Interplanetary Casimir Communication

A Vacuum Boundary–Driven Framework for Long-Range Mode Coupling

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Abstract

We propose a theoretical framework in which Earth and Mars act as spherical Casimir boundaries for a vacuum scalar field χ, representing a perturbative mode of vacuum energy density. Boundary modulation at Earth induces detectable variations in the vacuum stress tensor at Mars, defining a Casimir-mediated planetary communication channel. We derive the governing field equation, Hamiltonian formulation, and boundary-induced mode deformation. The model anticipates experimental signatures, discusses causal constraints, and outlines speculative extensions allowing superluminal effects without paradox.

1 Introduction

The propagation of disturbances in physical systems does not require continuous matter but rather interaction-mediating fields. Sound in water, despite intermolecular vacuum, emerges from electromagnetic tension among molecules. Likewise, the quantum vacuum possesses structure sensitive to boundary conditions, as demonstrated by the Casimir effect.

Here we extend this analogy to planetary scales: Earth and Mars are treated as global boundary conditions shaping the spectrum of a scalar vacuum field χ. Modulations of boundary coupling on Earth propagate through the vacuum, altering mode amplitudes at Mars, enabling a communication channel. The conceptual framework of this work is inspired by Weinberg's axiomatic formulation of quantum field theory, in which particles, modes, and interactions emerge from fundamental principles of symmetry, causality, and mathematical consistency. Following this perspective, we treat the vacuum field χ as a primary entity whose behavior is fully determined by the boundary conditions imposed by spacetime and by the macroscopic bodies that shape it. This viewpoint reinforces the legitimacy of exploring Casimir-like phenomena at planetary scales, as well as investigating possible vacuum-induced mechanisms for information transfer [1]. Our approach builds upon the foundational insight introduced by Casimir, who demonstrated that modifications of vacuum boundary conditions lead to measurable forces between perfectly conducting plates [2]. This landmark result revealed that the quantum vacuum is not an inert background but a dynamical medium whose mode structure responds sensitively to geometric constraints. Extending this principle to astrophysical scales, we consider Earth and Mars as macroscopic boundary surfaces capable of shaping the spectrum of vacuum fluctuations of the scalar field χ, thereby enabling vacuum-mediated interactions and potential information transfer mechanisms. The broader theoretical foundation for vacuum-induced forces was later generalized by Lifshitz, who demonstrated that Casimir-type interactions arise not only between ideal conductors but also between real materials with arbitrary dielectric properties [3]. This formulation showed that vacuum forces are fundamentally a consequence of how boundary conditions modify the electromagnetic (or more generally, field-theoretic) mode spectrum. In this spirit, our model extends the Lifshitz perspective to planetary scales by treating Earth and Mars as macroscopic boundaries capable of reshaping the fluctuation modes of the vacuum field χ. A comprehensive modern treatment of vacuum forces is presented by Milton, who emphasizes that the Casimir effect represents a broad class of physical manifestations of zero-point energy rather than a single special-case phenomenon [4]. His analysis highlights how geometry, material properties, and boundary configurations profoundly influence the structure of vacuum fluctuations. Building on this perspective, our framework considers the Earth–Mars system as a macroscopic configuration capable of reshaping the mode spectrum of the vacuum field χ, thereby extending Casimir physics into the planetary domain.

This work extends the framework introduced in PrezaGPT Vol. IXb, where boundary-mediated virtual sound modes in the quantum vacuum were first proposed as carriers of geometry-sensitive information [5]. In that formulation, vacuum fluctuations were shown to reorganize coherently under boundary constraints, suggesting the possibility of engineered vacuum-based transmission channels. Here we generalize this idea to planetary scales by treating Earth and Mars as macroscopic Casimir boundaries capable of shaping and modulating the mode spectrum of the vacuum field χ. By combining quantum boundary physics with macroscopic planetary geometry, this work explores whether vacuum field structures may support coherent, long-range information pathways beyond conventional electromagnetic communication.

2 Virtual Sound Field Equation

We define $\chi(t, \mathbf{x})$ as a small perturbation of vacuum energy density. The effective Lagrangian is

$$\mathcal{L} = \frac{1}{2}\alpha \left[\frac{1}{c_v^2}(\partial_t \chi)^2 - (\nabla \chi)^2 - m_v^2 \chi^2 \right], \tag{1}$$

leading to the governing equation

$$\frac{1}{c_v^2}\partial_t^2 \chi - \nabla^2 \chi + m_v^2 \chi = 0. \tag{2}$$

3 Hamiltonian Formulation

The conjugate momentum is $\Pi = \alpha \partial_t \chi / c_v^2$. The Hamiltonian density becomes

$$\mathcal{H}_0 = \frac{c_v^2}{2\alpha}\Pi^2 + \frac{\alpha}{2}\left[(\nabla \chi)^2 + m_v^2 \chi^2 \right]. \tag{3}$$

Planetary Casimir coupling is introduced via surface terms

$$H_{\text{int}} = \frac{1}{2}\sum_a \lambda_a \oint_{\Sigma_a} \chi^2 \, dS, \tag{4}$$

with Σ_a denoting Earth and Mars surfaces.

4 Earth–Mars Casimir Cavity

In the large-separation approximation, we reduce the system to spherical $l = 0$ modes. Boundary conditions of Dirichlet type,

$$\chi(R_E) = 0, \qquad \chi(L - R_M) = 0, \tag{5}$$

shape the mode spectrum $\{\omega_n\}$ of χ.

Modulation of Earth's boundary condition,

$$\chi(R_E, t) = \epsilon(t), \tag{6}$$

acts as a source $J_E(t)$ producing a field at Mars

$$\chi_M(t) = \int dt'\, G_{\text{ret}}(t - t', L)\, J_E(t'). \tag{7}$$

5 Communication Channel

For harmonic modulation $J_E(t) = J_0 \cos \Omega t$, the response is

$$\chi_M(t) \approx \frac{A(L)}{L} \cos\left[\Omega\left(t - \frac{L}{c_v}\right)\right]. \tag{8}$$

Marte's vacuum stress tensor responds through

$$\delta T_{00} \propto \langle \chi^2(t, \Sigma_M) \rangle, \tag{9}$$

producing a measurable Casimir pressure shift.

6 Discussion

For $c_v = c$, the channel is causal. Extensions allowing $c_v > c$ or nonlocal kernels may produce superluminal effects without causal paradox, provided appropriate constraints on matter coupling.

7 Conclusion

The Earth–Mars Casimir cavity offers a novel theoretical communication channel mediated by vacuum boundary conditions. The framework blends quantum field theory, Casimir physics, and planetary-scale boundary geometry.

Keywords

Casimir Effect; Quantum Vacuum; Virtual Sound; Earth–Mars Communication; Boundary Conditions; Scalar Field; Nonlocal Vacuum Modes.

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