# Gravitational-Polarity Symmetry: A New Balance of Matter, Antimatter, and Spacetime

**Juraj Povazanec**
Juraj.Povazanec@proton.me
Senior Director of Program Management, Maxlinear Singapore

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**Abstract**

This paper challenges the assumed equivalence of inertial and gravitational mass for antimatter. While this principle is well tested for ordinary matter, its unsupported extension to antimatter represents a fundamental philosophical error. We argue that rejecting this equivalence, while challenging conservation laws, reveals a critical disconnect between General Relativity and Quantum Field Theory. Forcing both frameworks to accommodate this result imposes a new symmetry, paving a novel path toward their unification.

***Keywords*** Gravitational Polarity · Antimatter · General Relativity · Quantum Field Theory · Symmetry

## 1 Disclaimer

All concepts of matter, antimatter, and spacetime curvature discussed here are grounded in established physics. However, the idea of Gravitational Polarity Symmetry (GPS) — including the possibility of repulsive antimatter shaping cosmic structure — is speculative. This article is a work of theoretical exploration, blending established science with informed conjecture. It is meant to invite discussion, not to assert new physical laws.

### 1.1 Beyond Spacetime:

Though General Relativity (GR) and Quantum Physics emerged almost simultaneously, they describe reality through very different lenses. GR treats spacetime as a smooth fabric of geometry, while Quantum Theory reveals a restless, discrete foundation beneath it.

Einstein once wrote:

> *"Time and space are modes by which we think, not conditions in which we live."*

This insight suggests that spacetime may be emergent rather than fundamental. GR successfully describes curved geometry and gravity, but it may not fully capture matter-energy interactions. These processes likely involve a deeper quantum substrate from which spacetime emerges.

# 2 Introduction

Antigravity is as fundamental as gravity, yet absent from our physical framework. Einstein sensed this imbalance when he introduced the cosmological constant—a mathematical device to counteract universal gravitational collapse. But what if this repulsive force has a deeper origin?

Two clues point toward the answer. Dirac's relativistic equations revealed negative energy solutions that led directly to antimatter's discovery. Separately, Einstein's cosmological constant suggests the universe requires gravitational balance. These mathematical hints from physics' greatest minds point to the same missing piece: the gravitational nature of antimatter itself.

We propose that antimatter possesses negative gravitational polarity—curving spacetime repulsively while retaining positive inertial mass. This simple extension of established physics, which we call Gravitational Polarity Symmetry (GPS), transforms our understanding of cosmic evolution.

Previous attempts at antimatter gravity faced critical problems. Hermann Bondi explored and rejected negative mass (1950) [1] due to violations of conservation laws. Massimo Villata's CPT approach (2011) [2] predicted antihydrogen would "fall upward"—decisively refuted by ALPHA experiments in 2023. Alexander Burinskii's Kerr geometry models (2020) [3] generated repulsive gravitational fields for positrons but dismissed them as "unphysical."

GPS succeeds where others failed by recognizing these mathematical features as clues rather than problems. The framework that emerges preserves all experimental results while revealing antimatter's hidden role in shaping the universe.

# 3 Gravitational Polarity Symmetry

**Gravitational Polarity (GP) — the intrinsic property of matter determining whether it curves spacetime attractively or repulsively, without altering its inertial mass.**

**Positive GP creates a concave curvature of spacetime — a gravitational "valley" that attracts.**

**Negative GP creates a convex curvature — a gravitational "hill" that repels.**

The prevailing view holds that antimatter possesses positive gravitational polarity. Here, we propose an alternative: antimatter with opposite GP, establishing the framework of Gravitational Polarity Symmetry (GPS).

## 3.1 Theoretical Foundation

Quantum Field Theory (QFT) assigns zero or positive inertial (rest) mass to all particles but does not directly define gravitational mass. This neutrality allows QFT to remain invariant under GPS, accommodating a broader symmetry landscape. GPS naturally extends the standard CPT symmetry by incorporating gravitational polarity as an additional aspect of charge conjugation.

General Relativity (GR) traditionally recognizes only concave curvature of spacetime—gravitational "valleys" that attract. Introducing convex curvature for antimatter expands GR's geometric framework while preserving its fundamental mathematical structure.

