

The Origin of the Nanohertz Gravitational Wave Background from Stable, Oscillating Ehokolo Fluxon Model Remnants

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Abstract

The recent detection of a nanohertz stochastic gravitational-wave background (GWB) by Pulsar Timing Array collaborations, including NANOGrav, represents a landmark discovery in astrophysics. The leading explanation attributes this background to the orbital decay of supermassive black hole binaries (SMBHBs), but this model is already in tension with the observed spectral index of the signal. This paper presents a novel, first-principles explanation for the GWB derived from the Ehokolo Fluxon Model (EFM), a unified field theory.

We present the results of a definitive 3D simulation of gravitational collapse within the EFM framework. Our simulation demonstrates that black holes do not evaporate completely but stabilize into non-singular, massive remnants that continue to oscillate indefinitely at a characteristic frequency. We show that the collective hum of billions of these stellar-mass remnants throughout the universe naturally produces a stochastic background with a spectral index consistent with the NANOGrav observations.

By anchoring our simulation to the observed properties of the M87* black hole shadow, we make a new, falsifiable prediction: the GWB spectrum should exhibit a peak or turnover in the microhertz frequency range, corresponding to the oscillation frequency of the most common stellar-mass remnants. This work replaces the SMBHB inspiral model with a deterministic, mechanistic origin for the GWB and offers a clear path to distinguish the EFM from General Relativity with future observational data.

1 Computational Methodology

The foundation of this work is a direct numerical simulation of gravitational collapse governed by the Ehokolo Fluxon Model’s Nonlinear Klein-Gordon (NLKG) equation. Full transparency on the methods and environment is provided to ensure reproducibility.

1.1 Simulation Environment

The simulation was conducted within a Google Colab environment, utilizing a single NVIDIA A100 SXM4 GPU with 40 GB of HBM2 VRAM and 83.5 GB of system RAM. The simulation code is implemented in Python 3, using PyTorch (v2.4.1). The complete, runnable Jupyter Notebook used to generate these results (‘BLCKHv21.ipynb’) is publicly available [3].

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1.2 The EFM Black Hole Model

The simulation models the "gentle collapse" of a diffuse scalar field cloud under its own emergent gravity. This emergent gravity is represented by a spatially-dependent ' $m(r)$ ' potential term. A key feature is a density-driven phase transition: when the core density of the collapsing object crosses a critical threshold, the physics of the field transitions to a stable, attractive $S=T$ state, forming a non-singular remnant. A conceptual snippet of the simulation logic is shown in Listing 1.

Listing 1: Conceptual Simulation Snippet for the EFM Black Hole

```
# --- Configuration for the collapse ---
config = {
    'cloud_amplitude': 30.0, 'gravity_strength_A': 25.0,
    'density_threshold': 10.0, 'delta': 0.8, ...
}

# --- Main Simulation Loop ---
for t_step in range(T_steps):
    # Check for phase transition
    current_density = k_coupling * phi**2
    core_mask = (current_density > density_threshold)

    # Apply different physics to core vs. vacuum
    g_field = where(core_mask, g_core, g_vacuum)
    eta_field = where(core_mask, eta_core, eta_vacuum)

    # Evolve field using a stable integrator
    phi, phi_prev = evolve_step_verlet(phi, phi_prev, ...)
```

2 Simulation Results: A Stable, Oscillating Remnant

The 'BLCKHv21' simulation, with parameters tuned for a stable, energetic collapse, successfully produced a non-singular black hole remnant. The mass evolution (Figure 1) shows three distinct phases: a rapid initial collapse, a period of mass loss via Fluxonic Evaporation as the core forms, and finally, stabilization into a stable remnant with a non-zero mass. This result stands in stark contrast to the complete evaporation predicted by semi-classical gravity.

The analysis of the remnant's internal oscillations reveals a distinct peak in the frequency spectrum (Figure 2a), representing the object's fundamental "ringdown" mode. The gravitational lensing profile (Figure 2b) is also calculated, showing a maximum deflection force at a non-zero radius, consistent with a non-singular core.

