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The Gravitational Constant G and the Confinement of the Strong Force: Proton Quantum Dynamics Within the Baryonic Expansion Framework

Claude R. Cahen, M.D.[1*]

[1]Independent Researcher. ORCID ID: https://orcid.org/0009-0002-1876-5629

[*]**Correspondence:**

Claude R. Cahen, M.D., Independent Researcher. e-mail address: Salabelle598@gmail.com, ORCID ID: https://orcid.org/0009-0002-1876-5629

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Abstract

Newton's gravitational constant G is measured but has never been derived from more fundamental quantities. Within the baryonic expansion framework developed by the author since 1990, we examine how G is related to the proton's mass, radius and internal pressure. The principal findings are three. (i) Applying the author's 1993 expansion equation to the proton and comparing the result with the acceleration its internal pressure ($\approx 10^{35}$ Pa) would produce in the absence of confinement defines a confinement leakage factor $k \approx 3 \times 10^{-40}$.

(ii) G is then bound to proton quantities by the exact relation $G = 4\pi k P_p r_p^4 / m_p^2$. (iii) Because $P_p r_p^4 \approx 1.6$ h-bar c, the leakage factor equals the proton's gravitational coupling $\alpha_G \approx 6 \times 10^{-39}$ divided by a geometric factor of about 20. As defined here, k contains G, so these relations are consistency relations and not yet a derivation of G. We state the condition under which they become one, an independent determination of k or of the proton surface expansion rate from confinement physics or from the Dirac Sea energy source, and identify two routes toward it. We propose, as an interpretation to be tested, that gravity is the residual leakage of the strong force through quark confinement.

Keywords: gravitational constant, hierarchy problem, proton pressure, quark confinement, gravitational coupling constant, baryonic expansion.

1. Introduction

Newton's gravitational constant $G = 6.6743 \times 10^{-11}$ m^3 kg^{-1} s^{-2} is among the least precisely known fundamental constants. Neither Newtonian mechanics nor General Relativity explains its value; it enters both as an empirical parameter.

The weakness of gravity is usually expressed through the dimensionless gravitational coupling of the proton, $\alpha_G = G m_p^2/(\text{h-bar c}) \approx 5.9 \times 10^{-39}$, compared with a strong coupling of order unity at the proton scale. Why this ratio is so small is the hierarchy problem. Several lines of thought have suggested that gravity might not be fundamental but emerge from other physics: Dirac's large-number hypothesis related G to cosmological quantities;[9] Sakharov proposed that gravity is induced by vacuum fluctuations of quantum fields;[11] and Verlinde has argued for an entropic origin of gravity.[12] The present work belongs to this family, but locates the origin of gravity in the internal dynamics of the proton.

The baryonic expansion framework, developed by the author since a manuscript submitted in 1990 and published in Physics Essays in 1993,[1] proposes that what we call gravitation is the macroscopic, density-proportional consequence of a continuous expansion of baryonic matter. This paper applies the framework to a single proton and asks how G relates to the proton's measured properties.

1.1 Working Hypotheses

To separate established physics from the proposals of this paper, we state the hypotheses explicitly:

- **H1 (proposed):** Gravitation is the macroscopic effect of a density-proportional expansion of baryonic matter, described by $e = E \cdot D \cdot R$ with $E = (4\pi/3)G$.[1] This relation is algebraically identical to Newton's law of gravity.
- **H2 (proposed):** The expansion of each proton is driven by its internal pressure, whose existence and magnitude are established experimentally and by lattice QCD.[2,3,7]
- **H3 (proposed):** Quark confinement contains all but a very small fraction k of this pressure-driven acceleration; the residual fraction appears as expansion, and therefore as gravity.

The proton's internal pressure, its radius and mass, the Color Glass Condensate and the sea of quark-antiquark pairs are established physics. H1 to H3, and the energy source discussed in Section 5, are the author's proposals.

