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Effects of Effective Dark Energy in Astrophysical Plasma

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INTRODUCTION & AIM

We study the application of Lorentz kinematic transformations deformed by critical velocity to a continuity equation. This generates a source structure for the continuity equation that is indistinguishable from a Nernst–Planck equation. In this case, the fluid flow is the source of excited states. This makes the fluid a type of self-source, where the flow is a force that compensates for its crystallization into excited states. Therefore, we can understand that the kinematic transformation adds a stress term to the fluid dynamics, which can be understood as a sort of dark energy.

We studied the effects of the currents that arise. Specifically, the dissipative and convective currents, which play a role of self-induction and mutual induction, are capable of generating local phase transitions in the fluid.

This construction is a step toward building a theory of gravity based on a theory of two self-interacting fluids. In future work, we will clarify the role of vorticity, include viscosity effects, and relate this to Helmholtz–Hodge decomposition. We will also clarify the dynamic role of critical velocity as a fundamental state and its effect on the causal structure of the fluid, in addition to investigating a possible condition of non-integrability, which should severely affect the construction of the causal structure

METHOD- Kinematic deformation

Deformed Kinematics:

$$\partial_{t'} = \psi(v)[\partial_t - \vec{v} - \mathrm{V} \cdot \nabla], \quad (1)$$

$$\nabla' = \psi(v)[\nabla - \vec{v} - \mathrm{V}\partial_t]. \quad (2)$$

Two Fluids Kinematics Frames: $S_V \to S'$:

$$\vec{v}'_{\parallel} = \frac{\vec{v}_{\parallel} - \vec{u} + \mathrm{V}}{1 + \frac{\vec{v}_{\parallel}}{c^2} \cdot (\mathrm{V} - \vec{u})}, .\vec{v}'_{\perp} = \frac{\mathrm{V}}{1 + \frac{\vec{v}_{\perp}}{c^2} \cdot (\mathrm{V} - \vec{u})}. \quad (3)$$

In Preferred-Frame

$$S_V$$

. The Preferred-Frame S_V is the reference frame associated with the fluid when the first excited state arises.

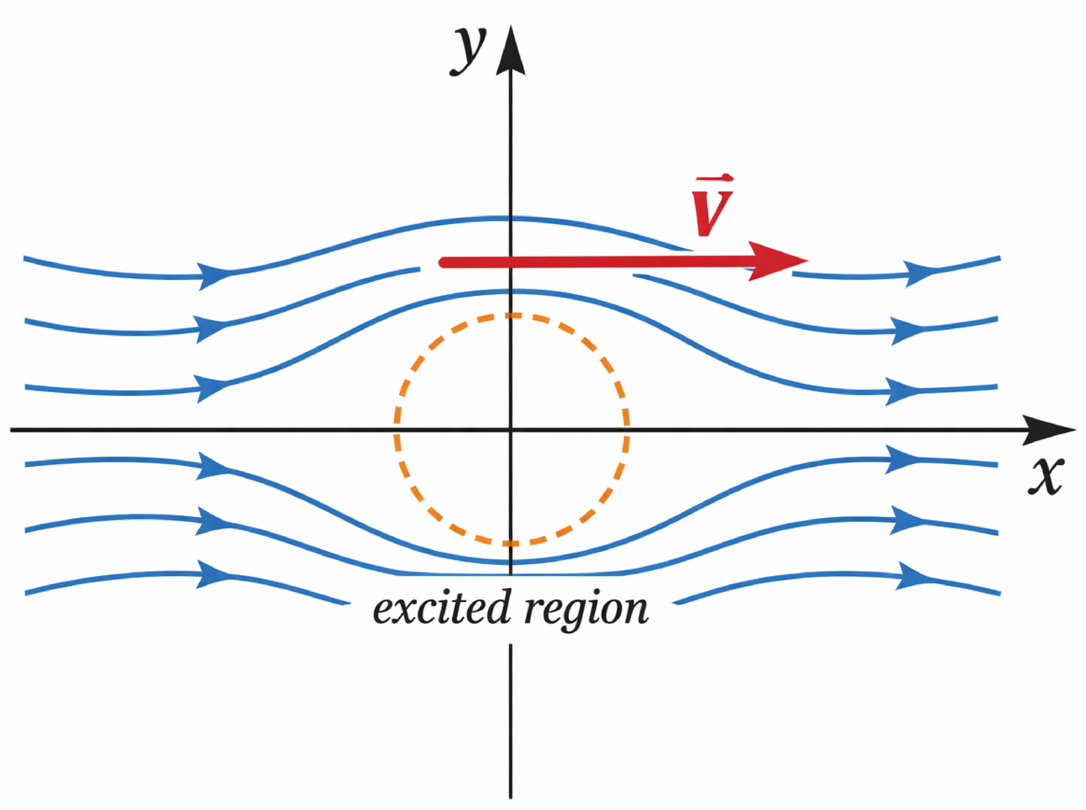
$$\vec{v}_{\parallel} = \frac{\vec{v}_{\parallel} + \vec{u} - \mathrm{V}}{1 + \frac{\vec{v}_{\parallel}}{c^2}(\vec{u} - \mathrm{V})}, \vec{v}_{\perp} = \frac{\left[1 - \frac{v^2}{c^2}\left(1 - \frac{V^2}{v^2}\right)^2\right] V}{1 + \frac{\vec{v}}{c^2}(\vec{u} - \mathrm{V})}, \quad (4)$$

