Unified Hypothesis of Cyclic Black Hole Eruptions in Higher-Dimensional Geometry

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Abstract

This paper presents a unified hypothesis of cyclic energetic eruptions of black holes, combining a model of gravity emergence from five-dimensional spacetime with a mechanism of controlled matter-antimatter conversion. We propose that when the density inside a black hole exceeds a critical value ($\rho > \rho_{cr}^{\text{loc}} \sim 10^{18}$ kg/m^3), spontaneous but stable conversion of matter (M) to antimatter (A) occurs. This process leads to cyclic energy release through temporary loss of the event horizon. The model simultaneously explains the absence of singularities, observed cosmic mega-explosions, and the conservation of global baryon number through coupling with an antimatter brane. The hypothesis predicts characteristic observational signatures, including a specific spectral profile in the gamma-ray range (300-511 keV) and eruption cyclicity with period $T \sim M/\dot{M}$.

Glossary of Abbreviations

- **CCP** - Crumbled Paper Sheet (matter state)
- **SCP** - Spread-out Paper Sheet (spacetime state)
- **5DSP** - 5-Dimensional Spacetime
- **NS** - Neutron Star
- **BH** - Black Hole
- B_{ma} - Matter brane
- B_{an} - Antimatter brane
- **GR** - General Relativity

1 Introduction

Classical general relativity, despite its successes, predicts the formation of singularities at the centers of black holes, indicating its incompleteness at Planck scales. Simultaneously, astronomical observations reveal the existence of colossal cosmic explosions (such as AT2021lwx with energy 10^{52} J) that cannot be explained by standard mechanisms.

We present here a unified approach that combines the emergent nature of gravity from five-dimensional spacetime with a controlled process of matter-antimatter conversion, offering a coherent explanation for both the singularity problem and the mechanism powering the most powerful explosions in the Universe.

2 Theoretical Foundations

2.1 Emergent Gravity and Equations of State

We propose a modification of the standard GR approach, where the energy-momentum tensor is viewed not as a source but as a function of curvature state induced by interaction with the antimatter brane (B_{an}) in 5D:

$$T_{\mu\nu} \approx \Lambda(\mathcal{C}) G_{\mu\nu} \tag{1}$$

where $\mathcal{C}$ is the condensation function ($0 \leq \mathcal{C} \leq 1$), determining the degree to which energy is localized in material form, and $\Lambda(\mathcal{C})$ is the coupling function describing how interaction with B_{an} (manifesting as curvature $G_{\mu\nu}$) "condenses" into matter form ($T_{\mu\nu}$).

2.2 Critical Role of Local Density

While the average density of a black hole (ρ_{avg}) decreases with its mass, the **local** density (ρ_{loc}) in its interior can reach extreme values. We propose that it is not the average but the **local density** that determines the initiation of matter-to-antimatter conversion.

When in some region inside the event horizon the matter density exceeds the critical value $\rho_{cr}^{\text{loc}} \sim 10^{18}$ kg/m^3, the process $M \to A$ occurs. This mechanism acts as a "safety valve," preventing the formation of a mathematical singularity of infinite density.

2.3 Conversion Conditions for Different Objects

For a black hole of mass M, the average density is:

$$\rho_{\text{avg}} = \frac{3c^6}{32\pi G^3 M^2} \tag{2}$$

Assuming conversion requires achieving $\rho_{\text{avg}} \geq \rho_{cr}^{\text{loc}}/k$ (where k is the concentration factor), for $\rho_{cr}^{\text{loc}} = 10^{18}$ kg/m^3 and $k \sim 100$:

$$M \leq \sqrt{\frac{3c^6}{32\pi G^3 (\rho_{cr}^{\text{loc}}/k)}} \approx 35 M_\odot \tag{3}$$

2.4 Implications

- **Stellar black holes** ($M < 100 M_\odot$): Can reach the conversion threshold in their central regions
- **Intermediate-mass black holes**: Strong candidates for cyclic eruptions
- **Supermassive black holes**: Can reach conversion conditions during episodes of intense accretion

- **Neutron stars**: Primary candidates for conversion in their cores!

3 Neutron Stars: Fundamental Laboratories

Unlike black holes, which must first compress accreting matter to extreme densities, neutron stars (NS) **already exist in a state of extreme compression**. This fundamental distinction makes them primary candidates for observing the proposed matter-to-antimatter conversion mechanism ($M \to A$).

