The Delay That Makes G: Gravitational Mass, the Schwarzschild Crossing-Time, and the Condensation Ladder

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Abstract. This note develops the condensed-space reading of inertia to its gravitational limit — the sibling of the electromagnetic-mass programme of Lorentz, Abraham, and Poincaré — and reports what falls out. If matter is condensed space, a mass is surrounded by a self-field whose energy, integrated inward to the Schwarzschild radius (not to infinity), is a fixed fraction of the rest energy: $U_{ext} = GM^2/2R$ evaluated at $R = r_s$ gives exactly $Mc^2/4$, for any mass, in the Newtonian heuristic. For the field to readjust when the mass moves takes a finite time, and that time is the light-crossing of the horizon, $\tau_s = r_s/c = 2GM/c^3$ — which inverts to $G = c^3\tau_s/2M$. Newton's constant, read backward, is a delay: the time light needs to cross a mass's own Schwarzschild radius. The delay grows with mass (Sun 10 µs, Earth 30 ps, electron 4.5×10^{-66} s), tracking inertia. Integrating the delay itself inward diverges logarithmically at the horizon (the Shapiro delay's limit — light stalls at r_s), the exact gravitational twin of the point-charge self-energy divergence, and it needs the same repair: a finite inner cutoff, the winding radius. One delay law, $\tau = r_s/c$, then spans eighty decades from the electron to the cosmos, and the cosmos sits at the ladder's saturation point: the critical-density condition $GM/Rc^2 = ½$ makes the universe's Schwarzschild radius equal its Hubble radius ($r_s = R$, verified to 1.000), so the universe is at its own horizon and its inertial delay is $\tau = 1/H$ = one Hubble time. "How condensed is a mass" becomes a single ratio, size/r_s, running from 3×10^{44} for the electron (a winding, far outside its horizon) to 1 for the universe (fully condensed). The note closes with the exponential-zoom structure of the infall and the place where the fine-structure constant must live in it — 140 e-folds of ladder, 28.5 α-compressions deep — stated as the framework's central open problem, not a result. Every formula is given; the load-bearing honesty (G is put in to get τ out) is stated in full.

1. The Premise and Its Distinguished Ancestor

The condensed-space postulate (P2 of this series) says matter is not an object on spacetime but a region where spacetime is extremely curved — condensed. Take this literally for inertia. A mass carries a gravitational field; to move the mass is to drag the field; the field's readjustment propagates at finite speed c; the lag is the resistance we call inertia. This is a whip whose far end is the field, and it has a distinguished nineteenth-and-twentieth-century ancestor: the **electromagnetic-mass programme** (J. J. Thomson 1881; Lorentz, Abraham, Poincaré 1900–1905), which tried to make the electron's entire inertia the momentum-lag of its own electromagnetic self-field. That programme got the right length scale (the classical electron radius $r_e = \alpha\cdot\bar{\lambda}_C$) and was abandoned for two reasons — a self-energy that diverges for a point source, and a factor-4/3 that required a non-electromagnetic binding stress (the "Poincaré stress"). This note runs the **gravitational** version of the same programme and shows that both failures are exactly the two things the condensed-space framework supplies: a finite inner size (the winding) and an intrinsic binding tension (the tension medium).

2. The Self-Field Energy, Integrated to the Horizon

The gravitational field strength outside a spherical mass M at radius r is $g = GM/r^2$. The energy density of a Newtonian gravitational field is $g^2/8\pi G$ (the standard field-energy density). Integrate the field energy in the region outside a floor radius R:

$$U_{\text{ext}}(R) = \int_R^\infty \frac{g^2}{8\pi G}\,4\pi r^2\,dr = \frac{GM^2}{2}\int_R^\infty \frac{dr}{r^2} = \frac{GM^2}{2R}. \tag{1}$$

The condensed-space instruction is to stop the integral not at infinity but at the object's own Schwarzschild radius, $R = r_s = 2GM/c^2$. Substituting:

$$\boxed{\,U_{\text{ext}}(r_s) = \frac{GM^2}{2\,r_s} = \frac{GM^2 c^2}{2\cdot 2GM} = \frac{Mc^2}{4}\,} \tag{2}$$

A quarter of the rest energy sits in the field outside the horizon, for every mass, independent of M. This is the black-hole form of "mass is self-energy," and it is honest precisely where the electromagnetic version was not: for the electron the gravitational self-energy far from the horizon is $\sim 10^{-44}$ of its mass and negligible, but *at the horizon* the field energy is always of order Mc^2. At its own Schwarzschild radius, and only there, a mass and its field become the same object.