### 3.2 Universe-Scale Balance

At cosmic scales, opposing gravitational polarities create perfect equilibrium. This balance produces today's observed flatness—not as coincidence, but as mathematical consequence.

### 3.3 Time Reversal Interpretation of black holes:

General Relativity predicts a time-reverse solution of the black hole — the white hole, an object that repels light and matter. In the standard model, built on positive gravitational polarity, this solution is mathematically unstable and physically problematic. GPS transforms this picture.

Imagine Sagittarius A*, a massive black hole made of matter particles. If time's arrow were reversed at its event horizon, the result would be an object that does the opposite — it repels everything. According to Feynman's interpretation, reversing time also swaps matter for antimatter. The change from attraction to repulsion hints at something profound: the repulsive nature outside the white hole could arise from the negative gravitational polarity of antimatter itself. See Figure 1.

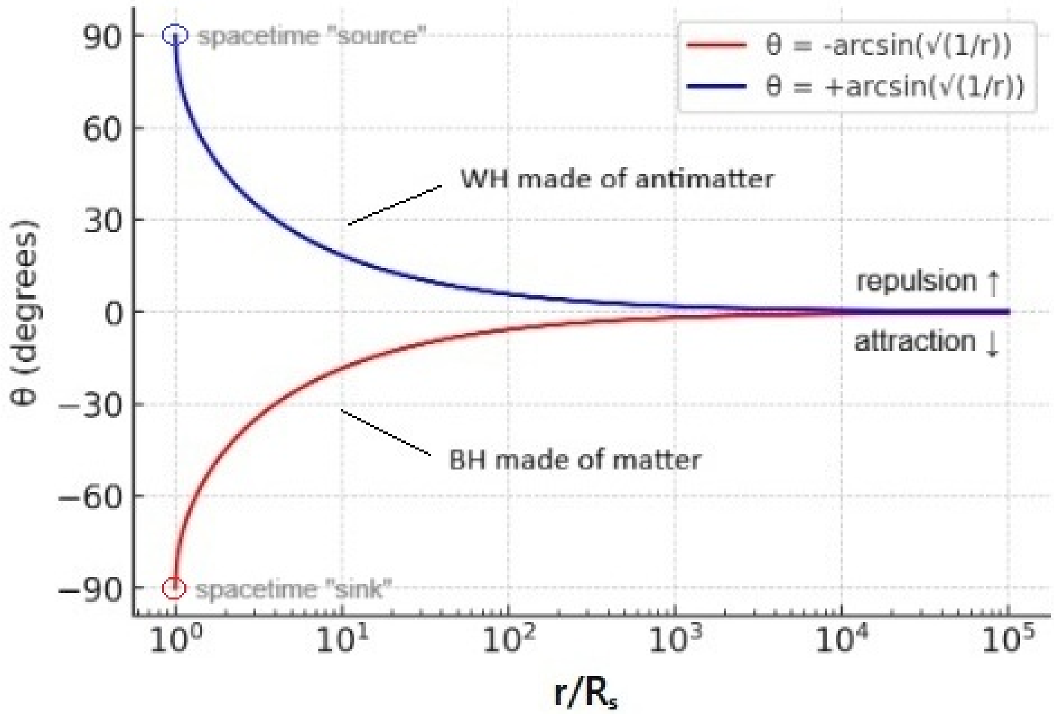


Figure 1: Black hole to white hole transformation under time reversal, where $\theta$ represents the temporal phase angle, as a function of distance in units of Schwarzschild radius: **Red**: A black hole made of ordinary matter attracts everything, including light. **Blue**: Under time reversal, the object becomes a white hole that repels everything.

GPS proposes a unified framework connecting black hole-white hole transformations with particle-antiparticle symmetries. This approach extends time reversal beyond established CPT symmetry by incorporating gravitational polarity, bridging the gap between quantum field theory and general relativity.

In this view, a white hole with negative GP is not chaotic but stable by design. However, each antimatter particle repels nearby mass gravitationally, making natural formation unlikely — no stars, no heavy atoms, just pure geometric repulsion of thinly distributed antihydrogen.

