Equation of Gravitational Pressure Waves in the PPC Law of Gravity and a Unification Equation with Electromagnetic Waves

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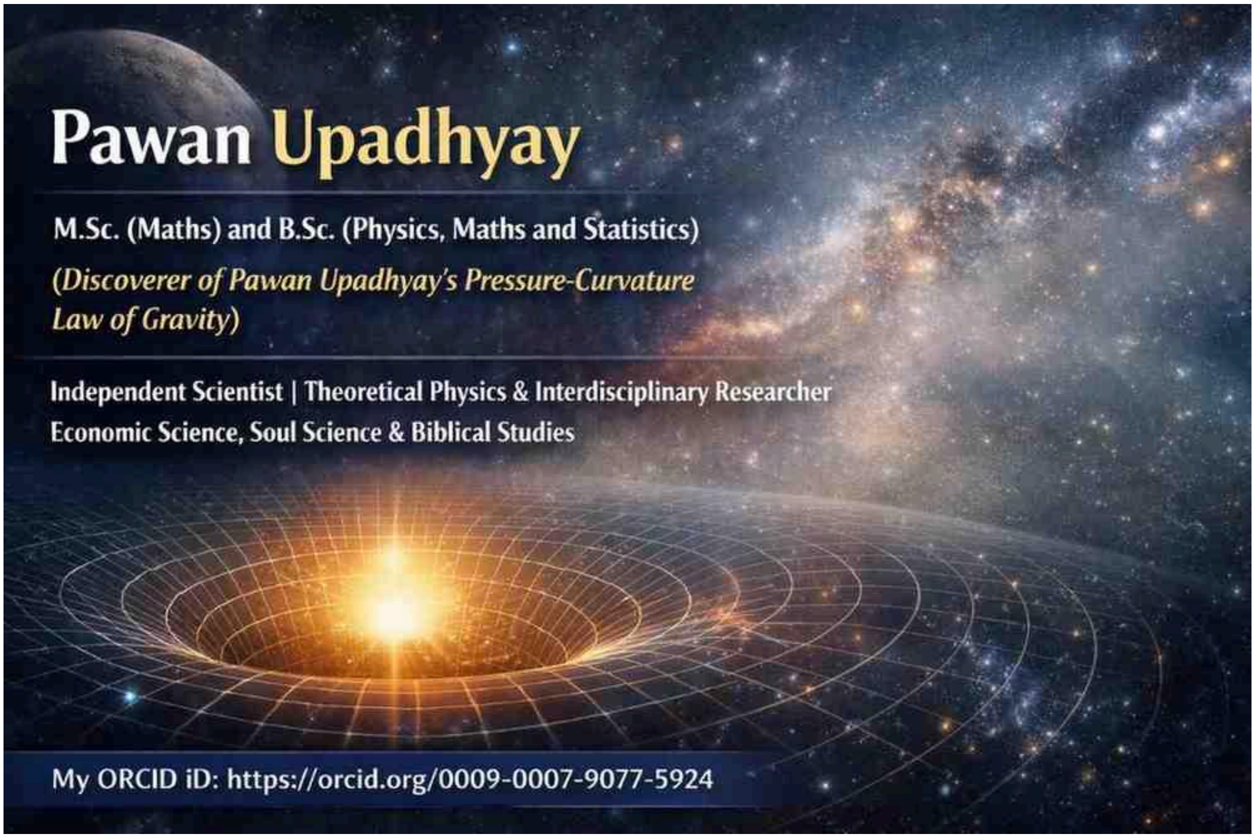

Abstract

This paper formulates the wave equation governing gravitational pressure–curvature disturbances within the framework of the Pressure–Curvature (PPC) Law of Gravity. In PPC, gravitational pressure arising from energy density generates spacetime curvature. Dynamic variations in curvature propagate as gravitational pressure waves. The linearized form of these waves is derived and compared with the electromagnetic wave equation. A geometric unification is proposed through the shared covariant d'Alembertian operator acting on massless fields. While gravitational and electromagnetic waves differ in tensorial structure, both obey the same null propagation condition and propagate at the invariant speed c. This work presents a geometric–causal unification rather than a field-theoretic merger.

1. Introduction

In relativistic physics, energy density—not mass alone—is the fundamental source of spacetime curvature. In the PPC interpretation:

$$P_g = \omega E_d$$

where:

- E_d = energy density
- P_g = gravitational pressure
- ω = equation-of-state parameter

Pressure contributes to the stress–energy tensor, which curves spacetime. When curvature varies dynamically, propagating disturbances arise. These disturbances are interpreted as gravitational pressure–curvature waves.

This paper derives their governing equation and establishes their geometric relationship with electromagnetic waves.

2. Linearized PPC Framework

In weak-field approximation, write the metric as:

$$g_{\mu\nu} = \eta_{\mu\nu} + h_{\mu\nu}, \quad |h_{\mu\nu}| \ll 1$$

Dynamic curvature variations correspond to small perturbations $h_{\mu\nu}$.

In vacuum (absence of matter sources), the linearized Einstein equations reduce to:

$$\Box \bar{h}_{\mu\nu} = 0$$

where:

$$\Box = \frac{1}{c^2}\frac{\partial^2}{\partial t^2} - \nabla^2$$

This is the fundamental gravitational wave equation.