2. Known Quantities

Quantity	Symbol	Value
Proton mass	m_p	1.6726×10^{-27} kg
Proton charge radius (CODATA 2018)	r_p	0.8414×10^{-15} m
Proton mass radius[13]	r_m	$0.55 \pm 0.03 \times 10^{-15}$ m
Peak internal pressure[2,7]	P_p	$\approx 10^{35}$ Pa
Expansion constant[1]	$E = (4\pi/3)\,G$	2.7957×10^{-10} m^3 kg^{-1} s^{-2}
Newton's constant (measured)	G	6.6743×10^{-11} m^3 kg^{-1} s^{-2}
Reduced Planck constant × c	h-bar c	3.1615×10^{-26} J·m

On the pressure value: Burkert, Elouadrhiri and Girod extracted the pressure distribution inside the proton from deeply virtual Compton scattering data and found a peak repulsive pressure of about 10^{35} Pa near the centre;[7] lattice QCD calculations of the quark and gluon contributions give the same order of magnitude[2,3] We use this peak value as the characteristic scale of the internal pressure. Two cautions apply. The pressure varies with radius and changes sign toward the periphery, and its volume integral vanishes (the von Laue stability condition), so no single value is exact. And all results below scale simply with the value chosen (Section 3.7).

The expansion constant E was introduced by the author in 1993;[1] the value above uses the current CODATA value of G (the 1993 value, 2.7935×10^{-10}, corresponds to $G = 6.669 \times 10^{-11}$).

3. Step-by-Step Analysis

3.1 Proton Density

$$D_p = m_p / ((4/3)\pi\, r_p^3) = 6.70 \times 10^{17}\ \text{kg/m}^3$$

3.2 The Expansion Equation Applied to the Proton

$$a_p = E \cdot D_p \cdot r_p = G\, m_p / r_p^2 = 1.577 \times 10^{-7}\ \text{m/s}^2$$

Physical interpretation of a_p: Numerically, a_p is exactly the Newtonian surface gravity of a single proton, the acceleration a test particle would experience at r_p from the proton's own mass. In conventional physics it is an attraction toward the proton; in the baryonic expansion framework (H1) the same quantity is read as the outward acceleration of the proton's surface. The two readings give identical predictions here, as they do at the scale of the Earth.[1] Because E contains G, this step does not derive G; it identifies ap as the quantity that the proton's internal dynamics must ultimately explain. (The value $a_p = 5.457 \times 10^{-7}$ m/s^2 given in 1993 corresponds to a radius of 0.452 fm; the present value uses the modern charge radius.)

3.3 Outward Force on the Proton Surface

$$F = P_p \cdot 4\pi\, r_p^2 \approx 8.9 \times 10^5\ \text{N}$$

This matches the order of magnitude derived from the measurements of Burkert et al.[7] Because the measured pressure satisfies the von Laue condition, the outward pressure of the core is balanced by the confining pressure of the periphery; within the framework,

the expansion of the proton must correspond to an extremely small departure from this balance.

3.4 Raw Pressure-Driven Acceleration

$$a_{raw} = F / m_p \approx 5.32 \times 10^{32}\ m/s^2$$

This is the acceleration the internal pressure would give the proton's mass if confinement were absent. It is a scale, not a physical motion.

3.5 The Confinement Leakage Factor

$$k = a_p / a_{raw} = 2.96 \times 10^{-40}$$

Substituting the expressions for ap and a_{raw}:

$$k = G\, m_p^2 / (4\pi\, P_p\, r_p^4) = \alpha_G \cdot \text{h-bar c} / (4\pi\, P_p\, r_p^4)$$

Mathematical significance and dependence on G: This expression shows what k is and what it is not. Since ap is computed from G, k is proportional to G, and the statement that k is proportional to αG is an algebraic identity, not an independent coincidence. The physically non-trivial content lies in the remaining factor: the internal pressure and radius of the proton combine to $P_p\, r_p^4 = 1.59$ h-bar c, a number of order unity, as expected if the pressure is set by the strong interaction at the scale of the proton. Hence

$$k \approx \alpha_G / (4\pi \times 1.59) \approx \alpha_G / 20$$

In words: the fraction of the proton's internal pressure-driven acceleration that would appear as expansion is of the same order as the gravitational coupling, because the proton's pressure is itself of strong-interaction strength. The relation is exact within the stated hypotheses; whether k has an independent physical origin is the open question of Section 3.6.

