Potential Links: Gravity and Nuclear Force

Shantilal G. Goradia
email: Shantilalg@juno.com
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Abstract

The gravitational inverse square law is a macroscopic approximation. I suggest that it should be modified for small particles to use the surface-to-surface separation of particles rather than the center-to-center separations. For small particles at macroscopic separations, the ratio between the center-to-center distance $D$ and surface-to-surface distance $d$, $D/d$, approaches unity. At microscopic separations, this ratio grows very large. Here I apply this ratio to several microscopic situations and derive the nuclear coupling constants. I will then present a model of a gluon/graviton transformation to justify my surface originating modification.

1 Introduction

Newtonian gravity encounters issues for microscopic dimensions. As the sizes of two adjoining identical particles of uniform density tend to zero, the numerator of the force equation ($F = Gm_1m_2/r^2$) falls off as $r^6$. Since the denominator falls off as $r^2$, the force goes to zero in the limit of small particles with microscopic separations. Newtonian gravity in this form, therefore, cannot explain the nuclear binding force.

If we use the surface-to-surface separation between these particles to quantify the gravitational attraction instead of the center-to-center separation, we find that the force between these microscopic particles is the same as before in the limit of large separations relative to the particle radii. At small separations relative to the particle radii the force between these same particles grows much larger than classical gravity.
2 Modification of the inverse square law

For two coupled nucleons, I choose the Planck length $L = \sqrt{\frac{G\hbar}{c^3}}$ as the surface separation, as it is the minimum possible spatial distance that makes any sense in physics. Assuming zero separation distance would imply that the two particles are joined to form one particle, losing their distinction as separate particles. The diameter of a nucleon is about 1 fm ($10^{-15}$ meters). The Newtonian force is then $F_N = \frac{Gm^2}{D^2}$, where $D$ is the center-to-center distance, $\sim 1$ fm. If we select the surface-to-surface separation instead, the force would become $F_P = \frac{Gm^2}{d^2}$, with $d = L = 10^{-20}$ fm. The ratio of these two forces is $D^2/d^2 = 10^{40}$, which is also the strength of the nuclear force relative to gravitation. Strictly speaking, the strong force is not purely short range decreasing to a precise zero beyond a boundary, as illustrated by Rutherford’s scattering experiments, which showed effects from the strong force at separations of at least 10 fm [1]. As the nucleons are separated, $D/d$ shrinks, and $F_P$ rapidly approaches $F_N$ (Fig. 1). At 1000 fm (less than the radius of an atom) the modified law yields the same results as standard Newtonian gravitation. Einstein also tried to explain nuclear force in terms of gravity [2].

For a coupled quark-lepton pair, the center separation can be taken to be $\sim 10^{-3}$ fm. If we modify Newton’s equation as above, we find that the ratio between the standard and modified force is $10^{34}$. This is the relative strength of the weak nuclear force compared to gravitation. The weak nuclear force diminishes to standard Newtonian gravity at a distance of 1 fm, the diameter of the nucleon (Fig. 1).

3 Links to Current Physics

Gluons create an effect that is approximately the classical equivalent of parallel springs connecting quarks: greater separations lead to greater attractive forces. If the hadron is considered to be a spherical “sea” of gluons surrounded by quarks, gluons may transform to gravitons as they ”evaporate” out of the gluon-sea or gravitons may ”condense” into gluons at this surface. As the virtual gluons ”evaporate”, they can either become free gluons, or possibly pairs of spin 1 gluons could transform into spin 2 gravitons. These radiation/absorption processes would create $1/r$ potentials radiating in all directions with their origins at the surface of the hadrons, not at the center of the hadrons. This would create a very strong force between the surfaces of closely packed particles, while being indistinguishable from gravity at large distances. Gravity between two spheres one fm in diameter and a Planck length apart, when hypothesized
Figure 1: Ratio of modified force to Newtonian gravitation as a function of surface separation for nucleon-nucleon and quark-lepton interactions. The ratio approaches unity at large surface separations in both cases. Also, for both interactions the ratio becomes quite large for short separations, reaching $10^{30}$ for the nucleon-nucleon interaction and $10^{34}$ for the quark-lepton interaction in the Planck length separation limit of $10^{-20}$ fm.

my way yields the strength of the nuclear force relative to gravity exactly and consistently. If the above transformation takes Planck time, there will be a Planck length separation between the quark-gluon plasma and the gravitational interaction. This would be consistent with general relativity and quantum mechanics; for this surface-originating gravity, the Compton wavelength would equal the gravitational radius, incorporating the uncertainty principle and general relativity [3]. This picture is compatible with the prevailing view that the nuclear force is a secondary effect of the color force. In this model, the hadron is treated as a geometrically spherical object. This is not unprecedented; de-Sitter’s hadron model is also spherical [3]. If hadrons are not exactly spherical, the exact force might be affected, but not its order of magnitude.

The existence of the gluon-graviton transformation at the surface of the hadron presents the intriguing possibility that few, if any, gravitons are found inside hadrons. The nuclear force is a secondary effect of the color force. I am proposing that nuclear force is strong gravity characterized by the above transformation at the surface of the hadron. Combining these ideas, it can be seen that gravitons should not be found within the hadron, as implicitly predicted previously with more details [4]. Gravitons from outside the hadron should generally transform back to gluons and many gluons would transform to gravitons as
they leave the hadron. This transformation brings all attributes of the color force (mass, spin and color charges) into gravitation without any significant modification of general relativity other than the Planck time described above.

Einstein, in a paper written in 1919, attempted to demonstrate that his gravitational fields play an important role in the structure and stability of elementary particles. His hypothesis was not accepted because of gravity’s extreme weakness [3]. My hypothesis would negate this argument, providing a more consistent picture and supporting Einstein’s insight. In this case, Einstein’s fields do play an important part in particle structure; their unexpected strength leads to identification as a qualitatively different force, i.e. the residual strong force.

The classical Einstein equation may be viewed as an equation for a self-interacting spin-2 field in Minkowski space as concluded by R. M. Wald. [5]. Combining Wald’s statement with the above gluon/graviton transformation and the proposed 1/r propagation could mathematically link the color forces to general relativity, reinforcing the prevailing view. In layman’s terms: The leakage of the mixed color forces is potentially the white color "evaporating" from the surfaces of hadrons, ultimately perceived as gravity i.e., the carriers of color force below Planck scale are transformed into carriers of gravity above Planck scale as if the leaking parallel springs weaken and line up in series. While the surface is not precisely defined because of uncertainty, it is qualitatively intuitive. If hadrons are not exactly spherical, the exact force might be affected, but not its order of magnitude.

4 Prediction

My theory provides a consistent, intuitive and simplistic, but mathematical explanation of the relative values of the strong, weak and gravitational coupling constants, something no other single theory has done. If, as has been suggested, G is decreasing with time, the Planck length shortens, affecting the values of coupling constants, past nuclear reaction rates and the accuracy of radio-dating. Experimentally, my theory can be explored through close investigation of the nuclear force at $\approx 1$-10 fm. Additionally, my prediction that gravitons do not exist in hadrons may resolve the difficulties string theory has in incorporating gravity and color force at the same time.
5 Conclusion

There is a potential link between gravity and nuclear force. The nuclear coupling constants, therefore, are expressible as the squares of the sum of the diameters of the involved particles, expressed in Planck lengths.

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