Caveats, at the series' standard. The factor ¼ is a Newtonian heuristic: general relativity does not permit a clean local energy density for the gravitational field (the equivalence principle lets it be transformed away pointwise), and the Schwarzschild mass parameter already contains the binding energy, so (2) double-books unless read as an order-of-magnitude statement. The robust content is the *scale* — $U_{ext}(r_s) \sim Mc^2$ — which is exact; the coefficient is convention-dependent between ¼ (floor at r_s) and ½ (floor at the gravitational radius GM/c^2).

3. The Delay That Makes G

For the field to respond when the mass moves, information must cross the condensed region. The characteristic time is the light-crossing of the Schwarzschild radius:

$$\tau_s = \frac{r_s}{c} = \frac{2GM}{c^3}. \tag{3}$$

Read the other way — the inverse question of this programme — Newton's constant *is* that delay:

$$\boxed{\,G = \frac{c^3\,\tau_s}{2M}\,} \tag{4}$$

Newton's constant, reconstructed from a mass and its intrinsic response-delay, returns 6.674×10^{-11} identically (the delay contains G by construction — see Section 7). The delay scales linearly with mass, which is the scaling inertia demands:

Mass	**Schwarzschild radius r_s**	**Delay $\tau_s = r_s/c$**
electron	1.35×10^{-57} m	4.51×10^{-66} s
proton	2.49×10^{-54} m	8.29×10^{-63} s
human (70 kg)	1.04×10^{-25} m	3.47×10^{-34} s
Earth	8.87 mm	2.96×10^{-11} s
Sun	2.95 km	9.85×10^{-6} s
Planck mass	$2\ell_P$	$2\, t_{Planck} = 1.08\times10^{-43}$ s

The Sun's self-field takes ten microseconds to "learn" the Sun has moved; the electron's, 10^{-66} s. The delay that encodes G for a mass M is the crossing-time of that mass's own horizon. Note the Planck-mass entry: its delay is exactly two Planck times — the delay law bottoms out at the Planck scale, as a scale-setting law should.

4. The Infall Integral and Its Divergence

Section 3 used the horizon-crossing as a single characteristic time. Integrating the delay properly through the infall geometry exposes something sharper. In the Schwarzschild/metric-D lapse, the coordinate time for a radial light signal to climb from r_1 to r_2 is

$$t = \frac{1}{c}\int_{r_1}^{r_2}\frac{dr}{1 - r_s/r} = \frac{1}{c}\Big[\,(r_2 - r_1) + r_s\ln\frac{r_2 - r_s}{r_1 - r_s}\,\Big]. \tag{5}$$

As the inner edge approaches the horizon, $r_1 \to r_s$, the logarithm **diverges**: light stalls at r_s, and the accumulated delay grows without bound in the last sliver above the horizon. This is the Shapiro delay carried to its limit — the reason an infalling signal appears, from outside, to freeze at the horizon. Physically: the condensed-space delay does not distribute evenly; it **piles up at the horizon**, formally to infinity.

This is the exact gravitational twin of the electromagnetic-mass divergence (a point charge has infinite self-energy because the field energy density integrates to infinity as $r \to 0$). Both are cured by the same move the framework already makes: a **finite inner cutoff**. In the electromagnetic case the cutoff is the classical radius / the winding; in the gravitational case the integral must stop just above r_s, at the winding radius R_f, not at the horizon itself. The cutoff that rendered the electron's self-energy finite renders the black hole's self-delay finite. One disease, one cure, at both ends of the ladder.

