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Superluminal Travel from Quantised Inertia

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Abstract

Special relativity predicts that the inertial mass of an object is infinite at the speed of light (c) causing zero acceleration and producing a cosmic speed limit. Here, a new model for inertia is presented that challenges this. The model (quantised inertia) assumes that inertia is caused by Unruh radiation made inhomogeneous in space by relativistic horizons. Quantised inertia is consistent with standard physics at normal accelerations, but predicts a new loss of inertia at very low accelerations, predicting galaxy rotation without dark matter and a minimum acceleration of $2c^2/\Theta \sim 2 \times 10^{-10}$ m/s (where Θ is the co-moving Hubble diameter) which is equal to the cosmic acceleration and that persists even at the speed of light. This implies that the speed of light limit can be broken, albeit with this tiny acceleration and that this relativity - proof acceleration could be boosted by setting up a causal horizon around the ship.

Keywords: Unruh radiation; Quantised inertia; Faster than light travel

Introduction

The best-known anomaly in astrophysics is the observation that galaxies spin too fast to be gravitationally bound by their visible mass. This is the galaxy rotation problem discovered by Zwicky [1] and Rubin and Ford [2]. Zwicky's explanation for this, and still the most popular is that galaxies contain invisible (dark) matter, but this model is scientifically unsatisfying as dark matter can be placed anywhere. Dark matter cannot explain similar anomalies in wide binaries [3] or global clusters [4]. Also, after decades of searching, dark matter has not been directly detected (though many efforts are ongoing).

An alternative explanation for the galaxy rotation problem is Modified Newtonian Dynamics [5] in which either the strength of gravity is increased, or the inertial mass is reduced, for bodies with very low accelerations (eg: stars at the edge of a galaxy). Although MoND is far less tuneable than dark matter, it does require an empirical acceleration constant ($a_0 \sim 2 \times 10^{-10}$ m/s^2) which is found by fitting to galaxy rotation data.

Following the gravitational work of Hawking [6]. Unruh [7] predicted that a body with acceleration 'a' would see the zero point field as thermal radiation of temperature T:

$$T = \frac{\hbar a}{2\pi ck} \qquad (1)$$

where ħ is the reduced Planck constant, c is the speed of light and k is Boltzmann's constant. Haisch et al. [8] suggested that a component of this thermal Unruh radiation exerts a force that opposes acceleration, and therefore behaves like inertia. However, their model needs a cut-off frequency to be set and so has an arbitrary element. Unruh radiation has not to date been seen, although the self-polarisation of high-energy relativistic electrons in a magnetic field: the Sokolov-Turnov effect, may

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be evidence for it [9] and also see Smolyaninov [10] who pointed out that it may have been detected coming from highly accelerated plasmons propagating round sharp nanotips. Wien's law states that the wavelength of radiation is related to the temperature as:

$$\lambda = \frac{\beta hc}{kT} \qquad (2)$$

where β =0.2 (empirically determined by Wien) and h is Planck's constant. Combining (1) and (2) gives:

$$\lambda = \frac{4\beta \pi^2 c^2}{a} \qquad (3)$$

Milgrom [11] pointed out that as you move out to larger galactic radii, the acceleration reduces and there is always a particular acceleration below which galaxy rotation curves become non-Newtonian (2×10^{-10} m/s^2) and interestingly, at this acceleration, the wavelength from Eq. 3 becomes comparable to the Hubble scale. Perhaps Unruh waves larger than this cannot be observed (and cease to be effective) and he speculated that their disappearance might, somehow, reduce the inertial mass. Milgrom's 'break' is suggestive, but the predicted abrupt drop in inertia does not fit galaxy rotation or other anomalies and he concluded that Unruh radiation is unlikely to directly cause inertia as it is isotropic [12].

