Can We Hide Gravitational Sources behind Rindler Horizons?

Michael Edward McCulloch

SoBMS, Plymouth University, Plymouth, UK. E-mail: mike.mcculloch@plymouth.ac.uk

When an object accelerates in one direction, a Rindler horizon forms in the opposite direction and information from behind it cannot reach the object. Here it is shown that it is possible to test for this effect since it predicts that if an object, say a disc, is rotationally accelerated by over $\sim 10^{10}$ m/s^2 then the Rindler horizon it sees should come close enough to hide part of the Earth and therefore it should not feel all the Earth's gravity. This effect could be detected by measuring the disc's weight.

1 Introduction

Hawking [1] showed that the strong gravity at the edge of a black hole produces an event horizon that can separate paired virtual particles leading to Hawking radiation and black hole evaporation. Fulling [2], Davies [3] and Unruh [4] showed that a similar effect occurs for accelerating objects in that a Rindler horizon [5] forms at a distance of c^2/a from the side they are accelerating away from (where c is the speed of light and a is the acceleration of the object). This horizon similarly produces radiation so that an accelerated object will perceive a warm background full of blackbody radiation whereas an unaccelerated body will see a cold background with no radiation. This is called Unruh radiation [4] and for typical accelerations it has too long a wavelength to be detectable, but it may have been observed coming from plasmons propagating at high acceleration around the surface of a gold nanotip [6].

McCulloch [7, 8] proposed a new model for inertia (called quantised 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 producing a radiation pressure differential that looks like inertial mass [8]. Also, when accelerations are extremely low the Unruh waves become very long and are also damped, this time in all directions, by the Hubble horizon (Hubble-scale Casimir effect). This leads to a new loss of inertia as accelerations become tiny. QI modifies the standard inertial mass (m) to a modified one (m_i) as follows:

$$m_i = m\left(1 - \frac{2c^2}{|a|\,\Theta}\right), \tag{1}$$

where c is the speed of light, Θ is twice the Hubble distance, $|a|$ is the magnitude of the relative acceleration of the object relative to surrounding matter. Eq. 1 predicts that for terrestrial accelerations (eg: $9.8\,\mathrm{m/s^2}$) the second term in the bracket is tiny and standard inertia is recovered, but in low acceleration environments, for example at the edges of galaxies (when a is tiny), the second term in the bracket becomes larger and the inertial mass decreases in a new way so that QI can predict galaxy rotation without the need for dark matter [9].

Putting Eq. 1 into Newton's second and gravity laws gives

$$F = ma = m\left(1 - \frac{2c^2}{|a|\,\Theta}\right) = \frac{GMm}{r^2} \tag{2}$$

and finally

$$a = \frac{GM}{r^2} + \frac{2c^2}{\Theta}\,. \tag{3}$$

This predicts cosmic acceleration (the new second term) without the need for dark energy [7]. In this paper this same result is derived a different way, simply using Ernst Mach's attitude that "what cannot be observed does not exist". It is argued that, since Rindler horizons are boundaries for information, then sources of gravity behind them disappear from the point of view of the accelerated object. It is shown here that this effect predicts cosmic acceleration, given the known baryonic mass of the cosmos, and may allow us to hide gravitational sources behind horizons producing new kinds of thrust.

2 Method

If we consider a photon travelling at the speed of light in the centre of its own Hubble sphere (see Fig. 1). Due to the impossibility of any light from the left hand side of the cosmos catching up to the photon, we can say that, as far as the photon knows, there is no mass there at all. All the mass is hidden by the Rindler horizon. Therefore, there is a gravitational imbalance as the photon can be aware of a lot of matter in front of it in the direction of its acceleration, but nothing behind. We can calculate this gravitational acceleration as follows

$$a = \frac{GM}{r^2}\,. \tag{4}$$

We can assume from standard geometry that the centre of mass of the semi-sphere in front of the photon is 3/8ths of the radius away, and the radius and baryonic mass of the cosmos are estimated to be 4.4×10^{-10} m and $10^{52\pm1}$ kg, so

$$a = \frac{6.67 \times 10^{-11} \times 10^{52\pm1}}{(3/8 \times 4.4 \times 10^{26})^2} = 2.45 \times 10^{-11\pm1}\mathrm{m/s^2}. \tag{5}$$

The predicted acceleration (given the error bars) agrees with the observed cosmic acceleration and with the critical acceleration below which galactic dynamics deviate from Newton: $2 \times 10^{-10}\mathrm{m/s^2}$.

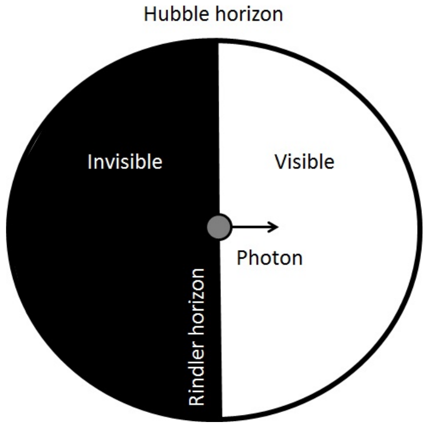

Fig. 1: A schematic showing the Hubble horizon (as a black circle). A photon (the central grey circle) moves rightwards at the speed of light, so it has a Rindler horizon passing through it, and no information from the black-shaded volume can get to it. This means that, following Mach, the gravitational mass from that black region is irrelevent and the gravitational pull from the right hand half of the cosmos now dominates, causing an acceleration which predicts the cosmic acceleration.

