A Frame-Equivalent Mechanism for Geomagnetic and Cosmological Sign Flips

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Abstract. We construct a unified mechanism in which Electrical Energy Extraction by Rotation of Earth via Torsion (EEERET) acts as the control parameter of a phase-transition-like dynamical system whose order parameter is the sign of large-scale rotation. The construction proceeds in five steps. First, in a rotating background of GRBMORS type (Gödel–Rindler–Brahe–Maxwell–Obukhov–Randall–Sundrum), the relative daily angular velocity between the Earth and the cosmological frame sources a torsion-induced four-current J_I^μ. Second, this current feeds the covariant Maxwell equations and drives an instability whose pseudoscalar invariant $\mathcal{I}_2 = F_{\mu\nu}\widetilde{F}^{\mu\nu}$ grows secularly. Third, the pseudoscalar invariant defines an effective electromagnetic chemical potential $\mu_{\rm EM}$ that tilts the symmetric Mexican-Hat potential governing the rotational order parameter R and renders rotation reversal directed rather than symmetric. Fourth, when $\mu_{\rm EM}$ crosses the cusp-catastrophe threshold $|\mu_c| = (8/3\sqrt{3})\lambda R_0^3$ the barrier collapses, producing the rapid rotation-reversal (RRR) regime, distinct from the gradual rotation-reversal (RR) regime in which a finite barrier survives. Fifth, the construction is shown to be *frame-equivalent*: the same observable consequences obtain whether one treats the Earth as rotating in a non-rotating cosmos, or treats the universe as rotating around a non-rotating Earth, because only the relative angular velocity $\Omega_{\rm rel} = \Omega_E - \Omega_U$ enters the source term. We give explicit RR and RRR onset times, indicate the role of a superconducting loop as a coherent realization of the mechanism, and list observational and laboratory signatures. The framework relies on, and complements, the chiral wave-function and conformally compactified Romano–Goebel construction developed in a companion preprint.

Keywords: cosmic rotation; Gödel cosmology; rotation reversal; geomagnetic reversals; torsion-induced current; Einstein–Cartan theory; chiral magnetic effect; cusp catastrophe; frame equivalence; superconducting analogue.

1 Introduction

The question of whether the angular velocity of the universe is identically zero, or merely very small, has been debated since the discovery of the rotating Gödel solution of Einstein's equations [1]. Current cosmological bounds derived from the Cosmic Microwave Background place $\omega_0/H_0 < 7 \times 10^{-10}$ at 95% confidence [2], and the Planck 2018 isotropy and statistics analysis [3] has further constrained large-scale anisotropic signatures of the CMB. A recent multi-probe assessment of the cosmological principle [4] shows that, while no compelling violation has been established, the empirical headroom for small-scale or low-multipole anomalies remains open, motivating continued theoretical exploration of rotating cosmologies. In a separate line of development, the proposal of Modgil [5] is that a cosmic angular velocity of *the order of one radian per sidereal day* is not in immediate conflict with observation provided that one reexamines the conventional decomposition of apparent diurnal motion into "Earth rotates" and "sky stands still." That proposal is the modern incarnation of the historical Tychonic alternative, and is referred to as the Gödel–Brahe Model of Rotation Sign (GRBMORS) universe.

The present paper develops one specific dynamical consequence of GRBMORS, namely the mechanism by which the relative daily rotation between the Earth and the cosmological frame can act as a driving source for an electromagnetic instability whose back-reaction reverses the sign of large-scale rotation. We call this mechanism *Electrical Energy Extraction by Rotation of Earth via Torsion*, abbreviated EEERET. Geophysically, EEERET is candidate-suggestive of geomagnetic reversals; cosmologically, it is candidate-suggestive of a long-term sign-flip of cosmic vorticity; conceptually, it is a falsifiable framework in which a small parity-odd electromagnetic invariant grows, behaves as a chemical potential for rotational chirality, and tilts a symmetric double-well potential until the barrier collapses.

The technical components on which the EEERET chain rests have all received substantial recent attention. The chiral magnetic effect, originally formulated in QCD and QED [13, 14, 17], has by now been observed in condensed-matter Dirac and Weyl semimetals [16] and reviewed comprehensively [15]. Einstein–Cartan cosmology has been revisited as a mechanism for parity violation in the gravitational sector [9] and as a class of torsion-driven dynamo seeds [12]. The geomagnetic-reversal record has been reanalyzed with modern paleomagnetic data [29], and Lorentz/CPT-violation tables have been updated regularly [32, 33]. The EEERET construction draws on all four of these lines.

