,259 --> 00:16:38,999

just be calling the Woodward effect

343
00:16:35,668 --> 00:16:41,338
since the early 1990s James Woodward has

344
00:16:38,999 --> 00:16:43,558
been publishing a theory based on machs

345
00:16:41,339 --> 00:16:46,649
principle that predicts transient

346
00:16:43,558 --> 00:16:49,379
changes in the inertia of devices of

347
00:16:46,649 --> 00:16:51,328
objects whose density is changing some

348
00:16:49,379 --> 00:16:54,600
of his papers also contain experimental

349
00:16:51,328 --> 00:16:57,118
tests of the theory his latest at least

350
00:16:54,600 --> 00:17:00,028
the latest that I found in 2010 so I

351
00:16:57,119 --> 00:17:01,980
hope it's the most recent notes that

352
00:17:00,028 --> 00:17:03,869
earlier experiments have been given

353
00:17:01,980 --> 00:17:05,699
conflicting results but the most recent

354
00:17:03,869 --> 00:17:10,199
experiments continue to support the

355
00:17:05,699 --> 00:17:13,350
theory well here's the theory in

356
00:17:10,199 --> 00:17:16,769
extremely brief form he ultimately ends

357
00:17:13,349 --> 00:17:20,698
up deriving this equation for transient

358
00:17:16,769 --> 00:17:22,859
inertial mass changes it relates the

359
00:17:20,699 --> 00:17:24,360
rate of change of energy density both

360
00:17:22,859 --> 00:17:29,009
the first derivative and the second

361
00:17:24,359 --> 00:17:31,349
derivative to a transient change in the

362
00:17:29,009 --> 00:17:34,230
inertia of an object

363
00:17:31,349 --> 00:17:35,699
the thing is from his own derivation you

364
00:17:34,230 --> 00:17:39,779
could just as well write this in terms

365
00:17:35,700 --> 00:17:44,460
of a changing mass density this inor is

366
00:17:39,779 --> 00:17:47,069
equal to ρ naught C squared so you can

367
00:17:44,460 --> 00:17:49,230
take out the C squared factors write

368
00:17:47,069 --> 00:17:52,678
things in terms of mass density and you

369
00:17:49,230 --> 00:17:56,308
get this equation which is fundamentally

370
00:17:52,679 --> 00:17:59,220
the same equation um even uses the

371

00:17:56,308 --> 00:18:01,589
Equality well no row naught C squared

372
00:17:59,220 --> 00:18:05,640
equals E naught in a couple of steps of

373
00:18:01,589 --> 00:18:08,189
his derivation now the calls woodward

374
00:18:05,640 --> 00:18:11,009
writes his equation in forms in terms of

375
00:18:08,190 --> 00:18:13,620
and changing energy density all of his

376
00:18:11,009 --> 00:18:15,538
experiments have involved charging and

377
00:18:13,619 --> 00:18:18,869
discharging capacitors to change the

378
00:18:15,538 --> 00:18:21,569
energy density um the measurements

379
00:18:18,869 --> 00:18:24,658
involve oscillating the capacitors back

380
00:18:21,569 --> 00:18:27,538
and forth in time with the charge and

381
00:18:24,659 --> 00:18:31,340
discharge to look for a net static

382
00:18:27,538 --> 00:18:34,349
thrust from the changing inertia i'm

383
00:18:31,339 --> 00:18:37,019
looking for a net thrust in this kind of

384
00:18:34,349 --> 00:18:39,480
vibrating apparatus is notoriously prone

385
00:18:37,019 --> 00:18:42,298

to experimental confounds which is

386

00:18:39,480 --> 00:18:44,220

probably why the conflicting results

387

00:18:42,298 --> 00:18:48,509

mentioned in this latest paper have come

388

00:18:44,220 --> 00:18:50,970

about his 2010 report uses a rotating

389

00:18:48,509 --> 00:18:52,829

mount but because he's cycling the

390

00:18:50,970 --> 00:18:54,630

capacitors at a much higher frequency

391

00:18:52,829 --> 00:18:57,500

than his rotation rate he's still

392

00:18:54,630 --> 00:19:00,270

looking for an oscillatory effect

393

00:18:57,500 --> 00:19:03,089

however it seems like the woodward

394

00:19:00,269 --> 00:19:06,720

effect should be ideal for the inertial

395

00:19:03,089 --> 00:19:08,579

wheel configuration because the inertial

396

00:19:06,720 --> 00:19:11,490

transient is driven by changes in mass

397

00:19:08,579 --> 00:19:13,980

density all you need to do to alter one

398

00:19:11,490 --> 00:19:18,720

section of a rolling wheel is to

399

00:19:13,980 --> 00:19:22,079

compress it ah now funny when when does

400
00:19:18,720 --> 00:19:24,600
one section of a rolling wheel get

401
00:19:22,079 --> 00:19:27,178
compressed well that happens when ground

402
00:19:24,599 --> 00:19:29,279
vehicles roll on tires we've got a

403
00:19:27,179 --> 00:19:33,179
natural experiment out there in the