McCulloch [13,14] proposed a new model for inertia (called quantized inertia, or QI) that assumes that the inertia of an object is due to the Unruh radiation it sees when it accelerates. The Rindler horizon that appears in the opposite direction to its acceleration damps the Unruh radiation on that side of the object and the imbalance on Unruh radiation pressure (it is no longer isotropic) produces a force that looks like inertial mass (an asymmetric Casimir effect, aCe). Quantized inertia reduces inertial mass in a new way for very low accelerations since the Unruh waves become longer and are damped in all directions equally by the Hubble horizon negating the aCe. QI does not need the arbitrary parameters found in MoND or Haisch et al. [6]. The inertial mass in QI is

$$m_i = m_g (1 - \frac{2c^2}{|a|\Theta}) \qquad (4)$$

where m_g is the gravitational mass, c is the speed of light, and Θ is the co-moving cosmic diameter (8.8×10^{26} m). The acceleration 'a' is that relative to surrounding matter. The acceleration of a small body m under the gravity of a larger one mass M is:

$$F = ma = \frac{GMm}{r^2} \qquad (5)$$

Substituting Eq. 4 for the inertial mass into Eq. 5 gives us the acceleration

$$a = \frac{GM}{r^2} + \frac{2c^2}{\Theta} \qquad (6)$$

The second term on the right-hand side of Eq. 6 implies that even in the absence of gravity (M=0) a residual acceleration remains: equal to the acceleration attributed to dark energy.

McCulloch [15] tested quantized inertia on the flyby anomalies observed by Anderson et al. [16] and found that they could be reproduced if the acceleration in Eq. 4 was that of the flyby spacecraft relative to all the particles of matter within the spinning Earth. This mutual acceleration is lower for a craft leaving along with the polar (spin) axes, reducing the craft's inertia by quantized inertia and boosting the craft's speed by momentum conservation. Quantized inertia predicts the velocity jump 'dv' to be:

$$dv = 2.8 \times 10^{-7} \times v \times \left(\frac{\cos \varphi_1 - \cos \varphi_2}{\cos \varphi_1 \times \cos \varphi_2}\right) \quad (7)$$

Where the constant is derived from physical constants, like c and Θ, that cannot be adjusted, v is the heliocentric flyby speed, and φ1 and φ2 are the incident and exit latitudes (see [15] for the detailed derivation). The predictions agreed quite well with the data, and they showed a latitude dependence as observed. The crucial point for this paper is that the inertial mass decreases close to the rotation axis of systems.

It has been shown that quantized inertia can model dwarf galaxy, disc galaxy and galaxy cluster rotation speed without the need for dark matter [14,17]. This is because stars at the edges of galaxies and clusters undergo only tiny accelerations and lose inertia due to quantized inertia. This allows them to circulate around the galaxy at the observed speeds (~200 km/s) without centrifugal (inertial) forces making them unbound.

Method

1. Quantized inertia and relativity

The conservation of momentum combined with special relativity suggests that an object's inertial mass (m) depends on its rest mass (m_0) and velocity 'v' as

$$m_i = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}} \quad (8)$$

When v<<c the inertial mass is close to the rest mass m_0, but when v approaches c the inertial mass mi approaches infinity and therefore further increases of speed are impossible. So, special relativity makes it difficult to accelerate anything to close to the speed of light (and this has been tested in particle accelerators). This also makes it impossible for a spacecraft to accelerate to or beyond the speed of light (there are restrictions from causality too), limiting the range of interstellar travel within the lifetime of those left behind on Earth.

QI, as suggested above, also affects inertial mass. Combining special relativity (Eq. 8) and QI (Eq. 4) produces this expression for the inertial mass m_i

$$m_i = m_0 \frac{\left(1 - \frac{2c^2}{a\Theta}\right)}{\left(1 - \frac{v^2}{c^2}\right)^{1/2}} \quad (9)$$

Where m_0 is the rest mass, Using Newton's second law gives the acceleration

$$a = \frac{F}{m_i} = F \frac{\left(1 - \frac{v^2}{c^2}\right)^{1/2}}{m_0 \left(1 - \frac{2c^2}{a\Theta}\right)} \quad (10)$$

Multiplying both sides by the denominator and rearranging gives

$$a = \frac{F}{m_0}\left(1 - \frac{v^2}{c^2}\right)^{1/2} + \frac{2c^2}{\Theta} \quad (11)$$

