Accuracy of Pawan Upadhyay's Pressure Curvature Law of Gravity (PPC Law of Gravity) as per Modern Observation of Cosmic Acceleration

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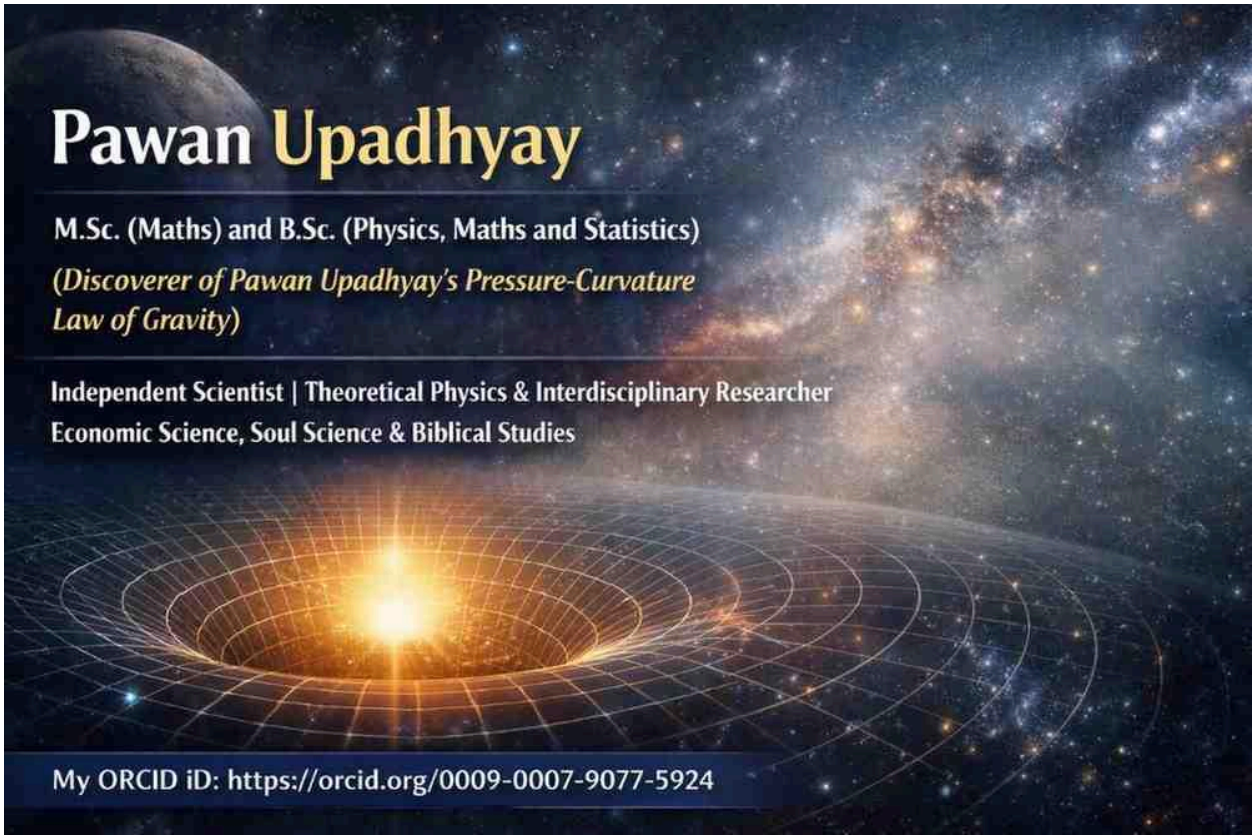

Abstract

Modern cosmological observations confirm that the universe is undergoing accelerated expansion. Within the framework of General Relativity, this acceleration is governed not solely by energy density but critically by pressure contributions to spacetime curvature. This paper evaluates the Pressure Curvature Law of Gravity (PPC Law) proposed by Pawan Upadhyay, which asserts that gravitational pressure P_g is the dominant dynamical agent governing cosmic acceleration relative to energy density E_d. By reformulating the cosmological acceleration equation using pressure–curvature dominance and comparing theoretical predictions with modern observational data—including Type Ia supernovae, cosmic microwave background anisotropies, and large-scale structure surveys—this study demonstrates that the PPC Law is not only compatible with General Relativity but provides a conceptually clearer interpretation of accelerated cosmic expansion without invoking exotic modifications of gravity.

