# Gravity and the Nuclear Froces: A Potential Link

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The electromagnetic and gravitational inverse square laws are microscopic approximations. I suggest that they should be modified for elementary particles to use the surface-to-surface separation of the particles rather than the center-to-center separations. For small particles at macroscopic separations, the ratio between the center-to-center distance $D$ and the 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 also discuss some of the astrophysical implications of this modification to the inverse square law.

## 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.

Physicists have attempted to explain the nuclear force in terms of perturbations to classical gravity [1]. However, in the end they concluded that a new force, the strong force, is responsible for nuclear binding. Quantum Chromodynamics was developed, following the form of Quantum Electrodynamics, to quantify the strong force. Experimentalists and string theorists faced a yet incomplete task of detecting and incorporating the spin 2 graviton into a fully quantized and renormalized theory.

We can follow the lead of those who have tried to explain the strong force in terms of gravity by attempting to modify the classical Newtonian theory of gravity in the case of small particles. 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. We can look at the effects of making this change in several specific situations.

## 2 Modification of the inverse square law

For two coupled nucleons (Fig. 1a), I choose the Planck length $L = (Gh/c^3)^{0.5}$ 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 distinctions as separate particles. The diameter of a nucleon is about 1 fm ($10^{-15}$ meters). The Newtonian gravitatinal force is then $F_N = Gm^2/D^2$, where $D$ is the center-to-center distance, $\sim 1$ fm. If we select the surface-to-surface separation instead, the force would become $F_P = Gm^2/d^2$, 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 [2]. As the nucleons are separated, $D/d$ shrinks, and $F_P$ rapidly approaches $F_N$ (Fig. 2). At 1000 fm (about the radius of an atom) the modified law yields the same results as standard Newtonian gravitation. This modification yields a force with high intensity at short range, rapidly falling off to a very low intensity at long range. It meets the boundary values of both gravitation and the strong force, and suggests that they could be the same interaction. My hypothesis would unify gravity with the prevailing view that the nuclear force is a scondary effect of the color force. Einstein also tried to explain nuclear force in terms of gravity [3], but did not use the Planck length in this way.

For a coupled quark-lepton pair (Fig. 1b), 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. 2). As the surface separation increases, the weak nuclear force diminishes just like the strong nuclear force. It becomes immeasurable more rapidly as it is much weaker to start with. It is understandably described as a contact force. We can also note that for a pair of leptons, which are point-like, there is no distinction between $D$ and $d$, and the ratio $F_P/F_N$ is unity.

We can examine the case of light passing by a nucleon in this manner as well. Einstein found that the deflection of a photon passing by the surface of the sun is $\theta = 4g'R/c^3$, where $g'_{\text{sun}} = 28g$ ($g$ is the acceleration due to gravity on the surface of the earth, 9.8 m/s$^2$) and $R$ is the radius of the sun. If we find $g'_{\text{nucleon}}$ for which $\theta = \theta_{\text{sun}}(8.5 \times 10^{-6})$ radians), we get $g' = 10^{40}g$. This is the same as the strength of the strong nuclear force relative to gravitation, again indicating a qualitative connection between the strong nuclear force and gravitation.

In the above calculation nucleon deformation was neglected, and nucleons were treated as spheres of material. Deformation effects should be small, as they would consist of relatively small changes in the particle diameters, and the order of magnitude of the ratio should stay the same. Quark-to-quark interactions were ignored, because forces between quarks are qualitatively different. Neither quarks nor gluons are observed in isolation. The modification remains consistent with general relativity, although it is not derived from the field equations in conventional mathematical form and ignores time dilation (time dilation effects should be small in this case). The angle of deflection for light that was used above is arbitrarily chosen as the same angle used to predict general relativity, but small changes in the angle will not yield changes in the order of magnitude of $g'_{\text{nucleon}}$. The angle was kept conservatively small because the accuracy of the deflection equation at large angles is questionable.

## 3 Astrophysical Implications

My theory could have an interesting implication for Dirac's Large Number Hypothesis (LNH). The LNH comes from the fact that the number $10^{40}$ occurs in several important places in physics, such as the strong force coupling constant and the Hubble time. Dirac suggested that there was some connection between these numbers. One implication of the LNH is that $G$ was about 10% higher for every one billion years in the past. If $G$ was higher, however, the earth sould have been close enough to the sun to boil off all the surface water at that time, preventing life from evolving here.