- **Near-Threshold Initial State:** The average density of NS ($\rho_{\text{avg}} \sim 10^{17} - 10^{18}$ kg/m^3) is **close to or even exceeds** the proposed threshold value ρ_{cr}^{loc}. This means their cores can **continuously exist in a near-critical state**, where even minor disturbances (accretion, "starquakes") can trigger conversion.
- **Absence of Event Horizon:** The lack of an event horizon is a key advantage of NS. It enables the **escape of conversion and annihilation products** (e.g., characteristic photons) into space, where they can be detected by observatories, providing direct evidence of the process.
- **Consistency with Observations:** NS, particularly magnetars, exhibit exactly the type of **cyclic, violent activity** (X-ray and gamma-ray flares, fast radio bursts - FRBs) that is central to the hypothesis's predictions. Their eruptions are not constant but occur after periods of stress accumulation, perfectly matching the proposed cycle: **accretion/stress buildup** $\to$ **reaching** $\rho_{cr}^{\mathbf{loc}}$ $\to$ **conversion** $M \to A$ **and annihilation** $\to$ **violent energy eruption** $\to$ **quiescence**.

Thanks to these properties, neutron stars are not merely "candidates" for conversion but are **ideal, natural laboratories** for testing the presented hypothesis.

4 Mathematical Model

4.1 Mechanism Refinement: Two Distance Scales

The mechanism of gravitational force emergence requires distinguishing two fundamentally different distance scales operating within 5-dimensional spacetime (5DSP):

- **Inter-brane distance (r_1):** This is a constant, global distance in 5DSP between the antimatter brane (B_{an}) and the matter brane (B_{ma}). Its scale is cosmological, probably on the order of the observable Universe's radius. The distance r_1, along with mass M_{an} and constant G_5, determines the **global tension level** of brane B_{ma}, tending to flatten it:
$$\text{Tension} \propto G_5 \frac{M_{an}}{r_1^3}$$
- **Inter-mass distance (r_2):** This is a variable, local distance *on the brane itself* B_{ma} between two "lumps" (masses). This is exactly the distance r appearing in Newton's law of universal gravitation. The distance r_2 determines how effectively two masses, through their local geometry, transform global tension into the observed force.

4.2 Nature of Branes and Interaction Source

A key element of the model is the reinterpretation of the concepts of "matter brane" and "antimatter brane." These are not separate entities but **distinguished regions or layers within one, coherent 5-dimensional spacetime (5DSP)**. They are characterized by a dominant type of SP "crumpling":

- On B_{ma} dominate "crumplings" identified as **matter (M)**.
- On B_{an} dominate "crumplings" identified as **antimatter (A)**.

The coupling mechanism between these regions is based on the following principle:

- **Interaction Source:** The interaction does not occur between "bare" branes but is mediated by the "crumplings" present on them. The B_{an} region, rich in antimatter, **repels mass (M)** located on the B_{ma} region. Since mass is inextricably linked to spacetime ("glued" to it at the most fundamental level of existence), the effect of this repulsion is **global tension** of spacetime, which locally manifests as **deformation of its metric** around mass.
- **Process Symmetry:** According to the symmetry principle, the B_{ma} region repels antimatter (A) located on B_{an}, leading to analogous deformation of the metric around antimatter on the "opposite" side.
- **Role of GR:** General Relativity remains a fundamentally correct description of the *effects* of this process – it describes the motion of bodies in an already existing, curved metric. The present hypothesis complements GR by revealing the *mechanism* behind this curvature, pointing to its source in the interaction between 5DSP regions.

In this configuration, the source of global tension is the different way antimatter couples to the spacetime metric. We postulate that, in addition to standard GR curvature (associated with its positive mass), antimatter induces in its surroundings a **reverse metric polarization** (analogous to the "hill" meniscus around a polystyrene ball on water). It is precisely this "buoyancy" or "reverse curvature" that is the primary source of repulsion relative to matter and global brane tension, which locally manifests as the force of gravity.

5 Global Baryon Number Conservation

A key objection to the matter-to-antimatter conversion mechanism ($M \to A$) is the violation of global conservation of baryon number (B) and lepton number (L). In the Standard Model, these processes are forbidden. However, this hypothesis offers a natural solution to this problem within higher-dimensional geometry.

We propose that conversion $M \to A$ occurring on our matter brane (B_{ma}) is **compensated** by a symmetric, inverse process of antimatter-to-matter conversion ($A \to M$) occurring on the coupled antimatter brane (B_{an}).

$$\Delta B_{\text{global}} = \Delta B_{ma} + \Delta B_{an} = (-1) + (+1) = 0 \tag{4}$$

where:

- $\Delta B_{ma} = -1$: loss of one unit of baryon number on brane B_{ma} (conversion $M \to A$).
- $\Delta B_{an} = +1$: gain of one unit of baryon number on brane B_{an} (conversion $A \to M$).

Both processes are triggered by achieving the critical local density ($\rho_{\text{loc}} \geq \rho_{cr}$) on their respective branes. In this configuration, the **global baryon number for the system composed of both branes is conserved**.

Our universe appears to be matter-dominated because processes on B_{an} are directly unobservable to us – they manifest only through their gravitational (repulsive) interaction with our brane, which we postulate as the source of tension leading to the emergence of the gravitational force.

