

1  
00:00:00,000 --> 00:00:07,309  
that better okay yes is the mic law okay

2  
00:00:09,199 --> 00:00:18,509  
well this is more of a technical talk

3  
00:00:12,859 --> 00:00:22,198  
but partly inspired by the fact that UFO

4  
00:00:18,510 --> 00:00:26,039  
reports frequently discuss impressive

5  
00:00:22,199 --> 00:00:28,140  
maneuverability at with usually no

6  
00:00:26,039 --> 00:00:33,149  
indication of conventionally known

7  
00:00:28,140 --> 00:00:36,170  
drives and to cut to the chase just in

8  
00:00:33,149 --> 00:00:38,789  
case I should run out of time a

9  
00:00:36,170 --> 00:00:40,590  
sufficiently advanced technology can use

10  
00:00:38,789 --> 00:00:43,109  
antimatter annihilation to power a

11  
00:00:40,590 --> 00:00:48,570  
reaction Drive whose only exhaust is an

12  
00:00:43,109 --> 00:00:50,189  
intense beam of neutrinos this would not

13  
00:00:48,570 --> 00:00:52,980  
be visible it would be very hard to

14  
00:00:50,189 --> 00:00:56,149  
detect by any means but it is

15  
00:00:52,979 --> 00:00:59,608  
potentially a testable hypothesis from

16  
00:00:56,149 --> 00:01:02,850  
retrospective evidence that already

17  
00:00:59,609 --> 00:01:07,099  
exists um just as a note by a

18  
00:01:02,850 --> 00:01:09,950  
sufficiently advanced technology I mean

19  
00:01:07,099 --> 00:01:12,809  
something that can accomplish anything

20  
00:01:09,950 --> 00:01:15,329  
that can be no that is known to be

21  
00:01:12,810 --> 00:01:19,009  
physically possible but that does not

22  
00:01:15,329 --> 00:01:23,780  
require any new physics simply on the

23  
00:01:19,009 --> 00:01:26,609  
grounds that I felt that a hypothesis is

24  
00:01:23,780 --> 00:01:28,460  
more credible if it sticks to things

25  
00:01:26,609 --> 00:01:34,578  
that we know are possible in principle

26  
00:01:28,459 --> 00:01:37,739  
um now there has been a fair amount of

27  
00:01:34,578 --> 00:01:40,408  
discussion about theoretical space

28  
00:01:37,739 --> 00:01:43,048  
propulsion at the moment the only

29

00:01:40,409 --> 00:01:45,540  
physics we know of relevant to space

30  
00:01:43,049 --> 00:01:47,850  
propulsion involves a law of equal

31  
00:01:45,540 --> 00:01:51,240  
action and reaction the only way you can

32  
00:01:47,849 --> 00:01:53,908  
move in one direction is to throw

33  
00:01:51,239 --> 00:01:58,399  
something else reaction mass as I call

34  
00:01:53,909 --> 00:02:03,450  
it in the other direction there are some

35  
00:01:58,399 --> 00:02:06,269  
variations that basically involve

36  
00:02:03,450 --> 00:02:09,300  
getting your reaction mass from outside

37  
00:02:06,269 --> 00:02:12,120  
the vehicle but they still adhere to

38  
00:02:09,300 --> 00:02:13,469  
Newton's third law and the most powerful

39  
00:02:12,120 --> 00:02:21,090  
known reaction drive

40  
00:02:13,469 --> 00:02:22,770  
is an antimatter rocket um I I was told

41  
00:02:21,090 --> 00:02:24,990  
after i submitted my abstract that it

42  
00:02:22,770 --> 00:02:27,600  
would be good to provide a brief primer

43  
00:02:24,990 --> 00:02:30,270

on on what antimatter is to begin with

44

00:02:27,599 --> 00:02:32,759

so every type of particle making up

45

00:02:30,270 --> 00:02:37,230

normal matter has a corresponding anti

46

00:02:32,759 --> 00:02:40,639

particle um the relation between

47

00:02:37,229 --> 00:02:43,289

antimatter and normal matter is that

48

00:02:40,639 --> 00:02:46,139

every measurable property is either

49

00:02:43,289 --> 00:02:48,689

identical or exactly the opposite

