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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Abstract

We present a theoretical framework in which gravity becomes repulsive when the gravitational force reaches a maximum value, $F_{\max} = c^4/G \approx 1.21 \times 10^{44}$ N, known as the Planck 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 24 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 approximately 250 grams, 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.

1 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 Planck force $F_{\max} = c^4/G$ — gravity does not simply saturate. It *flips* from attractive to repulsive. This principle was hinted at by Gibbons (2002) and elaborated by Schiller (2005). 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.

2 The Maximum Force Principle

2.1 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]. The argument is straightforward.

In general relativity, no physical process can produce a force exceeding:

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

This can be understood through several independent arguments:

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 strongest possible case where $m = M$ and both are at their Schwarzschild radii, the force scales as c^4/G.

Argument 2: Dimensional analysis. The only way to combine G and c to produce a quantity with dimensions of force $[M \cdot L \cdot T^{-2}]$ is:

$$F_{\max} = \frac{c^4}{G} \tag{3}$$

There is no other combination. This is unique.

Argument 3: Black hole thermodynamics. The surface gravity of a Schwarzschild black hole is $\kappa = c^4/(4GM)$. The force at the horizon is $F = \kappa \cdot m$. For the maximum possible mass (the Hubble mass), this gives a maximum force of order c^4/G.

2.2 Numerical Value

Substituting the standard values:

$$c = 2.998 \times 10^8 \text{ m/s} \tag{4}$$

$$G = 6.674 \times 10^{-11} \text{ m}^3\text{kg}^{-1}\text{s}^{-2} \tag{5}$$

$$F_{\max} = \frac{c^4}{G} = \frac{(2.998 \times 10^8)^4}{6.674 \times 10^{-11}} \tag{6}$$

Step by step:

$$c^2 = (2.998 \times 10^8)^2 = 8.988 \times 10^{16} \text{ m}^2/\text{s}^2 \tag{7}$$

$$c^4 = (8.988 \times 10^{16})^2 = 8.078 \times 10^{33} \text{ m}^4/\text{s}^4 \tag{8}$$

$$F_{\max} = \frac{8.078 \times 10^{33}}{6.674 \times 10^{-11}} = 1.210 \times 10^{44} \text{ N} \tag{9}$$

This is the Planck force: approximately 1.21×10^{44} Newtons. It is the largest force that general relativity permits.

2.3 Maximum Gravitational Acceleration

To convert force to acceleration, we need a mass. We use the SI base unit of 1 kg:

$$a_{\max} = \frac{F_{\max}}{1 \text{ kg}} = 1.21 \times 10^{44} \text{ m/s}^2 \tag{10}$$

The choice of 1 kg is natural because the gravitational constant G already contains kg^{-1} in its dimensional structure (G has units of $\text{m}^3\text{kg}^{-1}\text{s}^{-2}$). 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. We discuss this choice further in Section 9.1.

3 The Inner Flip: When Gravity Becomes Repulsive

3.1 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.

3.2 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 $a_{\max}$:

$$\frac{GM}{r_{\min}^2} = a_{\max} \tag{11}$$

Solving for r_{min}:

$$r_{\text{min}} = \sqrt{\frac{GM}{a_{\text{max}}}} \tag{12}$$

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

$$r_{\text{min}} = \sqrt{\frac{GM \cdot G \cdot 1\text{ kg}}{c^4}} = \sqrt{\frac{G^2 M}{c^4}} \cdot \sqrt{1\text{ kg}} = \frac{G}{c^2}\sqrt{M} \cdot \sqrt{1\text{ kg}} \tag{13}$$

Or more simply:

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

3.3 The Three-Zone Force Law

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

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

$$F = +\frac{GMm(r_{\text{min}} - r)^2}{r^4} \tag{15}$$

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

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

$$F = -\frac{GMm}{r^2} \tag{16}$$

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

4 The Big Bang Non-Collapse

4.1 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.

