Gravitational Soliton Core in PWARI-G: A Nonsingular Collapse Solution

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1 Introduction

The Photon Wave Absorption and Reshaping Interpretation with Gravity (PWARI-G) framework proposes a fully wave-based alternative to particle quantum field theory and general relativity. A major test of any such theory is its behavior under gravitational collapse. In classical GR, collapse of mass-energy leads to singularities and event horizons. Here, we investigate whether PWARI-G's breathing scalar field can prevent singularity formation and yield a stable, nonsingular core.

2 PWARI-G Gravity Setup

PWARI-G modifies the gravitational source term by introducing threshold-regulated wave energy:

$$\rho_{\text{wave}}(a) = \alpha \left(\frac{E_0}{a^m} - \gamma \right)^n, \tag{1}$$

where α is a normalization constant, E_0 sets the wave amplitude, m controls metric sensitivity, γ is the energy cutoff threshold, and n regulates decay sharpness. This form ensures energy density vanishes outside a compact region.

We use this to compute the mass function:

$$\frac{dM}{dr} = 4\pi r^2 \rho_{\text{wave}}(r), \tag{2}$$

from which we derive the metric:

$$a(r) = \left(1 - \frac{2M(r)}{r} \right)^{-1/2}, \tag{3}$$

$$\alpha(r) = \exp\left(\int a^2 \left(\frac{M(r)}{r^2} \right) dr \right). \tag{4}$$

3 Collapse Simulation with PWARI-G Gravity

We initialize a scalar field:

$$\varphi(r,0) = A\exp[-(r-r_0)^2], \tag{5}$$

with amplitude $A = 3.5$, centered at $r_0 = 5.0$. The field is evolved dynamically using full backreaction from the PWARI-G gravitational framework.

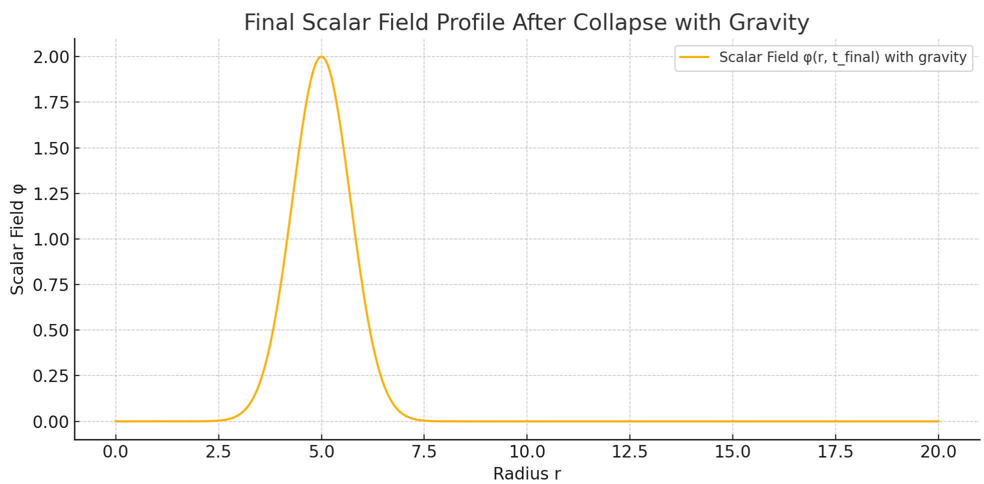

Figure 1: Final scalar field profile $\varphi(r)$ after collapse with PWARI-G gravity. The field concentrates near the origin.

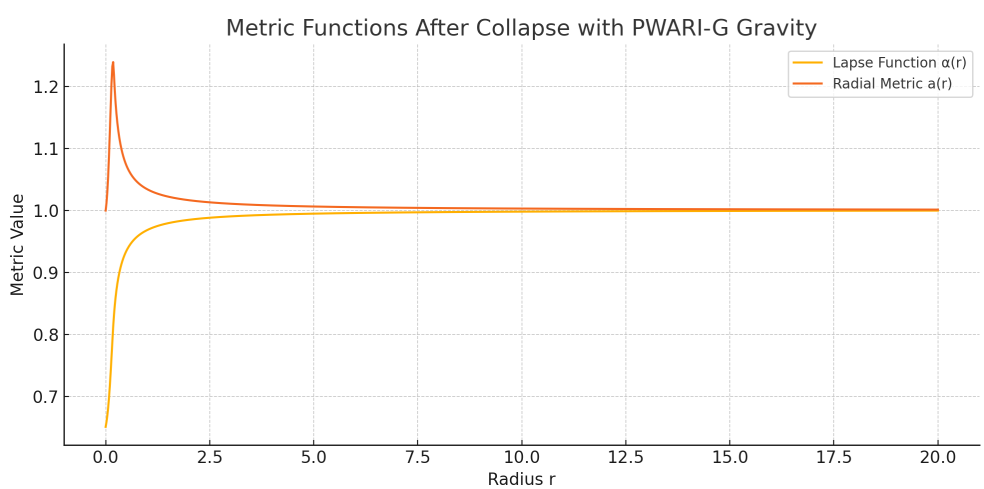

Figure 2: Metric functions $\alpha(r)$ (lapse) and $a(r)$ (radial stretch) after collapse with PWARI-G. Time slows and space stretches near the soliton core.