## 3.4 Experimental Consistency: The ALPHA Experiment

The ALPHA Antihydrogen Experiment at CERN confirmed that antihydrogen falls toward Earth at approximately 1g—identical to ordinary hydrogen, within experimental margins of error. This result might initially seem contradictory, but actually supports the framework perfectly.

Since antimatter retains positive inertial mass, it responds normally to existing gravitational fields. The key distinction: while antihydrogen falls normally toward Earth, it simultaneously generates repulsive spacetime curvature that exerts an outward gravitational force on the Earth.

The ALPHA experiment becomes even more consequential when viewed through Feynman's time reversal interpretation. Consider what happens under time reversal: if we reverse time's arrow in the experimental chamber, both particles—hydrogen and antihydrogen—would appear to continue falling toward Earth at 1g, maintaining identical behavior. However, the crucial insight emerges from a deeper consideration of the time reversal process. Under time reversal, Earth itself transforms into antimatter. Since antimatter possesses negative gravitational polarity, as we have established, this transformed Earth would consequently repel both particles. See Figure 2.

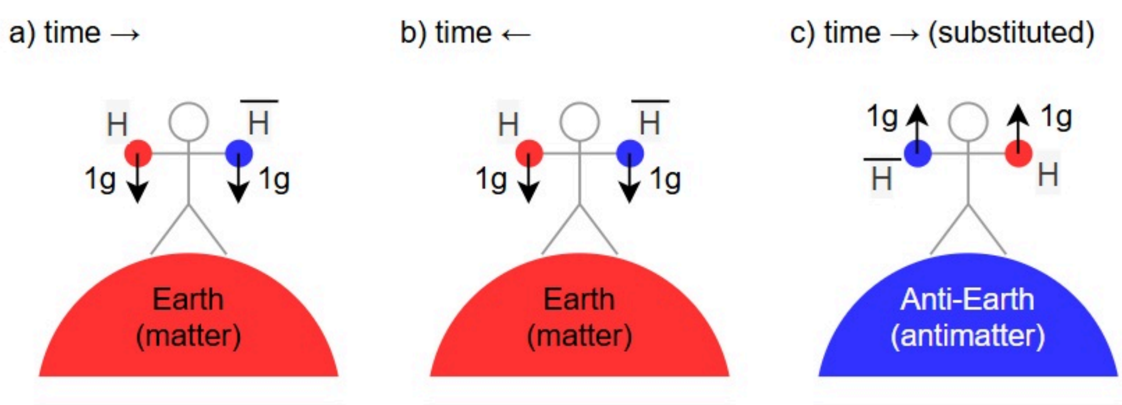


Figure 2: Feynman time reversal analysis of the ALPHA experiment. a) Standard time flow showing hydrogen (red) and antihydrogen (blue) both attracted to Earth. b) Time-reversed scenario where both particles are still attracted to Earth. c) In the transformed frame, matter and antimatter identities swap, making Anti-Earth (made of antimatter) repel both particles —like a white hole would.

This clearly demonstrates that gravitational force behaves differently from other fundamental forces—it is a source-dependent force where the nature of the gravitating object determines the interaction, rather than depending on properties of both interacting particles. To make GPS testable and precise, we need mathematical equations that capture these physical ideas.

# 4 Mathematical Framework: From Dirac to GPS

We now develop the mathematical formulation of GPS by building on insights from Einstein and Dirac's pioneering work on negative energy states.

## 4.1 Dirac's Energy Relation and Gravitational Polarity

Einstein's 1917 cosmological model acknowledged negative energy states as potentially fundamental to cosmic structure. Decades later, Dirac's electron theory revealed negative energy solutions that led directly to antimatter's discovery.

Dirac's relativistic energy-momentum relation contains both positive and negative solutions:

$$E = \pm\sqrt{(pc)^2 + (mc^2)^2} \tag{1}$$

The negative solution guided Dirac toward particles with opposite electric charge. We propose this mathematical structure also hints at gravitational polarity: antimatter particles may possess negative gravitational polarity $\varepsilon^G$ while retaining positive inertial mass $m_i$.

