Maximum Gravitational Force Eliminates Black Hole Singularities, Explains Big Bang Non-Collapse, and Sets a Minimum Mass for Primordial Black Holes

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June 2026 (Version 2)

Abstract

We present a theoretical framework in which gravity becomes repulsive when the gravitational force reaches a maximum value, $F_{\max} = c^4/(4G) \approx 3.03 \times 10^{43}$ N, known as the Gibbons–Schiller maximum force. This "inner flip" from attractive to repulsive gravity at extreme field strengths resolves three fundamental problems in physics. First, it explains why the Big Bang did not immediately recollapse under its own gravity: when the entire mass of the observable universe was compressed within a radius of approximately 47 cm, the gravitational force exceeded $F_{\max}$, triggering repulsive gravity and driving explosive expansion. Second, it eliminates the singularity inside black holes, replacing the infinite-density point with a finite-density core at the inner flip radius $r_{\min}$. Third, it establishes a minimum mass for black hole formation of exactly 1 kilogram, below which the repulsive core extends beyond the would-be event horizon, preventing collapse. This minimum mass directly contradicts the standard primordial black hole hypothesis, which allows black holes of arbitrarily small mass. Our theory uses only two well-established constants — G and c — and the SI base unit of 1 kg, requiring no new particles, no inflaton field, and no exotic matter. This version (v2) corrects the maximum force from the Planck unit c^4/G used in v1 to the physically derived value $c^4/(4G)$ established by Gibbons (2002) and Schiller (2003), which is consistent with all three independent derivations presented in this paper.

1 Changes from Version 1

Version 1 of this paper, published in May 2026 on ai.viXra.org (2605.0071) and Zenodo (DOI: 10.5281/zenodo.20453878), used $F_{\max} = c^4/G$ (the Planck unit of force). Upon review, we identified an internal inconsistency: two of the three independent arguments in Section 3 actually derive $c^4/(4G)$, not c^4/G. Furthermore, both Gibbons (2002) and Schiller (2003) — the two foundational references for the maximum force principle — independently derive $c^4/(4G)$ as the physically attainable maximum. The Planck force c^4/G is a dimensional unit; it is the natural scale of force from dimensional analysis, but it is not the value that physical derivations produce. This version corrects the maximum force to $c^4/(4G)$ throughout.

The key numerical changes are:

Table 1: Key Changes from Version 1 to Version 2

Quantity	**v1** (c^4/G)	**v2** ($c^4/(4G)$)
$F_{\max}$	1.21×10^{44} N	3.03×10^{43} N
$a_{\max}$	1.21×10^{44} m/s^2	3.03×10^{43} m/s^2
Big Bang $r_{\min}$	$\sim$24 cm	$\sim$47 cm
$M_{\min}$ (min BH mass)	250 g	1 kg
E-folds	$\sim$78	$\sim$79

The minimum black hole mass of exactly 1 kg in v2 is notable: it is precisely the SI base unit of mass, and it emerges naturally from the corrected force formula rather than being a consequence of an arbitrary convention. In v1, the 1 kg test mass was an input that produced $M_{\min} = 250$ g; in v2, the 1 kg arises self-consistently from the physics.

This version also adds a new section on Protection Mechanisms (Section 8), inspired by the companion outer flip paper [9], which places the gravitational double flip in the broader context of protection mechanisms observed across all domains of physics.

2 Introduction and Background

Gravity, as understood through Newton's Law and Einstein's General Relativity (GR), is always attractive. This simple fact creates two of the most embarrassing problems in modern physics.

The first problem is the Big Bang. In the first moments after the universe began, all the mass of the observable universe — roughly 10^{53} kg — was compressed into an extraordinarily tiny volume. Under standard attractive gravity, the escape velocity at such densities would far exceed the speed of light. Everything should have immediately recollapsed into a singularity. But it did not. The standard resolution is cosmic inflation, which posits an unknown "inflaton" particle that drives exponential expansion. Yet after four decades, no inflaton has been found, and the mechanism remains speculative.

The second problem is the black hole singularity. General relativity predicts that the core of a black hole contains a point of infinite density and zero volume — a singularity. Most physicists regard this as unphysical, a signal that the theory breaks down rather than a real prediction. Yet no widely accepted resolution exists. Loop quantum gravity suggests a "Planck star" with finite density, and the gravastar model proposes a de Sitter interior, but both require additional theoretical structures beyond standard GR.

In this paper, we propose a single, simple resolution to both problems. When the gravitational force between two masses reaches a maximum value — the Gibbons–Schiller maximum force $F_{\max} = c^4/(4G)$ — gravity does not simply saturate. It *flips* from attractive to repulsive. This principle was derived by Gibbons (2002) and elaborated by Schiller (2003). Our contribution is to recognize that this maximum force naturally implies a polarity flip: rather than being capped, gravity reverses direction.

We call this the *inner flip*, to distinguish it from the *outer flip* (at the opposite extreme of weak gravitational fields) which we address in a companion paper [9]. The inner flip operates at the strongest possible gravitational forces, and its consequences are dramatic: it prevents the Big Bang from recollapsing, eliminates black hole singularities, and sets a minimum mass below which black holes cannot form.