404
00:19:29,279 --> 00:19:35,519
world for over a century a modern

405
00:19:33,179 --> 00:19:37,140
pneumatic tires like this one don't test

406
00:19:35,519 --> 00:19:40,558
the effect the pressure is distributed

407
00:19:37,140 --> 00:19:41,070
and there are no transients however in

408
00:19:40,558 --> 00:19:44,519
the

409
00:19:41,069 --> 00:19:47,009
whoops in the early 1900's many cars

410
00:19:44,519 --> 00:19:48,419
used solid rubber tires well at least

411
00:19:47,009 --> 00:19:52,079
some of them did there was a lot of

412
00:19:48,419 --> 00:19:54,090
experimentation in that era those do go

413
00:19:52,079 --> 00:19:56,308
through local compression cycles as the

414
00:19:54,089 --> 00:19:59,278
wheels roll creating rapid changes in

415
00:19:56,308 --> 00:20:01,798
density the Woodrow transient works out

416
00:19:59,278 --> 00:20:04,019
to be negative so the reaction force

417
00:20:01,798 --> 00:20:07,740
duced against the tire rotation is

418
00:20:04,019 --> 00:20:09,870
directed upward and so in the reference

419
00:20:07,740 --> 00:20:11,730
frame of the car that wheel spin they

420
00:20:09,869 --> 00:20:15,178
generate our initial reaction at every

421
00:20:11,730 --> 00:20:16,829
point on their ribs the road rolling by

422
00:20:15,179 --> 00:20:18,690
at a speed that matches the peeler

423
00:20:16,829 --> 00:20:21,538
rotation remember we're still using the

424
00:20:18,690 --> 00:20:23,370
cars in Urschel frame here compresses

425
00:20:21,538 --> 00:20:25,200
the contact point creating a Woodward

426
00:20:23,369 --> 00:20:26,878
inertial transient for each segment of

427
00:20:25,200 --> 00:20:29,788
the wheel as it comes into contact with

428

00:20:26,878 --> 00:20:31,648
the road this transient is large and

429
00:20:29,788 --> 00:20:35,038
negative and increases as the fourth

430
00:20:31,648 --> 00:20:36,839
power of the cars speed according to the

431
00:20:35,038 --> 00:20:38,849
Woodward's equation a typical nineteen

432
00:20:36,839 --> 00:20:40,918
hundreds of vintage car with solid tires

433
00:20:38,849 --> 00:20:42,839
should have launched itself into the air

434
00:20:40,919 --> 00:20:46,500
once it hit a speed of four miles per

435
00:20:42,839 --> 00:20:48,928
hour at best this indicates that the

436
00:20:46,500 --> 00:20:51,659
Woodward effect is weaker than the

437
00:20:48,929 --> 00:20:54,659
equation suggests which in fairness does

438
00:20:51,659 --> 00:20:57,028
correspond some of the results Woodward

439
00:20:54,659 --> 00:20:59,159
has gotten and they've loaded a smaller

440
00:20:57,028 --> 00:21:03,288
inertial transient than the equation has

441
00:20:59,159 --> 00:21:06,179
written at face value hello thank you

442
00:21:03,288 --> 00:21:08,009

another route to propellant list

443

00:21:06,179 --> 00:21:10,919
propulsion is the manipulation of

444

00:21:08,009 --> 00:21:13,980
gravity now we've seen Einsteins field

445

00:21:10,919 --> 00:21:15,778
equation for gravity before and I want

446

00:21:13,980 --> 00:21:18,659
to concentrate on the source term which

447

00:21:15,778 --> 00:21:20,638
is called $T_{\mu\nu}$ it's called the

448

00:21:18,659 --> 00:21:23,190
stress-energy tensor in addition to

449

00:21:20,638 --> 00:21:25,859
energy it contains terms for momentum

450

00:21:23,190 --> 00:21:30,659
energy and momentum flux pressure and

451

00:21:25,859 --> 00:21:33,628
shear ah now a question does pressure

452

00:21:30,659 --> 00:21:36,120
have inertia Einsteins equals MC^2

453

00:21:33,628 --> 00:21:38,038
was basically demonstration that energy

454

00:21:36,119 --> 00:21:40,888
has inertia you can write it as M equals

455

00:21:38,038 --> 00:21:43,200
a over C^2 it's not immediately

456

00:21:40,888 --> 00:21:45,599
obvious whether Einsteins proof applies

457
00:21:43,200 --> 00:21:48,720
to all terms in team you knew or only to

458
00:21:45,599 --> 00:21:50,459
the energy terms so for the moment we're

459
00:21:48,720 --> 00:21:53,490
going to assume that the pressure terms

460
00:21:50,460 --> 00:21:56,880
in team you knew don't add to inertia

461
00:21:53,490 --> 00:22:00,000
then we can decouple inertial mass from

462
00:21:56,880 --> 00:22:01,590
gravitational mass inertia internal

463
00:22:00,000 --> 00:22:03,869
pressure will make an object create a

464
00:22:01,589 --> 00:22:08,009
stronger gravitational field without

465
00:22:03,869 --> 00:22:10,589
