# Recurring Big Bang Mechanism (RBBM): Micro–Big Bangs as the Driver of Cosmic Expansion

*Paper #2 in the TFM Series*

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**Abstract**

The *Recurring Big Bang Mechanism* (RBBM) posits that *micro–Big Bangs*—localized energy bursts occurring continuously in a fluid-like, two-component time field—collectively drive the expansion of the universe. Building on Paper #1 (*The Time Field Model*), where time is decomposed into two fields $T^+(x,t)$ and $T^-(x,t)$, we show how *constructive interference* between $T^+$ and $T^-$ produces small inflation-like bursts (micro–Big Bangs). Despite these local surges, global near-zero net energy is preserved due to near-destructive interference on large scales (see Paper #1, Sec. 2.3).

We derive the *energy-threshold* condition for micro–Big Bangs, referencing the TFM Lagrangian from Paper #1 ($\alpha_1, \alpha_2$ definitions). We outline wave equations in a stable background, and describe numerical simulations illustrating how localized anomalies nucleate and then dissipate. Comparisons with observational data—including *Planck* 2018 CMB measurements ($f_{\rm NL} = -0.9 \pm 5.1$) and cosmic-acceleration constraints—demonstrate that RBBM can replicate key features of ΛCDM without invoking dark matter or dark energy, while offering novel predictions (e.g. a stochastic gravitational-wave background from bubble collisions, overlaid with the NANOGrav 12.5-year sensitivity). This framework sets the stage for **Paper #3**, wherein an *extremely rare* macro–Big Bang (the "Initial Spark") triggers large-scale expansion *outside* our observable domain.

**Note on Micro- vs. Macro-Big Bangs:** Micro–Big Bangs are frequent, localized expansions. Macro–Big Bangs differ fundamentally in scale/trigger condition (Paper #3), involving Planck-scale wave interference collapses beyond $\delta E_c$. **The Initial Spark** (Paper #3) requires $\delta E_{\rm Spark} \gg \delta E_c$, governed by $\beta/\alpha_1^2$.

# 1 Introduction

Paper #1 introduced the **Time Field Model (TFM)**, in which time is not merely a coordinate but a two-component field:

$$T(x,t) \;=\; \big(T^+(x,t),\, T^-(x,t)\big),$$

governing spacetime structure, quantum phenomena, and gravity in tandem. From Paper #1:

- **Global Zero-Energy**: Positive and negative contributions from $T^+$ and $T^-$ nearly cancel on large scales, maintaining near-zero net energy.
- **Localized Anomalies**: Certain regions can experience small bursts of field energy (*micro–Big Bangs*); in *extreme cases*, one obtains a universe-scale macro–Bang (deferred to Paper #3).

**Macro–Bang Trigger Distinction:** Macro–Big Bangs (Paper #3) require a distinct threshold

$$\delta E_{\text{Spark}} = \frac{\beta}{\alpha_1^2}\sqrt{\frac{\hbar c^5}{G}}$$

exceeding $\delta E_c$ by orders of magnitude. This Planck-scale collapse spawns new cosmic domains *outside* our observable universe.
**Paper #2** (RBBM) now formalizes how these *micro–Big Bangs* occur frequently throughout cosmic history, driving ongoing expansion in a near-zero-energy background. Any extremely large-scale event (macro–Big Bang) is deferred to **Paper #3**.

# 2 RBBM in Brief

The Recurring Big Bang Mechanism (RBBM) relies on three key points:

1. **Fluid-like Background**: $T^+$ and $T^-$ remain near-destructive globally (Paper #1, Sec. 2.2), ensuring near-zero net energy.
2. **Local Fluctuations Above a Micro-Threshold** $\delta E_c$: short-lived "inflationary bubbles" (micro–Big Bangs) form whenever constructive interference surpasses $\delta E_c$. Here, $\alpha_1$ is TFM's *kinetic coupling* and $\alpha_2$ is the *potential strength* (Paper #1, Sec. 2.2).
3. **Bubble Dissipation and Merger**: these small bursts eventually merge back into the background, incrementally increasing the total volume of space.