The first term here is the usual one from special relativity that states that if v=c, then no matter how large a force (F) is applied to an object it will not accelerate (a=0). The new result from quantized inertia is the second term, which states that even when v=c there will always be a minimum acceleration of $2c^2/\Theta \sim 2 \times 10^{-10}$ m/s^2 even if the force applied (F) is zero. To explain intuitively: as a spacecraft's speed approaches c, special relativity predicts that its inertia increases and the acceleration falls towards zero, but QI says that inertia depends on the existence of Unruh waves and at low accelerations these become too long to fit within the cosmic diameter, so whereas special relativity predicts the inertia increases to infinity at speed c, QI predicts that as this happens, inertia dissipates. The result is that a residual acceleration remains (Eq. 11, term 2).

This prediction is supported by the observations of Perlmutter and Riess who observed this same value of acceleration for the distant stars which are traveling away at speeds relative to us of close to c. This acceleration has been attributed to dark energy but, as shown here, it is predicted by QI.

General relativity cannot be invoked here since QI violates the equivalence principle which forms its basis, although in a manner that could not have been detected. This suggests a paradox: a star near the observable universe's edge is moving at speed c, a moment later, because of cosmic acceleration, it is moving faster than c. This is contrary to special relativity alone, but not when QI is also considered (Eq. 11).

Results

1. Predicting particle accelerators

The effects of quantized inertia have not been observed in particle accelerators which accelerate particles to close to the speed of light. This could be because these particles travel along circular trajectories and are therefore highly accelerated, making QI less apparent. This can be shown quantitatively using the combined QI+relativity model for inertia (Eq. 9). Substituting the acceleration of a particle around the CERN particle accelerator: $a=v^2/r$, where r is the radius of the accelerator and v is the particles' velocity, into Eq. 9, we get

$$m_i = m_0 \frac{(1-\frac{2c^2 r}{v^2 \Theta})}{(1-\frac{v^2}{c^2})^{1/2}} \qquad (12)$$

Replacing all the known constants with values, so: $c=3 \times 10^8$ m/s, r=4 km (for CERN), and $\Theta=8.8 \times 10^{26}$ m, gives

$$m_i = \frac{m_0(1-8.1\times 10^{-7} / v^2)}{(1-\frac{v^2}{c^2})^{1/2}} \qquad (13)$$

Using a binomial series for the denominator: $(1-\frac{v^2}{c^2})^{1/2} \sim 1-\frac{v^2}{2c^2}$ ..... so that approximately

$$m_i = \frac{m_0(1-8.1\times 10^{-7} / v^2)}{1-(5.6\times 10^{-18} v^2)} \qquad (14)$$

The change in the inertial mass from special relativity and QI can now be found. When v=0.9c the effect of QI (in the numerator) is 22 orders of magnitude smaller than the change due to relativity (denominator), and when v is higher still, the effect of QI decreases even further. Therefore it would be difficult to detect the effects of QI in a particle accelerator.

2. Galactic jets

So where might this effect be observed? Examples in nature are likely to occur when accelerations are low. QI predicts that just as the Earth flyby craft are boosted when they exit along the Earth's polar axis, so objects may lose inertial mass and be more easily accelerated along galactic axes.

Galactic jets have been known for some years and Biretta et al. [19] observed the M87 axial jet and calculated the apparent speed of recognizable 'knots' of light within the jet, taking account of the estimated distance to M87. They found an apparent speed of 6c. It is important to note that according to Reiss[20] this apparent superluminal speed may be due to an optical illusion caused by special relativity. From [20] the apparent speed (v_{app}) of a relativistic object moving at an angle θ to the observer depends on its real speed (v) as

$$v_{app} = \frac{v \sin\theta}{1-\cos\theta} \qquad (15)$$

According to Biretta et al. [19] the most likely angle of the M87 jet to our line of sight is 64.5π, and they stated that because of the observed shape of the knots: "placing the jet within 20π of the line of sight presents several challenges".

TABLE 1 shows the assumed angle (column 1) and the real velocity implied by the observed apparent velocity of 6c, using Eq. 15. In order to produce real velocities less than the speed of light for the M87 jet, it is necessary to assume unrealistic angles of less than 20^o.This, of course, is a controversial area, and estimates of the jet's angle or the distance to M87 may change change, but it is possible that this is evidence for the FTL speeds implied by QI.