Building on this insight, we can extend Dirac's framework to include gravitational polarity:

$$E = \varepsilon^G\sqrt{(pc)^2 + (mc^2)^2} \tag{2}$$

## 4.2 Einstein Field Equations with Gravitational Polarity

To incorporate GPS into general relativity, we begin with Einstein's field equations. The standard form includes the cosmological constant $\Lambda$ that Einstein introduced to balance gravitational attraction:

Einstein's field equations with cosmological constant $\Lambda$:

$$R_{\mu\nu} - \frac{1}{2}Rg_{\mu\nu} + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4}\sum_i T^i_{\mu\nu} \tag{3}$$

Here $T_{\{\mu\nu\}} = \sum_i T^i_{\{\mu\nu\}}$ represents the total stress-energy tensor summed over all energy-momentum sources: matter, antimatter, radiation, and fields.

The cosmological constant $\Lambda$ was Einstein's mathematical device to balance gravitational attraction with cosmic repulsion. GPS suggests this balance emerges naturally from matter-antimatter polarity rather than requiring an external constant.

Guided by Dirac's energy relation (equation 2), we now incorporate gravitational polarity directly into the field equations. This yields the Einstein-Dirac-GPS field equations:

$$R_{\mu\nu} - \frac{1}{2}Rg_{\mu\nu} = \frac{8\pi G}{c^4}\sum_i \varepsilon^G_i T^i_{\mu\nu} \tag{4}$$

where:

- $\varepsilon^G_i = +1$ for matter, creating attractive curvature
- $\varepsilon^G_i = -1$ for antimatter, creating repulsive curvature

The $\varepsilon^G_i$ factor introduces gravitational polarity for each energy-momentum source, allowing attractive and repulsive contributions to coexist within the same framework.

This formulation eliminates the need for $\Lambda$ by encoding cosmic balance directly into the fundamental equations. The universe would maintain gravitational equilibrium through matter-antimatter symmetry.

Furthermore, incorporating repulsive curvature contributions from antimatter particles into Einstein's field equations would grant mathematical stability to previously problematic exotic objects such as white holes.

# 5 Stable White Hole, a pinnacle of GPS

In our framework, massive black holes cannot collapse into singularities because this would violate quantum behavior and prevent matter-antimatter annihilation from occurring. Below we demonstrate what we mean by well-behaved black hole - white hole mergers under GPS:

We consider a white hole to be an equal partner to a black hole, which we demonstrate in these two scenarios:

(1) Larger object (black hole; $\varepsilon^G = +1$): mass $M$; smaller object (white hole; $\varepsilon^G = -1$): mass $m$.

Their merger results in a black hole with mass $M - m$ and additional energy $E = 2mc^2$ emitted as photons during the annihilation process.

(2) Larger object (white hole; $\varepsilon^G = -1$): mass $M$; smaller object (black hole; $\varepsilon^G = +1$): mass $m$.

Their merger results in a white hole with mass $M - m$ and additional energy $E = 2mc^2$ released during annihilation.

This symmetry mirrors particle-antiparticle annihilation in QFT, linking curvature and energy elegantly — even if it defies standard GR.

We acknowledge that while the concept of white holes is theoretically fascinating, their physical existence is unlikely due to the repulsive nature of antimatter particles, which prevents the accumulation necessary for white hole formation. However, examining stable white holes under GPS serves a deeper purpose: it demonstrates the mathematical consistency and inherent symmetry of our framework. More importantly, these miniature black hole and white hole concepts provide a powerful theoretical tool for modeling gravitational interactions at the particle level. At this microscopic scale, a miniature white hole becomes a perfectly stable concept—mathematically elegant and physically meaningful.

GPS predicts something even more dramatic than stable white holes: runaway acceleration between matter and antimatter pairs.

# 6 Gravitational Acceleration Dynamics

Under GPS, a hydrogen-antihydrogen pair in vacuum exhibits asymmetric gravitational interactions: hydrogen's positive polarity attracts antihydrogen, while antihydrogen's negative polarity simultaneously repels hydrogen. This configuration generates runaway acceleration, with both particles gaining kinetic energy from the gravitational field geometry itself. See Figure 3.

To quantify this effect, we extend gravitational dynamics to include both polarity and relativistic effects:

$$a_i = \varepsilon_j^G \frac{G m_j \tau_j}{r^2} \tag{5}$$

where $\tau_j$ is the relativistic Lorentz factor for particle $j$:

$$\tau_j = \frac{1}{\sqrt{1 - \frac{v_j^2}{c^2}}} \tag{6}$$

This formulation (5) incorporates both gravitational polarity ($\varepsilon_j^G$) and relativistic corrections ($\tau_j$) into the acceleration dynamics, ensuring GPS remains consistent with special relativity even at high velocities.