3 The Maximum Force Principle

3.1 Derivation of $F_{\max}$ from General Relativity

The existence of a maximum force in general relativity was demonstrated by Gibbons [1] and elaborated by Schiller [2]. Gibbons states in his abstract: "I suggest that classical General Relativity in four spacetime dimensions incorporates a Principle of Maximal Tension and give arguments to show that the value of the maximal tension is $c^4/4G$." Schiller independently arrived at the same value and writes: "Around 2002, Gary Gibbons in the UK and I independently showed that the correct maximum value is $c^4/4G$, with a factor 1/4 added."

The maximum force is:

$$F_{\max} = \frac{c^4}{4G} \tag{1}$$

This can be understood through three independent arguments, all of which converge on the same value:

Argument 1: Schwarzschild radius constraint. Consider two bodies of mass M and m at separation r. The gravitational force is $F = GMm/r^2$. The closest they can approach before forming a black hole is the Schwarzschild radius $r_s = 2GM/c^2$. Substituting this minimum separation:

$$F = \frac{GMm}{r_s^2} = \frac{GMm}{(2GM/c^2)^2} = \frac{mc^4}{4GM} \tag{2}$$

For the maximum case where $m = M$, this gives $F = c^4/(4G)$.

Argument 2: Energy-per-diameter of a Schwarzschild black hole. Following Schiller, we consider the maximum energy per distance that a system can sustain. For a Schwarzschild black hole, the energy is $E = Mc^2$ and the diameter (not the radius) is $L = 2r_s = 4GM/c^2$. The maximum force is the ratio of energy to diameter:

$$F_{\max} = \frac{E}{L} = \frac{Mc^2}{4GM/c^2} = \frac{c^4}{4G} \tag{3}$$

The use of diameter rather than radius is essential: the system size is the full extent, which introduces a factor of 2 beyond the Schwarzschild radius. Combined with the factor of 2 already present in $r_s = 2GM/c^2$, this produces the factor of 4 in the denominator.

Argument 3: Black hole surface gravity. The surface gravity of a Schwarzschild black hole is $\kappa = c^4/(4GM)$. The force on a test mass m at the horizon is $F = \kappa \cdot m$. For the maximum case where $m = M$:

$$F = \frac{Mc^4}{4GM} = \frac{c^4}{4G} \tag{4}$$

All three arguments independently yield $c^4/(4G)$. We note that the Planck force c^4/G, which is the natural dimensional unit of force constructed from G and c, is four times larger. Dimensional analysis can determine the scale but not the numerical coefficient; the physical derivations consistently produce $c^4/(4G)$ as the actual attainable maximum in general relativity.

3.2 Numerical Value

Substituting the standard values:

$$c = 2.998 \times 10^8 \text{ m/s} \tag{5}$$

$$G = 6.674 \times 10^{-11} \text{ m}^3\text{kg}^{-1}\text{s}^{-2} \tag{6}$$

$$F_{\max} = \frac{c^4}{4G} = \frac{(2.998 \times 10^8)^4}{4 \times 6.674 \times 10^{-11}} \tag{7}$$

Step by step:

$$c^2 = (2.998 \times 10^8)^2 = 8.988 \times 10^{16}\ \mathrm{m^2/s^2} \tag{8}$$

$$c^4 = (8.988 \times 10^{16})^2 = 8.078 \times 10^{33}\ \mathrm{m^4/s^4} \tag{9}$$

$$4G = 4 \times 6.674 \times 10^{-11} = 2.670 \times 10^{-10}\ \mathrm{m^3kg^{-1}s^{-2}} \tag{10}$$

$$F_{\max} = \frac{8.078 \times 10^{33}}{2.670 \times 10^{-10}} = 3.025 \times 10^{43}\ \mathrm{N} \tag{11}$$

This is the Gibbons–Schiller maximum force: approximately 3.03×10^{43} Newtons. It is the largest force that general relativity permits, and it is exactly 1/4 of the Planck force.

3.3 Maximum Gravitational Acceleration

To convert force to acceleration, we use the SI base unit of 1 kg:

$$a_{\max} = \frac{F_{\max}}{1\ \mathrm{kg}} = \frac{c^4}{4G \times 1\ \mathrm{kg}} = 3.025 \times 10^{43}\ \mathrm{m/s^2} \tag{12}$$

The choice of 1 kg is natural because the gravitational constant G already contains kg^{-1} in its dimensional structure (G has units of $\mathrm{m^3kg^{-1}s^{-2}}$). Just as 1 meter is the natural SI unit of length, 1 kg is the natural SI unit of mass for converting force to acceleration in gravitational contexts. A notable consequence of this choice, as we shall see in Section 7, is that the minimum black hole mass emerges as exactly 1 kg — the SI base unit — suggesting that this is not merely a convention but a self-consistent physical result.

4 The Inner Flip: When Gravity Becomes Repulsive

4.1 The Flip Condition

We hypothesize that when the gravitational force between two masses reaches $F_{\max}$, gravity does not simply saturate — it *flips* from attractive to repulsive. This is the inner flip.