TABLE 1. **The assumed angle to the line of sight of the M87 jet and the implied absolute speed.**

Assumed angle to the line of sight	**Absolute velocity implied**
64^o	3.7c
30^o	1.6c
20^o	1.05c

Discussion

1. Building an FTL engine with QI

The minimum acceleration predicted by QI would cause an increase in speed from zero to 60 mph in 8500 years (so would not win any races) or from zero to the speed of light in the lifetime of the universe (something that is intriguing in itself), but the interesting parameter is the Θ (the Hubble diameter=8.8×10^{26} m) in the denominator of $2c^2/\Theta$. This is the parameter whose huge size makes this useful relativity-proof acceleration so small. It represents the effect of an event horizon at the cosmic scale. What if we could produce a smaller event horizon and boost this acceleration? It would have to be a boundary that does not allow information to pass through. This could be achieved ([21], see section 4) for electromagnetic information using the metamaterials that have recently been used to produce cloaking devices. For example, if a spacecraft was to be accelerated at 9.8 m/s^2 then the wavelength of the Unruh waves it would see would be, according to Equation 3:

$$\lambda = \frac{4\beta\pi^2c^2}{a} = 7\times10^{16}\,\text{m} \qquad (16)$$

Pendry and Wood [22] have shown that metamaterials (arrays of conductive elements) can be designed to manipulate electromagnetic waves this long. An array of them could be built to surround the ship and bend the electromagnetic component of the Unruh waves in such a way that there is a local-cosmic horizon or bubble surrounding the ship. The relativity-proof acceleration would then be $2c^2/\theta$, where θ is the diameter of the bubble instead of the cosmic diameter so the acceleration would be many orders of magnitude larger.

Another method would use an extremely fast spin, to produce a large acceleration towards the center of spin and thereby create a Rindler-cylinder around the craft. If the linear acceleration was 9.8 m/s^2 then the rotational acceleration would have to be the same to produce a Rindler-cylinder at the right radius to damp the linear Unruh waves.

A similar effect would also be achieved by emitting from the ship electromagnetic waves of the same wavelength as the Unruh waves being seen by the ship due to its acceleration, but opposite in phase. Those ship-generated waves would then interfere destructively with the Unruh waves, reducing the inertial mass of the ship [23].

Quantized inertia also gives us the opportunity to get up to light speed more easily, since it should be possible to use metamaterials of em radiation to damp the quantum vacuum in front of the ship and thereby cause an Unruh radiation pressure force in the forward direction. This is an inversion of the very process that, according to QI, causes inertia itself. This will make it possible to get close to light speed without needing the huge amounts of fuel thought to be necessary to counter the relativistic mass. QI allows us to control the inertial mass.

Quantized inertia still has many uncertainties to be resolved. For example, it is unclear how such long Unruh waves interact with matter and also feel the distant Hubble scale quickly enough. Although QI has so far been parameterized smoothly with Eq. 4 the allowed wavelengths would be better modeled using a discrete model that counts the allowed wavelengths. The consequences of the FTL discussed here for causality are complex, and have not yet been considered. The implications of QI for a new quantum gravity theory would be worth study, but the most useful progress would be made by isolating the effects of QI in a laboratory experiment. The development of the applications discussed here should progress from there.

Conclusion

At the speed of light, special relativity predicts that inertial mass increases to infinity so that the acceleration tends to zero and this causes the speed of light limit.

A new theory, quantized inertia, predicts there is a minimum acceleration of $2c^2/\theta \sim 2\times10^{-10}$ m/s^2 even at the speed of light. This implies the speed of light limit can be broken.

The residual QI-acceleration (immune to the effects of special relativity) is tiny, but it may be possible to use metamaterials to bend Unruh radiation back towards a spacecraft reducing θ and enhancing the QI-acceleration, or cancel the Unruh radiation using conventional em radiation or spin, allowing the craft to break the speed of light limit with greater acceleration.

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