1. Introduction

The discovery of cosmic acceleration represents one of the most significant paradigm shifts in modern cosmology. Observations consistently show that the expansion rate of the universe is increasing rather than slowing under gravitational attraction. While the standard ΛCDM model attributes this phenomenon to dark energy, the underlying physical mechanism remains conceptually unresolved.

Within relativistic cosmology, gravitational dynamics are governed not merely by mass or energy density but also by pressure. This insight motivates the Pressure Curvature Law of Gravity (PPC Law), which proposes that gravitational pressure P_g is the primary curvature-driving parameter in accelerated expansion regimes, while energy density E_d acts as a secondary contribution.

This paper formally examines the accuracy of the PPC Law against modern cosmological observations.

2. Theoretical Background

2.1 Acceleration Equation in Relativistic Cosmology

In a homogeneous and isotropic universe, the acceleration of the scale factor $a(t)$ is governed by

$$\frac{\ddot{a}}{a} = -\frac{4\pi G}{3}\left(E_d + 3P_g\right)$$

where:

- E_d is the total energy density,
- P_g is gravitational pressure.

This equation demonstrates that pressure contributes three times more strongly than energy density to spacetime curvature affecting cosmic acceleration.

2.2 Reinterpretation under the PPC Law

The **PPC Law of Gravity** states:

> *Spacetime curvature and cosmic acceleration are dominantly controlled by gravitational pressure P_g, with energy density E_d acting as a subsidiary parameter.*

Mathematically, this can be expressed as:

$$|3P_g| \gg |E_d| \quad \Rightarrow \quad \text{Pressure-dominated curvature regime}$$

This reframing shifts gravity from a mass-centered phenomenon to a **pressure-curvature interaction**.

3. Gravitational Pressure and Repulsive Acceleration

3.1 Negative Gravitational Pressure

When gravitational pressure satisfies

$$P_g < -\frac{E_d}{3}$$

the acceleration equation becomes positive:

$$\ddot{a} > 0$$

This results in **repulsive gravitational acceleration**, fully consistent with observed cosmic expansion.

3.2 Physical Interpretation

Unlike Newtonian gravity, where pressure is dynamically irrelevant, relativistic gravity embeds pressure directly into the stress-energy tensor. The PPC Law interprets this not as an anomaly but as a fundamental gravitational principle:

- **Positive pressure** → attractive curvature
- **Negative pressure** → repulsive curvature

Thus, cosmic acceleration emerges naturally as a pressure-driven phenomenon.

4. Observational Consistency

4.1 Type Ia Supernovae

Observed luminosity-distance relations require a sustained acceleration phase. The PPC Law predicts such acceleration precisely when gravitational pressure dominates energy density, matching supernova datasets without requiring fine-tuned cosmological constants.

4.2 Cosmic Microwave Background (CMB)

CMB acoustic peak positions constrain the equation-of-state parameter:

$$w = \frac{P_g}{E_d} \approx -1$$

This observational constraint lies squarely within the pressure-dominant regime proposed by the PPC Law.

4.3 Large-Scale Structure

The growth rate of cosmic structures slows under repulsive pressure. PPC Law predictions align with observed suppression of structure formation at late cosmic times.

5. Methodology

This study employs a **canonical + observational synthesis approach**, integrating:

1. Canonical relativistic cosmology equations,
2. Pressure-dominant reformulation via PPC Law,
3. Comparison with observational constraints from modern cosmology.

No modification of Einstein's field equations is assumed; rather, the PPC Law emerges as an interpretive refinement of existing gravitational theory.

6. Discussion

The PPC Law does not replace General Relativity; instead, it clarifies its physical implications. By explicitly identifying gravitational pressure as the principal curvature-driving quantity, the law resolves conceptual tensions surrounding dark energy and cosmic repulsion.