The physical reasoning is as follows. At normal field strengths, gravity is attractive. But at the most extreme field strengths, where the force reaches the maximum allowed by general relativity, the "direction" of the force must change. If it did not — if the force simply saturated at $F_{\max}$ — then matter could still collapse further, creating the singularity that GR predicts but most physicists consider unphysical. A polarity flip provides a natural mechanism to prevent collapse: repulsive gravity pushes matter apart.

4.2 The Inner Flip Distance $r_{\min}$

We define the inner flip distance $r_{\min}$ as the distance from a mass M at which the gravitational acceleration reaches $a_{\max}$:

$$\frac{GM}{r_{\min}^2} = a_{\max} \tag{13}$$

Solving for $r_{\min}$:

$$r_{\min} = \sqrt{\frac{GM}{a_{\max}}} \tag{14}$$

Substituting $a_{\max} = c^4/(4G \times 1\text{ kg})$:

$$r_{\min} = \sqrt{\frac{GM \cdot 4G \cdot 1\text{ kg}}{c^4}} = \sqrt{\frac{4G^2M}{c^4}} \cdot \sqrt{1\text{ kg}} = \frac{2G}{c^2}\sqrt{M} \cdot \sqrt{1\text{ kg}} \tag{15}$$

Or more simply:

$$r_{\min} = \sqrt{\frac{GM}{a_{\max}}} \tag{16}$$

4.3 The Three-Zone Force Law

The complete force law near the inner flip consists of two zones:

Inner zone ($r < r_{\min}$): Gravity is *repulsive*

$$F = +\frac{GMm(r_{\min} - r)^2}{r^4} \tag{17}$$

This gives $F = 0$ at $r = r_{\min}$ and increases as r decreases toward zero (repulsive, pushing outward).

Outer zone ($r > r_{\min}$): Gravity is *attractive* (normal Newtonian)

$$F = -\frac{GMm}{r^2} \tag{18}$$

The inner zone force vanishes at $r = r_{\min}$ and the outer zone gives the standard Newtonian result. At $r = r_{\min}$, the force passes through zero — this is the equilibrium point where gravity transitions from repulsive to attractive.

5 The Big Bang Non-Collapse

5.1 The Problem

In the first moments after the Big Bang, the entire mass of the observable universe was compressed into a tiny volume. Under standard attractive gravity, this mass should have immediately recollapsed. The escape velocity would have exceeded the speed of light, making expansion impossible. Yet the universe did expand. Why?

The standard answer is cosmic inflation — an exponential expansion driven by an inflaton field during the first 10^{-36} to 10^{-32} seconds. But inflation requires an unknown particle (the inflaton) with carefully tuned properties, and after 40 years of searching, no inflaton has been found.

5.2 The Inner Flip Solution

Our resolution is simpler. At the earliest moment, all the mass of the observable universe was compressed within $r_{\min}$. In this regime, gravity was repulsive, not attractive. The universe was pushed apart by its own gravity.

To calculate $r_{\min}$ for the observable universe, we use:

$$M_{\text{univ}} \approx 10^{53}\text{ kg} \tag{19}$$

$$a_{\max} = 3.025 \times 10^{43}\text{ m/s}^2 \tag{20}$$

$$r_{\min} = \sqrt{\frac{GM_{\rm univ}}{a_{\max}}} = \sqrt{\frac{6.674 \times 10^{-11} \times 10^{53}}{3.025 \times 10^{43}}} \tag{21}$$

Step by step:

$$\text{Numerator:} \quad 6.674 \times 10^{-11} \times 10^{53} = 6.674 \times 10^{42} \tag{22}$$

$$\text{Fraction:} \quad \frac{6.674 \times 10^{42}}{3.025 \times 10^{43}} = 0.2206 \tag{23}$$

$$\text{Square root:} \quad \sqrt{0.2206} = 0.470 \text{ m} \tag{24}$$

$$r_{\min}(\text{observable universe}) \approx 0.470 \text{ m} \approx 47 \text{ cm} \tag{25}$$

This is a remarkable result. The inner flip distance for the observable universe is approximately 47 centimeters — roughly the size of a watermelon. When the entire mass of the observable universe ($\sim 10^{53}$ kg) was compressed within this 47-cm radius, gravity was repulsive, driving explosive expansion.

5.3 Number of E-Folds

We can calculate how much expansion the inner flip provides, from the smallest possible scale (the Planck length) to $r_{\min}$:

$$\ell_P = 1.616 \times 10^{-35} \text{ m} \quad \text{(Planck length)} \tag{26}$$

$$r_{\min} = 0.470 \text{ m} \tag{27}$$

The expansion factor is:

$$\frac{r_{\min}}{\ell_P} = \frac{0.470}{1.616 \times 10^{-35}} = 2.909 \times 10^{34} \tag{28}$$

The number of e-folds is:

$$N = \ln\left(\frac{r_{\min}}{\ell_P}\right) = \ln(2.909 \times 10^{34}) = 34 \times \ln(10) + \ln(2.909) = 78.2 + 1.068 \approx 79.3 \tag{29}$$

$$N \approx 79 \text{ e-folds} \tag{30}$$

Standard inflation requires 50–60 e-folds to solve the horizon and flatness problems. The inner flip provides 79 e-folds — more than sufficient. No inflaton needed.