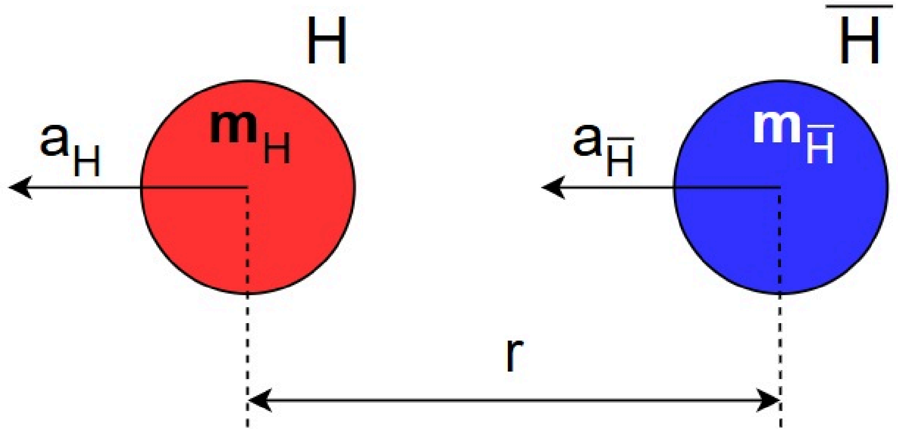


Figure 3: Runaway acceleration mechanism between hydrogen and antihydrogen under GPS. The hydrogen atom (red) attracts the antihydrogen atom (blue) gravitationally, while the antihydrogen simultaneously repels the hydrogen, creating asymmetric forces that drive both particles to accelerate while maintaining constant separation distance.

To assess the practical significance of this runaway mechanism, let us calculate the initial acceleration:

$$a_{\overline{H}} = \frac{Gm_H}{r^2} \tag{7}$$

Using typical values:

- Gravitational constant: $G = 6.674 \times 10^{-11}\ \frac{\text{m}^3}{\text{kg}} \cdot \text{s}^{-2}$
- Mass of hydrogen atom: $m = 1.67 \times 10^{-27}\ \ \text{kg}$
- Initial separation distance: $r = 1 \times 10^{-9}$ m (worst-case minimal distance without annihilation)

This yields an initial acceleration of approximately:

$$a_{\overline{H}} = 1.11 \times 10^{-19}\ \frac{\text{m}}{\text{s}^2} \tag{8}$$

Over the entire 14-billion-year lifetime of our universe, this acceleration would not produce relativistic speeds, remaining in the non-relativistic regime where energy gain is linear with time.

The energy gain rate can be expressed as:

$$\frac{dE}{dt} = ma^2t \tag{9}$$

Using calculated values:

- Acceleration: $a = 1.12 \times 10^{-19}\ \frac{\text{m}}{\text{s}^2}$
- Time: $t = 1$ s

$$\frac{dE}{dt} = 2.095 \times 10^{-65}\ \frac{\text{J}}{\text{s}} \tag{10}$$

Despite being extraordinarily minuscule, this mechanism reveals GPS's most profound implication: energy extraction from spacetime geometry itself.

In conclusion, the runaway mechanism, while theoretically present, operates on timescales far exceeding cosmic history. This runaway acceleration mechanism also could lead to a radical origin story for our universe.

# 7 Big Bang and Early Universe Dynamics

GPS runaway acceleration leads to a radical cosmological origin story. Consider the primordial moment when quantum fluctuations first generate a particle-antiparticle pair. This electrically neutral hydrogen-antihydrogen system creates the universe's initial gravitational dipole: antihydrogen becomes a spacetime source, hydrogen a spacetime sink. Figure 1 illustrates these spacetime “source” and “sink” configurations at the event horizon (considering miniature black and white holes).

This configuration transforms empty void into directed spacetime river flow, establishing both spatial extension and temporal direction for the first time. The gravitational asymmetry drives runaway acceleration—hydrogen pulls antihydrogen inward while antihydrogen pushes hydrogen outward, extracting ever-increasing kinetic energy from the gravitational field geometry itself.

