A Relation between Quantum Impedances and Gravity

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The Planck particle may be defined in two ways; for particles with mass, and for the photon. For massive particles the Compton wavelength and Schwarzschild radius are taken to be equal. The resulting radius is the Planck length, the scale at which space is thought to be in some sense quantized. The Planck particle as thus defined is strictly mechanical. It has no electromagnetic properties. The Planck particle may be similarly defined in terms of the photon, again as one whose wavelength and Schwarzschild radius are equal. The radius is again the Planck length. The Planck particle as thus defined is electromechanical, an electromagnetic black hole. The connection between gravitation and electromagnetism can be made more explicit by examining the impedance mismatch between such particles and the photon and electron. This mismatch is shown to be the ratio of the gravitational and electromagnetic forces.

INTRODUCTION

This letter presents a preliminary exploration of the role of quantum impedances[1] in gravitation. In the earlier work on impedances, the main players were the photon and the electron. That earlier work presented a model in which the unstable particles were seen as resonant excitations of the network of electron impedances by the photon. The present work looks at the extreme high energy limit of the interaction of the photon and the electron with a third player, the Planck particle[2].

In what follows the Planck particle is presented, and its gravitational and Coulomb interactions with the electron are introduced.

The impedance mismatch between the Planck particle and photon and electron is then shown to be equal to the ratio of the gravitational and electromagnetic forces at the staggeringly accurate level of four parts per billion (the empirically determined Newtonian gravitational constant G is measured with an accuracy of about a part in ten thousand).

This suggests that the gravitational force might be taken to be electromagnetic in origin. The enormous difference in strengths can be understood in terms of the equally enormous impedance mismatch of the electron and photon to the Planck particle.

THE PLANCK PARTICLES

We have two ways to define Planck particles, one each for massive and massless particles.

For **massive particles** we equate the reduced Compton wavelength and the Schwarzschild radius

$$\frac{\hbar}{mc} = \frac{mG}{c^2}$$

Solving for the mass m gives the reduced Planck mass[3]

$$m_{Pl} = \sqrt{\frac{\hbar c}{G}} \simeq 2.1765 * 10^{-8} kg \simeq 10^{19} GeV$$

and the reduced Planck length

$$L_{Pl} = \frac{\hbar}{m_{Pl} c} = \sqrt{\frac{\hbar G}{c^3}} \simeq 1.6162 * 10^{-35} m$$

For the **massless photon** it is the simple matter of the equivalence $E = mc^2$ of energy and mass. From that and $E = h\nu$ we have the photon wavelength

$$\lambda = \frac{c}{\nu} = \frac{hc}{E} = \frac{hc}{mc^2} = \frac{h}{mc}$$

and can proceed as for the massive particles.

THE INTERACTIONS

The **gravitational force** between the Planck particle and the electron can be written as

$$F_{grav} = G\frac{m_e m_{Pl}}{{\lambda_e}^2} = 8.873\ 419\ 056 * 10^{-24} N$$

where m_e is the mass and λ_e the reduced Compton wavelength of the electron.

The **Coulomb force** between the electron and a Planck particle carrying the charge of a positron is

$$F_{Coul} = \frac{1}{4\pi\epsilon_0}\frac{e^2}{{\lambda_e}^2} = 1.547\ 138\ 513 * 10^{-3} N$$

The **ratio** of these two forces is

$$ratio_F = \frac{F_{grav}}{F_{Coul}} = 1.743\ 565\ 251 * 10^{-20}$$

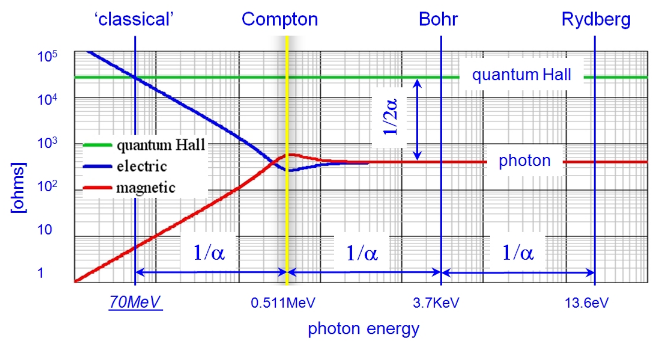

FIG. 1. Photon and quantum Hall impedances as a function of spatial scale as defined by photon energy. The role of the fine structure constant α is prominent in the figure

THE IMPEDANCES

Near and far field photon impedances[4] and the scale invariant quantum Hall impedance[5] are shown in the figure. The wavelength of the photon is the Compton wavelength of the electron. The energy of such a photon is 0.511MeV, the mass of the electron.

Similarly, we defined the Planck particle in two ways, one each for massive and massless particles, both with the same wavelength and energy. This is true in general. If the wavelength of a photon is the same as the Compton wavelength of a particle, then particle and photon have the same energy.

