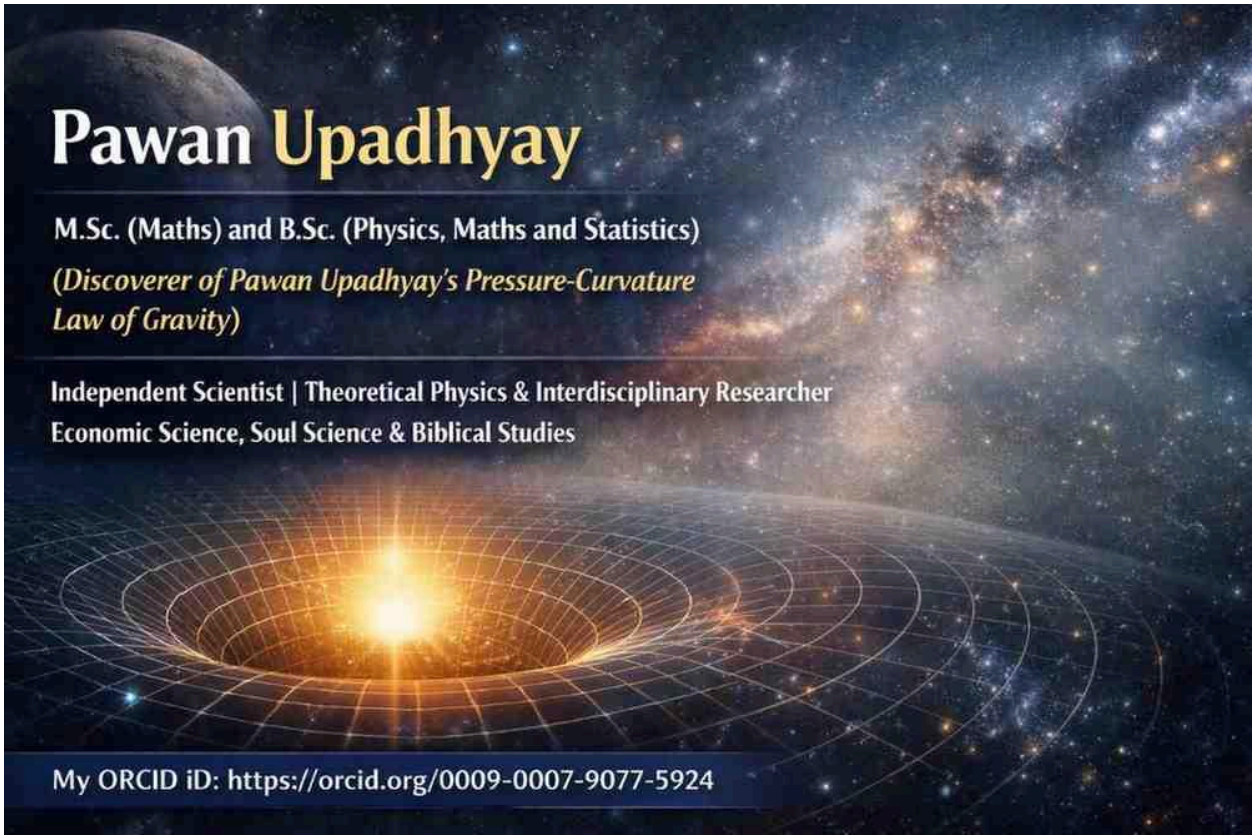
# Unification of Gravitational Pressure Waves and Electromagnetic Waves in Terms of Constant Speed c Everywhere in the Universe

**Author:** Pawan Upadhyay
**Affiliation:** Independent Researcher
**Year:** 2025-2026
**Email:** pawanupadhyay28@hotmail.com




---

## Abstract

Gravitational pressure–curvature waves and electromagnetic waves both propagate at the invariant speed c, the universal causal speed of spacetime. This invariant speed remains constant in weak gravitational fields (near Earth), stronger fields (near the Sun), and even extreme curvature (near black holes). Although coordinate descriptions may suggest apparent slowing in curved spacetime, local physical measurements always yield speed c. This paper argues that the preservation of constant propagation speed arises from the null-geodesic structure of spacetime. Electromagnetic waves are curvature-guided null disturbances, while gravitational pressure waves are oscillations of spacetime curvature itself. Their shared null propagation provides a geometric–causal unification rooted in spacetime structure.

---

## 1. Introduction

Two fundamental wave phenomena propagate through vacuum:

1. Electromagnetic waves
2. Gravitational waves

Electromagnetic waves are oscillations of the electromagnetic field described by Maxwell's equations.