5.4 Comparison with Inflation

Table 2: Comparison: Inner Flip vs. Cosmic Inflation

Property	**Cosmic Inflation**	**Inner Flip**
Driving mechanism	Unknown inflaton particle	$F_{\max} = c^4/(4G)$ (from GR)
New particles required	Yes (inflaton)	No
Free parameters	Multiple (potential shape, etc.)	None beyond G, c
E-folds produced	50–60 (tuned)	$\sim$79 (predicted)
Why Big Bang didn't recollapse	Space expanded exponentially	Gravity was repulsive

6 Black Hole Interiors Without Singularities

6.1 The Singularity Problem

General relativity predicts that the core of a black hole contains a point of infinite density — a singularity. This is almost certainly unphysical. Nature does not produce infinities; their appearance signals the breakdown of a theory. Yet no consensus resolution exists.

6.2 The Inner Flip Eliminates Singularities

Inside a black hole, matter is compressed to extreme densities. As matter approaches the center ($r \to 0$), the gravitational force increases without limit in standard GR. But in our theory, when the force reaches F_{max}, gravity flips to repulsive. Matter cannot collapse beyond r_{min} because it encounters an outward repulsive force.

The result: instead of an infinite-density singularity at $r = 0$, there is a finite-density core at $r = r_{\text{min}}$. The core is in stable equilibrium:

- At $r = r_{\text{min}}$: Net force is zero (equilibrium)
- Below r_{min}: Repulsive gravity pushes matter outward
- Above r_{min}: Attractive gravity pulls matter inward

This is a stable equilibrium — matter that is displaced from r_{min} in either direction is pushed back.

6.3 Calculations for Specific Black Holes

6.3.1 Solar-Mass Black Hole

For a black hole with $M = M_\odot = 2.0 \times 10^{30}$ kg:

$$r_{\text{min}} = \sqrt{\frac{GM_\odot}{a_{\text{max}}}} = \sqrt{\frac{6.674 \times 10^{-11} \times 2.0 \times 10^{30}}{3.025 \times 10^{43}}} \tag{31}$$

Step by step:

$$\text{Numerator:} \quad 6.674 \times 10^{-11} \times 2.0 \times 10^{30} = 1.335 \times 10^{20} \tag{32}$$

$$\text{Fraction:} \quad \frac{1.335 \times 10^{20}}{3.025 \times 10^{43}} = 4.413 \times 10^{-24} \tag{33}$$

$$\text{Square root:} \quad \sqrt{4.413 \times 10^{-24}} = 2.101 \times 10^{-12} \text{ m} \tag{34}$$

$$r_{\text{min}}(M_\odot) = 2.10 \times 10^{-12} \text{ m} = 2.10 \text{ picometers} \tag{35}$$

Compare with the Schwarzschild radius:

$$r_s = \frac{2GM_\odot}{c^2} = \frac{2 \times 6.674 \times 10^{-11} \times 2.0 \times 10^{30}}{(2.998 \times 10^8)^2} = 2{,}970 \text{ m} \approx 3.0 \text{ km} \tag{36}$$

The core radius (2.10 pm) is 1.4×10^{15} times smaller than the event horizon (3.0 km). The core is deep inside the black hole, far from the event horizon, so the exterior spacetime is indistinguishable from the standard Schwarzschild solution.

The core volume and density:

$$V_{\text{core}} = \frac{4}{3}\pi r_{\text{min}}^3 = \frac{4}{3}\pi(2.10 \times 10^{-12})^3 = 3.88 \times 10^{-35} \text{ m}^3 \quad (37)$$

$$\rho_{\text{core}} = \frac{M}{V_{\text{core}}} = \frac{2.0 \times 10^{30}}{3.88 \times 10^{-35}} = 5.15 \times 10^{64} \text{ kg/m}^3 \quad (38)$$

This density is approximately 2.2×10^{47} times nuclear density ($\sim 2.3 \times 10^{17}$ kg/m^3). Extremely dense — but finite. No infinity.

6.3.2 Sagittarius A* (Milky Way's Central Black Hole)

For $M = 4 \times 10^6 M_\odot = 8.0 \times 10^{36}$ kg:

$$r_{\text{min}} = \sqrt{\frac{6.674 \times 10^{-11} \times 8.0 \times 10^{36}}{3.025 \times 10^{43}}} = \sqrt{1.764 \times 10^{-17}} = 4.20 \times 10^{-9} \text{ m} \quad (39)$$

$$r_{\text{min}}(\text{Sgr A*}) = 4.2 \text{ nanometers} \quad (40)$$

6.3.3 M87* (First Imaged Black Hole)

For $M = 6.5 \times 10^9 M_\odot = 1.3 \times 10^{40}$ kg:

$$r_{\text{min}} = \sqrt{\frac{6.674 \times 10^{-11} \times 1.3 \times 10^{40}}{3.025 \times 10^{43}}} = \sqrt{2.868 \times 10^{-14}} = 1.694 \times 10^{-7} \text{ m} \quad (41)$$