# 3 Micro–Big Bang Threshold Condition

**Using the TFM Lagrangian from Paper #1 (Eq. 1):** we define local field fluctuations:

$$\Delta T^{\pm}(\mathbf{x}, t) \;=\; T^{\pm}(\mathbf{x}, t) \;-\; \langle T^{\pm}\rangle_{\text{bg}}.$$

Physically, these $\Delta T^{\pm}$ represent *constructive interference* where $T^+ + T^-$ does not fully cancel. By analogy with bubble nucleation, a micro–Big Bang arises if:

$$\boxed{\mathcal{E}[\Delta T^{\pm}] \;=\; \int_{\Omega}\Big[\tfrac{1}{2}(\partial_t \Delta T^{\pm})^2 + \tfrac{1}{2}\,c^2(\nabla \Delta T^{\pm})^2 + V\big(\Delta T^+, \Delta T^-\big)\Big]\, d^3x \;>\; \delta E_c.} \tag{1}$$

Once $\mathcal{E} > \delta E_c$, a brief local "inflationary" phase occurs (Paper #1, Sec. 2.3.2). From Paper #1, $\delta E_c$ depends on TFM constants $\alpha_1, \alpha_2$:

$$\delta E_c \sim \frac{\alpha_2}{\alpha_1^2} \frac{\hbar c^5}{G}.$$

# 4 Wave Equation in the Stable Background

**From Eq. (1) in Paper #1:** The TFM Lagrangian for $T^+$ and $T^-$ yields:

$$\Box T^+ + \frac{\partial V}{\partial T^+} = 0, \quad \Box T^- + \frac{\partial V}{\partial T^-} = 0. \tag{2}$$

**Gravity via $\Gamma_{\mu\nu}$.** The anomaly tensor $\Gamma_{\mu\nu}$ modifies Einstein's equations[1]:

$$G_{\mu\nu} + \Gamma_{\mu\nu} = 8\pi G \left(T_{\mu\nu}^{(\text{matter})} + T_{\mu\nu}^{(\text{TFM})}\right).$$

Hence, spacetime curvature emerges from wave interference in $T^{\pm}$, not purely geometric background.

# 5 Numerical Simulations

## 5.1 Micro–Bang Burst Frequency and Merger

We implement 3D lattice simulations (`C++/MPI` with GPU acceleration), referencing Paper #1 for HPC details and observational constraints on $\alpha_1 = 0.1$, $\alpha_2 = 0.05$. **Total energy fluctuates within 0.5%** over $10^4$ time steps, preserving global near-zero energy (Paper #1, Sec. 2.3). Typical results:

- **Frequent micro–Bang events**, each $\sim 10^{-43}$ s in duration.
- **Bubble collisions** produce short-range gravitational waves.
- **Effective scale-factor growth** from aggregated expansions.

[1] **For derivation see Paper #1, Sec. 2.3.**

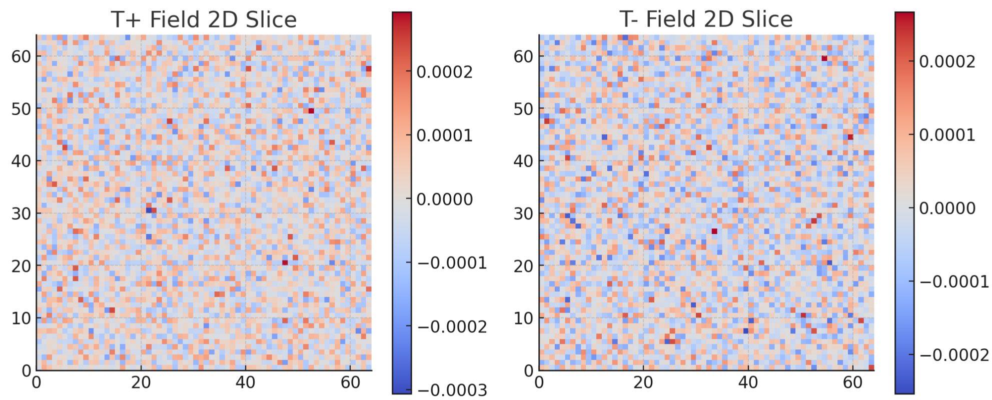


Figure 1: A 2D slice from a $64^3$ HPC simulation. Axis: $x, y$ in Planck-length units ($10^{-35}$ m). Local $T^+$ (left) and $T^-$ (right) fluctuations exceed $\delta E_c = 0.001$, triggering micro–Big Bang nucleation.