5. The Condensation Ladder

Equation (3) is scale-free: $\tau = r_s/c$ holds for any mass, from the electron to the cosmos, eighty decades of mass. What varies enormously along the ladder is not the delay law but **how close each object sits to its own horizon** — which is the precise, quantitative form of "how condensed is it":

$$\text{condensation} \equiv \frac{\text{physical size}}{r_s}. \tag{6}$$

- **Electron:** size/r_s = $(3.86\times10^{-13}$ m$)/(1.35\times10^{-57}$ m$)$ = $\mathbf{2.9\times10^{44}}$. Vastly outside its horizon — not a black hole but a *winding*, curvature rolled into the phase (the 10^{43} cheapness of the Metrics note), condensed space achieved without collapse.
- **Ordinary matter, stars:** intermediate; a neutron star reaches size/r_s ≈ 3 (Paper 1's collapse threshold is size/r_s → 1).
- **Universe:** size/r_s = **1** (Section 6). Fully condensed — at its own horizon.

So the black-hole reading of mass is not wrong; it is **scale-dependent**, and the controlling number is (6). "Mass is a suspended black hole whose lag makes G" is true at the top of the ladder and relaxes into "mass is a winding whose lag makes inertia" as one descends. Same whip, τ = r_s/c, cracking at every rung; only the proximity to the horizon changes.

6. Cosmic Saturation: The Universe at Its Own Horizon

Run (6) to the whole observable universe. At critical density, ρ_crit = $3H^2/8\pi G$, the mass within the Hubble radius R = c/H is M = $(4/3)\pi R^3\rho$_crit = $c^3/2GH$, giving

$$\frac{GM}{Rc^2} = \frac{1}{2} \quad\Longleftrightarrow\quad r_s(\text{universe}) = \frac{2GM}{c^2} = R. \tag{7}$$

Verified numerically to 1.000: the universe's Schwarzschild radius equals its Hubble radius. The observable universe sits *exactly at its own horizon* — the saturation endpoint of the condensation ladder, the Mach–Sciama condition (Sciama 1953) that makes inertia the gravitational back-reaction of all matter. Its inertial delay is the crossing-time of that horizon:

$$\tau_{\text{cosmos}} = \frac{R}{c} = \frac{1}{H} = \text{one Hubble time} = 14\ \text{Gyr}. \tag{8}$$

This is consonant with the whole of metric D: the tension medium with p_r = $-\rho c^2$, the universal acceleration a_0 = cH of the screw paper, and the bounded finite-volume cosmos of the Four Calculations note all live at exactly the GM/Rc^2 ~ 1 point. The universe is the one object in the ladder for which the condensed-space, black-hole reading of mass is literally, quantitatively true.

7. What Is Claimed, and What Is Not

Claimed. (i) The gravitational self-field energy down to the horizon is a fixed fraction of the rest energy, U_ext(r_s) = $Mc^2/4$ (heuristic factor). (ii) Newton's constant is the horizon-crossing delay, G = $c^3\tau$_s/2M, with τ_s = r_s/c growing linearly with mass as inertia requires. (iii) The delay integral diverges at the horizon exactly as the electromagnetic self-energy diverges at a point, and needs the same finite winding cutoff. (iv) One delay law spans electron to cosmos; the cosmos saturates it at size/r_s = 1, r_s = R, τ = 1/H.

Not claimed — the load-bearing honesty. Equation (4) puts G in to get τ_s out: τ_s = $2GM/c^3$ *contains G*. This is therefore a **reframing** — G recast as a delay, inertia recast as that delay's momentum-lag, unified by the equivalence principle (the winding that resists locally is the field that curves globally, per the Tick Count note) — and **not a derivation** of G. To derive G would be to compute the delay from the winding structure *without G already inside it*, which is the framework's central unpaid debt (the stiffness/gearbox problem). The programme is self-consistent and the right shape; turning the reframing into a derivation is the calculation the whole series is pointed at and has not reached.

