An Effective Field–Force and Pressure Formulation of Gravity in the PPC Framework (Extended Version)

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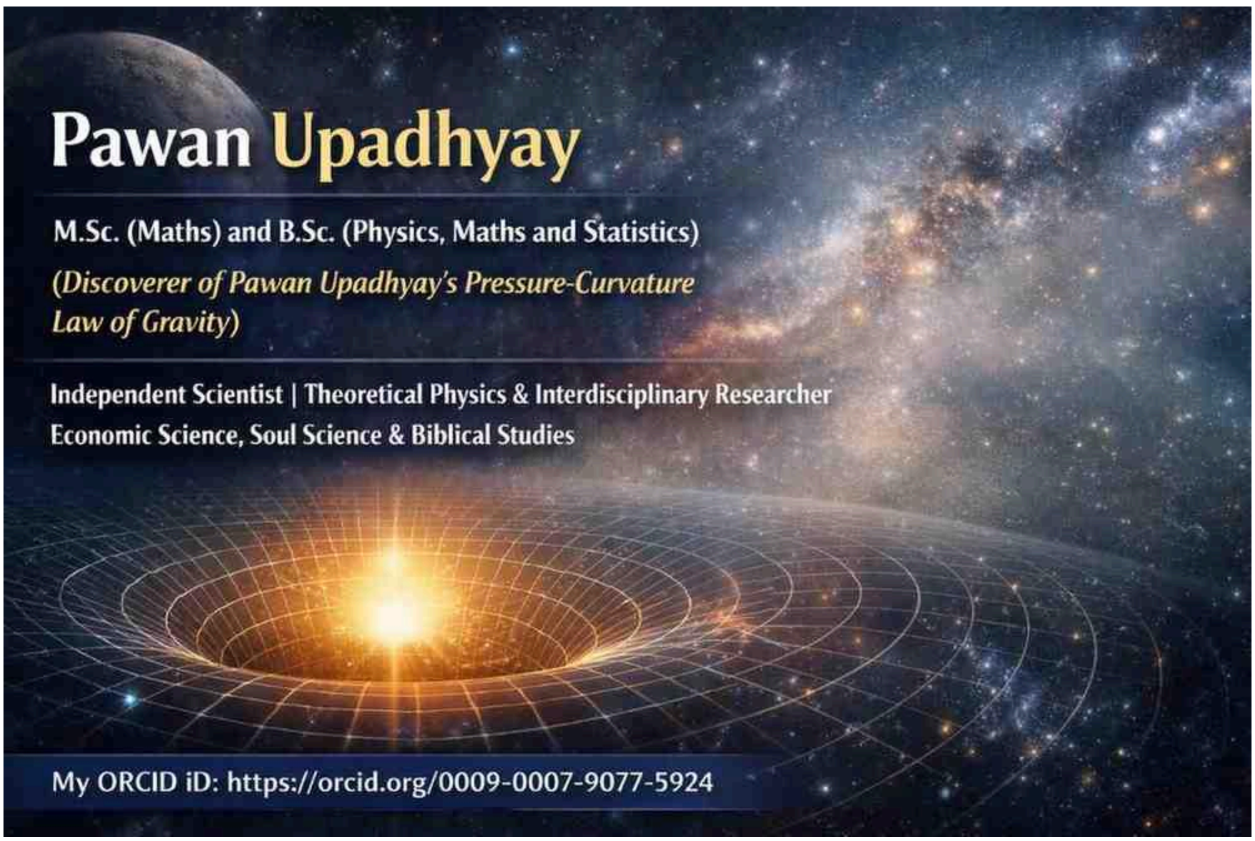

Abstract

In Pawan Upadhyay's Pressure–Curvature (PPC) framework, gravity is interpreted as an emergent phenomenon arising from gravitational pressure and its spatial variations. In this revised work, we clearly distinguish between exact field relations and effective geometric relations. The gravitational field force is treated as a force density generated by pressure gradients, while gravitational pressure itself is understood as an accumulated, geometry-dependent quantity. We show that the relations $P_g \approx \rho a L$ and $P_g \approx F L$ are not fundamental field equations, but effective geometric relations obtained by integrating exact field dynamics over a characteristic length scale. With this clarification, the formulation is fully consistent with continuum mechanics, stress–energy conservation, and General Relativity.

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1. Introduction

Classical gravity describes motion in terms of forces acting on masses, while General Relativity replaces force with spacetime geometry. Modern discoveries, however, have firmly established that acceleration is a real and measurable feature of the universe. Observations of distant supernovae, large-scale cosmic structure, and the cosmic microwave background demonstrate that cosmic expansion is accelerating.

These modern observations further show that acceleration can exist without a classical force acting on matter. Instead, acceleration arises from spacetime dynamics governed by energy density and pressure. In particular, negative pressure associated with dark energy produces large-scale repulsive acceleration. This shift in understanding motivates pressure-based interpretations of gravity, such as the Pressure–Curvature (PPC) framework.

The PPC framework provides a physically intuitive interpretation of gravity by identifying gravitational pressure as the scalar quantity responsible for curvature and motion. A key source of confusion in pressure-based formulations is the mixing of pointwise field equations with scale-dependent geometric relations. This paper resolves that issue explicitly by separating exact relations from effective ones.