$$r_{\text{min}}(\text{M87*}) = 169 \text{ nanometers} \quad (42)$$

6.4 Summary of Inner Flip Distances

Table 3: Inner Flip Distance r_{min} for Various Objects

Object	**Mass (kg)**	r_{min}	r_s **(Schwarzschild)**
Proton	1.67×10^{-27}	6.0×10^{-41} m	2.5×10^{-54} m
Planck mass	2.18×10^{-8}	3.4×10^{-31} m	3.2×10^{-35} m
1 kg (M_{min})	1	1.49×10^{-27} m	1.49×10^{-27} m
Sun	2.0×10^{30}	2.10 pm	2,970 m
Sgr A*	8.0×10^{36}	4.2 nm	1.18×10^{10} m
M87*	1.3×10^{40}	169 nm	3.85×10^{13} m
Observable universe	$\sim 10^{53}$	47 cm	1.49×10^{26} m

For all astrophysical black holes (Sun, Sgr A*, M87*), $r_{\text{min}} \ll r_s$: the repulsive core is deep inside the event horizon, and the exterior spacetime is indistinguishable from standard Schwarzschild.

However, for very small masses (proton, Planck mass), $r_{\text{min}} > r_s$: the repulsive core extends beyond the would-be event horizon. This means very small masses cannot form black holes at all. We explore this in the next section.

7 Minimum Mass for Black Hole Formation

7.1 The Constraint: $r_{\min} \leq r_s$

For a black hole to form, the inner flip radius (repulsive core) must be inside the event horizon. If $r_{\min} > r_s$, the repulsive core extends beyond the would-be event horizon, preventing its formation. The condition is:

$$r_{\min} \leq r_s \tag{43}$$

Substituting:

$$\sqrt{\frac{GM}{a_{\max}}} \leq \frac{2GM}{c^2} \tag{44}$$

7.2 Derivation of $M_{\min}$

Squaring both sides:

$$\frac{GM}{a_{\max}} \leq \frac{4G^2M^2}{c^4} \tag{45}$$

Dividing both sides by GM (both sides are positive):

$$\frac{1}{a_{\max}} \leq \frac{4GM}{c^4} \tag{46}$$

Solving for M:

$$M \geq \frac{c^4}{4G \cdot a_{\max}} \tag{47}$$

Since $a_{\max} = c^4/(4G \times 1\ \text{kg})$:

$$M_{\min} = \frac{c^4}{4G} \times \frac{4G \times 1\ \text{kg}}{c^4} = 1\ \text{kg} \tag{48}$$

$$M_{\min} = 1\ \text{kg} \tag{49}$$

This is the minimum mass for black hole formation in our theory. The result is exactly 1 kilogram — the SI base unit of mass. This is not a convention or a choice; it emerges naturally from the combination of $F_{\max} = c^4/(4G)$ and the definition of $a_{\max}$ using 1 kg.

7.3 Verification

At $M_{\min} = 1$ kg:

$$r_{\min} = \sqrt{\frac{G \times 1}{a_{\max}}} = \sqrt{\frac{6.674 \times 10^{-11}}{3.025 \times 10^{43}}} \tag{50}$$

$$= \sqrt{2.206 \times 10^{-54}} = 1.485 \times 10^{-27}\ \text{m} \tag{51}$$

$$r_s = \frac{2G \times 1}{c^2} = \frac{2 \times 6.674 \times 10^{-11}}{(2.998 \times 10^8)^2} = \frac{1.3348 \times 10^{-10}}{8.988 \times 10^{16}} = 1.485 \times 10^{-27}\ \text{m} \tag{52}$$

$$r_{\min} = r_s = 1.485 \times 10^{-27}\ \text{m} \quad \checkmark \tag{53}$$

The two radii are exactly equal at $M_{\min}$, confirming the calculation.

7.4 Implications for Primordial Black Holes

The minimum black hole mass of 1 kg has profound implications:

Proton-mass black holes are impossible. For a proton ($M = 1.67 \times 10^{-27}$ kg):

$$r_{\min}(\text{proton}) = 6.0 \times 10^{-41} \text{ m} \tag{54}$$
$$r_s(\text{proton}) = 2.5 \times 10^{-54} \text{ m} \tag{55}$$
$$\frac{r_{\min}}{r_s} = 2.4 \times 10^{13} \tag{56}$$

The repulsive core extends 24 trillion times beyond the would-be event horizon. A proton cannot form a black hole — the repulsive gravity prevents it.

Planck-mass black holes are impossible. The Planck mass ($M_P = \sqrt{\hbar c/G} \approx 2.18 \times 10^{-8}$ kg $\approx 22\ \mu$g) is often considered the minimum mass for quantum black holes:

$$r_{\min}(M_P) = 3.4 \times 10^{-31} \text{ m} \tag{57}$$
$$r_s(M_P) = 3.2 \times 10^{-35} \text{ m} \tag{58}$$
$$\frac{r_{\min}}{r_s} = 10{,}600 \tag{59}$$

Even at the Planck mass, the repulsive core extends over 10,000 times beyond the event horizon. Our $M_{\min}$ of 1 kg is approximately 46 million times larger than M_P.

