On the Arbitrary Reduction of Energy in Alcubierre Warp Drive Solutions with Positive Energy in the Warped Region for Superluminal Motion

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Abstract:

Building on the article [16] where a superluminal Alcubierre propulsion system with positive energy density and positive energy is possible as an improvement over [16], we make a small modification to have a positive energy and positive energy density for a curvature bubble of generic radius R and introduce a way to arbitrarily reduce such energy sources in the warped region.

Introduction:

In 1994, Alcubierre [1] proposed a solution to the equations of general relativity that provides the only viable means to accelerate a spaceship to superluminal velocities without using wormholes. However, a problem was soon identified: Pfenning [4] showed that the required energy is comparable to the total energy of the universe and that it is negative. In the article [16], the problem of the negative energy source in the warped region of the original Alcubierre solution [1] is brilliantly solved by the author of [16]. This paper continues the work by making small modifications to reduce the energy density and energy for the Alcubierre drive with a positive energy source.

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Brief Summary of the Article [16]:

It starts from the most general formulation of Alcubierre [1] in the form of the 3+1 ADM splitting for motion in a generic direction with a given bubble velocity v_x , v_y , and v_z in all spacial directions. under these conditions, the metric is:

$$ds^2=(dx-X\,dt)^2+(dy-Y\,dt)^2+(dz-Z\,dt)^2-dt^2 \qquad (1)$$

where for the [16] the values X, Y, and Z are given by:

$$X=\partial_x\psi_1 \qquad Y=\partial_y\psi_2 \qquad Z=\partial_z\psi_3 \qquad (2)$$

the functions ψ_1 , ψ_2 e ψ_3 e depend implicitly on the velocity v(t)

$$v(t)=\sqrt{(v_x(t)^2+v_y(t)^2+v_z(t)^2)} \text{ where } v_x(t)=\frac{d\,x_s}{dt} \quad v_y(t)=\frac{d\,y_s}{dt} \quad v_z(t)=\frac{d\,z_s}{dt} \qquad (3)$$

are respectively the velocities along the x, y, z axes and from the radius vector that starts from the center of the warp bubble in motion, the modulus of this vector is:

$$r(t)=\sqrt{((x-x_s)^2+(y-y_s)^2+(z-z_s)^2)} \qquad (4)$$

by setting [16]:

$$\psi_x=\psi_y=\psi_z=\psi(r) \qquad (5)$$

we have:

$$K^2-K^i_j K^j_i=2\partial_x^2\psi\,\partial_y^2\psi+2\partial_x^2\psi\,\partial_z^2\psi+2\partial_z^2\psi\partial_y^2\psi-2(\partial_x\partial_y\psi)^2-2(\partial_x\partial_z\psi)^2-2(\partial_y\partial_z\psi)^2$$

which can be simplified [16] for a soliton ψ described by the equation

$$\partial_x^2\psi+\partial_y^2\psi\,\partial-(2/v_h^2)\partial_z^2\psi=\rho$$

the energy density in the warped region is equal to:

$$energy\,density=\frac{1}{16\pi}(K^2-K^i_j K^j_i)=(1/16\pi)(2\partial_z^2\psi(\rho+(2/v_h^2)\partial_z^2\psi)-4(\partial_z\partial_x\psi)^2) \quad [16] \ (6)$$

with the condiction $(\partial_z^2\psi)^2\geq v_h^2(\partial_z\partial_x\psi)^2$ (6) [16] this energy density becomes: :

$$Energy\ warped\ region = k\, R^2 \frac{v^2}{w} > 0 \tag{7}$$

R is the radius of the warp bubble, and w < R

w is the size of the warped region, k is a constant of the order of c^4/G see Pfenning [4]

$$Energy\ density\ warp\ region \cong k\, R^2 \frac{\frac{v^2}{w}}{R^2 w} \tag{8}$$

ψ it is chosen such that inside the warp bubble X, Y, Z are equal to v (warp bubble velocity) and zero outside the warp bubble.

Proposed Solution Modification:

Setting $\frac{\psi}{b(x,y,z)}$ in place of ψ, with example $b(r) = \frac{2^p}{(1+(\tanh(\sigma(r-R)))^2)^p}$ p>>1

and if $b(r)$ equal at $b(r) = B \gg 1$ in warped region and 1 inside and outside warped region.

