TELETRASPORTO
“La via della metrica”

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Abstract

In this paper we talk about possibility of teleporting by means alteration of spacetime metric.

Riassunto

In questo terzo e, per il momento anche ultimo, nostro lavoro sul teletrasporto, dopo quelli sulla **via magnetica** e la via **quantistica**, parleremo brevemente della ancora molto avveniristica possibilità di teletrasporto, alterando la **metrica** dello spazio tempo.

Nel primo dei due lavori precedenti (Teletrasporto, la via magnetica) abbiamo citato il lavoro di Eric Davis “Teleportation Physics Study” (Rif.1) sulle varie possibilità di teletrasporto. Egli definisce la via metrica (alterazione artificiale dello spazio-tempo) come “vm - Teleportation”.

Ne riportiamo brevemente la sua definizione, a pag. 3:

“ 2.1 Engineering the Spacetime Metric
A comprehensive literature search for vm-Teleportation within the genre of spacetime metric engineering yielded no results. No one in the general relativity community has thought to apply the Einstein field equation to determine whether there are solutions compatible with the concept of teleportation.

Therefore, I will offer two solutions that I believe will satisfy the definition of vm-Teleportation. The first solution can be found from the class of traversable wormholes giving rise to what I call a true “stargate.”

A stargate is essentially a wormhole with a flat-face shape for the throat as opposed to the spherical-shaped throat of the Morris and Thorne (1988) traversable wormhole, which was derived from a spherically symmetric Lorentzian spacetime metric that prescribes the wormhole geometry (see also, Visser, 1995 for a complete review of traversable Lorentzian wormholes)…”

Ma riportiamo un più facile e comprensibile brano in italiano del libro di *Massimo Teodorani* "Teletrasporto" (Rif.2), Capitolo 3 "Il trasporto relativistico: un obiettivo ideale ma difficile" pag 81 – 82:

3.1 ALTERARE LO SPAZIO - TEMPO PER TELETRASPORTARE UOMINI E MEZZI

" L'idea di utilizzare tecniche che modificano la struttura dello spazio tempo era stata già studiata già nel 1994 dal fisico teorico messicano *Miguel Alcubierre*.

Secondo Alcubierre, la struttura stessa della relatività generale prevede la possibilità di alterare lo spazio-tempo in maniera tale da permettere ad un'astronave di viaggiare ad una velocità arbitrariamente grande.

In base ai calcoli di Alcubierre è possibile ottenere un regime di moto molto più veloce della velocità della luce – per un osservatore che si trovi fuori dalla regione perturbata dalla distorsione - facendo espandere localmente lo spazio-tempo dietro all'astronave e facendolo invece contrarre nella direzione opposta.

Questo non significa che gli astronauti viaggino realmente ad una velocità superiore a quella della luce, bensì che essi siano agevolati dal fatto che il punto di partenza e il punto di arrivo verrebbero enormemente avvicinati tra loro distorcendo, o meglio letteralmente incurvando, lo spazio-tempo in cui questi punti si trovano.

L'espansione dello spazio tempo permetterebbe all'astronave di allontanarsi dal punto di partenza, mentre una contrazione dello stesso le permetterebbe di avvicinarsi. Il percorso stesso della luce, che per la teoria della relatività generale è costretta a seguire delle "*geodetiche*" ovvero dei percorsi, i più brevi possibili all'interno dello spazio-tempo, sarebbe completamente incurvato.

Ciò significa che se un astronauta volesse recarsi su un pianeta di una stella comune come Epsilon Eridani, che si trova a 10,5 anni luce di distanza dalla Terra, potrebbe fare questo percorso in poche ore o minuti (a seconda della distorsione spazio-temporale): lo spazio-tempo che unisce la Terra a quel pianeta verrebbe alterato al punto tale che la terra e il pianeta quasi si toccherebbero, mentre la luce continuerebbe in realtà a viaggiare normalmente a 300.000 Km/sec.