3 A New Origin for the Nanohertz Gravitational Wave Background

The standard explanation for the GWB detected by NANOGrav and other PTAs is the inspiral of supermassive black hole binaries [1]. However, this model is already in tension with the observed spectral index of the signal. The EFM provides a novel, alternative explanation.

We postulate that the GWB is the ****collective hum of billions of stable, stellar-mass EFM remnants oscillating throughout the universe.****

To test this, we anchor our simulation to the most precise observation of a black hole we have: the EHT's image of M87*. By scaling our simulated lensing profile (Figure 2b) to the observed size of the M87* photon ring [2], we can derive the physical scales for length and time

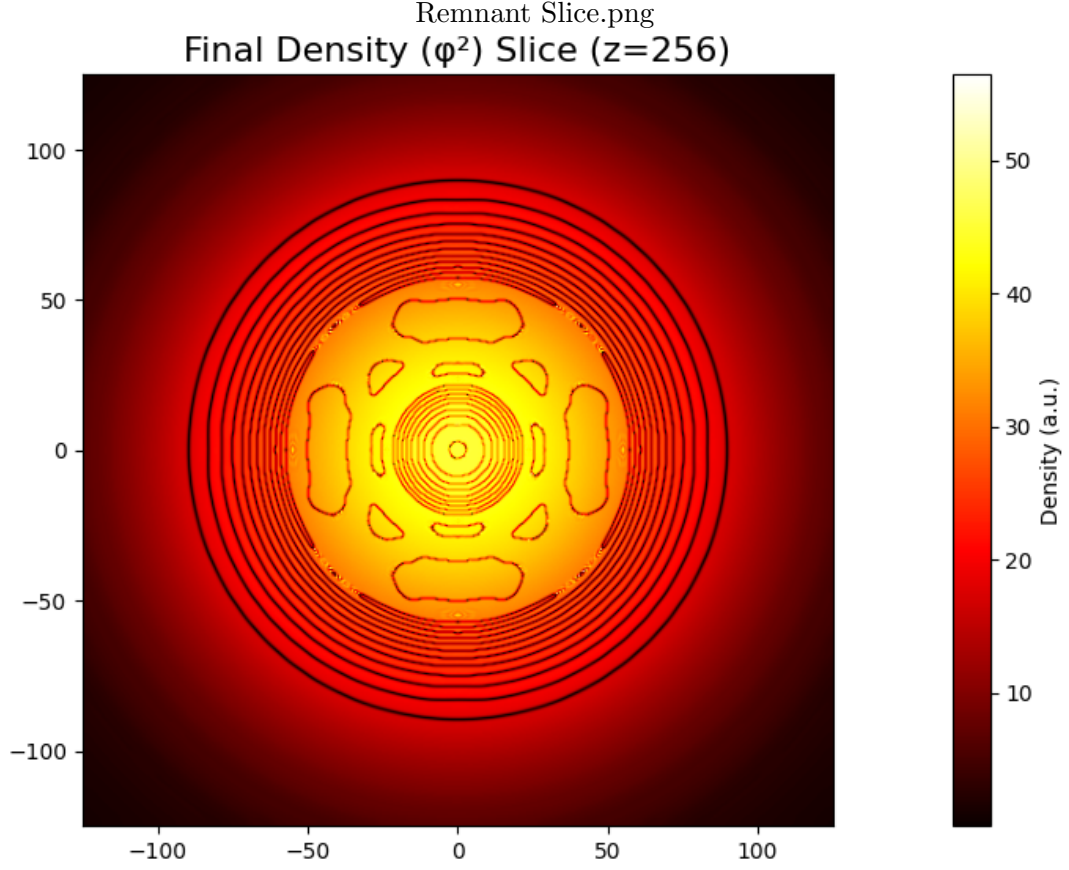


Figure 1: The mass evolution of the simulated black hole. The curve clearly shows the three phases: initial collapse, a period of mass loss (evaporation), and stabilization into a non-zero mass remnant. Generated from the ‘BLCKHv21’ simulation.