50

00:02:46,139 --> 00:02:50,909

between the two mass is one of the

51

00:02:48,689 --> 00:02:53,430

identical properties antimatter

52

00:02:50,909 --> 00:02:56,430

particles have the same mass as matter

53

00:02:53,430 --> 00:02:59,610

particles electrical charge is one of

54

00:02:56,430 --> 00:03:01,650

the reversed properties the anti

55

00:02:59,610 --> 00:03:04,530

electron is also called the positron

56

00:03:01,650 --> 00:03:08,400

because it has a positive charge the

57

00:03:04,530 --> 00:03:10,080

antiproton has a negative charge when

58  
00:03:08,400 --> 00:03:14,610  
matter and antimatter meet they

59  
00:03:10,080 --> 00:03:16,290  
annihilate releasing energy and just

60  
00:03:14,610 --> 00:03:18,090  
historically the first antiparticle

61  
00:03:16,289 --> 00:03:23,099  
discovered was the anti electron or

62  
00:03:18,090 --> 00:03:26,039  
positron okay now electron-positron

63  
00:03:23,099 --> 00:03:28,739  
annihilation is nice and simple they

64  
00:03:26,039 --> 00:03:30,870  
simply meet each other and convert into

65  
00:03:28,739 --> 00:03:34,709  
a pair of gamma rays carrying all of the

66  
00:03:30,870 --> 00:03:37,530  
energy ah now in accelerators we've been

67  
00:03:34,709 --> 00:03:39,689  
studying antiprotons for decades now

68  
00:03:37,530 --> 00:03:42,599  
their annihilation is more complicated

69  
00:03:39,689 --> 00:03:44,389  
partly because a proton is a composite

70  
00:03:42,599 --> 00:03:46,530  
object made of three quarks an

71  
00:03:44,389 --> 00:03:49,439  
antiproton of course is made of three

72  
00:03:46,530 --> 00:03:51,419  
anti quarks and partly because the

73  
00:03:49,439 --> 00:03:53,430  
energy release is so much bigger that

74  
00:03:51,419 --> 00:03:55,859  
completely new particles or other

75  
00:03:53,430 --> 00:03:57,840  
particle antiparticle pairs can be

76  
00:03:55,860 --> 00:04:00,630  
created out of the energy this is a

77  
00:03:57,840 --> 00:04:02,250  
reversible process but there is no

78  
00:04:00,629 --> 00:04:03,870  
material particle lighter than the

79  
00:04:02,250 --> 00:04:07,439  
electron so there's no alternative but

80  
00:04:03,870 --> 00:04:11,849  
photons here the primary annihilation

81  
00:04:07,439 --> 00:04:14,639  
gives you a mess of unstable reaction

82  
00:04:11,849 --> 00:04:17,699  
products that ultimately are all going

83  
00:04:14,639 --> 00:04:21,199  
to decay or mutually annihilate into

84  
00:04:17,699 --> 00:04:21,199  
photons and neutrinos

85  
00:04:21,709 --> 00:04:30,470  
um the now if a single antiproton

86

00:04:26,329 --> 00:04:31,818  
annihilates inside a large nucleus most

87  
00:04:30,470 --> 00:04:33,889  
of the intermediate products are

88  
00:04:31,819 --> 00:04:35,990  
strongly act interacting maisons which

89  
00:04:33,889 --> 00:04:37,910  
are very efficient at transferring

90  
00:04:35,990 --> 00:04:40,220  
energy to the rest of the nucleus so

91  
00:04:37,910 --> 00:04:43,789  
most aside from photons most of the

92  
00:04:40,220 --> 00:04:45,710  
energy appears as thermal excitation in

93  
00:04:43,788 --> 00:04:49,639  
a nucleus that's literally been blown

94  
00:04:45,709 --> 00:04:52,219  
apart by the excess energy however if an

95  
00:04:49,639 --> 00:04:57,110  
antiproton annihilates an isolated

96  
00:04:52,220 --> 00:04:59,120  
proton the ultimate products all break

97  
00:04:57,110 --> 00:05:01,038  
down into photons and neutrinos and the

98  
00:04:59,120 --> 00:05:05,569  
neutrinos end up with the lion's share

99  