There are two possibilities for calculating the impedance mismatch between the electron and the Planck particle, either by matching them directly or via the intermediary of the photon. The simpler approach, and the one in greater harmony with QED, utilizes the photon. There are at least two ways to accomplish this:

- match the near field impedance of a .511MeV photon to the scale invariant quantum Hall impedance of the Planck particle at the Planck length
- match the dipole mode of the electron to a 10^{19}GeV photon at the Planck length.

The first approach assumes that one of the Planck particle impedances can be taken to be the quantum Hall impedance[1], which is well documented in the literature. It requires that the Planck particle be given the attribute of electric charge, in this case the charge of the positron.

The second approach requires introduction of the quantum dipole impedance of the electron[6]. Both produce the same result. In the interest of simplicity and brevity, only the first will be presented here.

[1] the equality between the quantum Hall impedance and an inertial impedance associated with the centripetal force was presented in earlier work [1, 6]

The near and far field amplitudes of the electric and magnetic components of the dipole impedance seen by the photon can be written as [4]

$$Z_E = Z_0 \left| \frac{1 + \frac{\lambda}{ir} + \left(\frac{\lambda}{ir}\right)^2}{1 + \frac{\lambda}{ir}} \right|$$

$$Z_M = Z_0 \left| \frac{1 + \frac{\lambda}{ir}}{1 + \frac{\lambda}{ir} + \left(\frac{\lambda}{ir}\right)^2} \right|$$

where λ is the photon wavelength, r is the length scale of interest, and $Z_0 \simeq 377\Omega$ is the free space impedance seen by the photon in the far field. These are the photon impedances plotted in the figure. On the scale of this page the Planck particle sits slightly less than a full page width to the left of the electron Compton wavelength.

Looking first at the **electric component** of the photon near field impedance, and taking λ to be the electron Compton wavelength and r the Planck length gives

$$Z_E = 9.001\ 262\ 858 * 10^{24}\Omega$$

and

$$ratio_{Z_E} = \frac{\alpha Z_E}{Z_0} = 1.743\ 565\ 259 * 10^{-20}$$

At the part per billion level this is the ratio of the gravitational to Coulomb force calculated in the previous section, so that

$$\frac{ratio_{Z_E}}{ratio_F} = 1.000\ 000\ 004$$

The accuracy of this result might be surprising at first glance, given the much larger experimental uncertainty in the gravitational constant G. However G is present in both numerator (the impedance is calculated at the Planck length) and denominator (the gravitational coupling of the electron to the Planck particle) of this 'ratio of ratios' and hence cancels out. *The result is independent of the value of G.* The quantum impedance model is gravitationally gauge invariant.

The same calculation for the **magnetic component** of the photon near field impedance gives

$$Z_M = 1.576\ 731\ 302 * 10^{-20}\Omega$$

and

$$ratio_{Z_M} = \frac{\alpha Z_0}{Z_M} = 1.743\ 565\ 258 * 10^{-20}$$

so that, as for the electric component of the impedance

$$\frac{ratio_{Z_M}}{ratio_F} = 1.000\ 000\ 004$$

DISCUSSION

The reader might object that the Planck particle exists only in theory, that if such a particle could somehow be produced, it would not be stable, would immediately radiate its energy away. However, the possibility of interaction with the virtual Planck particle remains, just as interaction with the vacuum permits renormalization of QED.

The reasoning presented in the previous sections was adopted in the interest of making the simplest possible presentation of the role of quantum impedances in gravitation. It therefore employed only those impedances found in the commonly accepted body of physics knowledge, namely the photon and quantum Hall impedances.

The step to generalized quantum impedances requires the introduction of a model[1, 6] that is not completely necessary for the present purpose. The reader is encouraged to explore that model before returning to the present subject of gravitation, in the hope that the logical foundation of the calculations presented here will thereby become more transparent and additional new possibilities will reveal themselves.

CONCLUSION

The flow of energy is governed by impedances.

This understanding is common to electrical engineers, some mechanical engineers, most accelerator physicists, and a subset of the physics community, working almost exclusively in condensed matter. As applied to particle physics, it requires a sophistication of network analysis now accessible to electrical engineers and complex systems specialists.

The Planck particle can conceivably provide a much needed additional anchor point for the iterative software that might eventually sort out the mode structures and coupling mechanisms, and perhaps solve the localization problem[7, 8].

If in fact the equivalence principle applies here and the mass of the electron follows from electromagnetic interaction with the Planck particle, then it appears that this will be true for all massive particles, each via its own routes through the impedance networks.

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[2] http://en.wikipedia.org/wiki/Planck_particle

[3] SI units are used throughout. All constants are codata2006 except the fine structure constant, which is taken from G. Gabrielse, “New Measurement of the Electron Magnetic Moment and the Fine Structure Constant”, available at http://arxiv.org/pdf/0801.1134.pdf

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