We apply the transformations (1), (2) in kinematics to the continuity equation:

$$\partial_t \rho + \rho \nabla \cdot \vec{v} - (\nabla \rho) \cdot \vec{v} = (\vec{v} - \mathrm{V}) \cdot \frac{\vec{v}}{c^2} \partial_t \rho + \rho\,(\vec{v} - \mathrm{V}) \cdot \partial_t \vec{v}$$

- The equation shows that, under kinematic deformation by a critical vacuum velocity, astrophysical plasma ceases to be conservative: the classical flow (left side) is balanced by a self-induced source term (right side) that generates an effective tension identical to that of dark energy.
- Equations (3) and (4) constitute the composition of velocities between components perpendicular and parallel to the flow.
- The effect of this type of deformation is similar to introducing a body into a flow.

$$\partial_t \vec{v} = \frac{1}{2} \nabla (\vec{v} - \mathrm{V})^2 - (\vec{v} - \mathrm{V}) \times (\nabla \times \vec{v})$$



Comparison with Fokker–Planck and Nernst–Planck Equations

General form ▶ FP: velocity-space equation with diffusion and friction in v
- NP: $\partial_t c + \nabla \cdot \mathrm{J} = 0$, with $\mathrm{J} = -D\nabla c + c\mathrm{v} + \mu c \mathrm{E}$
- Present model: $\partial_t \rho + \nabla \cdot J_{\mathrm{eff}} = 0$, $J_{\mathrm{eff}} = \rho \vec{v} + K(\rho, \nabla \rho)$

Main variable ▶ FP: distribution function $f(\mathrm{x}, \mathrm{v}, t)$ (kinetic level)
- NP: concentration $c(\mathrm{x}, t)$ (macroscopic/fluid level)
- Present model: fluid density $\rho(\mathrm{x}, t)$ (effective hydrodynamics)

Origin of extra term ▶ FP: binary Coulomb collisions → velocity-space diffusion/friction
- NP: concentration gradient + external electric field
- Present model: kinematic deformation of vacuum frame → non-collisional self-source

Nature of extra term ▶ FP: dissipative (relaxes to Maxwellian)
- NP: conservative force (electrostatic)
- Present model: non-dissipative self-source (excites states, repulsive stress ∼ dark energy)

Plasma application ▶ FP: collisional transport, fusion, non-Maxwellian relaxation
- NP: ionic transport in electrolytes/weak plasmas (rare in astrophysics)
- Present model: near-collisionless astrophysical plasma with vacuum coupling → effective dark energy

Closest analogy ▶ FP: format similar but in velocity space
- NP: very close — K plays role of effective drift/migration (but induced by $\vec{v} - \mathrm{V}$, no external field)

RESULTS & DISCUSSION

- The term $\vec{v}^2 + \mathrm{V}^2$, can be understood as a chemical potential[1][2], which indicates that the interpretation we have been giving to the velocity V as the critical velocity for the emergence of excited states is fully corroborated.
- The critical velocity V plays a role of velocity normal to the movement of the fluid line
- The term $(\vec{v} - 2\mathrm{V}) \times \vec{w}$ is remarkably similar to $(1 - \alpha')\,\vec{v} \times \vec{w} + \alpha \vec{v}_n \times \vec{w}$. The value $2V$ is also found when we study causal structures, in a perspective proposed by Visser which we explored in a recent paper[2].
- Comparing with the equation in the book [3], we note that we are dealing with inertial forces, and the term $(\vec{v} - 2\mathrm{V}) \times \vec{w}$ so the appearance of new excited states implies the appearance of inertial forces on the hypothetical fluid[3]. We thus have a type of interaction in which a state and the fluid as a whole exchange inertia.

CONCLUSION

We show that a deformation in Lorentz transformations can induce superfluidity effects analogous to vacuum effects. This minimalist change in Lorentz transformations induces effects analogous to those observed in quantum fluids. such as Bose-Einstein condensates or quark-gluon plasma, opening up new perspectives for research into gravitational analogues.

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