Metamaterial or ordinary magneto-electric matter as an energy source for the Alcubierre Warp Drive for superluminal motion

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Abstract:

In this article, considering the work referenced in [16] that allows for motion up to ¼ of the speed of light, appropriate modifications have been considered where by classes of metamaterials or ordinary magneto-electric materials can be used for an Alcubierre drive that permits superluminal motion.

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. Given the paper [16], we consider a better choice of coordinates to calculate the energy source provided by the metamaterial in such a way as to satisfy the principles of thermodynamics, and to reduce the energy and energy density in the warped region, where the matter or energy source can be placed as desired.

Note: In the following we adopt the notation used by Landau and Lifshitz in the second volume ("The Classical Theory of Fields") of their well known Course of Theoretical Physics [15].

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The starting metric is that of Alcubierre, to which a coordinate transformation has been applied that, in a medium, is:

$$ds^2=(c/n)^2 dt^2-(dx-v\,f(x')\,dt)^2-dy^2-dz^2 \quad (1)$$

performing the coordinate transformation $dx'=dx-vdt$ we have

$$ds^2=(c/n)^2 dt^2-(dx'+v\,g(x')\,dt)^2-dy^2-dz^2 \quad (2)$$

$$g(x')=1-f(x')$$

$$ds^2=\left(\frac{1}{n^2}-\frac{v^2}{c^2}g(x')^2\right)c^2dt^2-dx'^2-2v\,g(x')\,dx'\,dt-dy^2-dz^2 \quad (3)$$

Maxwell's equations in this gravitational field can be written in three dimensions, where D, E, H, and g are vectors [15] and [16]:

$$D=\frac{E}{\sqrt{g_{00}}}+H\,x\,g \qquad B=\frac{H}{\sqrt{g_{00}}}+g\,x\,E \qquad [15] \quad (4)$$

where $g_{0i}=-g_{0i}/g_{00}$ (vector product x)

$$\varepsilon=\mu=(g_{00})^{(-1/2)}=\frac{1}{\sqrt{1/n^2-(v^2/c^2)g(x')^2}} \quad (5)$$

$$g_x=\frac{(v/c)\,g(x')}{1/n^2-(v^2/c^2)\,g(x')^2} \quad (6)$$

$$g_x^2\leq(\varepsilon-1)(\mu-1) \quad (7)$$

$f(r)$ is one inside warp region, is zero outside warped region is $0<f(r)<1$ in warped region

Now taking the modified metric:

$$ds^2=(c/n)^2 dt^2-\left(dx-v\frac{f(x')}{a(r)}dt\right)^2-dy^2-dz^2 \qquad (8)$$

and changing the coordinates, which are the most appropriate in this case:

$$dx'=dx-\frac{v}{a(r)}dt \quad \text{found} \quad ds^2=(c/n)^2 dt^2-\left(dx'+v\frac{g(x')}{a(r)}dt\right)^2-dy^2-dz^2 \qquad (9)$$

where $g(x')=1-f(x')$ and have $\varepsilon=\mu=(g_{00})^{(-1/2)}=\dfrac{1}{\sqrt{1/n^2-(v^2/c^2)\dfrac{g(x')^2}{a(r)^2}}}$ (10)

$$g_x=\frac{(v/c)\dfrac{g(x')}{a(r)}}{1/n^2-(v^2/c^2)\dfrac{g(x')^2}{a(r)^2}} \qquad (11) \qquad\qquad g_x^2\leq(\varepsilon-1)(\mu-1) \qquad (12)$$

$a(r)=1$ inside and outside warped region, $a(r)=A=constant\gg 1$ in warped region (discrete case) in the warped region (energy source, metamaterial, or ordinary matter)

analitycal case:

$$a(r)=\frac{2^p}{(1+(\tanh(\sigma(r-R)))^2)^p} \qquad p\gg 1 \quad \sigma\gg 1 \qquad [17]$$

Under these conditions g_x it can be reduced as desired and thus satisfy the condition (12) of not violating thermodynamics. For the equations, see [15] and [16].

Conclusion:

In this article, the introduction of a function $a(r)$ leads to the possibility of satisfying the thermodynamic relations (7), thus enabling a functional warp drive with potential superluminal $v>1$ motion. By choosing an appropriate value of $a(r)$ in the warped region, it is also possible to use ordinary magneto-electric matter such as $cr_2 o_3$ (magneto-electric susceptibility g_x with a value of $1.5\,10^{-3}$) in modest quantities.

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