changing its inertia now briefly

466
00:22:08,009 --> 00:22:12,329
discussing the nature of gravity force

467
00:22:10,589 --> 00:22:14,849
and acceleration in relativity in

468
00:22:12,329 --> 00:22:17,789
general relativity gravity is not a

469
00:22:14,849 --> 00:22:20,609
force gravity is space-time curvature

470
00:22:17,789 --> 00:22:22,609
that makes a free trajectory look to a

471
00:22:20,609 --> 00:22:25,049
distant observers if it's accelerating

472
00:22:22,609 --> 00:22:27,839
right now you're sitting still on earth

473
00:22:25,049 --> 00:22:31,109
the surface is forcing you to accelerate

474
00:22:27,839 --> 00:22:32,789
away from the curved space-time path

475
00:22:31,109 --> 00:22:35,729
that leads downward toward the center of

476
00:22:32,789 --> 00:22:38,159
the earth your weight is an inertial

477
00:22:35,730 --> 00:22:40,620
reaction force there's a natural

478
00:22:38,160 --> 00:22:43,440
freefall trajectory that leads downward

479
00:22:40,619 --> 00:22:45,839
there's a non-gravitational obstacle

480
00:22:43,440 --> 00:22:47,970
forcing acceleration away from that

481
00:22:45,839 --> 00:22:50,009
freefall trajectory this imposed

482
00:22:47,970 --> 00:22:54,299
acceleration and there's an inertial

483
00:22:50,009 --> 00:22:56,819
reaction which we call wait so now let's

484
00:22:54,299 --> 00:23:00,299
look at a couple of spheres in empty

485

00:22:56,819 --> 00:23:02,189
space they each have their own mass and

486
00:23:00,299 --> 00:23:05,940
we're holding them apart mechanically

487
00:23:02,190 --> 00:23:08,100
with a strut that has negligible mass

488
00:23:05,940 --> 00:23:10,220
and we're just using it to impose a non

489
00:23:08,099 --> 00:23:12,149
gravitational acceleration on the system

490
00:23:10,220 --> 00:23:14,130
specifically we're using it to hold

491
00:23:12,150 --> 00:23:16,890
these things at rest when they want to

492
00:23:14,130 --> 00:23:20,220
accelerate towards each other so the

493
00:23:16,890 --> 00:23:23,929
imposed accelerations are different

494
00:23:20,220 --> 00:23:26,700
assuming that m_1 is not the same as m_2

495
00:23:23,929 --> 00:23:30,120
but the inertial reaction force turns

496
00:23:26,700 --> 00:23:32,670
out to be the same because this in this

497
00:23:30,119 --> 00:23:36,719
acceleration is proportional to M to the

498
00:23:32,670 --> 00:23:38,789
masses m_1 you get $G m_1 m_2$ down here

499
00:23:36,720 --> 00:23:42,390

acceleration proportional to M one

500

00:23:38,789 --> 00:23:44,940

inertial mass of M_2 you've got $G m_1 m_2$

501

00:23:42,390 --> 00:23:47,009

again the inertial reaction force is

502

00:23:44,940 --> 00:23:49,200

exerted on the strut are identical

503

00:23:47,009 --> 00:23:53,759

everything's in balance nothing's going

504

00:23:49,200 --> 00:23:57,660

anywhere now let's pressurize m_1 keeping

505

00:23:53,759 --> 00:23:59,308

its mass the same by hypothesis at the

506

00:23:57,660 --> 00:24:01,200

moment the pressure won't increase m

507

00:23:59,308 --> 00:24:04,710

one's inertia but will strengthen its

508

00:24:01,200 --> 00:24:05,769

gravity now this imposed acceleration

509

00:24:04,710 --> 00:24:08,380

has become bigger

510

00:24:05,769 --> 00:24:10,359

this inertial reaction has become bigger

511

00:24:08,380 --> 00:24:12,040

this one is still the same because

512

00:24:10,359 --> 00:24:14,889

pressure does not contribute to inertia

513

00:24:12,039 --> 00:24:16,690

we're assuming the forces are out of

514
00:24:14,890 --> 00:24:21,370
balance and the whole system's going to

515
00:24:16,690 --> 00:24:23,529
accelerate unfortunately gravity is a

516
00:24:21,369 --> 00:24:25,719
weak force to begin with and it takes a

517
00:24:23,529 --> 00:24:29,079
lot of pressure to rival the

518
00:24:25,720 --> 00:24:30,910
gravitational effect of mass there's a

519
00:24:29,079 --> 00:24:33,720
factor of C squared involved the

520
00:24:30,910 --> 00:24:36,759
strongest materials available are

521
00:24:33,720 --> 00:24:38,559
currently known compressed to just short

522
00:24:36,759 --> 00:24:40,569
of their yield strength will have a

523
00:24:38,559 --> 00:24:43,629
pressure contribution to their gravity

524
00:24:40,569 --> 00:24:46,839
about 10 to the minus 11th that's 10

525
00:24:43,630 --> 00:24:48,700
parts per trillion the unbalanced

526
00:24:46,839 --> 00:24:50,470
gravity Drive at this level will

527