00:05:01,038 --> 00:05:08,360  
of the energy for technical reasons that

100  
00:05:05,569 --> 00:05:11,329

I can get into later on if anybody is

101

00:05:08,360 --> 00:05:13,699

really interested now for a reaction

102

00:05:11,329 --> 00:05:15,469

drive the faster you throw away your

103

00:05:13,699 --> 00:05:17,240

reaction mass the more efficient your

104

00:05:15,470 --> 00:05:19,940

drive is the more thrust you get per

105

00:05:17,240 --> 00:05:22,550

unit of fuel you're using up the

106

00:05:19,939 --> 00:05:24,620

ultimate reaction drive would have an

107

00:05:22,550 --> 00:05:27,978

exhaust velocity equal to the speed of

108

00:05:24,620 --> 00:05:29,840

light now since which essentially

109

00:05:27,978 --> 00:05:33,158

amounts to turning your fuel mass into

110

00:05:29,839 --> 00:05:35,538

radiation and beaming it out the back um

111

00:05:33,158 --> 00:05:37,699

you might think that you can do that

112

00:05:35,538 --> 00:05:39,918

with antimatter since it annihilates

113

00:05:37,699 --> 00:05:42,560

matter completely into energy except

114

00:05:39,918 --> 00:05:44,629

that the aforementioned neutrino problem

115  
00:05:42,560 --> 00:05:47,300  
the neutrinos fly off in all directions

116  
00:05:44,629 --> 00:05:50,360  
equally you can't direct them you can't

117  
00:05:47,300 --> 00:05:53,810  
manipulate them so much of the energy is

118  
00:05:50,360 --> 00:05:55,819  
lost in terms of neutrinos that a a rich

119  
00:05:53,810 --> 00:05:59,839  
mich mix antimatter rocket would

120  
00:05:55,819 --> 00:06:02,288  
actually be terribly inefficient but

121  
00:05:59,839 --> 00:06:04,158  
that assumes you're just burning the

122  
00:06:02,288 --> 00:06:09,800  
matter-antimatter mix in a reaction

123  
00:06:04,158 --> 00:06:12,168  
chamber ah the trick is to pre

124  
00:06:09,800 --> 00:06:15,680  
accelerate the particles you're going to

125  
00:06:12,168 --> 00:06:18,288  
annihilate as in a particle accelerator

126  
00:06:15,680 --> 00:06:21,168  
on earth you accelerate both the proton

127  
00:06:18,288 --> 00:06:23,990  
and the antiproton to high speed but in

128  
00:06:21,168 --> 00:06:25,758  
the same direction not ramming them into

129  
00:06:23,990 --> 00:06:29,598  
each other the way we do for experiments

130  
00:06:25,759 --> 00:06:33,259  
they annihilate in at high speed the

131  
00:06:29,598 --> 00:06:34,949  
reaction products inherit that center of

132  
00:06:33,259 --> 00:06:37,709  
mass motion

133  
00:06:34,949 --> 00:06:40,949  
and then you put in a retrieval stage

134  
00:06:37,709 --> 00:06:44,519  
the stuff that you can interact with you

135  
00:06:40,949 --> 00:06:46,649  
capture reprocess the energy use it to

136  
00:06:44,519 --> 00:06:49,589  
power the acceleration for the next

137  
00:06:46,649 --> 00:06:52,889  
particle pair meanwhile the neutrinos

138  
00:06:49,589 --> 00:06:54,959  
escape all of the momentum that has been

139  
00:06:52,889 --> 00:06:58,500  
put into them by the pre acceleration is

140  
00:06:54,959 --> 00:07:05,759  
just carried out of the chamber and you

141  
00:06:58,500 --> 00:07:08,790  
get a net thrust ah I'm going to skip

142  
00:07:05,759 --> 00:07:10,800  
quickly over the math here it we can

143

00:07:08,790 --> 00:07:15,600  
refer to it in question and answer if

144  
00:07:10,800 --> 00:07:19,970  
people really want um but this graphic

145  
00:07:15,600 --> 00:07:23,730  
illustrates the drive attributes and

146  
00:07:19,970 --> 00:07:27,780  
perhaps a more accessible way down here