Questo metodo viene chiamato "*warp-drive*" (in inglese significa letteralmente: spinta per distorsione)…" (vedi glossario)

Conclusione
Concludiamo questo breve lavoro sottolineando le enormi difficoltà tecniche attuali per ottenere una distorsione dello spazio-tempo, concepita da Miguel Alcubierre o altri fisici, e considerando più fattibile la cosiddetta “Via magnetica (Rif. 3)

Glossario (dal libro citato di Teodorani), pag. 149.

Metrica (***Relativistica***). In relatività generale la metrica (tecnicamente definita tramite il ***tensore metrico***) rappresenta l’oggetto fondamentale di studio. La metrica è in grado di inglobare in se tutta la struttura geometrica e causale (secondo il principio di causa – effetto dello spazio tempo. Usando la metrica diventa allora possibile definire nozioni come la distanza, il volume, l’angolo, il futuro, il passato e la curvatura (dello spazio- tempo).

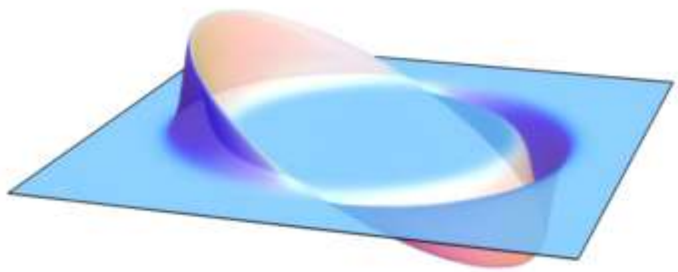
Spazio-tempo. Sistema di coordinate per individuare un evento. Nella fisica classica e relativistica vi sono tre coordinate spaziali ed una temporale, le quali, nella ***relatività*** sia speciale che ***generale*** , sono fra loro intimamente connesse. Mentre nella fisica pre-relativistica, il tempo era una quantità assoluta uguale in tutti i sistemi di riferimento e indipendente dallo spazio che veniva governato dalla geometria euclidea, nella teoria della ***relatività*** di Albert Einstein il tempo dipende dal sistema di riferimento. L’interdipendenza tra spazio e tempo viene descritta dalla matematica (non euclidea) di Herman Minkowski.

Warp - drive (da Wikipedia).

"**Warp drive**" is a common name for various types of faster-than-light drive, both fictional and hypothetical.

- The fictional warp drive of Star Trek is perhaps best known.
- The hypothetical Alcubierre drive is also called "warp drive"

Alcubierre drive (da Wikipedia) :



Concept of the Alcubierre drive, showing the opposing regions of expanding and contracting spacetime that propel the central region.

The **Alcubierre drive**, also known as the **Alcubierre metric**, is a speculative mathematical model of a spacetime exhibiting features reminiscent of the fictional "warp drive" from *Star Trek*, which can travel "faster than light", although not in a local sense.

In 1994, the Mexican physicist Miguel Alcubierre proposed a method of stretching space in a wave which would in theory cause the fabric of space ahead of a spacecraft to contract and the space behind it to expand.[1] The ship would ride this wave inside a region known as a *warp bubble* of flat space. Since the ship is not moving within this bubble, but carried along as the region itself moves, conventional relativistic effects such as time dilation do not apply in the way they would in the case of a ship moving at high velocity through flat spacetime relative to other objects.

Also, this method of travel does not actually involve moving faster than light in a local sense, since a light beam within the bubble would still always move faster than the ship; it is only "faster than light" in the sense that, thanks to the contraction of the space in front of it, the ship could reach its destination faster than a light beam restricted to travelling outside the warp bubble. Thus, the Alcubierre drive does not contradict the conventional claim that relativity forbids a slower-than-light object to accelerate to faster-than-light speeds. However, there are no known methods to create such a warp bubble in a region that does not already contain one, or to leave the bubble once inside it, so the Alcubierre drive remains a hypothetical concept at this **time.**

Alcubierre Metric

The **Alcubierre Metric** defines the so-called *warp drive spacetime*. This is a Lorentzian manifold which, if interpreted in the context of general relativity, allows a *warp bubble* to appear in previously flat spacetime and move off at effectively superluminal speed. Inhabitants of the bubble feel no inertial effects. The object(s) within the bubble are not moving (locally) faster than light, instead, the space around them shifts so that the object(s) arrives at its destination faster than light would in normal space.[2]

Alcubierre chose a specific form for the function *f*, but other choices give a simpler spacetime exhibiting the desired "warp drive" effects more clearly and simply.