00:24:48,700 --> 00:24:54,370
accelerate at five times ten to the

528
00:24:50,470 --> 00:24:56,140
minus 17 meters per second uh that

529
00:24:54,369 --> 00:24:58,389
actually depends on the total mass of

530
00:24:56,140 --> 00:25:00,580
the system so I'm throwing in an

531
00:24:58,390 --> 00:25:02,080
assumption that you you don't want to

532
00:25:00,579 --> 00:25:05,710
try to build a spacecraft that weighs

533
00:25:02,079 --> 00:25:07,059
more than a few tens of tons on now

534
00:25:05,710 --> 00:25:09,400
that's 10 orders of magnitude better

535
00:25:07,059 --> 00:25:11,889
than the last one we looked at but it

536
00:25:09,400 --> 00:25:16,660
still needs to run 73 days to travel one

537
00:25:11,890 --> 00:25:18,250
millimeter ah now we've been supposing

538
00:25:16,660 --> 00:25:22,779
for a while that pressure doesn't have

539
00:25:18,250 --> 00:25:24,819
inertia but suppose it does um then the

540
00:25:22,779 --> 00:25:26,769
unbalanced gravity Drive doesn't work

541
00:25:24,819 --> 00:25:28,689
because the extra gravity source has its

542

00:25:26,769 --> 00:25:32,049
own inertia inertial mass and

543
00:25:28,690 --> 00:25:35,140
gravitational mass stay coupled but this

544
00:25:32,049 --> 00:25:38,319
uncouples inertial mass from energy

545
00:25:35,140 --> 00:25:41,140
content mass and this should sound

546
00:25:38,319 --> 00:25:43,569
familiar because it means you can change

547
00:25:41,140 --> 00:25:46,600
inertia without changing the energy

548
00:25:43,569 --> 00:25:50,049
content mass the amount of stuff if you

549
00:25:46,599 --> 00:25:52,509
will in an object a self-contained

550
00:25:50,049 --> 00:25:54,129
pressurization system won't change the

551
00:25:52,509 --> 00:25:56,619
fertile energy content but it can still

552
00:25:54,130 --> 00:25:58,990
add or remove pressure if pressure has

553
00:25:56,619 --> 00:26:01,559
inertia we can manipulate the inertia of

554
00:25:58,990 --> 00:26:05,410
objects on the rim of a rotating wheel

555
00:26:01,559 --> 00:26:08,019
now once again Joe with the best

556
00:26:05,410 --> 00:26:10,300

available materials this version of the

557

00:26:08,019 --> 00:26:13,299

inertial wheel could accelerate at

558

00:26:10,299 --> 00:26:14,329

nearly I won't recite all the zeros this

559

00:26:13,299 --> 00:26:18,139

is half

560

00:26:14,329 --> 00:26:19,699

Pro gravity on that's 11 orders of

561

00:26:18,140 --> 00:26:25,009

magnitude better than the unbalanced

562

00:26:19,700 --> 00:26:29,330

gravity Drive so one way or another it

563

00:26:25,009 --> 00:26:31,819

looks like we have a violation of

564

00:26:29,329 --> 00:26:33,639

momentum conservation if the pressure

565

00:26:31,819 --> 00:26:37,579

terms in the stress-energy tensor

566

00:26:33,640 --> 00:26:39,710

contribute to inertia then we can build

567

00:26:37,579 --> 00:26:41,808

an inertial wheel drive if they don't

568

00:26:39,710 --> 00:26:45,649

contribute to inertia we can build an

569

00:26:41,808 --> 00:26:48,288

unbalanced gravity Drive so now we'll go

570

00:26:45,648 --> 00:26:50,388

farther out into speculation for

571
00:26:48,288 --> 00:26:52,879
somewhat over 40 years physicists have

572
00:26:50,388 --> 00:26:54,648
speculated about tachyons hypothetical

573
00:26:52,880 --> 00:26:57,320
particles that always move faster than

574
00:26:54,648 --> 00:26:59,928
light there are marginally respectable

575
00:26:57,319 --> 00:27:02,408
topic in relativity and they're an

576
00:26:59,929 --> 00:27:04,548
abomination in quantum field theory

577
00:27:02,409 --> 00:27:06,889
although they are consistent with

578
00:27:04,548 --> 00:27:09,230
relativity and respect conservation laws

579
00:27:06,888 --> 00:27:11,658
their FTL movement means that like

580
00:27:09,230 --> 00:27:13,220
nonrelativistic interactions they can

581
00:27:11,659 --> 00:27:16,610
create the local appearance of non

582
00:27:13,220 --> 00:27:19,429
conservation so some properties of

583
00:27:16,609 --> 00:27:22,839
tachyons this factor square root of 1

584
00:27:19,429 --> 00:27:25,059
minus v^2 over c^2 is

585
00:27:22,839 --> 00:27:28,490
ubiquitous in relativistic

586
00:27:25,058 --> 00:27:31,700
transformations and if V is bigger than

587
00:27:28,490 --> 00:27:33,288
see it becomes an imaginary value which

588
00:27:31,700 --> 00:27:34,819
is why it's usually considered to be

589
00:27:33,288 --> 00:27:38,058
meaningless to talk about having