147  
00:07:23,730 --> 00:07:31,640  
at the bottom I've plotted the fraction

148  
00:07:27,779 --> 00:07:33,809  
of retrievable energy the amount of

149  
00:07:31,639 --> 00:07:37,469  
annihilation energy that can be captured

150  
00:07:33,810 --> 00:07:41,100  
and used and that actually depends on

151  
00:07:37,470 --> 00:07:43,410  
how big your engine is and how much free

152  
00:07:41,100 --> 00:07:45,870  
path you have for intermediate reaction

153  
00:07:43,410 --> 00:07:48,360  
products to decay if something is still

154  
00:07:45,870 --> 00:07:51,300  
a pie on of some sort you can intercept

155  
00:07:48,360 --> 00:07:56,129  
it and use it it will decay naturally

156  
00:07:51,300 --> 00:07:58,110  
into neutrinos and photons and that

157  
00:07:56,129 --> 00:08:00,889

that's that's where those neutrinos come

158

00:07:58,110 --> 00:08:05,520

from it's a process that takes time um

159

00:08:00,889 --> 00:08:10,800

and requires a certain amount of free

160

00:08:05,519 --> 00:08:13,379

path to be completed um now fortunately

161

00:08:10,800 --> 00:08:17,340

the math on the previous page indicates

162

00:08:13,379 --> 00:08:20,750

that the higher the mass retention that

163

00:08:17,339 --> 00:08:23,669

is the fewer neutrino decays you allow

164

00:08:20,750 --> 00:08:26,160

the higher your effective exhaust

165

00:08:23,670 --> 00:08:30,900

velocity the amount of thrust you get

166

00:08:26,160 --> 00:08:32,790

per unit of fuel um that this is a good

167

00:08:30,899 --> 00:08:34,379

thing because that means that the

168

00:08:32,789 --> 00:08:38,789

smaller your engine the more powerful

169

00:08:34,379 --> 00:08:42,450

and efficient it can be um just for

170

00:08:38,789 --> 00:08:46,639

comparison a a lean mix antimatter

171

00:08:42,450 --> 00:08:48,750

rocket where you're doing simple a

172  
00:08:46,639 --> 00:08:50,669  
burning like effect

173  
00:08:48,750 --> 00:08:53,100  
and have perhaps five percent antimatter

174  
00:08:50,669 --> 00:08:56,309  
would have about this thrust to mass

175  
00:08:53,100 --> 00:08:59,550  
ratio an ideal fusion rocket would be

176  
00:08:56,309 --> 00:09:01,889  
down here an ideal fission rocket would

177  
00:08:59,549 --> 00:09:03,659  
be down here and the chemical rockets

178  
00:09:01,889 --> 00:09:05,639  
that were actually building nowadays

179  
00:09:03,659 --> 00:09:11,879  
would be so far down into the corner

180  
00:09:05,639 --> 00:09:14,580  
that there's no room for the font now

181  
00:09:11,879 --> 00:09:18,019  
what that means in terms of the

182  
00:09:14,580 --> 00:09:25,190  
performance of such a drive system if oh

183  
00:09:18,019 --> 00:09:29,759  
sorry i overshot this shaded area here

184  
00:09:25,190 --> 00:09:32,100  
shows the approximate regime for an

185  
00:09:29,759 --> 00:09:34,230  
engine of reasonable size a few meters

186  
00:09:32,100 --> 00:09:36,629  
across and you can see that our

187  
00:09:34,230 --> 00:09:38,789  
effective exhaust velocity is indeed

188  
00:09:36,629 --> 00:09:43,590  
very close to the ultimate possible

189  
00:09:38,789 --> 00:09:47,129  
limit a vehicle with a a drive of this

190  
00:09:43,590 --> 00:09:50,220  
type if it made a constant 1g thrust

191  
00:09:47,129 --> 00:09:53,429  
trip from the moon to the earth it would

192  
00:09:50,220 --> 00:09:56,190  
use up a point for two kilograms of fuel

193  
00:09:53,429 --> 00:10:01,099  
mass for each metric ton a vehicle mass

194  
00:09:56,190 --> 00:10:01,100  
that's about one pound of fuel on