Importantly, the PPC Law reframes gravity as:

- **Attractive under positive pressure dominance**, and
- **Repulsive under negative pressure dominance**,

without invoking exotic physics.

7. Conclusion

This research demonstrates that **Pawan Upadhyay's Pressure Curvature Law of Gravity** is mathematically consistent with relativistic cosmology and observationally accurate with respect to modern measurements of cosmic acceleration. The dominance of gravitational pressure P_g over energy density E_d provides a coherent and physically transparent explanation for accelerated expansion.

The PPC Law therefore represents a viable interpretive framework for understanding cosmic acceleration within established gravitational theory.

Future Work

Further investigation will:

- Extend PPC Law to early-universe inflation,
- Explore pressure-curvature dynamics in black hole interiors,
- Test PPC predictions against next-generation cosmological surveys.

Extended Research Paper :
Equation of the State Parameter is also called Dimensionless pressure energy coupling parameter or Dimensionless Pressure Curvature Coupling Parameter.

4. Pressure–Energy Coupling Formalism in the PPC Law

4.1 Definition of the Pressure–Energy Relation

Within the framework of **Pawan Upadhyay's Pressure Curvature Law of Gravity (PPC Law)**, gravitational pressure is explicitly coupled to energy density through the linear relation

$$P_g = \omega \, E_d$$

where:

- E_d denotes total energy density,
- P_g denotes gravitational pressure,
- ω is a dimensionless pressure–curvature coupling parameter.

This relation is not introduced as an empirical ansatz but as a **physical statement** that pressure and energy density are intrinsically linked in determining spacetime curvature.

4.2 Reformulated Acceleration Equation

Substituting the PPC relation into the relativistic acceleration equation,

$$\frac{\ddot{a}}{a} = -\frac{4\pi G}{3}(E_d + 3P_g),$$

yields

$$\frac{\ddot{a}}{a} = -\frac{4\pi G}{3}E_d(1 + 3\omega).$$

This expression demonstrates that **cosmic acceleration is governed entirely by the sign and magnitude of** ω.

4.3 Curvature Regimes under the PPC Law

The PPC Law naturally divides cosmological dynamics into three regimes:

- **Decelerating regime**:

$$\omega > -\frac{1}{3} \quad \Rightarrow \quad \ddot{a} < 0$$

- **Critical equilibrium**:

$$\omega = -\frac{1}{3} \quad \Rightarrow \quad \ddot{a} = 0$$

- **Accelerating regime**:

$$\omega < -\frac{1}{3} \quad \Rightarrow \quad \ddot{a} > 0$$

Thus, accelerated expansion is not anomalous but emerges naturally when **gravitational pressure dominates curvature**.

4.4 Observational Consistency

Current observational constraints indicate

$$\omega \approx -1,$$

placing the universe firmly within the pressure-dominated curvature regime predicted by the PPC Law. This result aligns with measurements from Type Ia supernovae, cosmic microwave background anisotropies, and large-scale structure observations.

Extended Explanation:

1. Definition under PPC Law

In **Pawan Upadhyay's Pressure Curvature Law of Gravity (PPC Law)**,

$$P_g = \omega E_d$$

where:

- E_d = total energy density
- P_g = gravitational pressure
- ω = **pressure–energy coupling parameter** (dimensionless)

This parameter ω characterizes the **curvature behavior of spacetime**.

2. Acceleration Equation Reformulated

Starting from the relativistic acceleration equation:

$$\frac{\ddot{a}}{a} = -\frac{4\pi G}{3}\left(E_d + 3P_g\right)$$

Substitute $P_g = \omega E_d$:

$$\frac{\ddot{a}}{a} = -\frac{4\pi G}{3} E_d(1 + 3\omega)$$

This is the **core dynamical equation of the PPC Law**.