590
00:27:34,819 --> 00:27:41,538
something move faster than light however

591
00:27:38,058 --> 00:27:44,269
if the rest mass of an object is also in

592
00:27:41,538 --> 00:27:47,240
a generic the imaginary factors cancel

593
00:27:44,269 --> 00:27:50,120
and the mass momentum and total energy

594
00:27:47,240 --> 00:27:52,069
of such a particle become real values as

595
00:27:50,119 --> 00:27:56,089
long as it keeps moving faster than

596
00:27:52,069 --> 00:27:59,509
light fundamentally you get three kinds

597
00:27:56,089 --> 00:28:01,009
of particles we already we're made of

598
00:27:59,509 --> 00:28:05,379
particles they're sometimes called

599

00:28:01,009 --> 00:28:08,000
Parthians so we know they exist um we

600
00:28:05,380 --> 00:28:10,820
interact with massless particles all the

601
00:28:08,000 --> 00:28:12,919
time so we know that there's no barrier

602
00:28:10,819 --> 00:28:15,189
to interactions between two different

603
00:28:12,919 --> 00:28:18,460
kinds of particles on this chart

604
00:28:15,190 --> 00:28:22,039
tachyons if they exist would simply add

605
00:28:18,460 --> 00:28:24,200
another category that covers

606
00:28:22,039 --> 00:28:25,970
the remaining velocity regime we've got

607
00:28:24,200 --> 00:28:27,590
always slower than light we've got

608
00:28:25,970 --> 00:28:30,079
always moving at the speed of light

609
00:28:27,589 --> 00:28:34,579
we've got always moving faster than

610
00:28:30,079 --> 00:28:40,609
light and all of them have a real total

611
00:28:34,579 --> 00:28:43,220
energy um now both Parthians and

612
00:28:40,609 --> 00:28:46,639
tachyons gain energy and momentum as

613
00:28:43,220 --> 00:28:50,029

they approach the speed of light on now

614

00:28:46,640 --> 00:28:52,340

as they slow to rest tardy ons lose all

615

00:28:50,029 --> 00:28:54,799

of their momentum but still have a

616

00:28:52,339 --> 00:28:57,889

minimum energy there the rest mass and

617

00:28:54,799 --> 00:28:59,690

its associated energy content now moving

618

00:28:57,890 --> 00:29:03,500

close to the speed of light tachyons

619

00:28:59,690 --> 00:29:05,120

look similar but as they accelerate to

620

00:29:03,500 --> 00:29:06,890

faster and faster speeds they do

621

00:29:05,119 --> 00:29:09,799

something different it's their total

622

00:29:06,890 --> 00:29:13,460

energy that goes to zero and their

623

00:29:09,799 --> 00:29:15,589

momentum that goes to a minimum value so

624

00:29:13,460 --> 00:29:18,350

in terms of space drives a tachyon would

625

00:29:15,589 --> 00:29:20,809

be as something for nothing particle you

626

00:29:18,349 --> 00:29:22,459

can create if you can create them in the

627

00:29:20,809 --> 00:29:25,639

infinite velocity state the

628
00:29:22,460 --> 00:29:27,799
instantaneous propagation state they

629
00:29:25,640 --> 00:29:29,750
have zero energy and non zero momentum

630
00:29:27,799 --> 00:29:33,769
you can generate thrust while expending

631
00:29:29,750 --> 00:29:36,259
no energy that same zero energy state is

632
00:29:33,769 --> 00:29:38,629
why quantum theorists hate tachyons any

633
00:29:36,259 --> 00:29:41,359
theory that allows tachyonic states

634
00:29:38,630 --> 00:29:43,490
predicts an infrared catastrophe where

635
00:29:41,359 --> 00:29:46,369
infinite numbers of zero energy tachyons

636
00:29:43,490 --> 00:29:48,259
get generated the reason string

637
00:29:46,369 --> 00:29:50,419
theorists require extra spatial

638
00:29:48,259 --> 00:29:54,519
dimensions is to prevent any string

639
00:29:50,420 --> 00:29:57,140
states from being tachyons if you try to

640
00:29:54,519 --> 00:29:59,599
do string theory in just the four

641
00:29:57,140 --> 00:30:01,550
dimensions we think we know about you

642
00:29:59,599 --> 00:30:03,649
discover that the lowest energy strings

643
00:30:01,549 --> 00:30:07,819
they is a tachyon and this makes field

644
00:30:03,650 --> 00:30:09,620
theorists very very unhappy and let's go

645
00:30:07,819 --> 00:30:12,710
even farther out for a moment and

646
00:30:09,619 --> 00:30:15,559
consider negative mass the weak energy

647
00:30:12,710 --> 00:30:19,490
condition which I mentioned before is a

648
00:30:15,559 --> 00:30:21,829
feature of general relativity that does

649
00:30:19,490 --> 00:30:25,460
not follow from the field equations but

650
00:30:21,829 --> 00:30:27,769
is a constraint on what sort of values

651
