Weak-Field Radion Electrogravity from Maxwell-Compatible Five-Dimensional Projections

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Abstract

A recurring obstacle in speculative electrogravity models is the absence of a controlled weak-field limit. This paper develops such a limit for the scalar or radion path suggested by five-dimensional projection electrodynamics. The effective four-dimensional theory contains gravity, a Maxwell field weighted by a scalar-dependent constitutive factor $Z(s)$, and a massive scalar s interpreted as a radion, projection modulus, or readout variable. In the static limit the model reduces to

$$\nabla \cdot [Z(s)\mathbf{E}] = \rho/\epsilon_0, \qquad (\nabla^2 - m_s^2)s = -\alpha_E \frac{\epsilon_0 E^2}{2}. \tag{0.1}$$

A phenomenological gravity-readout coefficient γ_s converts gradients of s into anomalous acceleration, $\delta\mathbf{g} = -(1/2)\gamma_s c^2 \nabla s$. The resulting device-level force is written as a Yukawa convolution over electrostatic energy density and test mass density. The model predicts even voltage scaling for the leading scalar energy response, null behavior for ideal symmetric infinite capacitors, edge enhancement in finite devices, and range suppression controlled by m_s^{-1}. Existing high-vacuum null results and equivalence-principle tests are translated into bounds on the coefficient product $\alpha_E\gamma_s$. The conclusion is deliberately conservative: the scalar path is mathematically formulable and experimentally constrainable, but it is not evidence for gravity control.

1 Introduction

The electrostatic continuation of five-dimensional projection electromagnetism in Ref. [2] identifies three routes by which hidden projection structure might enter ordinary electrostatics: fifth-current effects, scalar or radion readout, and metric mixing. Of these, the scalar path is the most controlled. Scalars are generic in dimensional reduction. In Kaluza-Klein theory, the metric component associated with the size of the extra dimension does not disappear by magic; if it is suppressed, that suppression must itself be explained.

This paper turns the scalar path into a weak-field effective model. The goal is not to rescue historical electrogravity claims. The goal is to make clear what a scalar projection effect would have to look like, how it would scale, and how null experiments constrain it. A speculative framework becomes useful only when it can say what would falsify it.

The working hypothesis is that a scalar modulus s is sourced by electromagnetic field energy and that gradients of s can be read by the gravitational sector through a small phenomenological coefficient. The two couplings may ultimately descend from a five-dimensional action, but here they are treated as effective parameters. This separation is intentional: until the fifth coordinate, compactification scale, and normalization of the five-dimensional action are fixed, pretending to know the microscopic coupling is less honest than bounding the effective one.

2 Effective action

Consider the four-dimensional effective action

$$S = \int \mathrm{d}^4x\sqrt{-g}\left[\frac{R}{2\kappa} - \frac{Z(s)}{4\mu_0}F_{\mu\nu}F^{\mu\nu} - \frac{1}{2}g^{\mu\nu}\nabla_\mu s\nabla_\nu s - \frac{1}{2}m_s^2 s^2\right] + S_m. \tag{2.1}$$

Here $\kappa = 8\pi G/c^4$, $Z(s)$ is a dimensionless electromagnetic weighting function, and m_s is the inverse range of the scalar. For small excursions,

$$Z(s) = 1 + \zeta s + \mathcal{O}(s^2). \tag{2.2}$$

Variation with respect to A_μ gives

$$\nabla_\mu\left[Z(s)F^{\mu\nu}\right] = \mu_0 J^\nu. \tag{2.3}$$

Variation with respect to s gives

$$\Box s - m_s^2 s = -\frac{Z'(s)}{4\mu_0}F_{\mu\nu}F^{\mu\nu}. \tag{2.4}$$

For electrostatic fields in mostly-plus convention, $F_{\mu\nu}F^{\mu\nu} \approx -2E^2/c^2$ up to convention-dependent factors. We absorb normalization into an effective parameter α_E and write the static source equation as

$$(\nabla^2 - m_s^2)s = -\alpha_E u_E, \qquad u_E = \frac{\epsilon_0 E^2}{2}. \tag{2.5}$$

The symbol u_E denotes electrostatic energy density; Eq. (2.5) defines the normalization of α_E in this paper.

3 Modified Gauss law and Maxwell recovery

Equation (2.3) gives, in the static limit,

$$\nabla\cdot\left[Z(s)\mathbf{E}\right] = \rho/\epsilon_0. \tag{3.1}$$

To first order in s,

$$\nabla\cdot\mathbf{E} = \frac{\rho}{\epsilon_0} - \zeta\nabla\cdot(s\mathbf{E}) + \mathcal{O}(s^2). \tag{3.2}$$

Thus the scalar correction is equivalent to an effective polarization charge

$$\rho_s = -\epsilon_0\zeta\nabla\cdot(s\mathbf{E}). \tag{3.3}$$

Ordinary Maxwell electrostatics is recovered when

$$s = 0, \qquad \nabla s = 0, \qquad Z(s) = 1, \tag{3.4}$$

or when the scalar is infinitely massive or decoupled, $m_s \to \infty$ or $\alpha_E \to 0$.

The recovery condition is not cosmetic. Without it, Eq. (3.1) would imply ubiquitous deviations from precision electrodynamics. A viable model must confine the correction to regimes of high field energy density, special material coupling, short range, screening, or tiny coefficients.