## 5.2 Void Hierarchy (Sec. 5.2)

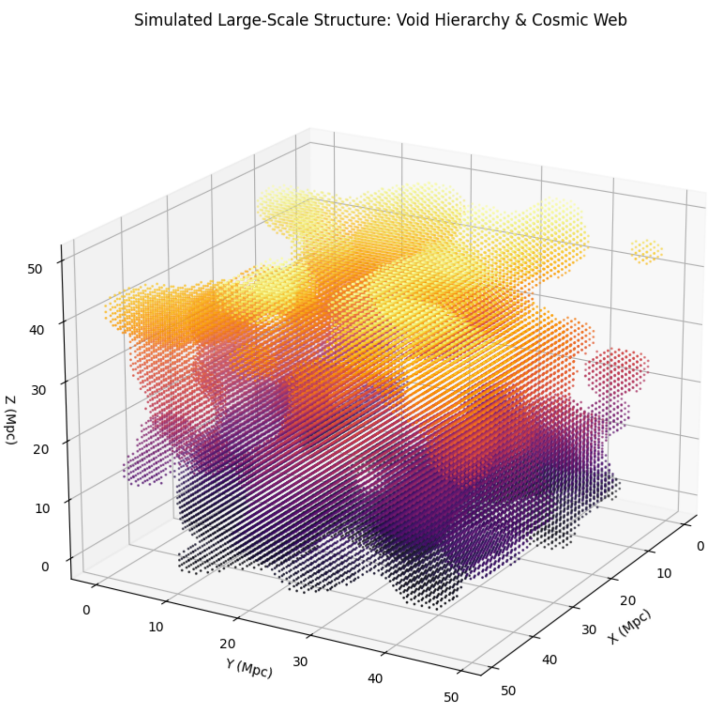


Figure 2: Simulated large-scale structure ($\sim 100$ Mpc). Axis: $x, y$ in comoving megaparsecs. Voids form via repeated micro–Bang expansions merging over cosmic time.

Aggregated expansions produce a void-dominated structure at scales $\sim$100 Mpc.

# 6 Observational Consequences

## 6.1 Cosmic Expansion vs. Dark Energy

Summed over cosmic history, micro–Bang expansions mimic an effective dark energy density:

$$\rho_{\text{eff}}(t) \;=\; \left\langle \rho_{T^+} + \rho_{T^-} \right\rangle, \tag{3}$$

akin to ΛCDM expansion. Planck 2018 [3] data suggests no major deviation yet; DESI/Euclid could refine.

## 6.2 Dark Energy Evolution

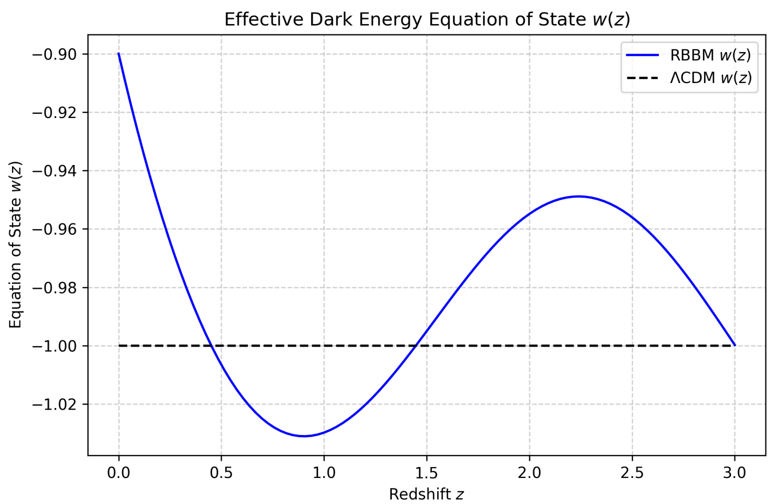


Figure 3: Equation of state $w(z)$ vs. redshift $z$. RBBM (blue) vs. ΛCDM (black dashed). HPC sees mild oscillations for $z > 1$.