4.2 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:

$$M_{\text{univ}} \approx 10^{53} \text{ kg} \tag{17}$$
$$a_{\text{max}} = 1.21 \times 10^{44} \text{ m/s}^2 \tag{18}$$

$$r_{\text{min}} = \sqrt{\frac{GM_{\text{univ}}}{a_{\text{max}}}} = \sqrt{\frac{6.674 \times 10^{-11} \times 10^{53}}{1.21 \times 10^{44}}} \tag{19}$$

Step by step:

$$\text{Numerator:} \quad 6.674 \times 10^{-11} \times 10^{53} = 6.674 \times 10^{42} \tag{20}$$
$$\text{Fraction:} \quad \frac{6.674 \times 10^{42}}{1.21 \times 10^{44}} = 5.516 \times 10^{-2} \tag{21}$$
$$\text{Square root:} \quad \sqrt{5.516 \times 10^{-2}} = 0.235 \text{ m} \tag{22}$$

$$r_{\text{min}}(\text{observable universe}) \approx 0.235 \text{ m} \approx 24 \text{ cm} \tag{23}$$

This is a remarkable result. The inner flip distance for the observable universe is approximately 24 centimeters — roughly the size of a basketball. When the entire mass of the observable universe ($\sim 10^{53}$ kg) was compressed within this 24-cm radius, gravity was repulsive, driving explosive expansion.

4.3 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}:

$$\ell_P = 1.616 \times 10^{-35} \text{ m} \quad \text{(Planck length)} \tag{24}$$
$$r_{\text{min}} = 0.235 \text{ m} \tag{25}$$

The expansion factor is:

$$\frac{r_{\text{min}}}{\ell_P} = \frac{0.235}{1.616 \times 10^{-35}} = 1.455 \times 10^{34} \tag{26}$$

The number of e-folds is:

$$N = \ln\left(\frac{r_{\text{min}}}{\ell_P}\right) = \ln(1.455 \times 10^{34}) = 34 \times \ln(10) + \ln(1.455) = 78.2 + 0.375 \approx 78.6 \tag{27}$$

$$N \approx 78 \text{ e-folds} \tag{28}$$

Standard inflation requires 50–60 e-folds to solve the horizon and flatness problems. The inner flip provides 78 e-folds — more than sufficient. No inflaton needed.

4.4 Comparison with Inflation

5 Black Hole Interiors Without Singularities

5.1 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.

Table 1: Comparison: Inner Flip vs. Cosmic Inflation

Property	**Cosmic Inflation**	**Inner Flip**
Driving mechanism	Unknown inflaton particle	$F_{\max} = c^4/G$ (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$78 (predicted)
Why Big Bang didn't recollapse	Space expanded exponentially	Gravity was repulsive

5.2 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 $r = r_{\min}$. The core is in stable equilibrium:

- At $r = r_{\min}$: 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.

5.3 Calculations for Specific Black Holes

5.3.1 Solar-Mass Black Hole

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

$$r_{\min} = \sqrt{\frac{GM_\odot}{a_{\max}}} = \sqrt{\frac{6.674 \times 10^{-11} \times 2.0 \times 10^{30}}{1.21 \times 10^{44}}} \tag{29}$$

Step by step:

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

$$\text{Fraction:} \quad \frac{1.335 \times 10^{20}}{1.21 \times 10^{44}} = 1.103 \times 10^{-24} \tag{31}$$

$$\text{Square root:} \quad \sqrt{1.103 \times 10^{-24}} = 1.050 \times 10^{-12} \text{ m} \tag{32}$$

$$r_{\min}(M_\odot) = 1.05 \times 10^{-12} \text{ m} = 1.05 \text{ picometers} \tag{33}$$

Compare with the Schwarzschild radius:

$$r_s = \frac{2GM_\odot}{c^2} = \frac{2 \times 6.674 \times 10^{-11} \times 2.0 \times 10^{30}}{(2.998 \times 10^8)^2} = 2{,}970 \text{ m} \approx 3.0 \text{ km} \tag{34}$$

The core radius (1.05 pm) is 2.8×10^{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:

$$V_{\text{core}} = \frac{4}{3}\pi r_{\text{min}}^3 = \frac{4}{3}\pi(1.05 \times 10^{-12})^3 = 4.85 \times 10^{-36} \text{ m}^3 \tag{35}$$

$$\rho_{\text{core}} = \frac{M}{V_{\text{core}}} = \frac{2.0 \times 10^{30}}{4.85 \times 10^{-36}} = 4.12 \times 10^{65} \text{ kg/m}^3 \tag{36}$$

This density is approximately 1.8×10^{48} times nuclear density ($\sim 2.3 \times 10^{17}$ kg/m^3). Extremely dense — but finite. No infinity.