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2. Exact Field Relations

At the local, pointwise level, gravitational dynamics are governed by exact continuum relations. The gravitational field force is defined as a field force density acting throughout space and matter.

The field force density is generated by the spatial variation of gravitational pressure:

$F = - \nabla P_g$

The same field force density is related to motion through the inertial response of matter:

$F = \rho a$

Where ρ is mass density and a is acceleration.

Together, these relations give the exact local equation of motion:

$\rho a = -\nabla P_g$

This equation is fully consistent with the Euler equation of fluid dynamics and with the weak-field limit of stress–energy conservation in General Relativity.

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3. Equation of State for Gravitational Pressure

Gravitational pressure is related to energy density through an equation-of-state–like relation:

$P_g = \omega E_d$

where E_d is the energy density and ω is a dimensionless parameter characterizing the pressure–energy relation. This relation determines the magnitude of gravitational pressure but does not by itself describe spatial dynamics.

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4. Effective Geometric Relations

In addition to exact field relations, the PPC framework employs effective geometric relations that summarize how field quantities accumulate over spacetime geometry. If the pressure gradient acts coherently over a characteristic geometric length scale L, then the magnitude of gravitational pressure may be estimated as the integrated effect of the field force density.

This leads to the effective relations:

$P_g \approx F L$

and equivalently:

$P_g \approx \rho a L$

Here, ρ denotes mass density, a denotes acceleration, and L denotes the characteristic curvature length scale of spacetime.

These expressions are not pointwise identities. Rather, they represent scale-dependent geometric relations that emerge from integrating the exact field equations over the characteristic length L. The length scale L may correspond to a curvature radius, horizon scale, stellar radius, or cosmological scale, depending on the physical system.

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5. Role of Effective Relations in PPC Gravity

The effective relations clarify the physical meaning of gravitational pressure. Pressure is not an independent cause of motion; instead, it is the accumulated manifestation of force density acting through spacetime geometry. Acceleration arises from pressure gradients, while pressure itself acts as the scalar source of curvature.

By explicitly distinguishing effective geometric relations from exact field equations, the PPC framework avoids dimensional inconsistencies and preserves compatibility with General Relativity.

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6. Surface Force and Macroscopic Effects

While the field force F represents a volume force density acting throughout spacetime, gravitational pressure also produces macroscopic forces on surfaces. The surface force generated by gravitational pressure acting on an area A is given by:

$F_p = P_g A$

Since gravitational pressure itself arises from the accumulation of field force density over a characteristic geometric length scale L, the surface force may equivalently be written as:

$F_p = F L A$

These relations show that surface forces are not fundamental interactions, but macroscopic manifestations of distributed field forces mediated through spacetime geometry. This distinction further clarifies the hierarchy between field force, pressure, and observable forces in the PPC framework.

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7. Discussion

The revised formulation demonstrates that pressure-based descriptions of gravity are viable and physically meaningful when exact and effective relations are clearly separated. The equations $P_g = \rho a L$ and $P_g = F L$ strengthen the interpretive clarity of PPC gravity when used appropriately as geometric relations rather than fundamental laws.

This structure mirrors standard practice in physics, where quantities such as work, potential, and pressure are often defined through integrated relations derived from local field equations.

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8. Conclusion

With the distinction between exact field relations and effective geometric relations made explicit, the PPC framework provides a coherent and physically transparent interpretation of gravity. The relations $P_g = \rho a L$ and $P_g = F L$ are confirmed as valid, scale-dependent expressions that complement, rather than replace, the fundamental field dynamics.

Gravity, in this formulation, emerges from the interplay of mass density, pressure gradients, and spacetime geometry, consistent with both continuum mechanics and General Relativity.

Final Boxed Equation Summary

For clarity, the complete PPC field–force formulation is summarized below. Exact relations and effective geometric relations are explicitly separated.

Exact (Local Field) Relations

Field force density: $F = \rho a$

Pressure-gradient force law: $F = -\nabla P_g$

Local equation of motion: $\rho a = -\nabla P_g$

Equation of state: $P_g = \omega E_d$

Energy–density relation: $E_d = \rho c^2$

Effective (Geometric / Scale-Dependent) Relations

Gravitational pressure from field force density: $P_g \approx F L$

Equivalent pressure–acceleration relation: $P_g \approx \rho a L$

Surface force generated by pressure: $F_p = P_g A$

Surface force in terms of field force density: $F_p \approx F L A$

Interpretive Hierarchy

Mass density → field force density → gravitational pressure → surface force / curvature → motion

These relations together form a closed, internally consistent system within the PPC interpretation of gravity.

Acknowledgments

The author acknowledges the foundational role of General Relativity and continuum physics in informing the PPC interpretation of gravity.

Final takeaway:

“Modern observational discoveries establish that acceleration is a real and fundamental feature of the universe, arising from spacetime dynamics governed by energy density and pressure rather than from classical forces.”

Final takeaway (one line)

Modern physics does not question whether acceleration exists — it reveals that acceleration is geometric, pressure-driven, and intrinsic to spacetime itself.