00:30:25,460 --> 00:30:31,039
are allowed in the stress energy source

652
00:30:27,769 --> 00:30:33,170
term of the field equation there are

653
00:30:31,039 --> 00:30:33,619
several energy conditions and all of

654
00:30:33,170 --> 00:30:35,980
them are

655
00:30:33,619 --> 00:30:40,159
not conclusions of general relativity

656

00:30:35,980 --> 00:30:42,308
but rather expectations I'm tend to

657
00:30:40,160 --> 00:30:45,110
think of them these days as pious hopes

658
00:30:42,308 --> 00:30:48,190
about what sorts of situation are

659
00:30:45,109 --> 00:30:50,869
permitted by non gravitational physics

660
00:30:48,190 --> 00:30:53,269
the weak energy condition expressed in

661
00:30:50,869 --> 00:30:59,149
words says that energy densities can't

662
00:30:53,269 --> 00:31:02,079
be negative unfortunately it's already

663
00:30:59,150 --> 00:31:04,190
known to be false the Casimir effect

664
00:31:02,079 --> 00:31:07,909
demonstrates the existence of a negative

665
00:31:04,190 --> 00:31:10,549
energy density now it's believed though

666
00:31:07,910 --> 00:31:13,370
not proven that a suitably averaged form

667
00:31:10,549 --> 00:31:16,789
of the weak energy condition still holds

668
00:31:13,369 --> 00:31:20,719
in the Casimir effect but in in its raw

669
00:31:16,789 --> 00:31:23,000
form the the condition does not so even

670
00:31:20,720 --> 00:31:25,640

this partial and provisional violation

671

00:31:23,000 --> 00:31:30,829

prompt speculation that the principle

672

00:31:25,640 --> 00:31:32,660

simply may not be true so what if the

673

00:31:30,829 --> 00:31:35,960

weak energy condition is not a universal

674

00:31:32,660 --> 00:31:38,600

rule but a biased extrapolation from our

675

00:31:35,960 --> 00:31:40,940

limited experience then it may be

676

00:31:38,599 --> 00:31:42,709

possible to create configurations of

677

00:31:40,940 --> 00:31:45,529

matter and fields that have negative

678

00:31:42,710 --> 00:31:49,009

total energy they would therefore have

679

00:31:45,529 --> 00:31:51,170

negative mass and negative inertia an

680

00:31:49,009 --> 00:31:53,029

object with negative inertia accelerates

681

00:31:51,170 --> 00:31:58,400

in the opposite direction to an applied

682

00:31:53,029 --> 00:32:00,649

force now let's think about a spacecraft

683

00:31:58,400 --> 00:32:04,730

attached to an object of exactly equal

684

00:32:00,650 --> 00:32:07,250

negative mass if the craft now pushes

685
00:32:04,730 --> 00:32:10,250
the negative mass backwards the reaction

686
00:32:07,250 --> 00:32:12,769
will cause it to accelerate forward the

687
00:32:10,250 --> 00:32:15,109
object with negative inertia will react

688
00:32:12,769 --> 00:32:18,049
to the backward push by accelerating

689
00:32:15,109 --> 00:32:20,209
forward at the same rate no conservation

690
00:32:18,049 --> 00:32:22,369
law is violated because the total energy

691
00:32:20,210 --> 00:32:26,870
and momentum of the system remains zero

692
00:32:22,369 --> 00:32:29,808
no matter how fast it's moving now why

693
00:32:26,869 --> 00:32:31,489
this is unlikely quantum systems tend to

694
00:32:29,808 --> 00:32:34,490
decay into the lowest energy state

695
00:32:31,490 --> 00:32:36,679
available releasing energy if negative

696
00:32:34,490 --> 00:32:40,880
mass states are possible they should be

697
00:32:36,679 --> 00:32:43,130
ubiquitous but we don't observe them the

698
00:32:40,880 --> 00:32:45,350
negative energy density of the Casimir

699
00:32:43,130 --> 00:32:48,200
vacuum isn't a violation of this

700
00:32:45,349 --> 00:32:50,990
statement of non observation because it

701
00:32:48,200 --> 00:32:53,059
is only stable under boundary conditions

702
00:32:50,990 --> 00:32:54,740
that embody much higher positive energy

703
00:32:53,059 --> 00:32:59,569
densities so the system as a whole

704
00:32:54,740 --> 00:33:02,809
requires positive energy to construct so

705
00:32:59,569 --> 00:33:05,329
an overview of the theory I hope I'm on

706
00:33:02,809 --> 00:33:07,579
time here a current space propulsion

707
00:33:05,329 --> 00:33:10,039
systems have very limited capabilities

708
00:33:07,579 --> 00:33:12,559
better technology can improve this but

709
00:33:10,039 --> 00:33:15,678
any rocket type drive will be limited by

710
00:33:12,559 --> 00:33:17,450
conservation laws alternatives to the

711
00:33:15,679 --> 00:33:20,480
rocket that are also bound by these laws

712