Mathematics of the Alcubierre drive

Using the 3+1 formalism of general relativity, the spacetime is described by a foliation of space-like hypersurfaces of constant coordinate time *t*. The general form of the Alcubierre metric is:

$$ds^2 = -\left(\alpha^2 - \beta_i\beta^i\right)\, dt^2 + 2\beta_i\, dx^i\, dt + \gamma_{ij}\, dx^i\, dx^j$$

where α is the lapse function that gives the interval of proper time between nearby hypersurfaces, β^i is the shift vector that relates the spatial coordinate systems on different hypersurfaces and γ_{ij} is a positive definite metric on each of the hypersurfaces. The particular form that Alcubierre studied[1] is defined by:

$$\alpha = 1$$
$$\beta^x = -v_s(t) f\left(r_s(t)\right),$$
$$\beta^y = \beta^z = 0$$
$$\gamma_{ij} = \delta_{ij}$$

where

$$v_s(t) = \frac{dx_s(t)}{dt},$$
$$r_s(t) = \sqrt{(x - x_s(t))^2 + y^2 + z^2}$$

and

$$f(r_s) = \frac{\tanh(\sigma(r_s + R)) - \tanh(\sigma(r_s - R))}{2\tanh(\sigma R)}$$

with $R > 0$ and $\sigma > 0$ arbitrary parameters. Alcubierre's specific form of the metric can thus be written;

$$ds^2 = \left(v_s(t)^2 f(r_s(t))^2 - 1\right)\, dt^2 - 2 v_s(t) f(r_s(t))\, dx\, dt + dx^2 + dy^2 + dz^2$$

With this particular form of the metric, it can be shown that the energy density measured by observers whose 4-velocity is normal to the hypersurfaces is given by

$$-\frac{c^4}{8\pi G}\frac{v_s^2(y^2 + z^2)}{4g^2 r_s^2}\left(\frac{df}{dr_s}\right)^2$$

where g is the determinant of the metric tensor. Thus, as the energy density is negative, one needs exotic matter to travel faster than the speed of light.[1] The existence of exotic matter is not theoretically ruled out, the Casimir effect and the accelerating universe both lending support to the proposed existence of such matter.

However, generating enough exotic matter and sustaining it to perform feats such as faster-than-light travel (and also to keep open the 'throat' of a wormhole) is thought to be impractical. Low has argued that within the context of general relativity, it is impossible to construct a warp drive in the absence of exotic matter.[3] It is generally believed that a consistent theory of quantum gravity will resolve such issues once and for all.

Physics of the Alcubierre drive

For those familiar with the effects of special relativity, such as Lorentz contraction and time dilation, the Alcubierre metric has some apparently peculiar aspects. In particular, Alcubierre has shown that even when the ship is accelerating, it travels on a free-fall geodesic.

In other words, a ship using the warp to accelerate and decelerate is always in free fall, and the crew would experience no accelerational g-forces.

Enormous tidal forces would be present near the edges of the flat-space volume because of the large space curvature there, but by suitable specification of the metric, these would be made very small within the volume occupied by the ship.[1]

The original warp drive metric, and simple variants of it, happen to have the *ADM form* which is often used in discussing the initial-value formulation of general relativity. This may explain the widespread misconception that this spacetime is a *solution* of the field equation of general relativity. Metrics in ADM form are *adapted* to a certain family of inertial observers, but these observers are not really physically distinguished from other such families. Alcubierre interpreted his "warp bubble" in terms of a contraction of "space" ahead of the bubble and an expansion behind. But this interpretation might be misleading,[4] since the contraction and expansion actually refers to the relative motion of nearby members of the family of ADM observers.

