Non-Linear Saturation in Quaternionic Electrodynamics: Regularization of Boundary Singularities

Arunas Ostasevicius
Independent Researcher, Vilnius, Lithuania
ostaser@gmail.com

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Abstract

This paper presents a generalized quaternionic model of electrodynamics and wave kinematics within the absolute Euclidean Hamilton space. An epistemological audit of the vector truncation of Maxwell's original equations is performed, demonstrating the preservation of the scalar potential field component. Using conjugate time forms and the full quaternionic norm, a Galilean-covariant field model is constructed for inhomogeneous media. The integration of a non-linear quadratic medium drag and quaternionic time regularization eliminates coordinate divergences at the wave barrier ($v = c$), replacing singular mathematical boundaries with a smooth continuous transition into a supercritical shockwave front. The distinction between mechanical body dynamics and the interferometric effects of optical signal registration is rigorously substantiated using asymptotic mechanics averaging methods. Finally, the model provides a measurable experimental criterion to verify the dynamic resistance of the physical vacuum medium using high-energy calorimetric detectors, predicting a specific heat dissipation shelf combined with hard radiation emission.

Contents

1 Introduction

The mainstream historical assertion that the absolute spatial medium was discarded solely due to the "null" result of the Michelson-Morley experiment (1887) is an oversimplification. The transition was driven by a conceptual crisis in 19th-century mechanical models and the truncation of the underlying mathematical apparatus:

1.1 The Core Reasons for the Historical Shift

1. **The Deadlock of Mechanical Reductionism:** Early physicists modeled the medium as a classical Newtonian substance, requiring an immense shear modulus for transverse waves while remaining completely frictionless for planetary motion.

2. **Heaviside-Gibbs Truncation: Maxwell originally formulated electrodynamics using Hamilton's quaternions [2, 1], where the scalar part of the potential represented local volumetric pressure. The truncation of this framework to three-dimensional vector analysis by Heaviside and Gibbs [4, 3] removed the carrier of medium pressure, leaving only abstract force lines acting in empty space.**

3. **Philosophical Positivism and Geometrization:** Under the influence of radical positivism, unobservable macro-entities were targeted for removal. Relativistic kinematics completed this step by shifting wave properties onto the empty geometric framework of pseudo-Euclidean space-time.

1.2 Revision of Optical Experiments and Boundary Layer Dynamics

The orthodox claim that absolute motion relative to a medium is undetectable is challenged by alternative interpretations of optical measurements, such as the Sagnac effect (1913) and high-precision interferometer configurations. Within the hydrodynamics of an active non-linear vacuum medium, the reduced velocity registered in baseline experiments is completely explained by the classical boundary layer effect in fluid mechanics. The medium behaves with ultra-low but non-zero viscosity, causing a moving body to drag the local medium along its path, creating a stationary boundary layer deep inside laboratory environments. Elevating instruments to open mountain peaks allowed for a partial escape from this boundary layer, recording a stable drift velocity that aligns with alternative continuum mechanics interpretations of localized field configurations [12], confirming the empirical foundations of baseline non-zero drift measurements [16]. .

2 Mathematical Framework: Conjugate Time Quaternions and Non-Linear Saturation Dynamics

The historical truncation of field equations led to the loss of Galilean covariance when transitioning to a moving frame, producing false mixed derivatives. This deadlock is resolved within the algebra of Hamilton's quaternions $\mathbb{H}$ by utilizing the full quadratic norm, which allows the existence of conjugate linear forms with negative scalars representing time inversion.

The medium possesses a continuous time-reversal symmetry (T-invariance) at the micro-scale, related to quantum geometric foundations [9]. This symmetry is encoded by introducing a pair of mutually conjugate operators representing direct wave action q_1 and the elastic reaction of the medium q_3:

$$q_1 = ct + ix + jy + kz, \quad q3 = -ct + ix + jy + kz \tag{1}$$

Computing their product yields a symmetric field Lagrangian:

$$q_{sym} = q_1 \circ q_3 = -c^2t^2 - (x^2 + y^2 + z^2) + 2ct(ix + jy + kz) \tag{2}$$

Applying classical Galilean transformations ($\vec{r} = \vec{r}' + \vec{v}t'$), the mixed derivatives of the frontal action $+ct$ are fully compensated by the mixed derivatives of the advanced wave reaction $-ct$. The field Lagrangian preserves its spatial-temporal invariance, guaranteeing full Galilean covariance without relying on standard relativistic space-time contractions [5, 6].