In PPC language:

$$\text{Dynamic gravitational pressure} \rightarrow \text{Dynamic curvature} \rightarrow \text{Wave propagation}$$

Thus gravitational pressure waves satisfy:

$$\boxed{\frac{\partial^2 \bar{h}_{\mu\nu}}{\partial t^2} = c^2 \nabla^2 \bar{h}_{\mu\nu}}$$

3. Linearized Gravitational Pressure Wave Equation

In weak-field approximation:

$$g_{\mu\nu} = \eta_{\mu\nu} + h_{\mu\nu}, \quad |h_{\mu\nu}| \ll 1$$

Define the trace-reversed perturbation:

$$\bar{h}_{\mu\nu} = h_{\mu\nu} - \tfrac{1}{2}\eta_{\mu\nu}h$$

Impose the harmonic (Lorenz) gauge condition:

$$\partial^\mu \bar{h}_{\mu\nu} = 0$$

In vacuum, Einstein's equations reduce to:

$$\boxed{\Box \bar{h}_{\mu\nu} = 0}$$

Where the d'Alembert operator is:

$$\Box = \frac{1}{c^2}\frac{\partial^2}{\partial t^2} - \nabla^2$$

Expanded form:

$$\boxed{\frac{\partial^2 \bar{h}_{\mu\nu}}{\partial t^2} = c^2 \nabla^2 \bar{h}_{\mu\nu}}$$

This is the gravitational wave equation.

In PPC interpretation:

Dynamic gravitational pressure
→ Dynamic curvature
→ Pressure–curvature wave propagation

4. Electromagnetic Wave Equation

Maxwell’s equations in vacuum:

$$\nabla_\mu F^{\mu\nu} = 0$$

With:

$$F_{\mu\nu} = \partial_\mu A_\nu - \partial_\nu A_\mu$$

Impose the Lorenz gauge:

$$\partial_\mu A^\mu = 0$$

The resulting wave equation:

$$\boxed{\Box A^\mu = 0}$$

Expanded:

$$\boxed{\frac{\partial^2 A^\mu}{\partial t^2} = c^2 \nabla^2 A^\mu}$$

5. Structural Comparison

Gravitational waves:

$$\Box \bar{h}_{\mu\nu} = 0$$

Electromagnetic waves:

$$\Box A^{\mu} = 0$$

Both share the same wave operator:

$$\Box = \frac{1}{c^2}\frac{\partial^2}{\partial t^2} - \nabla^2$$

Key difference:

- A^{μ} → spin-1 vector field
- $\bar{h}_{\mu\nu}$ → spin-2 tensor field

Thus tensor rank differs, but the propagation operator is identical.

5. Unified Geometric Wave Equation

In curved spacetime, replace partial derivatives with covariant derivatives:

$$\Box_g = g^{\mu\nu} \nabla_\mu \nabla_\nu$$

The unified geometric form becomes:

$$\boxed{\Box_g \Psi = 0}$$

Where:

$$\Psi = \begin{cases} A^\mu & \text{(Electromagnetic field)} \\ \bar{h}_{\mu\nu} & \text{(Gravitational pressure–curvature perturbation)} \end{cases}$$

This equation expresses geometric unification:

- Same covariant wave operator
- Same null propagation condition
- Same invariant speed c

6. Null Condition and Invariant Speed

Massless propagation satisfies:

$$g_{\mu\nu} dx^\mu dx^\nu = 0$$

This defines null geodesics.

Both electromagnetic and gravitational pressure waves propagate along null directions.

Therefore:

$$v = c$$

independent of gravitational field strength.

Curvature may bend trajectories but does not alter local propagation speed.

7. Interpretation within PPC

In PPC terms:

- Energy density → gravitational pressure
- Pressure → curvature
- Dynamic curvature → pressure–curvature waves

Electromagnetic waves:

- Do not arise from curvature
- But propagate along curvature-determined null geodesics

Thus:

- Gravitational waves are oscillations of curvature
- Electromagnetic waves are curvature-guided oscillations

They intersect geometrically in spacetime's null structure.

8. Nature of the Unification

This unification is:

✔ Operator-based
✔ Geometric
✔ Causal

It is not:

✘ A single-field gauge unification
✘ A merging of spin-1 and spin-2 fields

The unification arises from shared null geometry and identical wave operators.

9. Conclusion

Within the PPC interpretation:

- Energy density generates gravitational pressure.
- Pressure contributes to curvature.
- Dynamic curvature variations propagate as gravitational pressure waves.

The governing equation:

$$\Box \bar{h}_{\mu\nu} = 0$$

shares the same wave operator as the electromagnetic equation:

$$\Box A^{\mu} = 0$$

Both are massless fields propagating at invariant speed c, governed by spacetime's null structure.

Thus electromagnetic waves and gravitational pressure–curvature waves are geometrically unified through the covariant wave operator of spacetime.

Core Unified Equation

$$\boxed{\Box_g \Psi = 0}$$

9. Final Unified Equation

$$\boxed{\Box_g \Psi = 0}$$

with:

$$\Psi = \{A^\mu,\ \bar{h}_{\mu\nu}\}$$

This expresses the geometric unification of gravitational pressure waves and electromagnetic waves through spacetime's invariant wave operator.

10. Conclusion

The PPC interpretation of gravity allows gravitational waves to be described as pressure–curvature waves arising from dynamic gravitational pressure.

Their governing equation in vacuum:

$$\Box \bar{h}_{\mu\nu} = 0$$

matches the structural form of Maxwell's wave equation:

$$\Box A^{\mu} = 0$$

Both propagate at invariant speed c, governed by the same null-geodesic structure.

The resulting unification is geometric rather than dynamical, rooted in spacetime's causal framework.

Core Statement

> Gravitational pressure–curvature waves and electromagnetic waves are distinct tensorial phenomena that obey the same covariant wave operator and propagate at invariant speed c, demonstrating geometric–causal unification within spacetime structure.