In general relativity, one often first specifies a plausible distribution of matter and energy, and then finds the geometry of the spacetime associated with it; but it is also possible to run the Einstein field equations in the other direction, first specifying a metric and then finding the energy-momentum tensor associated with it, and this is what Alcubierre did in building his metric. This practice means that the solution can violate various energy conditions and require exotic matter. The need for exotic matter leads to questions about whether it is actually possible to find a way to distribute the matter in an initial spacetime which lacks a "warp bubble" in such a way that the bubble will be created at a later time. Yet another problem is that, according to Serguei Krasnikov,[5] it would be impossible to generate the bubble without being able to force the exotic matter to move at *locally* FTL speeds, which would require the existence of tachyons. Some methods have been suggested which would avoid the problem of tachyonic motion, but would probably generate a naked singularity at the front of the bubble.[6][7]

Difficulties

Significant problems with the metric of this form stem from the fact that all known warp drive spacetimes violate various energy conditions. It is true that certain experimentally verified quantum phenomena, such as the Casimir effect, when described in the context of the quantum field theories, lead to stress-energy tensors which also violate the energy conditions and so one might hope that Alcubierre type warp drives could perhaps be physically realized by clever engineering taking advantage of such quantum effects. However, if certain quantum inequalities conjectured by Ford and Roman hold,[8] then the energy requirements for some warp drives may be absurdly gigantic, e.g. the energy equivalent of 10^{67} grams might be required[9] to transport a small spaceship across the Milky Way galaxy. This is orders of magnitude greater than the mass of the universe. Counterarguments to these apparent problems have been offered,[2] but not everyone is convinced they can be overcome

Chris Van Den Broeck, in 1999, has tried to address the potential issues.[10] By contracting the 3+1 dimensional surface area of the 'bubble' being transported by the drive, while at the same time expanding the 3 dimensional volume contained inside,

Van Den Broeck was able to reduce the total energy needed to transport small atoms to less than 3 solar masses. Later, by slightly modifying the Van Den Broeck metric, Krasnikov reduced the necessary total amount of negative energy to a few milligrams.[2]

Krasnikov proposed that, if tachyonic matter cannot be found or used, then a solution might be to arrange for masses along the path of the vessel to be set in motion in such a way that the required field was produced. But in this case, the Alcubierre Drive vessel is not able to go dashing around the galaxy at will. It is only able to travel routes which, like a railroad, have first been equipped with the necessary infrastructure. The pilot inside the bubble is causally disconnected with its walls and cannot carry out any action outside the bubble. Thus, because the pilot cannot place infrastructure ahead of the bubble while "in transit", the bubble cannot be used for the *first* trip to a distant star. In other words, to travel to Vega (which is 25 light-years from the Earth) one first has to arrange everything so that the bubble moving toward Vega with a superluminal velocity would appear and these arrangements will always take more than 25 years.[5]

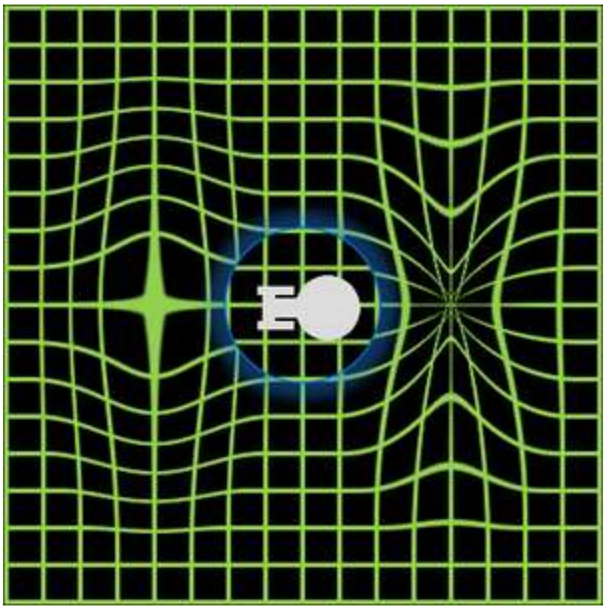
Coule has argued that schemes such as the one proposed by Alcubierre are not feasible because the matter to be placed on the road beforehand has to be placed at superluminal speed. Thus, according to Coule, an Alcubierre Drive is required in order to build an Alcubierre Drive. Since none have been proven to exist already then the drive is impossible to construct, even if the metric is physically meaningful. Coule argues that an analogous objection will apply to *any* proposed method of constructing an Alcubierre Drive.[7]