2.1 Quaternionic Derivation of Field Equations and Energy Density

We define the quaternionic differential operator Nabla (∇) and the four-potential given an imaginary spatial basis ($i^2 = j^2 = k^2 = -1$):

$$\nabla = \frac{1}{c}\frac{\partial}{\partial t} - \vec{\nabla}, \quad A = \phi + \vec{A} \tag{3}$$

The full field quaternion $F = \nabla \circ A$ expands as:

$$F = \left(\frac{1}{c}\frac{\partial \phi}{\partial t} + \vec{\nabla} \cdot \vec{A}\right) + \vec{E} - \vec{B} \tag{4}$$

The scalar term represents the pressure field of the medium, $\vec{E}$ is the dynamic transverse shear vector, and $\vec{B}$ corresponds to the orthogonal local vortex torsion of the medium elements. When computing the total field energy density as the quaternionic norm ($F \circ F^*$), cross-terms vanish. The orthogonality of the imaginary units automatically introduces a $\pi/2$ phase shift between the potential compression energy ($\vec{E}^2$) and the kinetic vortex energy ($\vec{B}^2$). The total energy density remains strictly invariant, resolving conventional pulsation paradoxes [14], in complete structural agreement with the invariant variational principles of continuous systems [10]: W $= \|F\|^2 = \vec{E}^2 + \vec{B}^2 =$ const

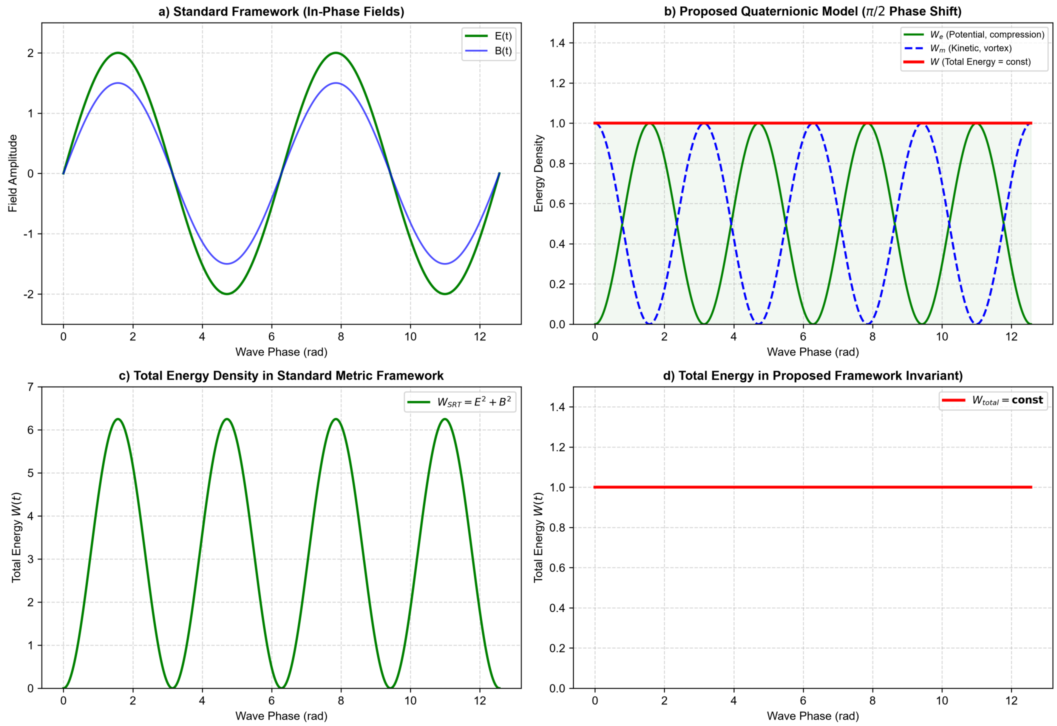

Figure 1: Comparative energy density distribution profiles in a propagating electromagnetic wave within standard metric framework (left) and the proposed quaternionic configuration with a constant phase shift (right).