This effect has caused Dirac's Hypothesis to be put on the shelf. However, in my modified theory, the strong coupling constant is inversely proportional to $G$, and the longer Planck length resulting from an increase in $G$ would cause the strong coupling constant to be smaller. This would slow down nuclear reaction rates. Lower coupling constants could have reduced the binding energies of fusion nuclei, reducing the power output of the sun per reaction. This might compensate for the difference in the distance to the sun. There is some experimental evidence in favor of the LNH, quoted by physical cosmologist Jayant Narlikar, based on an assessment of data on the moon's

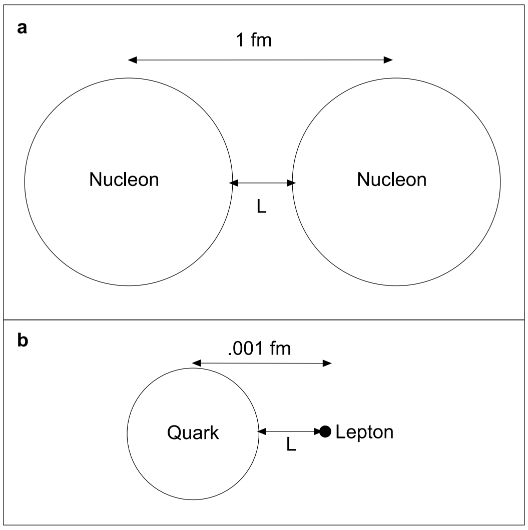


Figure 1. Pictorial view of gravitational interaction, showing surface and center separations (not to scale). $L$ is the Planck length, $10^{-20}$ fm. a, Two nucleons at minimum separation; b, A quark and a lepton, also at minimum separation. The standard inverse-square law would use the center-to-center distances to calculate the force between the particles; using the surface-to-surface distance yields a much stonger force for these separations, equal to the relative strengths of the strong and weak nuclear forces, respectively.

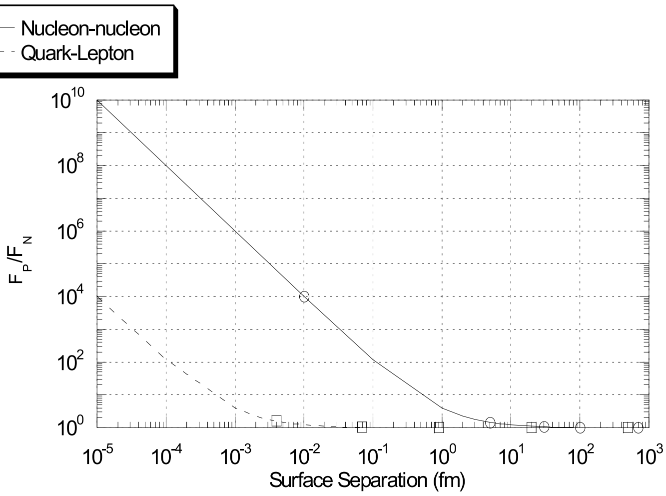


Figure 2. Ratio of modified force to Newtonian gravitation as a function of surface separation for nucleon-nucleon and quark-lepton interactions. The ratio approaches unity at large surface separations in both cases. Also, for both interactions the ratio becomes quite large for short separations, reaching $10^{40}$ for the nucleon-nucleon interaction and $10^{34}$ for the quark-lepton interaction in the Planck length separation limit of $10^{-20}$ fm.

motions made by Thomas Van Flandern of the U.S. Naval Observatory [4]. According to this work, $G$ may be decreasing by a few parts per billion per century! If this is so, my theory provides an explanation for life being able to evolve.

Another implication of my theory combined with the LNH is that radiopactive dating data are wrong. A change in the rate of nuclear reactions over time nullifies a central assumption of radioactive dating, i.e., constant half-lives. If this rate is changing in a known way, as is suggested by the LNH, adjustments could be made. In the case of radiocarbon dating for example, the change would be negligible over the time period in question. However, other dating methods using longer-lived isotopes could see significant changes from their currently assumed ages from a slowly changing $G$.

## 4 Historical perspective

There is reason to believe that Newton had masterminded the insight I am bringing on the surface, as it is evident from his delay in the publication of his theory of graviation for 20 years. Newton published his theory under pressure from the Royal society. His struggle with his formula is evident from the following statement in the Principia (Book III, Proposition 8): "After I had found that the force of gravity towards a whole planet did arise from, and was compounded of the forces of gravity towards all its parts, and towards every one part, was in the reciprocal proportion of the squares of the distances from the part: I was yet in doubt, whether that reciprocal duplicate proportion did accurately hold, or but nearly so, in the total froce compunded of so many partial ones." [5].

When Rutherford discovered the strong nuclear force in 1919, he proposed this high intensity force to be gravitation [1]. Not being able to describe the force in terms of gravity, it was decided that high intensity force was due to effects other than gravitation. Gravity's weakness is described as the main reason why the strong nuclear force is considered a separate force. I suggest the strong nuclear force can be explained in terms of modification to Newtonian gravity to the microscopic scale.

## 5 Conclusion

The inverse-square relationship of the classical Newtonian gravity can be modified for the microscopic case. These modifications lead to the derivation of the nuclear coupling constants as the relative strength of the modified inverse-square force when the appropriate particles are in contact (i.e. their separation is minimized). The nuclear coupling constants, therefore, are expressible as the squares of the sum of the diameters of the involved particles expressed in Planck lengths. This implies a close connection between gravity and nuclear forces. The classical description of particles in terms of their diameters is justified based on the consistency of the results in deriving coupling constants. My suggestion, that gravity is the cumulative effect of long-range nuclear forces from a large number of particles as predicted by my modified equation, has profound potential implications.

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