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P2 2 Star Trekkin'

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Abstract

In this paper, we discuss the properties of warp travel discussed in the science fiction universe of *Star Trek*. We find a relationship for the specific energy required for selected warp speeds both relativistically and classically, and investigate the viability of using available energy sources to power the different iterations of the starship *NCC-1701 Enterprise*. We find that the Sun could support 16 million *Enterprise-Ds* each day at a modest warp factor 0.5.

Introduction

Warp travel and warp speed, is a fictitious method of travel that relies mostly on the ability to travel faster than the speed of light. The scale is based on warp 1 being the speed of light, and is described by one of several nearly identical different relationships, depending upon the *Star Trek* show you use as a baseline. The one we have chosen to use is as follows [1] [2]:

$$w = (\frac{v}{c})^{\frac{3}{10}} \tag{1}$$

Where v is velocity, c is the speed of light in a vacuum, and w defines the value for warp speed. The limit set on w is warp 10. This limit is set in-universe as the point where warp travel breaks down and the object becomes present everywhere in space.

We investigate the possibility of powering a *Star Trek* starship using the energy available on Earth and in our solar system. We focus our investigation on sublight speeds ($w < 1$) as the warp speeds that are realistically possible and constrain ourselves to only consider the effects of special relativity.

Method

Classically, the energy required in a system to have an object of mass m travel at a velocity v is given by:

$$K_{clas} = \frac{1}{2}mv^2 \tag{2}$$

As we consider speeds that approach c, we must also consider relativistic corrections. We do so using the relativistic kinetic energy:

$$K_{rel} = (\gamma - 1)mc^2 \tag{3}$$

The Lorentz factor γ [3] is defined by:

$$\gamma = \frac{1}{\sqrt{1-\beta^2}} \tag{4}$$

And β is the ratio:

$$\beta = \frac{v}{c} = w^{\frac{10}{3}} \tag{5}$$

We consider the divergence between the classical approximation and the relativistic energy, binomially expanding the relativistic expression up to the second term, and find the error σ to be:

$$\frac{K_{rel} - K_{clas}}{K_{rel}} = \frac{3\beta^2}{4} = \sigma \tag{6}$$

We choose an acceptable error of 1% and by combining equations 5 and 6 we find that the classical and relativistic expressions are in good agreement up to a warp factor of $w \approx 0.52$.

We then investigated the specific energy u that would be required as a function of warp factor. Combining equations 3 through 5, we find the specific energy to vary as a function of w:

$$u_{rel} = \left(\frac{1}{\sqrt{1 - w^{\frac{20}{3}}}} - 1 \right) c^2 \tag{7}$$

This relation was plotted to investigate the energy demands of an increasing warp factor. We then explored how the energy demands scale with mass for some fixed warp factors, making comparisons to the known masses of the various *Enterprises* of *Star Trek*.

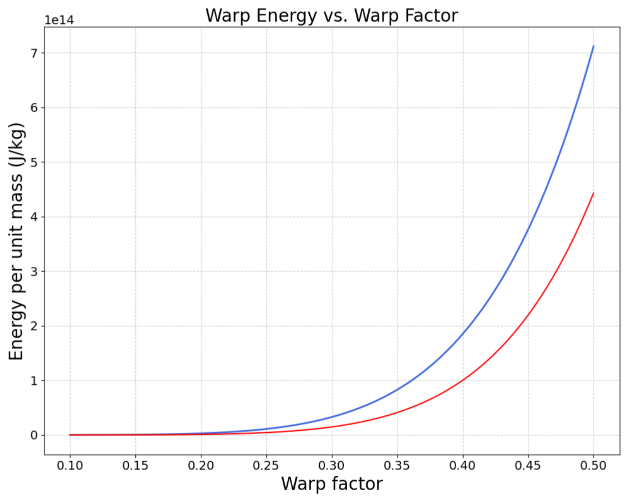

Figure 1: Relationship between warp factor w and relativistic specific energy u_{rel} in blue and classical specific energy in red. Note that the y-axis has a range of 0 to 700 TJ/kg.

Discussion & Conclusion

In Figure 1, for a test mass to travel at warp 0.5, we find that it would require an energy of 4.5×10^{24} J. In Figure 2, we see how this energy scales with increasing mass. There is an order of magnitude difference in the energy requirements of *Enterprise-A* compared to C and D at warp factor 0.5.

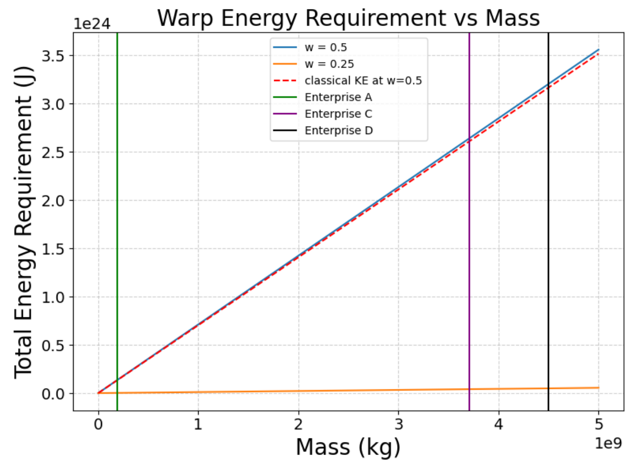

Figure 2: Relationship between kinetic energy and mass for fixed warp factors of 0.25 in orange and 0.5 in blue and dotted red. Classical and relativistic energy are plotted for warp 0.5, with classical energy being the dotted red line, and the masses of various iterations of the *Enterprise* are displayed. Note that the energy has units of order 10^{24}J and the mass has units equivalent to Tg. In green, the *Enterprise-A* has a mass of 0.19 Tg. In purple, the *Enterprise-C* has mass 3.71 Tg, and in black, the *Enterprise-D* has mass 4.5 Tg. For warp 0.25, the classical and relativistic energies show no noticeable divergence and therefore only the relativistic energy is shown.

Considering the luminosity of the Sun [4], we can calculate that 16 million *Enterprise-D* starships can be powered at warp 0.5 per day. In contrast, the estimated energy output from Earth [5] would power one thousandth of the *Enterprise-A* and one ten thousandth of the *Enterprise-D* every year.

It is important to note that we have only considered the energy of constant motion and have not factored in the energy required for life support, shields, or other auxiliary systems that the *Enterprises* are shown to have. These considerations would increase the energy required to power a given *Enterprise*, likely by multiple orders of magnitude. This model provides a reasonable estimate of the required energetics of the *Enterprise* but could be further improved by introducing concepts from general relativity and considering interactions with planetary bodies and interstellar phenomena such as cosmic dust.

References

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