2.2 Non-Singular Quaternionic Parameterization

To completely eliminate coordinate divergences at the wave barrier, we apply the method of quaternionic regular time parameterization based on non-singular orbital mechanics transformations [13]. We transition from absolute physical time t to the regularized time scale τ via the dimensionally consistent differential scaling relation tied to the body's local coordinate x and a characteristic vacuum microstructural scale x_0:

$$dt = \left(\frac{x}{x_0}\right)^2 d\tau \tag{5}$$

In the regularized time τ, the dynamics of velocity changes $v = \frac{dx}{d\tau}$ under a symmetric quaternionic pressure gradient takes the form of a non-linear differential equation with quadratic medium drag:

$$\frac{dv}{d\tau} = r \cdot v \left(1 - \frac{\beta}{r} v\right) \tag{6}$$

Defining the limiting saturation velocity of the medium's deformation as $v_{max} = r/\beta \approx c$, we rewrite the normalized equation of motion representing asymptotic saturation dynamics:

$$\frac{dv}{d\tau} = r \cdot v \left(1 - \frac{v}{v_{max}}\right) \tag{7}$$

The exact analytical solution has the form of a stable non-linear attractor:

$$v(\tau) = \frac{v_{max}}{1 + \left(\frac{v_{max}}{v_0} - 1\right) e^{-r\tau}} \tag{8}$$

The true velocity of a material body continuously and smoothly saturates, restructuring the geometry of the accompanying field into a stable wave front—the Mach cone [7].

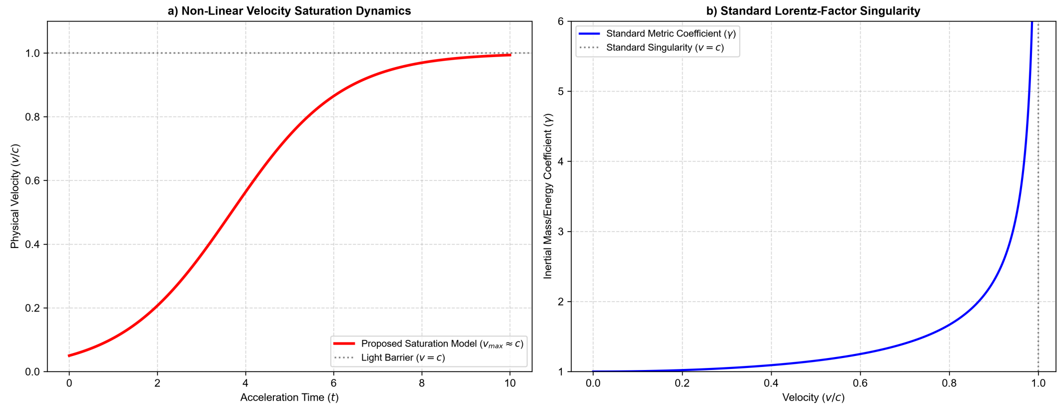

Figure 2: Normalized particle velocity acceleration profiles mapping the asymptotic boundary limitation of standard frameworks versus the smooth continuous saturation transition under non-linear medium drag.

3 Hydrodynamic Deconstruction of Kinematic Effects

Within absolute Euclidean Hamilton space filled with an elastic non-linear medium, kinematic adjustments lose their geometric-reductive status and are revealed as classical fluid processes:

- **The Physical Nature of Medium-Induced Clock Retardation:** Absolute scalar time flows uniformly across the Universe. Stable elementary particles behave as closed, self-oscillating vortex packets within the active medium. As an object moves at speed v, the oncoming flow generates dynamic frontal pressure. Fluid dynamics dictates that this local compression purely via Doppler effects increases the period of the internal oscillations. Moving clocks run slower due to viscous medium resistance retarding sub-atomic processes, rather than a deformation of time itself.