3 A test

If we consider a spinning disc, then every particle within it is accelerating towards the spin axis, and each particle perceives a Rindler horizon that is outside the disc. As the rotational acceleration is increased the horizon moves closer to the spin axis. What would happen if the horizon was closer than the Sun or the Earth? Would this hide their gravitational effect from the point of view of the accelerated object? (see an earlier brief discussion of this in [10]).

To calculate the spin rate required to pull the Rindler horizon in closer than a distance d_R we assume a disc of any material of radius r, spinning at R rpm (rotations per minute). The centripetal acceleration (a) at different radii (r) of the disc is given by

$$a = \frac{v^2}{r} = \frac{(2\pi rR/60)^2}{r} = \frac{4\pi^2 rR^2}{3600}, \tag{6}$$

where the 60 comes from the number of seconds in a minute. The Rindler horizon forms in the direction opposite to the acceleration at a distance given by

$$d_R = \frac{c^2}{a}. \tag{7}$$

We can now substitute Eq. 6 in Eq. 7

$$d_R = \frac{3600\,c^2}{4\pi^2 rR^2} = \frac{900\,c^2}{\pi^2 rR^2}. \tag{8}$$

Eq. 8 shows the distance of the Rindler horizon (d_R) for a particle within a disc spinning at R rpm and at a radius r from the spin centre. It shows that the faster the disc spins (R increases) the distance to the Rindler horizon decreases very rapidly and the Rindler horizon is closer for particles at the disc's edge (when r is large).

4 Results & discussion

Eq. 8 can be rearranged to calculate the rotation rate R (in rpm) needed to bring the Rindler horizon closer than a body a distance d_R away

$$R = \sqrt{\frac{900\,c^2}{\pi^2 r d_R}}. \tag{9}$$

The following table shows the object to be hidden by the Rindler horizon in the first column. The second column shows its distance (d) away from a lab on the Earth's surface. The third column shows the acceleration needed, in a linear sense, to hide the object. The fourth column shows the rpm required for a spinning disc to achieve that acceleration, at a radius of 0.1 m. The fifth column shows the gravitational acceleration ($a_g = GM/d^2$) produced by that object that will disappear and affect the dynamics of the disc (but only those parts of it above the critical acceleration).

Object	Distance	a	rpm	a_g
		Eq. 7	Eq. 9	
		(m/s^2)		(m/s^2)
Sun	1 AU	600,000	23 k	0.006
Earth	6371 km	1.43×10^{10}	3589 k	9.8

Table 1: The Table shows for two objects (column 1), the distances from a lab on the Earth's surface to the object (column 2), the accelerations needed to hide the object behind Rindler horizons (column 3), the rpm needed for that acceleration for a disc at a radius of 0.1 m (column 4) and the acceleration exerted by the object on the disc (column 5).

The rotation required to hide the Sun should be achievable since gyroscopes often have rotation rates of 30,000 rpm and medical centrifuges can spin at 100,000 rpm. The rotation rate required would be lower for a larger disc. Of course, only the part of the disc that has an acceleration vector pointing away from the Sun (the Sunward side) would feel the disappearence of the Sun's effect, including its gravitational force. The gravitational acceleration due to the Sun is $GM_\odot/r^2 = 0.006\,\text{m/s}^2$ (this is 0.06% of g). The Sun's width in the sky is about half a degree so only an area of about 1/(360*2) of the disc would be affected and then also only the area of the disc outside the radius of 0.1m. So if the disc was 0.2m in radius the affected area would be the total area times $(1/720)\times(3/4)$. Therefore, the average acceleration for the whole disc would be $0.006 \times (1/720) \times (3/4) = 6.25 \times 10^{-6}\text{m/s}^2$.

From a practical point of view it would be far more useful to hide the Earth's gravity since then launching objects would become easier. The acceleration required to do so: 1.43×10^{10} (see Table 1), has just been achieved for the first time by [11] who spun a microscopic sphere of radius $r = 4\times10^{-6}$ m using circularly polarised light to suspend and rotate it in vacuo at $R = 6\times10^{8}$ rpm. This is an acceleration, using Eq. 6 of $1.58\times10^{10}\text{m/s}^2$ which agrees with the acceleration needed to pull the Rindler horizon close enough to hide the Earth's gravity (Table 1, column 3).

5 Conclusion

It is proposed here that Rindler horizons have physical consequences beyond their effects on light: they are able to hide gravitational sources.

It is shown that assuming that gravitational sources can be hidden in this way, predicts the cosmic acceleration.

The effect could be tested using discs with extreme spins, which should break free from distant gravitational sources.

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