8. The Exponential Zoom, and Where α Must Live

The infall is exponential — the metric-D scale factor is $a(d) = e^{Hd/c}$, the lapse $N = e^{-Hd/c}$. An exponential geometry is **scale-free**: every e-fold of depth looks like every other (constant curvature), which is *why* one delay law (3) spans eighty decades and *why* the family law $T \cdot R$ = const holds at every rung. The observer's bookkept light speed is c at the surface and $c \cdot N$ deep in the well — the "zoom" between the observer and the bottom of the rabbit hole is a pure exponential factor.

A dimensionless coupling, in a scale-free geometry, must be a **pure ratio** — and in an exponential ladder, pure ratios are e-fold counts. This is exactly where the fine-structure constant α is forced to live. The framework already records the arithmetic (Metrics note):

- One α-compression is one step of the electron's cell ladder, $a_0 \to \alpha \cdot a_0 \to \alpha^2 \cdot a_0$, and in e-folds it is **ln(1/α) = 4.920 e-folds**.
- The full ladder from the Planck length to the Hubble radius spans $\ln(R_H/\ell_P)$ = **140.3 e-folds**.
- Therefore the universe is **140.3 / 4.92 = 28.5 α-compressions deep** — twenty-eight and a half zooms of α from the smallest length to the largest.

So the intuition that α lives in the exponential zoom is correct in smell and already half-quantified: **α is the natural compression step of the cosmic exponential, measured at 4.92 e-folds.** But two hard flags keep this a curiosity, not a result. First, *deriving* α from the zoom — explaining why the step is 4.92 e-folds rather than measuring it — is the gearbox problem, open. Second, and sharper: the electromagnetic zoom (steps of α) and the gravitational infall zoom (steps of $e^{Hd/c}$) are **not known to be the same exponential**. The Metrics note records the collision explicitly — naive Kaluza–Klein wants the electromagnetic fiber at ~11.7 Planck lengths while the mass identification wants it sixteen orders larger, at 2.46×10^{-18} m. That sixteen-order gap is the hierarchy problem wearing geometric clothes, and it is precisely the statement that the α-zoom and the H-zoom do not yet connect. α is in the zoom; *which* zoom, and *why* 4.92, is the unsolved core.

9. Open Runs

The condensed-space model, with the delay law (3) and the exponential zoom of Section 8, points at several defined calculations, listed for the future: (i) the finite-cutoff regularization of the divergent infall integral (5), using R_f as the floor, to produce a finite self-delay and hence a finite inertial mass from geometry alone; (ii) the mass spectrum as zoom-steps — whether the particle masses sit at α-spaced or e-fold-spaced rungs of the ladder (the weak-fiber harmonics of the discrete-orbits note are the first test); (iii) closing the α-zoom / H-zoom collision of Section 8, which is the hierarchy problem and the gearbox in one; (iv) the equivalence-principle identity — proving that the local self-delay (inertia) and the global lapse gradient (gravity) are one quantity, which would upgrade Section 7's reframing toward a derivation. Each is stated in advance, with its debt in public.

References

J. J. Thomson (1881); H. A. Lorentz, M. Abraham, H. Poincaré (1900–1906) — the electromagnetic-mass programme and the Poincaré stress; I. I. Shapiro, Phys. Rev. Lett. 13, 789 (1964) — the radar time-delay; D. W. Sciama, MNRAS 113, 34 (1953) — inertia as gravitational back-reaction; K. Schwarzschild (1916); and the papers and notes of this series (Paper 1 — the vacuum metric and the collapse threshold; the Metrics of the Living Spaces — the α-ladder, the 28.5-step curiosity, and the two-fiber collision; the Four Calculations note — metric D and $GM/Rc^2 \sim 1$; the Tick Count — inertia as winding rate and the equivalence-principle bet; the Postulates — the family law). Verification script: delayG_check.py. *(Citations from memory; the literature-verification pass — caveat (ix) of the foundations paper — applies to every one.)*

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