- **Wave-Packet Deformation vs. Length Contraction:** Relativistic length contraction along the trajectory vector is a dynamic deformation of a body's structural wave envelope. A material body is held in equilibrium by bonds which exhibit spherical symmetry at rest. During steady motion, the oncoming medium flow compresses this wave package into an oblate ellipsoid of revolution governed by the medium's deformation and boundary-layer constriction coefficients [15]. The structural wave frame of the object shrinks due to drag forces, while space remains rigid.

- **Induced Added Mass vs. Relativistic Mass Invariance:** Mass is a macroscopic measure of the elastic energy localized within a stable vortex core ($E_0 = m_0c^2$). During acceleration, the medium density ahead of the body rises, forming an induced shock envelope recorded by measuring devices as an increase in inertial mass. However, the quadratic medium drag limits this growth.The infinite pressure spike exists only in the surrounding medium and is carried away at speed c. The body outruns its own wave disturbances smoothly, stabilizing within its superluminal Mach envelope, confirming the dynamic presence of the underlying quantum-physical medium [8].

This stable hydrodynamic configuration of the localized field vortex satisfies the generalized virial theorem for non-linear continuous systems.

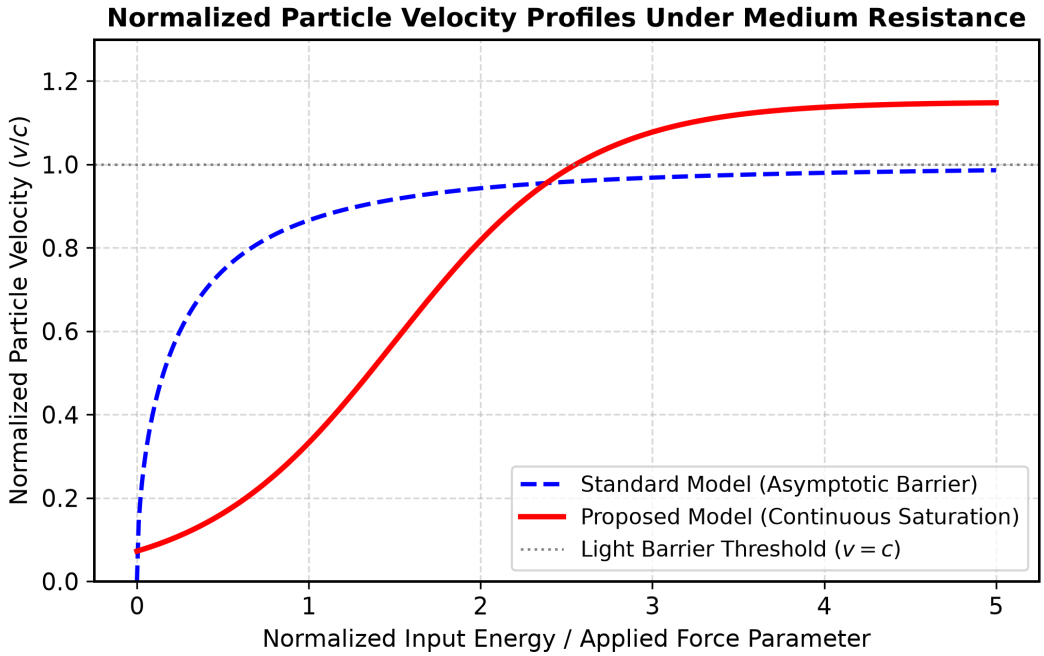

Figure 3: Radial energy density distribution of a localized stable field vortex configuration satisfying the generalized virial theorem for non-linear continuous systems.

4 Quantitative Predictions for Calorimetric Tests

For experimental verification using high-energy detectors, let us consider the process of full absorption (stopping) of an ultra-relativistic particle with rest mass m_0, accelerated to a sub-light velocity $v \to c$.

1. **Prediction according to Standard Geometrization:** Standard kinematic models assume that kinetic energy is purely relativistic-geometric, transforming completely into the thermal energy of the target lattice upon stopping:

$$Q_{STO} = \frac{m_0 c^2}{\sqrt{1 - \frac{v^2}{c^2}}} - m_0 c^2 \tag{9}$$

   As $v \to c$, the thermal dissipation tends toward infinity.