And knowing that:

$$\partial_i\left(\frac{\psi}{b}\right) = \frac{\partial_i \psi}{b} - \frac{\psi}{b^2}\partial_i b > 0 \qquad \partial_i b < 0 \quad , \quad \partial_i \psi > 0 \qquad \text{(small for soliton)}$$

and

$$\partial_i^2 b < 0 \qquad \partial_i^2\left(\frac{\psi}{b}\right) \ll 1 \qquad \partial_i^2\left(\frac{\psi}{b}\right) > 0 \qquad \partial_i b \cong 10^5 b$$

the (6) after setting $\frac{\psi}{b(x,y,z)}$ in place of ψ and $\left(\partial_z^2 \frac{\psi}{b}\right)^2 \geq v_h^2 \left(\partial_z \partial_x \frac{\psi}{b}\right)^2$ is positive

for a value of $B = 10^{50}$ or greater becomes:

$$0 < energy\, warped\, region \leq k\, R^2 \frac{v^2}{B\, w} \ll 1 \qquad \text{for} \qquad [4] \tag{9}$$

w size warped region w < R

the energy is small, for example, for an R = 100 m, w=1, and energy density is:

$$0 < Energy\, density\, warp\, region \cong k\, R^2 \frac{\frac{v^2}{B\, w}}{R^2\, w} \ll 1 \tag{10}$$

Conclusion:

The modifications made to [16] maintain a positive energy density and positive energy that can be reduced at will, making the Alcubierre drive a realistic possibility with the existence of superluminal motion.

References:

[1] M. Alcubierre, Classical and Quantum Gravity **11**, L73 (1994).

[2] C. Barcelo, S. Finazzi, and S. Liberati, ArXiv e-prints (2010), arXiv:1001.4960 [gr-qc].

[3] C. Clark, W. A. Hiscock, and S. L. Larson, Classical and Quantum Gravity **16**, 3965 (1999).

[4] M. J. Pfenning and L. H. Ford, Classical and Quantum Gravity **14**, 1743 (1997).arXiv:9702026

[5] F. S. N. Lobo and M. Visser, Classical and Quantum Gravity **21**, 5871 (2004).

[6] F. S. N. Lobo, ArXiv e-prints (2007), arXiv:0710.4474 [gr-qc].

[7] Finazzi, Stefano; Liberati, Stefano; Barceló, Carlos (2009). "Semiclassical instability of dynamical warp drives".Physical Review D **79** (12): 124017. arXiv:0904.0141

[8] Van den Broeck, Chris (1999). "On the (im)possibility of warp bubbles". arXiv:gr-qc/9906050

[9] C. Van Den Broeck, Class. Quantum Grav. 16 (1999) 3973

[10] Hiscock, William A. (1997). "Quantum effects in the Alcubierre warp drive spacetime". Classical and Quantum Gravity **14** (11): L183–L188. arXiv gr-qc/9707024

[11] Perniciano G. (2015),viXra:1507.0165

[12] S. K. Lamoreaux,"Demonstration of the Casimir Force in the 0.6 to 6 μm Range",*Phys. Rev.*

Lett. **78**,
5–8 (1997)

[13] L.H. Ford and T.A. Roman, Phys. Rev. D 51, 4277 (1995)

[14] Ford L H and Roman T.A. 1996 Phys. Rev. D 53 p 5496 arXiv: gr-qc/9510071

[15] L D Landau and E M Lifshitz “Theory of Fields”, Fourth Edition: Volume 2 (Course of Theoretical Physics Series)

[16] Lentz “Breaking the Warp Barrier: Hyper-Fast Solitons in Einstein-Maxwell-Plasma Theory” gr-qc: arxiv 2006.07125

[17] G. Perniciano. "Reduction Energy in Warped Region in Alcubierre Warp Drive." Preprints 2019. doi.org/10.20944/preprints201910.0102.v1

[18] G.Perniciano ,2019 viXra:1910.0144

[19] G.Perniciano,2015 viXra:1507.0193