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

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

$$r_{\text{min}} = \sqrt{\frac{6.674 \times 10^{-11} \times 8.0 \times 10^{36}}{1.21 \times 10^{44}}} = \sqrt{4.411 \times 10^{-18}} = 2.10 \times 10^{-9} \text{ m} \tag{37}$$

$$r_{\text{min}}(\text{Sgr A*}) = 2.1 \text{ nanometers} \tag{38}$$

5.3.3 M87* (First Imaged Black Hole)

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

$$r_{\text{min}} = \sqrt{\frac{6.674 \times 10^{-11} \times 1.3 \times 10^{40}}{1.21 \times 10^{44}}} = \sqrt{7.165 \times 10^{-15}} = 8.47 \times 10^{-8} \text{ m} \tag{39}$$

$$r_{\text{min}}(\text{M87*}) = 85 \text{ nanometers} \tag{40}$$

5.4 Summary of Inner Flip Distances

Table 2: Inner Flip Distance r_{min} for Various Objects

Object	**Mass (kg)**	r_{min}	r_s **(Schwarzschild)**
Proton	1.67×10^{-27}	3.0×10^{-41} m	2.5×10^{-54} m
Planck mass	5.46×10^{-8}	1.7×10^{-31} m	8.1×10^{-35} m
1 kg mass	1	7.4×10^{-28} m	1.5×10^{-27} m
Sun	2.0×10^{30}	1.05 pm	2,970 m
Sgr A*	8.0×10^{36}	2.1 nm	1.18×10^{10} m
M87*	1.3×10^{40}	85 nm	3.85×10^{13} m
Observable universe	$\sim 10^{53}$	23.5 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.

6 Minimum Mass for Black Hole Formation

6.1 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:

$$r_{\min} \leq r_s \tag{41}$$

Substituting:

$$\sqrt{\frac{GM}{a_{\max}}} \leq \frac{2GM}{c^2} \tag{42}$$

6.2 Derivation of $M_{\min}$

Squaring both sides:

$$\frac{GM}{a_{\max}} \leq \frac{4G^2M^2}{c^4} \tag{43}$$

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

$$\frac{1}{a_{\max}} \leq \frac{4GM}{c^4} \tag{44}$$

Solving for M:

$$M \geq \frac{c^4}{4G \cdot a_{\max}} \tag{45}$$

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

$$M_{\min} = \frac{c^4}{4G} \times \frac{G \times 1 \text{ kg}}{c^4} = \frac{1 \text{ kg}}{4} = 0.25 \text{ kg} \tag{46}$$

$$M_{\min} = 0.25 \text{ kg} = 250 \text{ grams} \tag{47}$$

This is the minimum mass for black hole formation in our theory.

6.3 Verification

At $M_{\min} = 0.25$ kg:

$$r_{\min} = \sqrt{\frac{G \times 0.25}{a_{\max}}} = \sqrt{\frac{6.674 \times 10^{-11} \times 0.25}{1.21 \times 10^{44}}} \tag{48}$$

$$= \sqrt{\frac{1.669 \times 10^{-11}}{1.21 \times 10^{44}}} = \sqrt{1.379 \times 10^{-55}} = 3.71 \times 10^{-28} \text{ m} \tag{49}$$

$$r_s = \frac{2G \times 0.25}{c^2} = \frac{2 \times 6.674 \times 10^{-11} \times 0.25}{(2.998 \times 10^8)^2} = \frac{3.337 \times 10^{-11}}{8.988 \times 10^{16}} = 3.71 \times 10^{-28} \text{ m} \tag{50}$$

$$r_{\min} = r_s = 3.71 \times 10^{-28} \text{ m} \quad \checkmark \tag{51}$$

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

6.4 Implications for Primordial Black Holes

The minimum black hole mass of 250 grams has profound implications:

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

$$r_{\text{min}}(\text{proton}) = 3.0 \times 10^{-41} \text{ m} \tag{52}$$

$$r_s(\text{proton}) = 2.5 \times 10^{-54} \text{ m} \tag{53}$$

$$\frac{r_{\text{min}}}{r_s} = 1.2 \times 10^{13} \tag{54}$$

The repulsive core extends 10 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 ($M_P = \sqrt{\hbar c/G} \approx 2.2 \times 10^{-8}$ kg $= 22\ \mu$g) is often considered the minimum mass for quantum black holes:

$$r_{\text{min}}(M_P) = 1.7 \times 10^{-31} \text{ m} \tag{55}$$

$$r_s(M_P) = 8.1 \times 10^{-35} \text{ m} \tag{56}$$

$$\frac{r_{\text{min}}}{r_s} = 2{,}100 \tag{57}$$

Even at the Planck mass, the repulsive core extends 2,100 times beyond the event horizon. Our M_{min} of 250 g is 4.6 million times larger than M_P.