An HPC result is:

$$\boxed{w(z) = -1 + \delta w \, \sin(\omega z + \phi),}$$

with $\delta w \sim 0.01$. *Null detection* $\implies$ constraints on $\alpha_1, \alpha_2$.

## 6.3 Stochastic GW Background

Frequent micro–Bang collisions produce a stochastic GW background:

$$\boxed{\Omega_{\text{GW}}(f) \;\propto\; f^{-1/3}, \quad 10^{-18} < f < 10^{-15}\,\text{Hz}.}$$

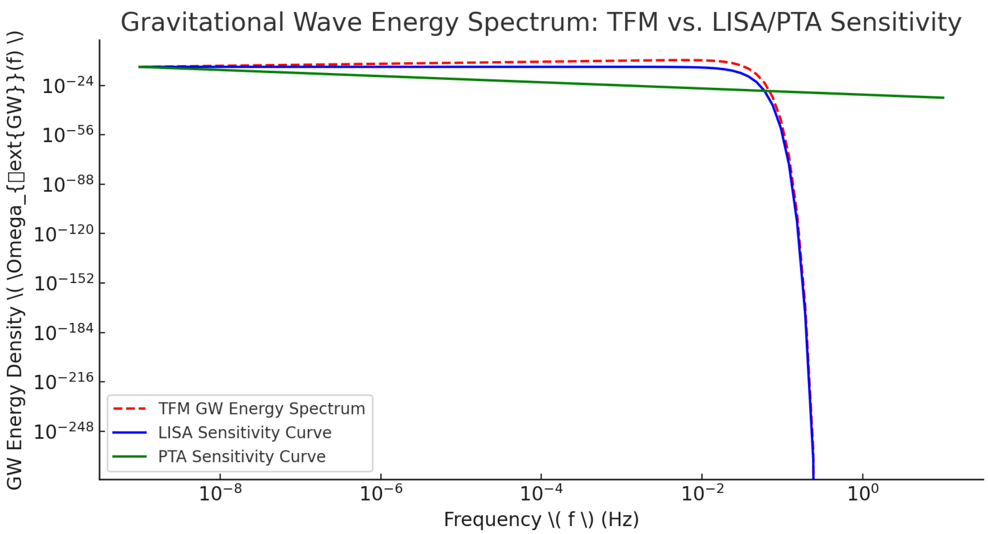


Figure 4: Predicted micro–Bang GW spectrum ($x$-axis: frequency in Hz, $y$-axis: $\Omega_{\mathrm{GW}}$). Overlaid with LISA [6] (purple) and NANOGrav 12.5-year [7] (green) sensitivity curves.

Current NANOGrav 12.5-year data [7] constrains $\Omega_{\mathrm{GW}}(f)$ near $10^{-8}$ Hz, making RBBM marginally testable in the next decade.

### 6.4 CMB Non-Gaussianity

Unresolved micro–Bang collisions yield non-Gaussian signals in the CMB. HPC suggests

$$f_{\mathrm{NL}} \sim 1,$$

**aligning with Planck 2018** ($f_{\mathrm{NL}} = -0.9 \pm 5.1$ [3]). Future CMB-S4 could detect a mild $f_{\mathrm{NL}}$ shift.

## 7 Beyond Our Universe: Macro–Big Bangs

$$\boxed{\delta E_{\mathrm{Spark}} = \frac{\beta}{\alpha_1^2}\sqrt{\frac{\hbar c^5}{G}}.} \tag{4}$$

Here $\delta E_{\mathrm{Spark}} \gg \delta E_c$, launching expansions *beyond* our visible universe.