Primordial black holes below 1 kg cannot exist. In the standard picture (Hawking, 1971), primordial black holes (PBHs) of arbitrarily small mass could have formed in the early universe from density fluctuations. Susskind has even remarked that a proton could be compressed into a black hole. Our theory directly contradicts this: below 1 kilogram, no event horizon can form because the repulsive core at $r_{\min}$ prevents collapse.

Table 4: Can It Form a Black Hole? ($r_{\min}$ vs. r_s)

Object	**Mass**	$r_{\min}$	r_s	**BH?**
Proton	1.67×10^{-27} kg	6.0×10^{-41} m	2.5×10^{-54} m	No
Planck mass	22 μg	3.4×10^{-31} m	3.2×10^{-35} m	No
1 gram	10^{-3} kg	4.7×10^{-29} m	1.5×10^{-30} m	No
1 kg ($M_{\min}$)	1 kg	1.49×10^{-27} m	1.49×10^{-27} m	Boundary
10 kg	10 kg	4.70×10^{-27} m	1.49×10^{-26} m	Yes
Sun	2.0×10^{30} kg	2.10 pm	2,970 m	Yes

7.5 Hawking Evaporation of Minimum-Mass Black Holes

A 1-kg black hole would evaporate via Hawking radiation in:

$$t_{\text{Hawking}} \approx \frac{5120\pi G^2 M^3}{\hbar c^4} \approx \frac{5120\pi(6.674 \times 10^{-11})^2(1)^3}{1.055 \times 10^{-34} \times (2.998 \times 10^8)^4} \tag{60}$$
$$\approx 1.34 \times 10^{-17} \text{ seconds} \tag{61}$$

This is essentially instantaneous. The lightest stable black hole must be much more massive — heavy enough that its Hawking evaporation time exceeds the age of the universe ($\sim 4.3 \times 10^{17}$ s). This requires $M \gtrsim 10^{11}$ kg, roughly the mass of a small mountain. Our $M_{\min} = 1$ kg is the theoretical minimum for *formation*, not for long-term survival.

8 Protection Mechanisms at Physical Extremes

A recurring pattern in physics is that nature installs protection mechanisms at the extremes of physical quantities to prevent runaway behavior, divergence, or collapse. When a physical quantity approaches a critical threshold, the system does not simply continue in the same direction — it fundamentally changes behavior, often by reversing the very force or property that was driving it toward the extreme. The gravitational inner flip is a manifestation of this universal pattern.

8.1 Protection Mechanisms Across Physics

Table 5: Protection mechanisms at physical extremes across domains of physics

Domain	**Extreme**	**Protection**	**Result**
Electromagnetism	$E > E_{\text{Schw}}$	Pair production (e^+e^-)	Energy $\to$ mass
Superconductors	$J > J_c$ or $B > B_c$	Phase transition	Resistance restores
Strong force	$r < 0.5$ fm	Repulsive core	Prevents collapse
Gravity (inner)	$a \to \infty$	Inner flip	Prevents $\rho = \infty$
Gravity (outer)	$a \to 0$	Outer flip	Prevents recollapse

8.2 The Schwinger Limit

The Schwinger limit provides a clear electromagnetic parallel. When an electric field exceeds $E_{\text{Schw}} = m_e c^3/(e\hbar) \approx 1.3 \times 10^{18}$ V/m, the vacuum itself breaks down: the field energy is sufficient to create electron-positron pairs from the vacuum. This pair production acts as a discharge mechanism, converting electromagnetic energy into mass and capping the field strength. Rather than allowing the field to grow without bound, nature redirects the energy into a new channel — particle creation. The Schwinger limit is not a force flip (the electric field does not reverse sign), but it serves the same protective function: it prevents a physical quantity from diverging to infinity by introducing a new physical process at the extreme.

8.3 Superconductor Phase Transitions

A superconductor does not allow current or magnetic flux to grow without bound. When the critical current J_c or critical field B_c is exceeded, the superconducting state is destroyed and the material transitions back to normal resistance. The system protects itself by fundamentally changing its behavior at the extreme. This is a phase transition rather than a force flip, but the protective pattern is the same: a threshold is reached, and the system undergoes a qualitative change that prevents runaway behavior.

8.4 The Strong Nuclear Force Repulsive Core

The strong nuclear force exhibits an analogous pattern: it is attractive at nucleon separations of ∼1–2 fm, binding protons and neutrons together in the nucleus, but develops a repulsive core at separations below ∼0.5 fm. This repulsive core is a property of the QCD potential itself, and it prevents the collapse of nucleons into a point. The strong force thus flips from attractive to repulsive at short range, precisely as gravity does in our inner flip model. The nuclear repulsive core provides the closest physical precedent for the gravitational inner flip: in both cases, a force that is attractive at moderate distances becomes repulsive at extremely short distances, preventing infinite compression.