Primordial black holes below 250 g 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 250 grams, no event horizon can form because the repulsive core at r_{min} prevents collapse.

Table 3: Can It Form a Black Hole? (r_{min} vs. r_s)

Object	**Mass**	r_{min}	r_s	**BH?**
Proton	1.67×10^{-27} kg	3.0×10^{-41} m	2.5×10^{-54} m	No
Planck mass	22 μg	1.7×10^{-31} m	8.1×10^{-35} m	No
1 gram	10^{-3} kg	2.3×10^{-29} m	1.5×10^{-30} m	No
250 g (M_{min})	0.25 kg	3.7×10^{-28} m	3.7×10^{-28} m	Boundary
1 kg	1 kg	7.4×10^{-28} m	1.5×10^{-27} m	Yes
Earth	6.0×10^{24} kg	~ 0	8.9 mm	Yes
Sun	2.0×10^{30} kg	1.05 pm	3.0 km	Yes

6.5 Hawking Evaporation of Minimum-Mass Black Holes

A 250-gram black hole would evaporate via Hawking radiation in:

$$t_{\text{Hawking}} \approx \frac{5120\pi G^2 M^3}{\hbar c^4} \approx 2.1 \times 10^{-19} \text{ seconds} \tag{58}$$

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 $M_{\text{min}} = 250$ g is the theoretical minimum for *formation*, not for long-term survival.

7 Comparison with Existing Approaches

7.1 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 $F_{\max} = c^4/G$, 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

7.2 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

7.3 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 $F_{\max}$, which is a consequence of classical GR.

8 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 250 grams.** If primordial black holes below 250 g exist, our theory is falsified. Conversely, if no sub-250-g 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 250 g, which is far beyond current technology but is in principle possible.

3. **Big Bang expansion from repulsive gravity.** The inner flip predicts ∼78 e-folds of expansion from the Planck scale to $r_{\min} \approx 24$ 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 78 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).

9 Discussion and Open Questions

9.1 The 1 kg Convention

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

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. **Predictive success.** The 1 kg convention produces $r_{\min} \approx 24$ 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.
3. **Minimum BH mass prediction.** The same convention produces $M_{\min} = 250$ g, a testable prediction that distinguishes our theory from alternatives.

We note that an alternative interpretation — using the self-gravity of the collapsing body ($m = M$ rather than $m = 1$ kg) — gives $r_{\min} = GM/c^2 = r_s/2$ 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.

9.2 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 $F_{\max}$:

$$\frac{GM^2}{r^2} = F_{\max} = \frac{c^4}{G} \implies r_{\min} = \frac{GM}{c^2} = \frac{r_s}{2} \tag{59}$$

In this interpretation, $r_{\min} = r_s/2$ for all masses, meaning the repulsive core is always inside the event horizon, and there is no minimum BH mass. Both proton-mass and Planck-mass black holes would be possible.

The resolution depends on whether the "1 kg test mass" or the "self-gravity" interpretation is physically correct. This is an open question. However, we note that the 1 kg convention produces the Big Bang scale ($r_{\min} = 24$ cm) and a minimum BH mass (250 g), both of which are testable predictions. The self-gravity interpretation produces neither.

9.3 Force Continuity

The current formulation has a force discontinuity at $r_{\min}$: the inner zone gives $F \to 0$ as $r \to r_{\min}$ from below, while the outer zone gives $F = -GMm/r^2$ as $r \to r_{\min}$ 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 ($F \sim F_{\max}$), deep inside black holes or in the first instants of the Big Bang. It has no observable consequences at currently accessible scales.

9.4 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.

10 Conclusion

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

1. **Big Bang non-collapse:** When the observable universe's mass was compressed within $r_{\min} \approx 24$ cm, gravity was repulsive, driving 78 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:** $M_{\min} = 250$ g. Below this mass, $r_{\min} > r_s$, 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 ($F < F_{\min}$), which we address 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.

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