This mechanism not only solves the baryon number conservation problem in the context of conversion but also offers an elegant explanation for the **great matter-antimatter asymmetry** in our observable world: it is merely local to our brane B_{ma}, while the full Universe in 5D is perfectly symmetric.

6 Cyclic Annihilation Model

6.1 Postulate of Temporary Event Horizon Loss

A key and essential element of the proposed model is the following postulate:
Postulate of Temporary Event Horizon Loss
We propose that the extreme radiation pressure generated during matter-antimatter annihilation in the central region is able – in a quantum manner not described by classical GR – to **temporarily nullify or make transparent the event horizon**. In this transitional state (henceforth referred to as *State 2*), the object ceases to be a black hole in the strict sense, allowing energy and information to escape outward. The duration of *State 2* is on the order of the object's dynamic time scale ($t \sim R_s/c$), after which the event horizon reconstitutes itself, and the object returns to a state of stable accretion (*State 1*).

This postulate is fundamental to the observability of the entire mechanism. Without it, any energy released through annihilation would remain trapped behind the horizon, preventing the observed eruption from occurring. This mechanism can be viewed as a quantum "rupture" or "blurring" of the horizon singularity under the pressure of extreme radiation, being a direct consequence of the $M \to A$ conversion process at critical density.

6.2 Equilibrium and Stability Conditions

The equilibrium condition between the **density of gravitational force** compressing the object and the **pressure gradient** generated by the annihilation process opposing it takes the form:

$$\rho\, \vec{g} \approx -\vec{\nabla} P_{\text{ani}} \tag{5}$$

where the gravitational acceleration near the event horizon is $|\vec{g}| \approx \frac{GM}{R^2}$, and the annihilation pressure is estimated by $P_{\text{ani}} \approx \frac{1}{3}\epsilon\rho c^2$, with ϵ being the mass-to-energy conversion efficiency.

Approximating the pressure gradient for a characteristic length scale on the order of radius R, $|\vec{\nabla} P_{\text{ani}}| \sim \frac{P_{\text{ani}}}{R}$, we obtain the following equilibrium condition **to order of magnitude**:

$$\rho \cdot \frac{GM}{R^2} \approx \frac{1}{R} \cdot \frac{\epsilon\rho c^2}{3} \tag{6}$$

Multiplying both sides by R^2 and simplifying (assuming $\rho > 0$), we obtain the fundamental condition for the process to occur:

$$\frac{GM}{R} \approx \frac{\epsilon c^2}{3} \tag{7}$$

This condition means that for effective annihilation ($\epsilon \sim 1$), the gravitational potential at the object's surface $\frac{GM}{R}$ must be on the order of a fraction of c^2. For a black hole, where $R \approx R_s = \frac{2GM}{c^2}$, this condition is automatically satisfied to within a factor of order unity:

$$\frac{GM}{R_s} = \frac{GMc^2}{2GM} = \frac{c^2}{2} \approx \frac{\epsilon c^2}{3} \quad \Rightarrow \quad \epsilon \approx \frac{3}{2}$$

This suggests that the extreme gravity of black holes **naturally creates conditions** for highly efficient matter conversion. It is worth noting that the theoretically obtained efficiency $\varepsilon > 1$ suggests that the M→A conversion process draws energy not only from the rest mass but also from the gravitational energy stored in spacetime tension, which is consistent with the general idea of the hypothesis.

For Sgr A* we obtain the cycle parameters:

- Accretion time: $t_{\text{acc}} = \frac{\Delta M}{\dot{M}} \approx 100$ years
- Annihilation time: $t_{\text{ani}} \approx \frac{R_s}{c} \approx 30$ s (assuming the process is limited by free-fall time through the conversion zone)
- Cycle period: $T \approx t_{\text{acc}} + t_{\text{ani}} \approx 100$ years (since $t_{\text{ani}} \ll t_{\text{acc}}$)

6.3 Cosmological Source of Tension

A key question is the energy source powering the described mechanism. The answer to this lies in the earliest phases of Universe evolution.

We propose that the primary source of energy and brane separation was the violent expansion of the Big Bang (BB). In our hypothesis, most of the matter and antimatter created then underwent annihilation, releasing colossal energy that provided the "primordial impulse" putting the system into a state of global tension. However, thanks to a fundamental difference in interaction with the spacetime metric, described as the "buoyancy effect," asymmetric separation occurred:

- **Matter (M)**, characterized by "sinking" in 4D SP, remained localized in the region we identify as our matter brane B_{ma}.
- **Antimatter (A)**, characterized by "buoyancy" in 4D SP, was pushed out and separated into the B_{an} region in 5-dimensional spacetime.