2. **Prediction according to Non-Linear Saturation:** Within the proposed model, the particle's mass remains invariant ($m = m_0$), and the truncation of acceleration efficiency is caused by the quadratic resistance of the medium. The work performed by external forces is distributed between the true non-relativistic kinetic energy of the particle and the potential compression energy of the accompanying vacuum shockwave (Mach cone). Upon impact, the particle transfers only its mechanical kinetic energy to the target, generating a limited thermal response:

$$Q_{Verh} = \frac{m_0 v^2}{2} \approx \frac{m_0 c^2}{2} \tag{10}$$

The remaining energy accumulated in the deformed vacuum shell is shed into the surrounding space as a pulse of hard X-ray radiation with energy E_{rad}:

$$E_{rad} = Q_{STO} - Q_{Verh} = m_0 c^2 \left(\frac{1}{\sqrt{1 - \frac{v^2}{c^2}}} - 1 - \frac{v^2}{2c^2} \right) \tag{11}$$

Thus, at ultra-relativistic velocities, a measurable calorimetric heat deficit arises ($\Delta Q = Q_{STO} - Q_{Verh} = E_{rad}$), serving as an experimental criterion for verification.

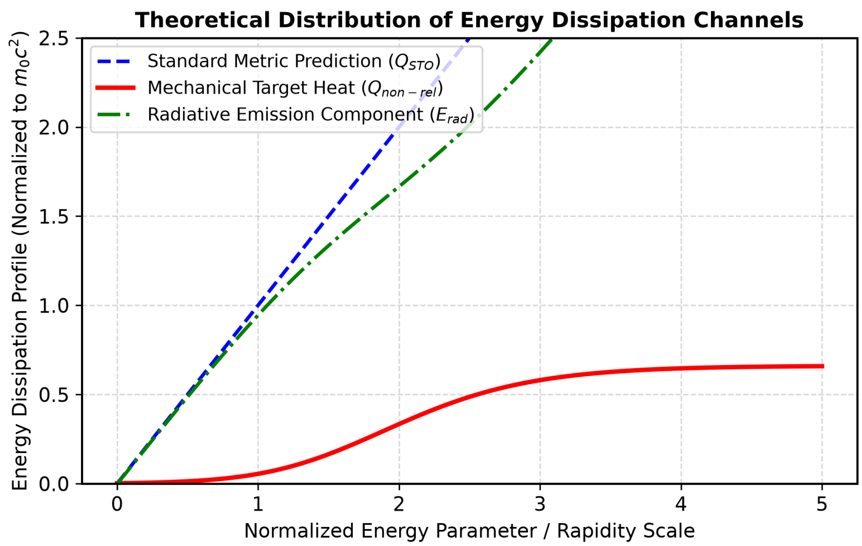

Figure 4: Theoretical distribution of energy dissipation channels during ultra-relativistic particle absorption inside a calorimetric target, indicating the expected radiation emission threshold.

5 Conclusion and Outlines

This paper establishes a methodological transition from geometric reductionism to a self-contained, quaternionic hydrodynamics of the absolute spatial medium, fully consistent with the general principles of the energy dynamics of inhomogeneous media [11].

The primary results are summarized as follows:

1. It is demonstrated that the original imaginary spatial basis of Hamilton's quaternions $\mathbb{H}$ naturally describes volumetric transverse shear deformations of the medium, automatically enforcing a $\pi/2$ phase shift between the field vectors and guaranteeing the absolute invariance of local wave energy density [14].

2. The combination of conjugate temporal forms ($\pm ct$) within an absolute Euclidean space allows for the complete compensation of false mixed derivatives during Galilean transformations, restoring full Galilean covariance of the field equations at any mechanical velocity.

3. By merging quaternionic time regularization via a characteristic microstructural scale x_0 with a non-linear quadratic medium drag, a non-singular velocity equation was derived directly from quaternionic geometry. The resulting velocity addition law proves that physical transgression of the wave barrier is smooth and continuous, resulting in a transition into a stable supercritical shockwave front.

4. Standard kinematic effects (clock retardation, wave-packet deformation, and induced added mass) are successfully deconstructed into classical processes of medium drag and boundary-layer interaction, proving that acceleration bounds arise from a degradation of force efficiency rather than an intrinsic deformation of space or time.

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