Given enough time, aeons, the system could accumulate energy until reaching sufficient amount —comparable to our universe's estimated total energy content. At this critical threshold, the pair undergoes catastrophic annihilation, explosively releasing hydrogen and antihydrogen atoms in perfectly balanced expansion.

## 7.1 The Big Bang Mechanism

This explosive release creates precisely the conditions QFT demands: equal amounts of particles and antiparticles. Most pairs immediately annihilate in the intense early environment, but about $10^{53}$ kg of each type survives, preserving perfect baryon symmetry. The universe begins gravitationally balanced—by design.

This dense matter-antimatter mixture should have collapsed into a massive black hole, but GPS prevents that catastrophe. Spacetime becomes a landscape of alternating gravitational valleys (matter) and hills (antimatter). The overall gravitational balance means no net gravitational collapse—the universe is gravitationally poised for expansion rather than contraction.

Annihilation energy from the pairs that were destroyed provides natural expansion pressure, allowing the universe to grow freely without net gravitational attraction. The Big Bang emerges directly from the runaway mathematics—no complex theories needed, just the inevitable result of gravitational balance and accumulated energy release.

# 8 Cosmic Structure Formation

Having established the theoretical foundation, we now turn to cosmological implications. The interplay between matter and antimatter's opposing gravitational polarities fundamentally reshapes our understanding of how cosmic structures emerged and evolved. From the rapid condensation of primordial galaxies to the vast empty voids that span space, GPS provides a unified explanation for the universe's large-scale architecture—one that emerges naturally from gravitational balance rather than mysterious dark forces.

## 8.1 Formation of Galaxies and Cosmic Voids

In this gravitationally balanced universe, galaxy formation could proceed faster than in standard models — perhaps twice as fast — because local attraction from matter and local repulsion from antimatter aided the process.

Where matter dominated, condensation and star formation thrived; where antimatter prevailed, gravitational hills pushed matter aside, sculpting the vast cosmic voids we observe today.

Regions rich in antimatter naturally became seeds for these voids, providing a simple explanation for their size, shape, and persistence. Without these antimatter seeds, the existence and stability of such enormous voids would be much harder to account for.

This accelerated structure formation produces the cosmic architecture we observe today.

## 8.2 Large-Scale Structure of the Universe

Astronomers mapping millions of galaxies reveal a stunning **cosmic web**: a foam-like network of filaments, clusters, and enormous voids. Galaxies trace the filaments like points on a lattice, while vast nearly empty spaces — the voids — can stretch across hundreds of millions to over a billion light-years. See Figure 4.