It was this act of primordial separation that "charged" the system, creating a permanent, repulsive coupling between B_{an} and B_{ma}. This repulsion is the source of global tension in our brane, which – as described in Section 3 – locally manifests as the force of gravity. The energy stored in this tension is gradually released in cyclic processes of conversion and annihilation, constituting the source of observed mega-explosions.

In other words, the phenomena observed today represent the "repayment of the energy debt" incurred during the Big Bang, and gravity is an emergent force arising from the system's tendency toward equilibrium through cyclic reduction of this tension.

7 Observational Tests of the Hypothesis

7.1 Cosmic Mega-Explosions

Objects such as AT2021lwx ($E \sim 10^{52}$ J) could be direct manifestations of the described mechanism:

$$E_{\text{AT2021lwx}} \sim \eta k M c^2 \quad \Rightarrow \quad M \sim \frac{E_{\text{AT2021lwx}}}{\eta k c^2} \sim 10^9\, M_\odot \tag{8}$$

where $\eta \sim 1$ and $k \sim 0.01$ were adopted.

7.2 Annihilation Signatures and Gravitational Shift

This mechanism makes unique observational predictions. Unlike annihilation in the interstellar medium, where a narrow 511 keV line is expected, annihilation in the strong gravitational field of a black hole leads to the formation of a **broad and asymmetric spectral profile** in the gamma-ray range.

- **Shifted and Broadened Annihilation Line:** Photons from electron-positron annihilation are emitted at various distances from the gravity center ($r > R_s$). Each photon undergoes redshift to a different degree, depending on its emission point:
$$E_{\text{obs}} = E_{\text{emit}} \sqrt{1 - \frac{R_s}{r}} = 511\,\text{keV} \cdot \sqrt{1 - \frac{R_s}{r}} \tag{9}$$
As a result, the single 511 keV line "smears out" into a broad continuum, ranging from almost 0 keV (for photons emitted near R_s) to 511 keV (for photons emitted at infinity). For an external observer, this creates a **characteristic, steeply sloping profile** with a maximum around 300-400 keV and a long "tail" toward lower energies.
- **Mass Dependence:** For objects with **shorter dynamic timescales** (lighter black holes, neutron stars), the annihilation process may be more violent and localized in a narrower range of distances, leading to a **narrower profile**. For **supermassive black holes**, the profile will be **wider** and more "blurred." Searching for this correlation between object mass and annihilation profile shape constitutes a key test of the hypothesis.
- **Symmetric Light Curve:** The duration of a single eruption is on the order of the object's dynamic time scale ($t_{\text{dyn}} \sim R_s/c \sim$ hours-days for SMBH).
- **Location in Galaxy Centers:** Sources of such signatures should be point-like and located in the centers of active galaxies, not in their disks.

7.3 Periodicity Predictions

The hypothesis predicts a strict dependence of eruption periodicity on mass:

$$T \sim \frac{M}{\dot{M}} \tag{10}$$

- For Sgr A* ($4.3 \times 10^6 M_\odot$): $T \sim 100$ years
- For M87* ($6.5 \times 10^9 M_\odot$): $T \sim 10^7$ years

Table 1: Proposed observational signatures of the mechanism

Signature	**Status**	**Potential example**
Broad, asymmetric annihilation profile (0-511 keV)	Hypothetical	Active galactic nuclei
Orphan flare	Hypothetical	AT2021lwx, FBOTs
Symmetric light curve	Hypothetical	AT2018cow, some TDEs
Location in galaxy center	Hypothetical	AT2021lwx

8 Discussion and Open Problems

8.1 Topology and Stability of Branes

A key open problem remains the **topology of fundamental 5DSP**. Is it a hypersphere, torus, or another compact manifold? Answering this question requires further research combining the depth of differential geometry with the physical intuition presented in this work.

8.2 Implications for Fundamental Physics

The model suggests that:

- Gravity is an emergent effect from higher-dimensional geometry
- Matter and antimatter are symmetrically distributed between branes
- Singularities are removed by the quantum conversion mechanism

8.3 Directions for Observational Research

We propose the following research directions:

1. Search for the characteristic spectral profile in the 300-511 keV range in spectra of active galaxies
2. Monitoring cyclicity of flares in various classes of black holes
3. Precise measurements of mega-explosion light curves
4. Study of correlation between object mass and annihilation profile shape

9 Conclusions

The presented unified hypothesis offers:

1. **Coherent explanation** for the absence of singularities in black holes
2. **Driving mechanism** for cosmic mega-explosions
3. **Solution** to the baryon number conservation problem
4. **Testable** observational predictions

5. **Emergent interpretation** of gravity as a manifestation of global spacetime tension

The model demonstrates how extreme densities initiate controlled matter-to-antimatter conversion, leading to cyclic energy release through temporary loss of the event horizon. The proposed mechanisms represent a promising path toward a unified description of astrophysical and cosmological phenomena within a coherent physical model.

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