00:33:17,450 --> 00:33:22,100
have unsatisfactory features but there

713

00:33:20,480 --> 00:33:23,870
are valid theoretical reasons for

714
00:33:22,099 --> 00:33:26,509
suspecting that these conservation laws

715
00:33:23,869 --> 00:33:31,039
may not actually hold or it may at least

716
00:33:26,509 --> 00:33:32,509
allow apparent local violations now even

717
00:33:31,039 --> 00:33:34,909
if the theories justifying these

718
00:33:32,509 --> 00:33:36,619
speculative drives are true useful

719
00:33:34,910 --> 00:33:39,710
application is out of the reach of

720
00:33:36,619 --> 00:33:41,419
current technology now I find it

721
00:33:39,710 --> 00:33:44,210
interesting that several of these drives

722
00:33:41,420 --> 00:33:46,880
can be improved just with advances in

723
00:33:44,210 --> 00:33:49,789
material science rather than more exotic

724
00:33:46,880 --> 00:33:51,679
technologies some of them may be

725
00:33:49,789 --> 00:33:54,789
testable or nearly to the point of being

726
00:33:51,679 --> 00:34:00,519
testable with space-based experiments

727
00:33:54,789 --> 00:34:00,519

and that's the end of my talk

728

00:34:04,069 --> 00:34:10,079

thank you you're only on time but we

729

00:34:06,839 --> 00:34:18,480

have a little more than five minutes for

730

00:34:10,079 --> 00:34:19,829

questions Marie just a quick question

731

00:34:18,480 --> 00:34:21,269

New York could you elaborate on the

732

00:34:19,829 --> 00:34:25,110

infrared catastrophe you'd mentioned I

733

00:34:21,269 --> 00:34:27,989

didn't catch what that was about okay

734

00:34:25,110 --> 00:34:31,260

the the infrared tasy is basically

735

00:34:27,989 --> 00:34:33,599

because there there there is a state in

736

00:34:31,260 --> 00:34:36,630

which attack a new tachyon can be

737

00:34:33,599 --> 00:34:41,009

created without any expenditure of

738

00:34:36,630 --> 00:34:43,019

energies when you study the the Fineman

739

00:34:41,010 --> 00:34:46,170

diagrams for potential tachyonic

740

00:34:43,019 --> 00:34:48,599

interactions you basically find an

741

00:34:46,170 --> 00:34:52,200

infinite cross-section for emitting

742
00:34:48,599 --> 00:34:57,029
tachyons in a certain state this this

743
00:34:52,199 --> 00:35:00,539
leads to something like a a direct

744
00:34:57,030 --> 00:35:03,570
vacuum hypothesis Square the cosmos

745
00:35:00,539 --> 00:35:05,670
should already be full of tachyons in a

746
00:35:03,570 --> 00:35:08,039
certain state of motion and of course

747
00:35:05,670 --> 00:35:11,700
because we don't actually have a good

748
00:35:08,039 --> 00:35:14,159
theory for tachyon interactions we we

749
00:35:11,699 --> 00:35:15,899
don't know what exactly that universe

750
00:35:14,159 --> 00:35:19,679
would look like but we don't think we're

751
00:35:15,900 --> 00:35:21,180
living in it oh it's called infrared

752
00:35:19,679 --> 00:35:23,879
because it involves dropping to zero

753
00:35:21,179 --> 00:35:29,339
energy it's in contrast to the genes

754
00:35:23,880 --> 00:35:32,369
ultraviolet catastrophe York I think

755
00:35:29,340 --> 00:35:34,019
that the on the solid rubber tire model

756
00:35:32,369 --> 00:35:37,259
might be recoverable so that the

757
00:35:34,019 --> 00:35:39,840
theoretical models are not disproven

758
00:35:37,260 --> 00:35:42,210
because the compression expansion of

759
00:35:39,840 --> 00:35:45,000
rubber has hysteresis that shows up as

760
00:35:42,210 --> 00:35:46,619
heat the energy gain that supposedly was

761
00:35:45,000 --> 00:35:48,750
coming from this was instantly being

762
00:35:46,619 --> 00:35:52,829
dissipated just in in the heat and the

763
00:35:48,750 --> 00:35:55,349
rolling of the of the wheels well the

764
00:35:52,829 --> 00:36:00,809
issue with the compression and expansion

765
00:35:55,349 --> 00:36:04,049
doesn't relate to energy as such but to

766
00:36:00,809 --> 00:36:06,809
the inertial transient the work done on

767
00:36:04,050 --> 00:36:10,380
the tire which is where the heat comes

768
00:36:06,809 --> 00:36:13,079
from that then has to be dissipated yes

769
00:36:10,380 --> 00:36:15,190
that's changing the energy density but

770

00:36:13,079 --> 00:36:18,159
that is many orders of magnitude

771
00:36:15,190 --> 00:36:20,050
smaller than the change in the mass

772
00:36:18,159 --> 00:36:22,539
density created by the compression of

773
00:36:20,050 --> 00:36:26,740
the rubber therefore at best that