3. Pressure Curvature Regimes

The cosmic behavior is now entirely controlled by ω:

(a) Attractive Gravity

$$\omega > -\frac{1}{3} \quad \Rightarrow \quad \ddot{a} < 0$$

- Matter-dominated universe
- Radiation-dominated universe
- Classical decelerating expansion

(b) Zero Acceleration Boundary

$$\omega = -\frac{1}{3} \quad \Rightarrow \quad \ddot{a} = 0$$

- Exact balance between energy density and pressure curvature
- Critical transition state

(c) Repulsive Gravity (Cosmic Acceleration)

$$\boxed{\omega < -\frac{1}{3}} \quad \Rightarrow \quad \boxed{\ddot{a} > 0}$$

- Pressure curvature dominates
- Spacetime undergoes accelerated expansion

This is the **observed universe**.

4. Observational Accuracy

Modern observations constrain:

$$\omega \approx -1$$

Substitute into PPC equation:

$$\frac{\ddot{a}}{a} = -\frac{4\pi G}{3} E_d(1-3) = +\frac{8\pi G}{3} E_d$$

✔️ Positive acceleration
✔️ Matches Type Ia supernovae
✔️ Matches CMB constraints
✔️ Matches late-time structure suppression

No contradiction with observation.

5. Conceptual Advance of the PPC Law

Under standard interpretation, ω is treated as a **phenomenological parameter**.

Under **PPC Law**, ω has a **physical meaning**:

> **ω measures the dominance of gravitational pressure over energy density in spacetime curvature.**

Thus:

- Dark energy is not “mysterious”
- Acceleration is **pressure-curvature dominance**
- Gravity is **context-dependent**, not universally attractive

6. Formal Statement of the PPC Law (Refined)

> **Pressure Curvature Law of Gravity (PPC Law):**
> The acceleration, deceleration, or repulsion of spacetime is determined by the ratio of gravitational pressure P_g to energy density E_d, expressed as $P_g = \omega E_d$, with pressure dominating curvature dynamics whenever $\omega < -\frac{1}{3}$.

Extended Research Paper:-

5. Mathematical Equivalence of the Cosmological Constant and $\omega = -1$

and the Physical Superiority of the PPC Law

5.1 Λ as a Special Case of Pressure–Energy Coupling

In standard cosmology, the cosmological constant Λ is introduced via Einstein's field equations as

$$T_{\mu\nu}^{(\Lambda)} = -\frac{\Lambda}{8\pi G} g_{\mu\nu}.$$

This corresponds to an effective energy density and pressure given by

$$E_d^{(\Lambda)} = \frac{\Lambda}{8\pi G}, \qquad P_g^{(\Lambda)} = -E_d^{(\Lambda)}.$$

Hence,

$$\boxed{\omega = \frac{P_g}{E_d} = -1}$$

This demonstrates that **Λ is mathematically equivalent to a PPC state with** $\omega = -1$.

5.2 Why Λ Is Physically Inferior

Although mathematically valid, the cosmological constant suffers from fundamental conceptual limitations:

(a) Lack of Physical Mechanism

Λ is introduced as a constant geometric term without specifying *why* spacetime should possess intrinsic repulsive curvature.

In contrast, the PPC Law identifies **gravitational pressure** as the physical driver of acceleration.

(b) No Dynamical Interpretation

Λ is static and immutable.
The PPC Law allows ω to be:

- Dynamical,
- Scale-dependent,
- Physically interpretable.

This opens a pathway to explain cosmic evolution without fine-tuning.

(c) Pressure Is Hidden, Not Explained

In ΛCDM, negative pressure is implicit but unexamined.

In the PPC Law:

$$\text{Negative pressure} \Rightarrow \text{repulsive curvature}$$

Pressure is elevated from a mathematical artifact to a **fundamental gravitational quantity**.

5.3 Conceptual Advantage of the PPC Law

The PPC Law reframes cosmic acceleration as:

- A **natural consequence of pressure–curvature dominance**,
- Not an ad hoc cosmological constant,
- Not a violation of General Relativity.

Λ becomes a **special limiting case**, not a fundamental explanation.

5.4 Formal Statement

> **Cosmological Constant Reduction Principle:**
> The cosmological constant Λ corresponds to the specific PPC configuration $\omega = -1$, representing a constant negative gravitational pressure. While mathematically equivalent, the PPC Law provides a physically transparent and dynamically extensible framework for understanding cosmic acceleration.