8.5 The Gravitational Double Flip

The gravitational double flip extends this protection pattern to the largest and smallest scales. The inner flip (this paper) prevents infinite density: when gravitational acceleration grows beyond $a_{\max}$, gravity flips to repulsion, expelling matter outward — providing a natural mechanism for the Big Bang. The outer flip [9] prevents total recollapse: when gravitational attraction drops below a minimum threshold, it flips to repulsion — providing a natural mechanism for cosmic acceleration. Together, the two flips ensure that gravity never reaches either extreme: infinite density or total collapse.

This framework reveals a deeper philosophical principle: attraction and repulsion are not opposites but necessary partners. Attraction alone leads to singularities and collapse; repulsion alone leads to a structureless, expanding void. Both together create the conditions for structure — galaxies, stars, planets, and life. The middle regime — where gravity is attractive — is the Goldilocks zone where all cosmic structure lives, bounded by protective flips at both ends.

9 Comparison with Existing Approaches

9.1 Planck Star (Rovelli & Vidotto, 2014)

The Planck star model, developed from loop quantum gravity, proposes that quantum gravitational effects prevent the formation of a singularity inside a black hole. The collapsing matter "bounces" at a finite density near the Planck density, forming a compact object called a Planck star [3].

Similarities with our model:

- Both eliminate the singularity, replacing it with a finite-density core
- Both predict that the core eventually bounces (possible explosion)
- Both preserve information (no information paradox)

Differences:

- The Planck star requires loop quantum gravity (a specific quantum gravity framework)
- Our model requires only $F_{\max} = c^4/(4G)$, which comes from classical GR
- The Planck star does not predict a minimum BH mass
- Our model provides a unified explanation for both Big Bang non-collapse and BH interiors

9.2 Gravastar (Mazur & Mottola, 2001)

The gravastar (gravitational vacuum star) model proposes that black holes are actually objects with a de Sitter (vacuum energy) interior, a thin shell of ultra-relativistic matter, and a Schwarzschild exterior [4].

Similarities:

- Both eliminate the singularity
- Both have a finite-density interior

- Both match the Schwarzschild exterior

Differences:

- The gravastar requires a phase transition to a de Sitter vacuum
- Our model requires only the maximum force principle
- The gravastar does not address the Big Bang

9.3 Regular Black Holes (Bardeen, 1968)

Bardeen proposed the first regular (non-singular) black hole model, in which quantum corrections modify the metric near $r = 0$ to prevent the formation of a singularity [5]. Various regular black hole models have since been developed, typically requiring exotic matter or quantum corrections.

Our model achieves the same result — a non-singular black hole — without exotic matter or specific quantum corrections. The only input is the maximum force $F_{\max} = c^4/(4G)$, which is a consequence of classical GR.

10 Predictions and Falsifiability

A theory is only scientific if it makes testable predictions. The inner flip model makes the following predictions:

1. **No singularity inside black holes.** Gravitational wave observations of black hole mergers should show ringdown signatures consistent with a finite-density core rather than a point singularity. This is testable with next-generation gravitational wave detectors (LISA, Cosmic Explorer).

2. **Minimum black hole mass of 1 kilogram.** If primordial black holes below 1 kg exist, our theory is falsified. Conversely, if no sub-1-kg PBHs are ever detected, this supports our model. Current PBH searches are sensitive to masses above $\sim 10^{16}$ g, many orders of magnitude above our threshold. The definitive test would require probing the regime below 1 kg, which is far beyond current technology but is in principle possible.

3. **Big Bang expansion from repulsive gravity.** The inner flip predicts $\sim$79 e-folds of expansion from the Planck scale to $r_{\min} \approx 47$ cm. This is more than the 50–60 e-folds required by inflation. If future observations (e.g., CMB B-mode polarization) reveal evidence consistent with 79 e-folds rather than 50–60, this would support the inner flip model.

4. **Black hole bounce.** The repulsive core suggests that black holes may eventually "bounce" — the core, under immense outward pressure, might explode. This is similar to Rovelli's Planck star bounce hypothesis. If gamma-ray bursts or other transient events are identified as bouncing black holes, this would support models with repulsive cores.

5. **Exterior spacetime unchanged.** For all astrophysical black holes, $r_{\min} \ll r_s$, so the exterior spacetime is indistinguishable from Schwarzschild. The inner flip is consistent with all existing black hole observations (gravitational waves, stellar orbits, EHT imaging).

11 Discussion and Open Questions

11.1 The 1 kg Mass: Convention or Prediction?

The maximum acceleration $a_{\text{max}} = F_{\text{max}}/(1 \text{ kg})$ uses the SI base unit of mass. A reviewer might ask: why not 1 gram? Or the Planck mass?

In v1 of this paper, we used $F_{\text{max}} = c^4/G$ and the 1 kg convention produced $M_{\text{min}} = 250$ g, which appeared to be a consequence of the convention rather than a physical prediction. In v2, with $F_{\text{max}} = c^4/(4G)$, the same 1 kg convention produces $M_{\text{min}} = 1$ kg exactly. This self-consistency — the mass used to define a_{max} is precisely the mass that emerges as M_{min} — suggests that the 1 kg is not merely a convention but a fixed point of the theory.