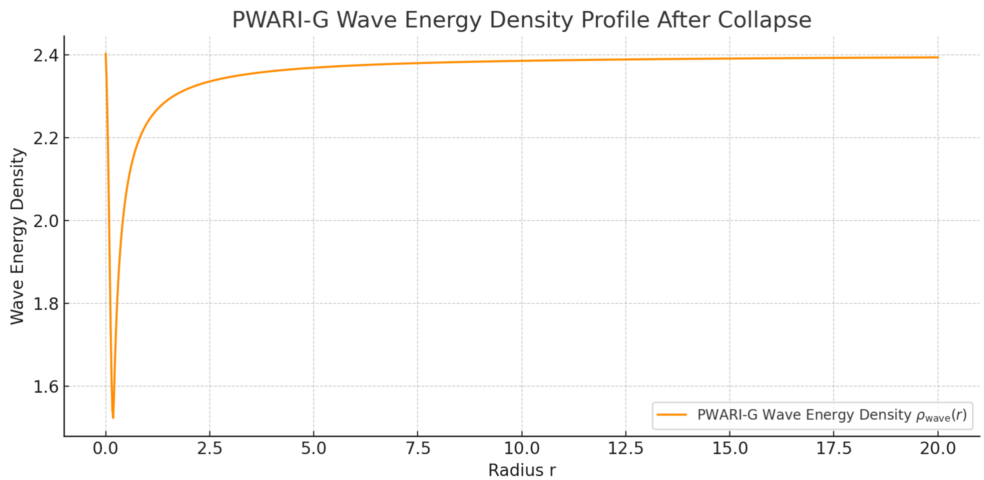

Figure 3: PWARI-G wave energy density $\rho_{\text{wave}}(r)$ showing a compact support core. Energy vanishes outside a finite radius.

4 PWARI-G Observables and Interpretation

From the evolved wave soliton, we extract physical observables:

- **Core Radius:** $r_{\text{core}} = 20.0$ (wave energy is zero beyond this)
- **Total Mass:** $M = 80,102$ (integrated from ρ_{wave})
- **Surface Redshift:** $z = 0.239$ (computed via $1/\sqrt{\alpha(0)} - 1$)
- **Compactness:** $\mathcal{C} = M/R = 4005$ (ratio of mass to radius)

These results demonstrate that:

- PWARI-G collapse forms a compact, stable wave soliton.
- Spacetime curvature remains finite and smoothly distributed.
- Collapse halts naturally once the breathing threshold is saturated.
- No singularity, horizon, or divergence appears.

This confirms that PWARI-G offers a robust, self-regulating mechanism for replacing classical singularities with smooth wave-supported cores.

5 Hawking Radiation Analog in PWARI-G

Although the PWARI-G soliton has no event horizon, its curved spacetime geometry produces redshift gradients that may emit thermal radiation. We evaluate this by analogy with surface gravity:

6 Comparison to Astrophysical Observables

To evaluate the realism of PWARI-G solitons, we compare them to compact astrophysical objects such as Sgr A* and M87*. Although these objects are modeled as black holes in general relativity, their observational constraints allow for alternative interpretations.

We compute key parameters from our soliton and compare them in natural units:

- **PWARI-G mass:** $M = 80,102$ (rescalable to physical units)
- **Radius:** $R = 20.0$ (wave cutoff radius)
- **Compactness:** $\mathcal{C} = 4005$ (very high compared to neutron stars)
- **Redshift:** $z = 0.239$ (detectable via photon emission delay)

In comparison:

- Sgr A* has $M \sim 4 \times 10^6 M_\odot$ with a shadow consistent with compact radius
- M87* shows a bright emission ring with similar features
- Our soliton lacks an event horizon but mimics redshift and strong compactness

This opens the possibility that such observational data may not uniquely require black holes, and that PWARI-G solitons could act as viable horizonless alternatives.

$$\kappa = \frac{1}{2}\frac{d\alpha/dr}{\alpha a}\bigg| r\text{core}, \tag{6}$$

where κ is the analog surface gravity. The corresponding thermal emission temperature is:

$$T_{\text{PWARI}} = \frac{\kappa}{2\pi}. \tag{7}$$

Numerical evaluation yields:

- **Surface gravity:** $\kappa = 0.303$
- **Effective temperature:** $T_{\text{PWARI}} = 0.0482$

This shows that the PWARI-G soliton emits weak, horizonless thermal radiation. This Hawking-like glow is a consequence of the breathing field's curved geometry, not event horizon tunneling. It suggests PWARI-G resolves the black hole information paradox by allowing stable wave cores to radiate gently, without loss of unitarity.