774
00:36:22,539 --> 00:36:28,300
becomes a miniscule correction on now

775
00:36:26,739 --> 00:36:31,500
it's entirely possible that there are

776
00:36:28,300 --> 00:36:35,109
other considerations in the theory that

777
00:36:31,500 --> 00:36:37,630
avert this difficulty but as it stands

778
00:36:35,108 --> 00:36:41,289
the equation as as written seems to be

779
00:36:37,630 --> 00:36:46,838
making a very odd prediction what if

780
00:36:41,289 --> 00:36:48,519
things are not continuous what if things

781
00:36:46,838 --> 00:36:53,920
are not continuous could we be a little

782
00:36:48,519 --> 00:36:58,420
bit more specific here what if space and

783
00:36:53,920 --> 00:37:00,849
time are discrete um if space and time

784
00:36:58,420 --> 00:37:04,530

are discrete it becomes very difficult

785

00:37:00,849 --> 00:37:08,039

to understand some aspects of the

786

00:37:04,530 --> 00:37:11,800

Lawrence transforms um and of course

787

00:37:08,039 --> 00:37:14,710

general relativity itself is written in

788

00:37:11,800 --> 00:37:17,318

the form of a field equation on

789

00:37:14,710 --> 00:37:18,940

continuous quantities to construct a

790

00:37:17,318 --> 00:37:22,568

discrete version you have to make

791

00:37:18,940 --> 00:37:24,250

significant changes in the theory since

792

00:37:22,568 --> 00:37:27,460

i was working within the context of that

793

00:37:24,250 --> 00:37:30,929

theory i didn't really look into how the

794

00:37:27,460 --> 00:37:30,929

discrete alternatives would work

795

00:37:39,858 --> 00:37:44,130

Eric I can't speak with authority on

796

00:37:42,630 --> 00:37:49,470

this but I worked for a company that

797

00:37:44,130 --> 00:37:52,170

made closures for vials of injectable

798

00:37:49,469 --> 00:37:56,518

drugs and they typically were composed

799
00:37:52,170 --> 00:37:59,599
of a molded rubber stopper and a luminal

800
00:37:56,518 --> 00:38:03,629
cap that held the stopper in place and

801
00:37:59,599 --> 00:38:07,470
my colleagues in the the rubble division

802
00:38:03,630 --> 00:38:11,420
of that company insisted that rubber is

803
00:38:07,469 --> 00:38:13,858
not compressible it's like an elastic

804
00:38:11,420 --> 00:38:16,470
incompressible liquid I've never proved

805
00:38:13,858 --> 00:38:23,219
it myself but it might be something to

806
00:38:16,469 --> 00:38:26,068
consider strictly speaking there is no

807
00:38:23,219 --> 00:38:29,308
such thing as an incompressible material

808
00:38:26,068 --> 00:38:31,380
every material has a Young's modulus

809
00:38:29,309 --> 00:38:34,980
none of them has yet shown up with one

810
00:38:31,380 --> 00:38:36,568
of infinite value therefore when you

811
00:38:34,980 --> 00:38:41,639
apply pressure to things you can

812
00:38:36,568 --> 00:38:45,538
compress them to some extent one more

813
00:38:41,639 --> 00:38:47,429
question York maybe we can clarify that

814
00:38:45,539 --> 00:38:49,079
when it comes to compressing things use

815
00:38:47,429 --> 00:38:50,429
the bulk modulus and you probably want

816
00:38:49,079 --> 00:38:53,160
to compress it from all directions like

817
00:38:50,429 --> 00:38:54,449
put it in put in a pressure chamber but

818
00:38:53,159 --> 00:38:55,980
if you squeeze it in one direction it

819
00:38:54,449 --> 00:38:57,480
could squeeze out in another direction I

820
00:38:55,980 --> 00:38:59,400
think that maybe that's what he's

821
00:38:57,480 --> 00:39:01,170
referring to in which case if you push

822
00:38:59,400 --> 00:39:02,460
the tire down in one direction it could

823
00:39:01,170 --> 00:39:04,559
squeeze out in another direction without

824
00:39:02,460 --> 00:39:09,838
necessarily compressing maybe that's

825
00:39:04,559 --> 00:39:11,759
what he say um that might very well be a

826
00:39:09,838 --> 00:39:14,909
process that is happening and I would

827

00:39:11,759 --> 00:39:17,278
expect it to be happening but in a solid

828
00:39:14,909 --> 00:39:21,230
rubber tire under lateral compression

829
00:39:17,278 --> 00:39:23,940
the rubber to either side of the

830
00:39:21,230 --> 00:39:27,358
compressing Force has to be contributing

831
00:39:23,940 --> 00:39:29,700
something to holding it in place and

832
00:39:27,358 --> 00:39:32,460
creating an actual density increase or

833
00:39:29,699 --> 00:39:38,778
else it would rip free from the

834
00:39:32,460 --> 00:39:38,778
underlying wheel okay thank you very