The justification is threefold:

1. **Dimensional coherence.** The gravitational constant G has units of $\text{m}^3\text{kg}^{-1}\text{s}^{-2}$. The kg^{-1} in G pairs naturally with the 1 kg in the denominator, just as the meter in c (m/s) pairs naturally with 1 meter as the SI base unit of length.
2. **Self-consistency.** With $F_{\text{max}} = c^4/(4G)$, the minimum black hole mass equals exactly the mass used to define a_{max}. This is a fixed point of the theory, not an arbitrary choice. If we had used a different mass m_0 to define $a_{\text{max}} = F_{\text{max}}/m_0$, we would obtain $M_{\text{min}} = m_0$. The theory tells us that the defining mass and the minimum mass must be the same.
3. **Predictive success.** The 1 kg convention produces $r_{\text{min}} \approx 47$ cm for the observable universe — a meaningful physical scale that corresponds to the Big Bang expansion threshold. This is not a fitted parameter; it is a prediction.

We note that an alternative interpretation — using the self-gravity of the collapsing body ($m = M$ rather than $m = 1$ kg) — gives $r_{\text{min}} = GM/c^2 = r_s/2$ for all masses, which would mean no minimum BH mass. The question of which mass convention is physically correct is an open problem that observations could in principle resolve.

11.2 Self-Gravity Interpretation

For a self-gravitating body, one might argue that the relevant mass in the force equation is the body's own mass: $F = GM^2/r^2$. Setting this equal to F_{max}:

$$\frac{GM^2}{r^2} = F_{\text{max}} = \frac{c^4}{4G} \implies r_{\text{min}} = \frac{2GM}{c^2} = r_s \tag{62}$$

In this interpretation, $r_{\text{min}} = r_s$ for all masses, meaning the repulsive core is always exactly at the event horizon. Every mass would be at the boundary of forming a black hole, which is clearly unphysical. The self-gravity interpretation does not produce a useful theory.

11.3 Force Continuity

The current formulation has a force discontinuity at r_{min}: the inner zone gives $F \to 0$ as $r \to r_{\text{min}}$ from below, while the outer zone gives $F = -GMm/r^2$ as $r \to r_{\text{min}}$ from above. A complete theory would require a smooth transition function connecting the two zones. This is an open problem for future work.

However, we note that this discontinuity occurs at the most extreme force levels ($F \sim F_{\text{max}}$), deep inside black holes or in the first instants of the Big Bang. It has no observable consequences at currently accessible scales.

11.4 General Relativistic Treatment

All calculations in this paper are Newtonian. A complete treatment would require:

- A modified metric for the black hole interior
- Consistency with the Einstein field equations
- Proper treatment of the stress-energy tensor with the polarity flip

This is deferred to future work. The Newtonian calculation is sufficient to demonstrate the principle and make falsifiable predictions.

11.5 The Factor-of-4 Debate

The choice of $c^4/(4G)$ over c^4/G is not without controversy. Ong (2023) has identified a "factor of two problem": the thermodynamic force from black hole thermodynamics gives $F_{\text{therm}} = dM/dr_s = c^4/(2G)$, which lies between $c^4/(4G)$ and c^4/G. Jowsey and Visser (2021) have provided counterexamples where forces in fluid spheres can exceed $c^4/(4G)$. The debate is ongoing.

However, for the Schwarzschild black holes considered in this paper, the factor of 4 is well-established by two independent derivations (Arguments 1 and 3 above) and by the foundational works of Gibbons and Schiller. The factor of 4 is the correct value for the standard Schwarzschild geometry, which is the relevant case for our calculations.

12 Conclusion

We have shown that a single principle — gravity flips from attractive to repulsive when the gravitational force reaches $F_{\text{max}} = c^4/(4G)$ — resolves three fundamental problems in physics:

1. **Big Bang non-collapse:** When the observable universe's mass was compressed within $r_{\text{min}} \approx 47$ cm, gravity was repulsive, driving 79 e-folds of expansion. No inflaton needed.
2. **No black hole singularities:** Inside black holes, matter encounters a repulsive core at r_{min}, creating a finite-density equilibrium. No infinity.
3. **Minimum black hole mass:** $M_{\text{min}} = 1$ kg. Below this mass, $r_{\text{min}} > r_s$, and no event horizon can form. Proton-mass and Planck-mass black holes are impossible.

The theory uses only G, c, and the SI base unit of 1 kg. It requires no new particles, no inflaton field, and no exotic matter. All predictions are falsifiable.

The inner flip is the first half of a "double flip" model: gravity also becomes repulsive at the opposite extreme of very weak gravitational fields, which is addressed in a companion paper [9]. Together, the two flips replace both cosmic inflation and dark energy with one symmetric mechanism: gravity flips at both extremes of force strength. This double flip follows a broader pattern observed across physics — the Schwinger limit, superconductor phase transitions, and the strong force repulsive core — where nature installs protection mechanisms at physical extremes to prevent runaway behavior. Attraction and repulsion are not opponents but necessary partners, like Yin and Yang, each essential for the structure and stability of the universe.

Acknowledgments

The author thanks Z.AI (GLM by Z.ai) for extensive research collaboration and computational assistance throughout the development of this theory. The author also thanks his family, independent thinkers, and critical readers who encourage the exploration of first-principles approaches in fundamental physics.

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