Gravitational waves are oscillations of spacetime curvature described by General Relativity.

Despite their distinct mathematical origins, both propagate at:

c = 299,792,458 m/s

This propagation speed remains invariant c:

- In weak gravitational fields (near Earth)
- In stronger gravitational fields (near the Sun)
- In extreme curvature regions (near black holes)

This universal constancy suggests a deep geometric principle.

---

## 2. Weak Field Limit: Near Earth and Near the Sun

In weak-field regions such as near Earth:

- Spacetime curvature is small.
- Gravitational pressure waves propagate locally at speed c.
- Electromagnetic waves propagate locally at speed c.

Near the Sun, curvature is stronger but still weak relative to black holes:

- Paths of both waves bend.
- Clocks experience gravitational time dilation.
- Coordinate descriptions may show altered speeds.

However, the local physical propagation speed remains exactly c.

Gravitational pressure waves do not slow down in weak fields.

---

### 3. Local Speed vs Coordinate Speed

In curved spacetime, two notions of speed exist:

## 3.1 Local Physical Speed

Measured by a nearby observer using local clocks and rulers.

Result:

$$v_{\text{local}} = c$$

Always.

This follows from:

- Local Lorentz invariance
- The Equivalence Principle
- The null condition $ds^2 = 0$

## 3.2 Coordinate Speed

In curved coordinates (e.g., Schwarzschild coordinates):

- Time coordinates stretch.
- Radial distances distort.
- Coordinate velocity may appear reduced.

This is a coordinate artifact, not a physical slowing.

Both electromagnetic waves and gravitational waves exhibit this same coordinate behavior.

---

## 4. Null Geodesic Structure

Massless propagation in spacetime satisfies:

$$ds^2 = g_{\mu\nu} dx^\mu dx^\nu = 0$$

This defines null geodesics.

Electromagnetic waves:

- Follow null geodesics.
- Are curvature-guided disturbances.

Gravitational waves:

- Are perturbations of curvature.
- Also propagate along null directions.

Thus both are constrained by the same null geometry.

**Curvature may tilt light cones but does not change their local opening angle. That opening angle determines the invariant speed c.**

# 5. Gravitational Pressure–Curvature Waves

In General Relativity, small metric perturbations:

$$g_{\mu\nu} = \eta_{\mu\nu} + h_{\mu\nu}$$

lead to wave equations:

$$\Box h_{\mu\nu} = 0$$

These waves propagate at speed $c$.

In a pressure–curvature interpretation:

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

Thus gravitational waves may be interpreted as pressure–curvature waves, while preserving their null propagation.

## 6. Geometric–Causal Unification

The unification proposed here is geometric rather than dynamical.

Electromagnetic waves:

- Are oscillations of the electromagnetic field.
- Travel along null geodesics determined by geometry.

Gravitational waves:

- Are oscillations of spacetime geometry itself.
- Propagate along null directions.

They intersect in:

> The null structure of spacetime.

Both are:

- Massless disturbances
- Constrained by Lorentz invariance
- Bound by the same causal speed

Thus:

$$c = \text{Fundamental causal propagation speed of spacetime}$$

This invariant speed remains unchanged in:

- Weak fields
- Strong fields
- Flat spacetime
- Curved spacetime

## 7. Strong Gravity and Invariance of *c*

Even near black holes:

- Coordinate speeds may approach zero.
- Time dilation becomes extreme.

Yet locally:

$$v = c$$

remains valid.

Gravity alters geometry, not the invariant causal slope of light cones.

Therefore, gravitational field strength does not change the fundamental propagation speed.

## 8. Conceptual Clarifications

It is essential to maintain distinctions:

- Electromagnetism is a spin-1 gauge field.
- Gravity is a spin-2 tensor field.
- Their field equations differ fundamentally.

Shared propagation speed does not imply identical field origin.

It implies shared geometric constraints imposed by spacetime’s null structure.

## 9. Conclusion

Gravitational pressure–curvature waves and electromagnetic waves propagate at invariant speed $c$ everywhere in the universe, independent of gravitational field strength.

Apparent slowing in weak or strong fields arises only from coordinate descriptions.

Both phenomena are governed by:

$$ds^2 = 0$$

The null-geodesic structure of spacetime ensures constant local speed.

Electromagnetic waves are curvature-guided disturbances.
Gravitational waves are curvature disturbances.

They are geometrically unified through spacetime’s null structure, preserving invariant causal propagation in all gravitational environments.

## Core Statement

> The invariant null structure of spacetime geometrically unifies electromagnetic and gravitational pressure–curvature wave propagation, ensuring constant local speed $c$ in weak and strong gravitational fields alike.

---