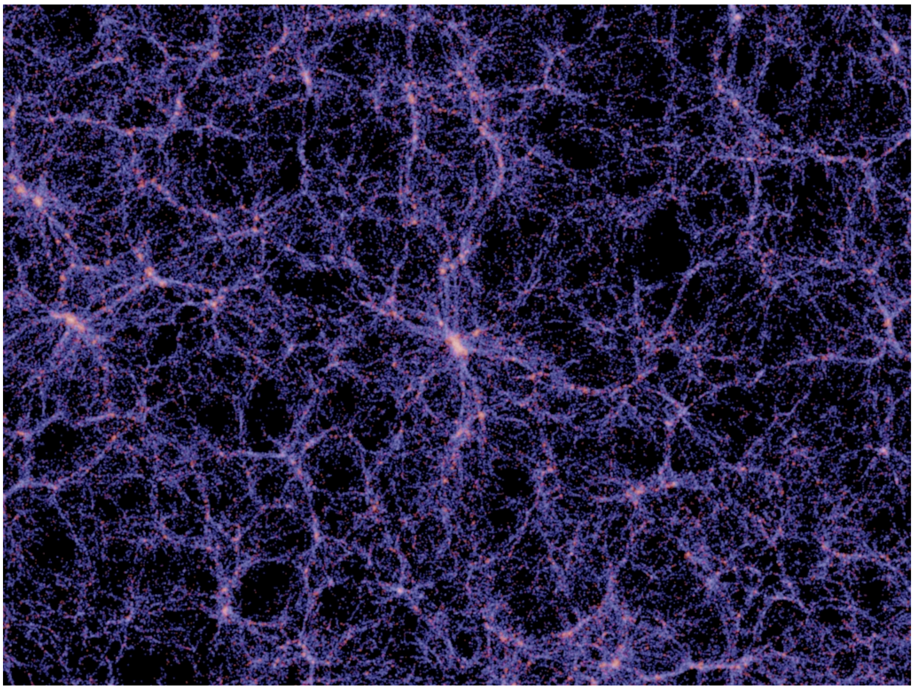

Figure 4: The cosmic web revealed by the Millennium Simulation showing the large-scale structure of the universe. Dark matter forms a foam-like network of filaments and nodes, with vast voids between them. Image credit: Millennium Simulation Project, Max Planck Institute for Astrophysics. [4]

In the context of GPS, this architecture takes on a new interpretation. Matter forms the filaments and nodes — the "soap" of the cosmic web — while thinly spread antimatter acts as the "air" inside the bubbles. The repulsive effect of antimatter naturally pushes matter into filaments and leaves vast voids between them, giving the universe its characteristic foam-like appearance.

This perspective explains the striking contrast between dense filaments and empty voids without invoking exotic forces: the universe's shape emerges naturally from the push-and-pull interplay of matter and antimatter, sculpted by gravitational polarity.

But if antimatter is truly everywhere shaping cosmic structure, why don't we see it?

## 8.3 Antimatter Across the Universe

The answer lies in its distribution: all $10^{53}$ kg of antimatter is spread thinly across intergalactic space at less than one antihydrogen atom per cubic meter. Invisible, non-luminous, and repulsive on cosmic scales, this antimatter silently shapes the universe.

Closer to stars like the Sun, solar wind and radiation sweep antihydrogen away, leaving our local region nearly pure matter. However, antimatter concentrations may persist around galactic centers, where dense gravitational fields and active processes create conditions conducive to antimatter accumulation. Far from galaxies, antimatter occupies the cosmic voids, subtly pushing on surrounding matter and contributing to the structure of the cosmic web.

Even at such low density, the cumulative effect of these particles is measurable. It could offer an alternative explanation in principle for small anomalies in galaxy-edge motions and other patterns traditionally attributed to dark matter or dark energy — without invoking unknown forces.

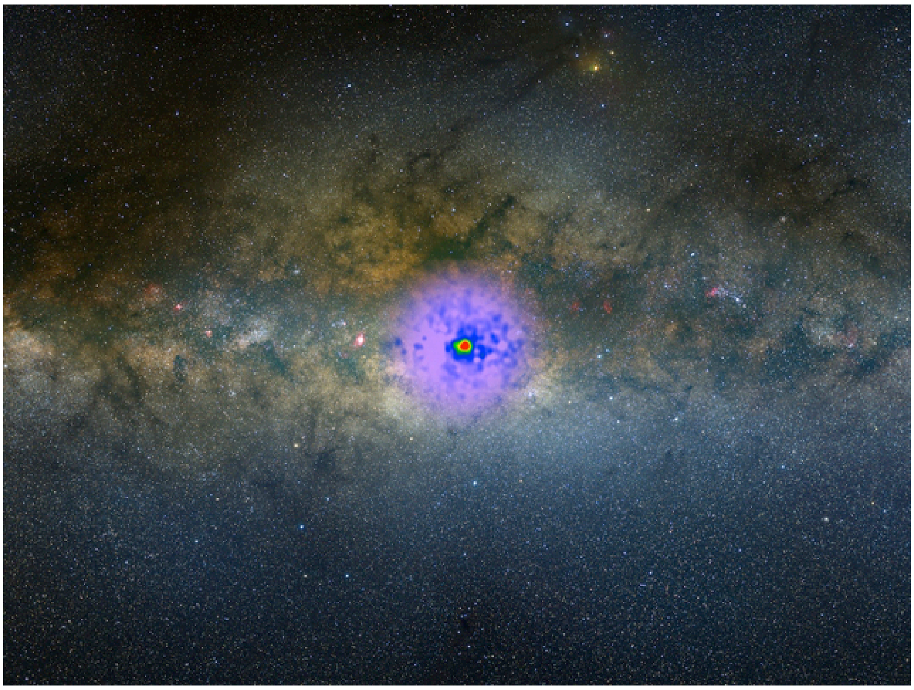

Figure 5: Excess gamma-ray emission from the Galactic center observed by NASA's Fermi Gamma-ray Space Telescope. After subtracting known gamma-ray sources, a patch of excess emission remains, most prominent at energies between 1-3 GeV and extending at least 5,000 light-years from the center. Image credit: NASA/DOE/Fermi LAT Collaboration [5].

