The Proton Radius Anomaly from the Sheltering of Unruh Radiation

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It has been found that in muonic hydrogen either the proton radius is 4% smaller than usual (a 7σ anomaly) or an unexplained extra binding energy of 320 μeV is present. Here it is shown that 55% of this extra energy can be explained if Unruh radiation seen by the orbiting muon can push on it, and is being asymmetrically blocked by the proton.

1 Introduction

The proton radius has been measured for many years to be 0.88 fm, with experiments using electron-proton scattering and by using atomic spectoscopy to look at the Lamb shift seen by an orbiting electron, a shift which depends on the proton radius [1].

More recently, it was realised that a more accurate proton radius could be obtained by replacing the electron in the atom with its heavier twin: the muon, but when this was done, the, more accurate, proton radius was found to be 0.84 fm, 4% smaller and a difference seven times larger than the uncertainty in the original measurement [2]. This was confirmed in 2013 [3] and has also been confirmed using a muon orbiting a deuterium nucleus [4].

The standard model has no mechanism that allows the proton to change size in the proximity of a muon as opposed to an electron, so this is a crucial finding. Another possibility however, is that the proton size is not changing but that a new binding energy equal to 320 μeV is appearing [1]. It is the contention of this paper that this extra binding energy comes from sheltering by the hypothesised Unruh radiation.

[5] suggested that black hole event horizons can separate pairs of particles in the zero point field, swallowing one and allowing the other to escape as a real particle, thus allowing black holes to radiate. [6], [7] and [8] then suggested that the same thing may occur when objects accelerate since then a horizon appears, and may similarly seperate paired virtual particles making half of them real. This is now called Unruh radiation.

[9] and [10] suggested that inertia is caused by Unruh radiation: the acceleration of an object causes a Rindler horizon to form on the side opposite to the acceleration vector and this damps Unruh radiation on that side of the object, causing a net imblance in Unruh radiation pressure that pushes it back against the original acceleration. This new process predicts inertial mass [10] and [11] and also predicts deviations from the standard inertial mass that explains the galaxy rotation problem without the need for dark matter [12] and also cosmic acceleration [13]. The crucial point here is that Unruh radiation is taken to exist and to be able to push on particles.

In this paper it is argued that the usually isotropic Unruh radiation seen by the orbiting muon is blocked by the central proton, which subtends a much larger solid angle at the close-orbiting muon than at the distantly-orbiting electron. It is shown that this sheltering effect on Unruh radiation can account for about half of the proton radius anomaly in muonic hydrogen.

2 Method and Results

Let us imagine a muon orbiting around a proton as shown in Figure 1.

In quantum mechanics of course it is not possible to specify an exact orbital speed for the muon, but one can estimate the probable speed: $v \sim \alpha c$ where α is the fine structure constant and c is the speed of light. The acceleration of the muon as it orbits at a radius R is then

$$a = \frac{v^2}{R} = \frac{(\alpha c)^2}{R} \tag{1}$$

where $\alpha \sim 1/137$. The wavelength of Unruh radiation seen by the muon while orbiting can be found using Wien's law for the wavelength emitted by a body of temperature T, $\lambda = \beta hc/kT$ where $\beta = 0.2$, h is Planck's constant, c is the speed

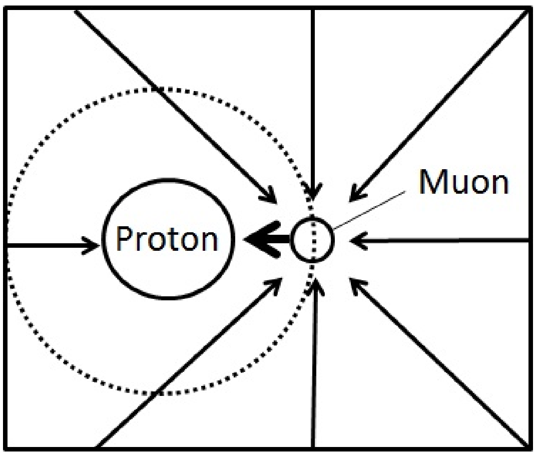

Fig. 1: Schematic showing a muon (the small right hand circle) orbiting close to a proton (the large left hand circle). The muon is pushed by the Unruh radiation associated with its acceleration (the arrows) from all directions except from the direction of the blocking proton (the truncated arrow). So there is a new net force pushing the muon towards the proton. The size of this force produces 55% of the proton radius anomaly.

of light and k is Boltzmann's constant, and combining it with the temperature of Unruh radiation seen at an acceleration a: $T = \hbar a/2\pi ck$, so that

$$\lambda_U \sim \frac{8c^2}{a}. \tag{2}$$

The de Broglie energy associated with this wavelength is

$$E = \frac{hc}{\lambda_U}. \tag{3}$$

Using (2) we get

$$E \sim \frac{ha}{8c} \tag{4}$$

and using (1) we get

$$E \sim \frac{h\alpha^2 c}{8R}. \tag{5}$$

This is the energy in the Unruh radiation field at the muon, which usually strikes the muon isotropically so does not push it in any net direction. However, we shall assume that the proton, as seen from the muon, blocks all the Unruh radiation coming from that direction (Fig. 1). The amount will be proportional to the solid angle of the proton as seen by the muon, which is $\pi r_P^2/2\pi R^2 = 5.7\times10^{-6}$, where r_P is the proton radius and R is the muon-proton distance. Note that we are only looking at one side of the muon, to work out the energy asymmetry that pushes on the muon, so it is the half-sphere we consider.

As energy is being blocked on the side of the muon closer to the proton, this represents a new source of energy pushing the muon towards the proton, and adding to its boundedness. The specific amount of energy is

$$E \sim \frac{h\alpha^2 c}{8R} \times \frac{\pi r_P^2}{2\pi R^2} = 2.8 \times 10^{-23}\mathrm{J}. \tag{6}$$

The extra binding energy required to account for the observed proton radius anomaly is 320μeV or 5.1×10^{-23} J. Therefore a sheltering of Unruh radiation by the proton predicts roughly 55% or 180 μeV of the energy needed to explain the observed proton radius anomaly for muonic hydrogen.

This extra Unruh binding energy is far smaller in the case of the electron. Electrons orbit the proton about 200 times further out than the muon and so the solid angle of the proton at the electron is much smaller. The energy released in the electron case would be

$$E \sim \frac{h\alpha^2 c}{8R} \times \frac{\pi r_P^2}{2\pi R^2} = 7.1 \times 10^{-28}\mathrm{J} \tag{7}$$

or about 5 orders of magnitude smaller than for the muon. So there is no anomaly for normal hydrogen. When the electron is replaced by a muon there is a difference of roughly 180 μeV, or 55% of the observed anomaly.

3 Conclusion

It has been observed that the radius of the proton, as determined by the Lamb shift, is apparently 4% less when measured using an orbiting muon instead of an electron. This can be interpreted as an anomalous increase in the proton-muon binding energy of 320 μeV.

Assuming that Unruh radiation is able to push on particles, and that the proton can block it, predicts an extra proton-muon binding energy of 180 μeV, about 55% of the observed anomaly.

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