A paper by José Natário published in 2002 showed that it would be impossible for the ship to send signals to the front of the bubble, meaning that crew members could not control, steer or stop the ship.[11]

A more recent paper by Carlos Barceló, Stefano Finazzi, and Stefano Liberati makes use of quantum theory to show that the Alcubierre Drive at FTL velocities is impossible; mostly due to extremely high temperatures caused by Hawking radiation destroying anything inside the bubble at superluminal velocities and leading to instability of the bubble itself. These problems do not arise if the bubble velocity is kept subluminal, but it is still necessary to furnish exotic matter for the drive to work.[12].

More difficulties emerge in regards to the amount of exotic matter required for such a propulsion. According to Pfenning and Allen Everett of Tufts, a warp bubble traveling at 10 times light-speed must have a wall thickness of no more than 10^{-32} meters. This is only slightly longer than the Planck length, 10^{-35}. A bubble macroscopically large enough to enclose a ship 200 meters across would require a total amount of exotic matter equal to 10 billion times the mass of the observable universe. Of course, straining the exotic matter to an extremely thin band of 10^{-32} meters is considered impractical. Similar constraints apply to Krasnikov's superluminal subway. A modification of Alcubierre's model was recently constructed by Chris van den Broeck of the Catholic University of Louvain in Belgium. It requires much less exotic matter but places the ship in a curved space-time "bottle" whose neck is about 10^{-32} meters. So-called cosmic strings, hypothesized in some cosmological theories, involve very large energy densities in long, narrow lines. But ll known physically reasonable cosmic-string models have positive (positive space-time warping effects) energy densities. These results seem to make it rather unlikely that one could construct Alcubierre warp drives using exotic matter generated by quantum effects…."

Propulsione a curvatura (da omonima voce di Wikipedia) :
Da Wikipedia, l'enciclopedia libera.



Rappresentazione della curvatura; si notino la contrazione dello spaziotempo (prima e dopo l'astronave) e la bolla di curvatura che racchiude il mezzo

La **propulsione a curvatura** (*warp drive* nell'originale inglese) è un immaginario tipo di propulsione che permette alle navi stellari dell'universo fantascientifico di *Star Trek* di viaggiare ad una velocità superiore a quella della luce. Nelle serie e nei film di *Star Trek* la propulsione a curvatura è un espediente narrativo indispensabile in quanto giustifica la possibilità del viaggio interstellare "alla ricerca di nuovi mondi e nuove civiltà".

La genesi della tecnologia a curvatura terrestre viene narrata nel film *Star Trek: Primo contatto*: il primo motore a curvatura del pianeta Terra viene costruito in data ignota [1] dal dott. Zefram Cochrane e usato dallo stesso scienziato in un lancio di prova, nell'aprile del 2063. Quel primo viaggio spaziale a velocità di curvatura innesca anche il primo contatto della Terra con una civiltà extraterrestre, quella vulcaniana, che dispone da secoli di tale tecnologia. All'epoca la prassi vulcaniana è di contattare un pianeta solo dal momento in cui gli abitanti dispongono della propulsione a curvatura, sicché quando un'astronave vulcaniana di pattuglia rileva il volo del prototipo terrestre, i Vulcaniani atterrano sul pianeta. Questa prassi è incorporata nella Prima Direttiva della Federazione dei Pianeti Uniti che nasce in seguito …".

Riferimenti

1) Teleportation Physics Study - Eric W. Davis - Warp Drive Metrics 4849 San Rafael Ave. Las Vegas, NV 89120 August 2004 al sito: www.fas.org/sgp/eprint/teleport.pdf

2) Massimo Teodorani , Teletrasporto, Macroedizioni, (Capitolo 3)

3) Gruppo Eratostene, “Appunti sul Teletrasporto” in sezione “articoli di Fisica - Matematica

4) Gruppo Eratostene, “ Teletrasporto - La via magnetica “ in sezione “Articoli di Fisica – Matematica”