Detecting individual antihydrogen atoms directly is beyond current capabilities, but their gravitational fingerprints may already be visible in void shapes, galaxy distribution, and fine details of large-scale structure.

The Fermi Gamma-ray Space Telescope has already detected unexplained excess gamma-ray emission from the galactic center (see Figure 5). GPS offers a natural explanation: this excess represents matter-antimatter annihilation signatures in regions traditionally attributed to dark matter.

Repulsive antimatter provides a coherent explanation for several cosmic phenomena — balancing structure formation, galaxy dynamics, and cosmic voids under one principle.

# 9 Implications and Insights

GPS offers elegant solutions and new insights across cosmology:

- **Arrow of Time:** Spacetime can be seen as a river flowing from the “sources” (antimatter) into the “sinks” (matter).
- **Resolution of Baryon Symmetry:** Matter and antimatter exist in equal amounts from the Big Bang.
- **Explanation for Cosmic Flatness:** Opposite spacetime curvatures cancel out, producing observed flatness.
- **Avoidance of Early Black Hole Collapse:** Repulsive antimatter prevents collapse despite extreme density.
- **Energetically Favorable Expansion:** Less energy is required to redistribute matter; annihilation energy provides a push.
- **Natural Formation of Cosmic Voids:** Antimatter-dominated regions push matter aside, forming stable voids.
- **Accelerated Formation of Galaxies:** Matter condenses efficiently while nearby antimatter guides structure.
- **Large-Scale Structure Explained:** Foam-like cosmic web emerges naturally from matter-antimatter interplay.
- **Alternative to Dark Matter:** Sparse antimatter explains anomalies in galaxy-edge dynamics.
- **Alternative to Dark Energy:** Local repulsive regions mimic dark energy effects without unknown forces.
- **Black hole evaporation:** Simple attraction of abundant antimatter from environment, annihilation that consequently releases gamma photons.
- **Consistency with Laboratory Physics:** Antimatter falls normally under gravity, preserving all tested results.
- **Runaway scenario:** This could explain why there is something rather than nothing. In the future, it may enable humanity to harness this energy—and perhaps even reach for the stars.

# 10 Research Pathways

Rather than attempting direct measurements of antimatter gravitational polarity—a formidable experimental challenge—GPS can be evaluated through computational approaches that test its predictions against observations:

## 10.1 Large-Scale Structure Modeling

Computational cosmology can test whether incorporating repulsive antimatter particles improves models of cosmic structure formation. Current simulations struggle to explain the rapid formation and vast scale of observed cosmic voids. GPS-enhanced models, with repulsive antimatter naturally sculpting these voids, may provide better fits to large-scale structure.

### 10.2 Early Galaxy Formation Analysis

The James Webb Space Telescope reveals unexpectedly massive, well-formed galaxies in the early universe—challenging standard formation timelines. GPS predicts accelerated structure formation through matter-antimatter gravitational dynamics. Comparing GPS-based models with JWST observations could demonstrate whether this framework better explains early cosmic evolution.

## 11 Conclusion

Gravitational Polarity Symmetry offers a simple yet elegant framework for understanding the universe, explaining cosmic flatness, void formation, and the foam-like cosmic web — without invoking exotic dark energy or unknown forces.

The early universe, dense with equal parts matter and antimatter, expands effortlessly, avoiding collapse into a universal black hole. Today, dispersed antihydrogen subtly shapes the cosmos, balancing matter and sculpting large-scale structure.

GPS provides a single, unifying principle that preserves all verified physics while revealing the universe's most profound insight: perfect balance emerges naturally from the interplay of matter and antimatter across cosmic time. What we observe today — from the smallest particles to the largest voids — may be the inevitable result of spacetime's deepest symmetry expressing itself through gravitational polarity.

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