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Peer Review

Review of: "Conditions for Emergent Gravitational Light Bending from a Logarithmic Superfluid Vacuum"

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Review:

1) Summary (what the paper tries to do)

This preprint addresses whether the historic failure of “pure scalar gravity” to reproduce the observed gravitational light deflection (PPN parameter ($\gamma \simeq 1$)) can be overcome by treating the vacuum as a complex superfluid with logarithmic self-interaction and using the Madelung (fluid) formulation and associated acoustic-metric methods. The manuscript develops a “logical chain”:

1. For a **real scalar wave equation** with a standard D’Alembertian kinetic term, the characteristic propagation speed is fixed by the principal part, so background-dependent “light speed” effects are absent and one recovers the “half-bending” result often summarized as ($\gamma=0$).
2. In the **complex logarithmic** theory, the Madelung representation exposes **density** and **flow velocity** degrees of freedom and yields a density-dependent sound speed ($c_s(\rho)$).
3. The *static* acoustic metric gives a PPN-like ($\gamma_{\text{static}} = (1-\alpha)/(1+\alpha)$) with ($\alpha = d\ln c_s/d\ln\rho$), and the manuscript argues that ($\gamma=1$) cannot be obtained from static barotropic configurations without trivializing deflection.
4. A *flowing* acoustic metric can match Schwarzschild (and hence ($\gamma=1$)) if the background flow is **Painlevé–Gullstrand/free-fall**, ($v(r)=\sqrt{2G_{\text{eff}} M/r}$).
5. A Bondi-type calculation is presented indicating that the logarithmic EOS does *not* naturally yield this PG profile in the far field, and the microscopic origin of the needed macroscopic flow is left as an open problem.

doi.org/10.32388/9V49EI

2) Major strengths (what is genuinely useful)

(S1) The "kinematic trap" point is a valuable clarification.

The manuscript correctly highlights that for real scalar wave equations with a standard D'Alembertian principal part, characteristics and high-frequency propagation are controlled by the kinetic operator; altering the potential alone does not create background-dependent signal speeds. This is a useful conceptual contribution for readers thinking about scalar alternatives and "index-of-refraction" analogies.

(S2) The paper isolates a clear necessary condition for ($\gamma=1$) within the chosen acoustic-metric framework: the PG/free-fall profile.

As a "conditions paper," the identification of this requirement is potentially valuable.

3) Central issue: where the logical chain breaks (flow ⇒ ($\gamma=1$), but dynamics ($\nrightarrow) flow)

The manuscript's ($\gamma=1$) result is **conditional**: ($\gamma=1$) follows once a PG/free-fall flow profile is assumed. However, the manuscript's own dynamical check (Bondi accretion) indicates that the proposed logarithmic EOS does **not** generate the needed ($ v\propto r^{-1/2} $) scaling in the far field (instead ($ v\propto r^{-2}$) in the subsonic regime).

As a result, the work currently establishes **(i) a kinematic route** to ($\gamma=1$) *if* PG flow exists, but does not yet provide **(ii) a derived physical mechanism**—a "source"—that produces that PG flow from the microphysics actually specified. The explanatory burden is therefore shifted from "why ($\gamma=1$)" to "why the vacuum develops precisely the PG flow field around mass (M)."

A related conceptual point is that the manuscript argues the PG solution "closes the loop for any barotropic EOS." If the EOS details do not matter once PG flow is imposed, then the ($\gamma=1$) success appears to depend primarily on the **chosen flow profile**, not on the **logarithmic potential** per se. This should be clarified explicitly: what unique, testable role does the logarithmic microphysics play beyond providing one possible medium description?

The author should also clarify if the proposed density-dependent sound speed $c_s(\rho)$ correctly

reproduces the Shapiro time delay as measured by the Cassini mission, or if the fluid density profile introduces timing discrepancies not present in the geometric Schwarzschild solution.

4) The "Three observational hurdles" (clear, testable, currently unaddressed)

(K1) Prism problem: achromaticity / dispersion is not demonstrated

The manuscript interprets an **acoustic metric** (standard for perturbations in a medium) as governing "light bending," but does not provide an explicit electromagnetic sector or dispersion law showing that real photons follow the same effective geometry and that lensing/time delay are achromatic. In analogue systems, effective metrics often hold in the low-energy/long-wavelength regime; dispersive corrections can lead to "rainbow" metrics where propagation depends on wavenumber/energy and where phase/group velocities differ.

Request: clarify what "light" is in this theory (EM vs condensate excitation), provide the relevant dispersion relation, and show (or bound) any predicted frequency dependence of deflection/time delay.

(K2) Headwind / preferred-frame detectability if (v(r)) is a real vacuum flow

The PG profile implies a physical inflow speed of order (10^{-3}c) near the solar limb (hundreds of km/s). If this is a real medium velocity field, it invites strong constraints from preferred-frame/"ether wind" type detectability and from possible secular momentum exchange effects. The manuscript does not show why such a flow would not produce measurable anisotropies or other non-gravitational signatures in high-precision experiments.

Request: provide an operational definition of the vacuum rest frame/flow, and explain why local experiments do not detect this flow (or quantify expected signals).

(K3) Weak Equivalence Principle (WEP): universality of free fall is not established

In GR, WEP follows from universal coupling to the metric; in a medium/flow picture, forces associated with coupling to a substrate can generically depend on composition, internal structure, or dissipative channels. The present manuscript does not provide a matter-sector coupling showing that *all* materials respond identically to the proposed vacuum dynamics (including the flowing case). This is crucial because WEP is constrained experimentally at the ($\sim10^{-15}$) level (Eötvös parameter) by precision tests such as MICROSCOPE.

Request: specify the coupling of massive matter/solitons to the condensate and demonstrate composition-independent free fall (or provide bounds/estimates for predicted violations consistent with existing constraints).

5) "Collective mechanism" and "jets" (hypotheses vs results)

The manuscript appropriately acknowledges that the microscopic origin of the macroscopic PG flow remains open and suggests collective vortex/soliton effects and axial outflows/jets as a resolution of steady-state continuity. This is an interesting direction, but in the present paper it is **not derived** and should be clearly labeled as conjectural.

Request: rephrase these components as explicit hypotheses and (ideally) add at least a toy model or scaling argument showing how an ensemble of solitons generates ($v^2\propto 1/r$) (or equivalently ($v\propto r^{-1/2}$)).

6) Recommended revision posture (constructive, non-"executioner")

I view this manuscript as potentially valuable **as a "conditions/constraints" paper**: it clarifies a kinematic obstruction for real scalar wave equations and identifies the condition under which an acoustic-metric construction can reproduce ($\gamma=1$).
However, the present version does **not yet** constitute a complete physical explanation of gravitational light bending because:

- the ($\gamma=1$) result hinges on an imposed PG flow profile,
- the proposed microphysics does not derive that profile (Bondi failure), and
- it does not address the three key observational hurdles: **achromaticity**, **headwind/preferred frame detectability**, and **WEP universality**.

Accordingly, I recommend **major revision**, with the primary goals of:

i. specifying what "light" is and establishing achromaticity/bounding dispersion,
ii. providing (or clearly delimiting the absence of) a dynamical mechanism that generates the PG flow,
iii. demonstrating WEP universality (or estimating composition-dependent violations and confronting constraints).

I would consider raising the overall rating if a revised version provides (i) a concrete photon/matter coupling with achromaticity bounds, (ii) a derivation or quantitative toy model for PG flow emergence, and (iii) a WEP/EP discussion with estimates consistent with current limits.

Declarations

Potential competing interests: No potential competing interests to declare.