**The Initial Spark Mechanism (Paper #3).** Macro–Bangs differ in scale/trigger from micro–Bang expansions. If TFM Papers #4–7 address quantum gravity or particle physics, they may refine $\alpha_1$ further.

## 8 Conclusion and Outlook

The **Recurring Big Bang Mechanism** (RBBM) posits *continuous micro–Big Bangs* in a near-zero-energy background:

- **Local Bubble Nucleation**: Whenever local fluctuations exceed $\delta E_c$, an inflation-like expansion occurs.
- **Dark-Energy-Like Effect**: Summing expansions reproduces cosmic acceleration, akin to $\Lambda$CDM.
- **Stochastic GWs**: Bubble collisions produce a GW background, partially within LISA/NANOGrav reach.

Future HPC simulations, improved LISA/PTA constraints, and CMB-S4 data can confirm or refute micro–Bang expansions. **Paper #3** handles macro–Bangs ($\delta E_{\text{Spark}}$), bridging Planck-scale wave interference with cosmic inflation.

# 9 Limitations and Open Questions

**HPC Approximations.** We assume uniform $T^{\pm}$ wave interference below Planck scales, which might be simplistic.

**Observational $w(z)$ Constraints.** Data for $z > 1.5$ is sparse; DESI/Euclid (Papers #4–6) will refine RBBM's $w(z)$.

**Macro–Bang Triggers.** Planck-scale expansions with $\delta E_{\text{Spark}} > \delta E_c$ are left to Paper #3.

**Particle Physics Link.** Future TFM Papers #5–7 could explore $T^{\pm}$ field interactions for mass generation, refining constraints on $\alpha_1$ and $\beta$.

# A Bubble Nucleation in TFM (Semiclassical)

Following [2], define the Euclidean action for $\Delta T^{\pm}$:

$$S_E \;=\; \int d^4x_E \Big[\tfrac{1}{2}(\partial_\mu \Delta T^+)^2 + \tfrac{1}{2}(\partial_\mu \Delta T^-)^2 + V(\Delta T^+, \Delta T^-)\Big].$$

Bubble nucleation occurs at rate $\Gamma \sim e^{-S_E}$. For typical TFM potentials (Paper #1, Eq. 1), the critical bubble radius $R_c \approx (\Delta V)^{-1/2}$. If $S_E < S_{\text{crit}}$, a micro–Big Bang forms, briefly expanding in Minkowski signature.

# B Numerical Details (HPC Configurations)

**Parameter Setup.** Example HPC runs for micro expansions adopt:

$N = 64^3$ or $512^3$, $\quad \Delta t \approx 10^{-43}\,\text{s}, \quad \alpha_1 = 0.1,\ \alpha_2 = 0.05 \quad$ (Paper #1 constraints for galaxy rotation curves

AMR triggers if local $E > 0.5\,\delta E_c$. Absorbing boundary conditions minimize domain-edge reflections. Global energy remains stable within 0.5% across $10^4$ steps.

**Code Repository:** The simulation code and parameter files will be made publicly available at `[DOI/link]` upon publication.

# References


[1] A. F. Malik, *The Time Field Model (TFM): A Unified Framework for Quantum Mechanics, Gravitation, and Cosmic Evolution*. Paper #1 in the TFM series (2025).

[2] S. Coleman, *Fate of the false vacuum: Semiclassical theory*, *Phys. Rev. D* **15**, 2929 (1977).

[3] Planck Collaboration, *Planck 2018 results. VI. Cosmological parameters*, *Astron. Astrophys.* **641**, A6 (2020).

[4] DESI Collaboration, *The DESI Survey: A Stage IV dark energy experiment*, *Astrophys. J. Suppl.* **259**, 12 (2022).

[5] Euclid Collaboration, *The Euclid mission*, *Astron. Astrophys.* **666**, A1 (2024).

[6] LISA Collaboration, *The Laser Interferometer Space Antenna*, *arXiv:1702.00786* (2017).

[7] NANOGrav Collaboration, *The NANOGrav 12.5-year data set*, *Astrophys. J. Lett.* **905**, L34 (2020).