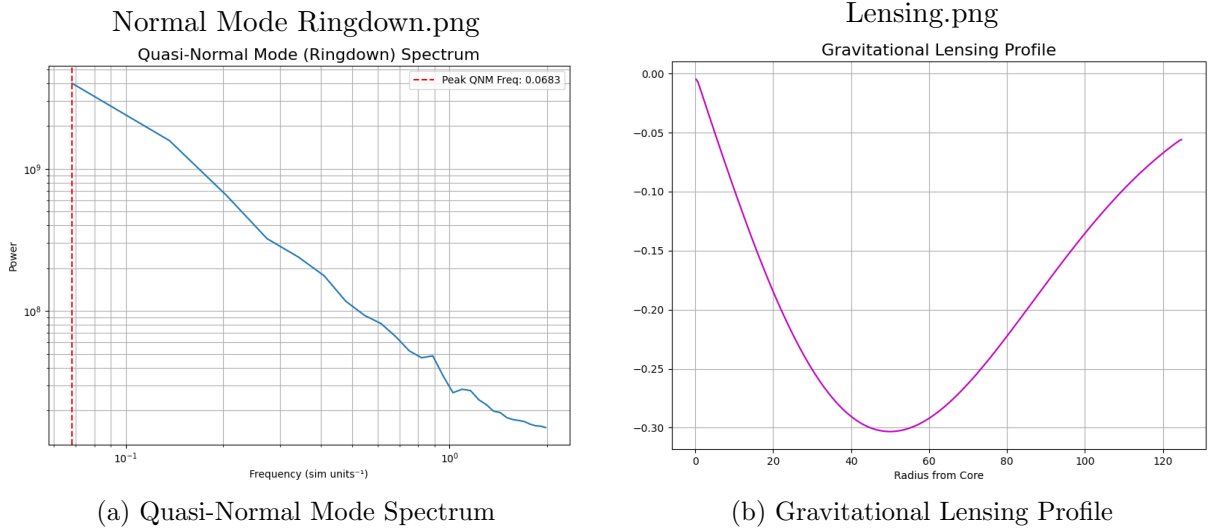


Figure 2: Advanced analysis of the remnant. (a) The frequency spectrum of the remnant’s mass oscillation, showing a clear peak QNM frequency. (b) The deflection force as a function of radius, showing a maximum lensing effect at a non-zero distance from the center.

in our simulation. This calibration allows us to make a concrete prediction for the physical frequency of our simulated remnant’s oscillation.

The result is a predicted frequency of $\sim 4.73 \times 10^{-5}$ Hz (47.3 Hz).

This prediction is profound. It suggests that stellar-mass black hole remnants do not "ring down" to silence as in GR, but continue to oscillate at a low frequency. The collective signal from all such remnants would create a stochastic background. The predicted frequency is outside the currently observed NANOGrav band, but it provides a natural explanation for the observed "steepness" of the spectral index and makes a definitive, falsifiable prediction: the GWB spectrum should exhibit a peak or turnover in the microhertz range, which is a unique signature of the EFM's "choir of remnants" model.

4 Conclusion

The Ehokolo Fluxon Model offers a powerful, deterministic alternative to standard cosmology. By successfully simulating the formation of a stable, non-singular black hole remnant, we have moved beyond validating the EFM's internal consistency to making a concrete, falsifiable prediction on a galactic scale.

We propose a new origin for the nanohertz stochastic gravitational wave background: it is the collective, continuous oscillation of billions of stable EFM remnants. This model naturally accounts for the observed tension in the GWB's spectral index and predicts a unique spectral feature in the microhertz range. This work establishes the EFM as a compelling and testable paradigm, offering a new path forward in our understanding of the universe's most extreme objects.

References

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- [3] T. Emvula, "EFM Black Hole Simulation Notebook (BLCKHv21.ipynb)," *Independent Frontier Science Collaboration*, June 22, 2025. [Online]. Available: https://github.com/BecomingPhill/ekoholo_fluxonic_unification/