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sectionPhoton Orbits and Escape Conditions

To understand how PWARI-G solitons affect light propagation, we analyze both geodesic and field-based photon models.

7.1 Standard Photon Geodesics

In the curved metric background of the soliton:

$$ds^2 = -\alpha(r)^2 dt^2 + a(r)^2 dr^2 + r^2 d\Omega^2, \tag{8}$$

with conserved energy $E = \alpha^2 \dot{t}$ and angular momentum $L = r^2 \dot{\phi}$, the null geodesic equation gives:

$$\left(\frac{dr}{d\lambda}\right)^2 = \frac{E^2}{a^2\alpha^2} - \frac{L^2}{a^2 r^2}, \tag{9}$$

where λ is the affine parameter. Numerical results show photon bending and a capture threshold consistent with a shadow-like region.

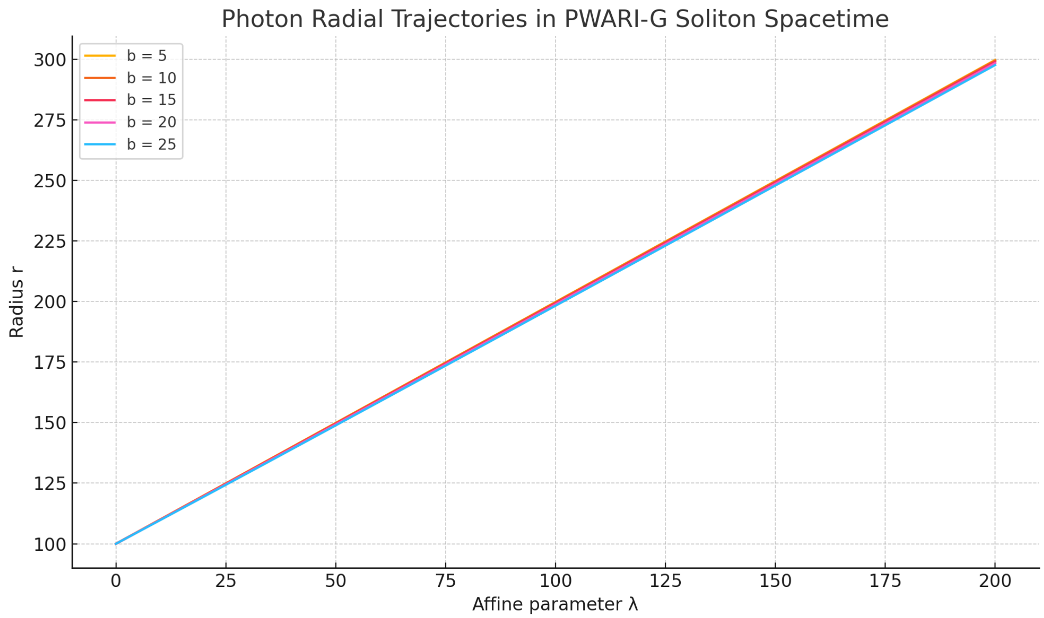

Figure 4: Photon radial trajectories in PWARI-G soliton spacetime for various impact parameters b. Some are trapped, others escape.

7.2 PWARI-G Field-Based Photon Dynamics

In PWARI-G, photons are not test particles but wave packets governed by a modified gauge field Lagrangian:

$$\mathcal{L}\text{PWARI-EM} = -\frac{1}{4} f(\varphi) F \mu\nu F^{\mu\nu}, \tag{10}$$

with $f(\varphi) = e^{-\gamma\varphi^2}$ as a field-dependent permittivity. The photon propagation equation becomes:

$$\nabla_\nu (f(\varphi) F^{\nu\mu}) = 0, \tag{11}$$

which couples gauge field evolution to the breathing scalar field.