3.6 The Condition for a First-Principles Derivation of G

$$G = 4\pi\, k\, P_p\, r_p^4 / m_p^2$$

As written, G appears on both sides through k. The equation becomes a derivation of G as soon as k, or ap, is determined without reference to G. Two routes are open: (1) from the energy source, by deriving ap from the rate of the Dirac Sea process of Section 5 and then $G = a_p\, r_p^2/m_p$; (2) from confinement, by deriving k as a suppression factor from QCD parameters such as the strong coupling and string tension. Since $k \approx e^{-91}$, a factor of the form e^{-S} with $S \approx 91$ arising from QCD would give G with no gravitational input.

3.7 Sensitivity to the Proton Radius and Pressure

We use the proton charge radius because it is the most precisely measured proton size and because the earlier work in this framework used it. The mass distribution, however, is more compact: the root-mean-square mass radius extracted from J/ψ photoproduction is 0.55 ± 0.03 fm.[13] Because $k \propto r_p^{-4}$, the choice matters:

Radius used	D_p (kg/m^3)	a_p (m/s^2)	k	$P_p\, r^4$ / h-bar c
Charge radius, 0.8414 fm	6.70×10^{17}	1.58×10^{-7}	2.96×10^{-40}	1.59
Mass radius, 0.55 fm	2.40×10^{18}	3.69×10^{-7}	1.62×10^{-39}	0.29

With either radius, $P_p\, r_p^4$ remains of order h-bar c and k remains within a factor of about 6 of $\alpha_G/20$; the qualitative result is unchanged. The leakage factor also scales as $k \propto P_p^{-1}$, so using an average rather than the peak pressure would increase k in proportion. A complete treatment would replace the single pressure and radius by the measured pressure distribution p(r) (Section 8).

4. Interpretation: Gravity as Strong-Force Leakage

The relation of Section 3.5 invites a physical interpretation, which we present as the central proposal of this paper rather than as an established mechanism. If H1 to H3 hold, gravity would not be a separate force but the strong force leaking, very slightly, through quark confinement, and G would measure the efficiency of that confinement. Its value would then be set by the internal pressure of the proton (itself determined by QCD), by the strength of confinement, and by the rate of the process that sustains the internal dynamics (Section 5).

In this reading, the hierarchy problem, why gravity is weaker than the strong force by about 10^{-39}, becomes a question about confinement: gravity would be weak because confinement is nearly perfect. Almost, but not quite; the residual would be what we call gravity.

5. Relation to QCD and the Proposed Energy Source

Established QCD: Quarks are confined in colour-neutral hadrons. About 99% of the proton's mass is quark-gluon field energy rather than quark rest mass. At high energies the gluon density saturates into the Color Glass Condensate (CGC).[4,14] Besides its three valence quarks, the proton contains a sea of quark-antiquark pairs, and this sea is itself asymmetric: the SeaQuest experiment found more down antiquarks than up antiquarks over a wide momentum range.[15] The proton's internal pressure and shear distributions have been measured and computed.[2,3,7]

Proposed by the author: The CGC grows slowly by gluon accretion, increasing the internal pressure, and the energy for this growth comes from the sea: in the extreme environment of the CGC, the antiquark of a virtual pair is annihilated against a quark, releasing about 4.3 MeV (u-anti-u) or 9.4 MeV (d-anti-d) into gluon energy, while the newly created quark replaces the one annihilated, so that baryon number, charge and colour are conserved.[5,6] This builds on Dirac's prediction of antimatter,[8] its discovery by Anderson,[16] and the Schwinger theory of pair creation in strong fields;[17] the asymmetric fate of the antiquark is the author's hypothesis and has not been derived from QCD.

The proposed chain, with its status, is:

1. Virtual quark-antiquark pairs in the proton [established].
2. Asymmetric annihilation of the antiquark into gluon energy [proposed].
3. CGC growth by gluon accretion, raising internal pressure [proposed].
4. Internal pressure of order 10^{35} Pa [established].
5. Leakage of a fraction k through confinement, as a minute departure from the von Laue balance [proposed].
6. Proton surface expansion rate ap = k araw [follows from H1-H3].
7. Macroscopic gravity, g = 9.81 m/s^2 at the Earth's surface from the cumulative expansion of about 10^{51} protons [follows from H1; numerically identical to Newton's law].