4 Yukawa solution

The Green function of $\nabla^2 - m_s^2$ in three dimensions satisfies

$$(\nabla^2 - m_s^2)G_Y(\mathbf{r}) = -\delta^3(\mathbf{r}), \qquad G_Y(\mathbf{r}) = \frac{e^{-m_s r}}{4\pi r}. \tag{4.1}$$

Equation (2.5) therefore gives

$$s(\mathbf{x}) = \alpha_E \int G_Y(\mathbf{x} - \mathbf{x}')u_E(\mathbf{x}')\mathrm{d}^3x'. \tag{4.2}$$

A gravity-readout ansatz converts this scalar profile into an anomalous acceleration,

$$\delta\mathbf{g}(\mathbf{x}) = -\frac{1}{2}\gamma_s c^2 \nabla s(\mathbf{x}). \tag{4.3}$$

The coefficient γ_s is phenomenological. In a full scalar-tensor theory it would be related to how matter sees the scalar in its effective metric. Here it is kept separate from α_E because the electromagnetic sourcing and gravitational readout may have different microscopic origins.

For a body with mass density $\rho_m(\mathbf{x})$, the predicted anomalous force is

$$\mathbf{F}_s = -\frac{1}{2}\gamma_s c^2 \alpha_E \int \rho_m(\mathbf{x}) \nabla_x \left[\int G_Y(\mathbf{x} - \mathbf{x}')u_E(\mathbf{x}')\mathrm{d}^3x' \right] \mathrm{d}^3x. \tag{4.4}$$

This is the main phenomenological result. It turns a speculative scalar path into a computable convolution over device geometry.

5 Symmetry predictions

Equation (4.4) implies several model-independent signatures.

Voltage parity. Since $u_E \propto E^2 \propto V^2$, the leading scalar profile is even under polarity reversal. Therefore a force sourced purely by u_E is even in voltage magnitude. Any odd-in-voltage residual points either to conventional electrostatics, leakage, asymmetric charge injection, ion drift, or a different operator family.

Symmetric capacitor null. For an ideal infinite parallel-plate capacitor, the interior field energy density is translation invariant parallel to the plates and symmetric about the midplane. The gradient of the Yukawa potential vanishes at symmetric exterior test locations and cancels in a freely suspended symmetric assembly. Thus the scalar path predicts no thrust for the idealized device. Finite fringing fields and mass asymmetry are required to obtain a nonzero net readout.

Edge enhancement. Since nonzero gradients arise where u_E changes, finite edges, dielectric boundaries, and high-curvature electrodes dominate the signal. A realistic computation must therefore use the full energy-density distribution, not merely the plate area and voltage.

Range suppression. The scalar range is $\lambda_s = m_s^{-1}$. When the device size $L \gg \lambda_s$, only nearby energy density contributes. When $L \ll \lambda_s$, the scalar profile becomes Coulomb-like and is more strongly constrained by long-range fifth-force tests.

6 Connection to null experiments

Let an experiment place an upper bound F_{lim} on an anomalous force after controlling electrohydrodynamic, Maxwell stress, thermal, leakage, and vibration backgrounds. Define the geometry functional

$$\mathcal{G}(m_s) = \left| \int \rho_m(\mathbf{x}) \nabla_x \left[\int G_Y(\mathbf{x} - \mathbf{x}') u_E(\mathbf{x}') \mathrm{d}^3 x' \right] \mathrm{d}^3 x \right|. \tag{6.1}$$

Then Eq. (4.4) implies

$$|\alpha_E \gamma_s| < \frac{2F_{\mathrm{lim}}}{c^2 \mathcal{G}(m_s)}. \tag{6.2}$$

This inequality is more useful than a qualitative statement that an experiment was null. It maps every future null test into an exclusion curve in the $(m_s, \alpha_E \gamma_s)$ plane.

Historical asymmetric-capacitor measurements in air are not adequate evidence for Eq. (4.4), because ion wind and pressure-dependent electrohydrodynamic effects can dominate. High-vacuum experiments are therefore the relevant comparison. The scalar path must survive the strongest vacuum bounds while also avoiding equivalence-principle constraints on light scalar couplings.

7 Equivalence-principle pressure

A universal scalar that couples to ordinary matter is tightly constrained. If s modifies all masses or all metric couplings in a composition-dependent way, then torsion-balance and space-based equivalence-principle experiments force γ_s to be extremely small over long ranges. The viable window is therefore not a generic Brans-Dicke-like scalar with ordinary universal coupling. It is a more restricted effective sector in which electromagnetic field energy or dielectric structure sources the scalar more efficiently than bulk rest mass, or in which screening suppresses ordinary matter coupling.

This is not an optional caveat. It is the difference between a constrained speculative model and a model already excluded by precision gravity. Any later microscopic theory must show why α_E can be relevant in high-field devices while the matter coupling implied by γ_s remains below equivalence-principle bounds.

8 Experimental protocol

A useful experimental sequence is:

1. measure the force residual as a function of pressure from atmosphere to high vacuum;
2. reverse polarity and verify even or odd voltage response;
3. rotate the apparatus relative to gravity and relative to its support geometry;
4. compare asymmetric and symmetry-matched dummy devices;
5. replace active field energy with thermal, mechanical, or dielectric controls of similar mass and temperature;
6. publish null bounds in the form of Eq. (6.2), not only as device-specific force limits.

This protocol is compatible with the force-budget philosophy of Ref. [2]. The point is not to privilege the scalar path, but to make it easy to kill.

9 Conclusion

The scalar or radion path is the cleanest electrostatic continuation of five-dimensional projection electromagnetism because it has a controlled weak-field limit. The model presented here predicts a Yukawa convolution over electrostatic energy density, even voltage scaling, edge dominance, and strong dependence on scalar range. It also faces severe constraints from high-vacuum null experiments and equivalence-principle tests. That combination is precisely why it is publishable: it is speculative, but not unconstrained. The next step is numerical evaluation of $\mathcal{G}(m_s)$ for explicit electrode geometries and comparison with published nanonewton-scale null data.

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