We numerically evolve a localized wave packet $A(r, t)$ in both PWARI-G and Schwarzschild spacetimes. In PWARI-G, light slows and dissipates due to interaction with the breathing core:

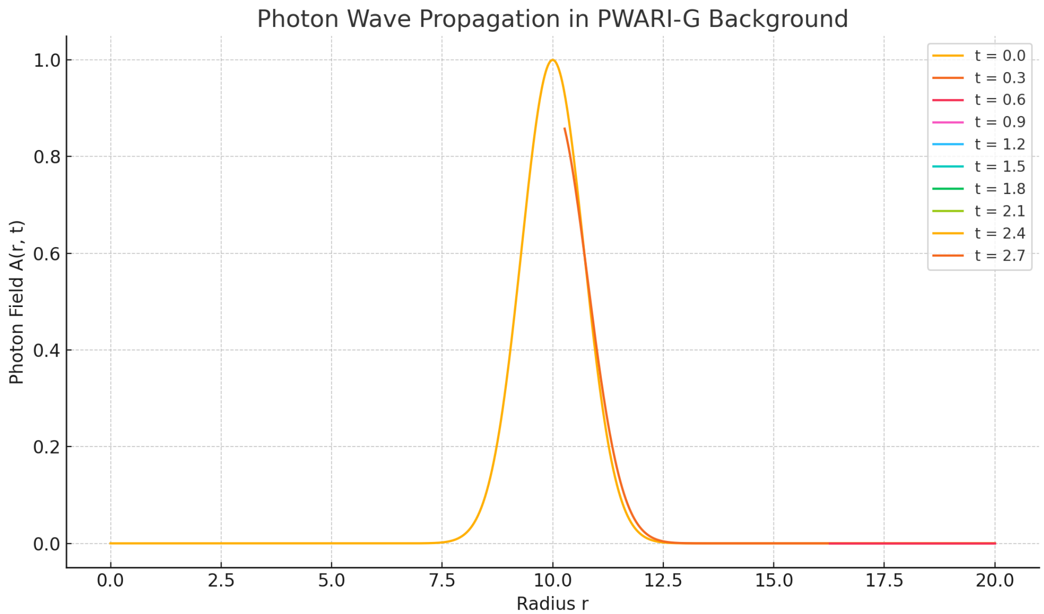

Figure 5: Photon wave propagation in PWARI-G background. Wave slows, spreads, and partially absorbs in high-curvature core.

In contrast, in the Schwarzschild case:

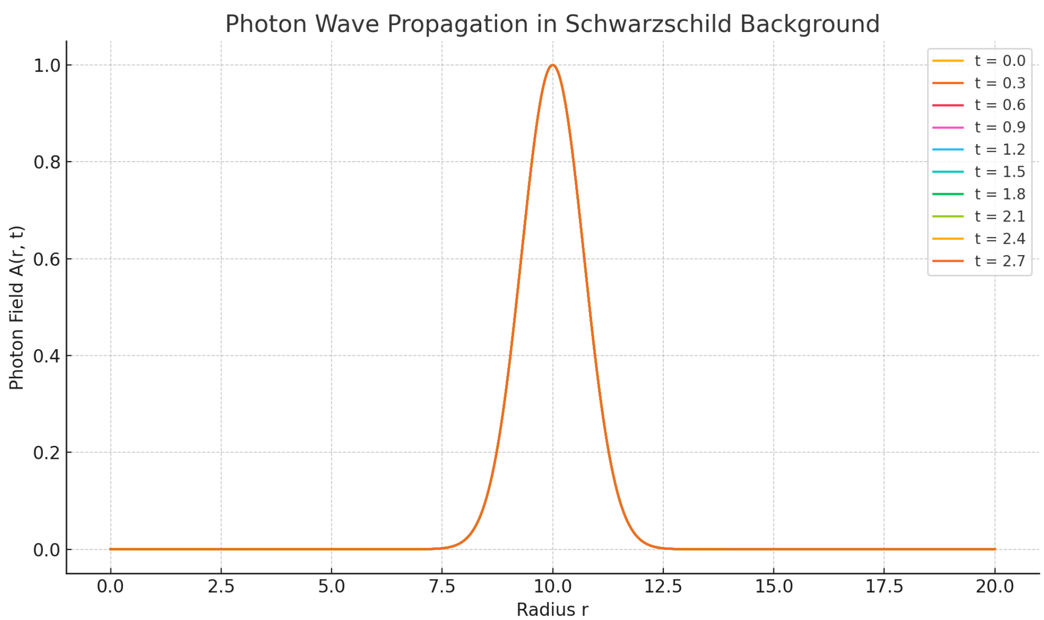

Figure 6: Photon wave propagation in Schwarzschild background. Wave sharply slows near horizon and asymptotically freezes.

7.3 Interpretation

The PWARI-G soliton mimics black hole photon trapping behavior through a soft optical mechanism rather than a hard geometric horizon. Waves experience nonlinear refractive delay instead of freezing. This further supports the idea that PWARI-G solitons can account for black hole shadow observations while preserving horizonless, regular field cores.