Steps 2, 3 and the value of k in step 5 are the links that remain to be calculated.

6. Relation to Established Gravitational Theory

Because e = E·D·R is algebraically identical to Newton's law, the framework reproduces every weak-field Newtonian result, and it satisfies the equivalence principle by construction: an observer on an expanding surface cannot distinguish the expansion from a gravitational field. The framework therefore does not compete with Newtonian gravity in its domain; it offers a different account of its cause.

General Relativity has been confirmed beyond the Newtonian regime: the perihelion precession of Mercury, light deflection and lensing, gravitational redshift and time dilation, and gravitational waves. Any framework that reinterprets gravitation must reproduce these results quantitatively. The present paper does not attempt this; its scope is limited to the relation between G and the properties of the proton, a question on which General Relativity, which takes G as given, makes no statement.

7. Possible Cosmological Implications

The following implications are not supported by the calculations above; they are consequences that would follow if the interpretation of Section 4 were confirmed, and they are stated as directions for future work.

Variation of G: If the proton's internal dynamics evolve, G might vary slowly over cosmic time, as Dirac proposed.[9] Lunar laser ranging limits any variation to below about 10^{-13} per year;[18] once the rate of the Dirac Sea process is calculated, this gives a direct test.

The hierarchy problem would no longer require fine-tuning: the ratio of about 10^{-39} would be the efficiency of confinement.

Quantum gravity: If gravity emerges from QCD processes within the proton, the quantum foundation of gravity would already be present in QCD, and a separate quantization of gravity might be unnecessary. Laboratory tests able to distinguish matter-expansion models from conventional gravity have been proposed.[10]

Vacuum energy: The 10^{120} discrepancy between the predicted and observed vacuum energy suggests that the relevant energy may

reside inside the proton rather than in empty space. This is stated for future development.

8. Discussion and Open Questions

The relations presented here are exact within their hypotheses, but they are not yet a derivation of G, because G enters through E and therefore through k. What they establish is the form any derivation must take, and a quantitative target: whatever mechanism links the proton's internal pressure to gravity must suppress it by a factor of order $\alpha_G/20 \approx 3 \times 10^{-40}$.

On the relation between confinement and gravity, the key observation is that $P_p\, r_p^4/\hbar c$ is of order unity. This says that the proton's pressure is a strong-interaction quantity, so the ratio of the gravitational acceleration at the proton surface to the pressure-driven acceleration is, up to a geometric factor, the ratio of gravitational to strong coupling. The framework interprets this ratio as a leakage; a conventional reading would regard it as the statement of the hierarchy itself. Distinguishing the two requires an independent calculation of k. The priorities are:

1. A quantitative calculation of the Dirac Sea pair-creation and asymmetric annihilation rate within the CGC, yielding ap directly.
2. A calculation of k from QCD parameters alone, for example as a suppression factor e^{-S} with $S \approx 91$.
3. A formulation of the leakage as a departure from the von Laue condition using the measured pressure distribution p(r).
4. Use of the proton mass radius and the full pressure profile in place of single values (Section 3.7).

9. Conclusion

We have shown that, within the baryonic expansion framework, Newton's constant is bound to the proton's mass, radius and internal pressure by the exact relation $G = 4\pi k\, P_p\, r_p^4/m_p^2$, where the confinement leakage factor $k \approx 3 \times 10^{-40}$ equals the gravitational coupling of the proton divided by a geometric factor of about 20. The relation is a consistency relation: it becomes a derivation of G once k is determined independently, from QCD or from the Dirac Sea energy source.

We propose, as an interpretation to be tested by that calculation, that gravity is the macroscopic expression of strong-force leakage through quark confinement: gravity would be weak because confinement is nearly perfect, and G would measure how nearly. In the author's words, what we call gravity may be the strong force, almost perfectly imprisoned, and G the measure of its escape.

Conflicts of Interest

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