1.1 The googly

A central observation is that all empirically accessible quantities in the EEERET chain depend only on the *relative* angular velocity,

$$\Omega_{\rm rel} = \Omega_E - \Omega_U, \tag{1}$$

where Ω_E is the angular velocity of the Earth and Ω_U is the angular velocity of the cosmological background. Because $\Omega_{\rm rel}$ is invariant under the simultaneous shift

$$\Omega_E \to \Omega_E - \Omega_0, \qquad \Omega_U \to \Omega_U - \Omega_0, \tag{2}$$

the conventional Newtonian decomposition $(\Omega_E, \Omega_U) = (2\pi/\text{day}, 0)$ and the GRBMORS decomposition $(\Omega_E, \Omega_U) = (0, -2\pi/\text{day})$ produce the same value of $\Omega_{\rm rel}$ and therefore the same EEERET source current, the same instability, the same tilted Mexican-Hat potential, and the same RR/RRR phase diagram. We refer to the ambiguity in the absolute decomposition of $\Omega_{\rm rel}$ as "the googly," borrowing the cricketing term for a delivery whose true direction is hidden inside the bowler's wrist action. The googly is not a paradox; it is a statement that EEERET-driven rotation reversal is a frame-equivalent phenomenon, robust under the absolute choice between "Earth spins" and "cosmos spins."

The googly is the unifying conceptual hook of this paper. The detailed development of the chiral wave-function formulation that makes the sign of rotation a true quantum-mechanical degree of freedom is a subject of separate work in preparation; the geometric details of the GRBMORS metric are quoted in compact form from [5]. The goal of the present paper is the EEERET chain itself.

1.2 Plan

Section 2 fixes the GRBMORS background in compact notation. Section 3 constructs the torsion-induced four-current from the relative angular velocity. Section 4 couples this current to the covariant Maxwell equations and shows that the parity-odd invariant $\mathcal{I}_2$ grows secularly. Section 5 converts $\mathcal{I}_2$ into an effective chemical potential $\mu_{\rm EM}$ and demonstrates that the resulting Mexican-Hat tilt makes rotation reversal directed. Section 6 solves the cusp catastrophe and gives explicit RR and RRR onset times. Section 7 formalizes the frame-equivalence (googly) statement. Section 8 describes a superconducting loop as the simplest coherent realization of EEERET. Section 9 lists observational and laboratory signatures, including the kinematic predictions for length-of-day, geomagnetic reversal rate, and apparent solar motion. Section 10 discusses limitations and falsifiability, and Section 11 concludes.

2 The GRBMORS background in compact notation

We adopt the GRBMORS metric of [5] in compact notation,

$$\begin{aligned} ds^2 = W(z)\big[&c^2 P^2(z)\, dt^2 - S^2(t)\, dr^2 \\ &- V(r)\, d\phi^2 + 2\sqrt{2}\, P(z)\, U(r)\, dt\, d\phi\big] - dz^2, \end{aligned} \tag{3}$$

where the auxiliary functions are

$$\begin{aligned} W(z) &= e^{f(z)}, \qquad P(z) = z\alpha(z), \\ S(t) &= A \sin\left(\frac{2\pi t}{T}\right) + B, \\ U(r) &= \sinh^2 r, \qquad V(r) = \sinh^2 r - \sinh^4 r. \end{aligned} \tag{4}$$

The non-vanishing covariant metric components are

$$\begin{aligned} g_{00} &= W c^2 P^2, \qquad & g_{11} &= -W S^2, \\ g_{22} &= -WV, \qquad & g_{02} &= g_{20} = \sqrt{2}\, WPU, \\ g_{33} &= -1. \end{aligned} \tag{5}$$

The determinant of the (t, ϕ) block is

$$g_{00} g_{22} - g_{02}^2 = -W^2 P^2 \Delta(r), \qquad \Delta(r) \equiv c^2 V + 2U^2, \tag{6}$$

and the invariant volume element is

$$\sqrt{-g} = W^{3/2}\, S\, P\, \sqrt{\Delta}. \tag{7}$$

The geometric frame-dragging angular velocity associated with the off-diagonal metric component is

$$\Omega_{\rm geom}(r, z) = \frac{g_{02}}{g_{22}} = -\frac{\sqrt{2}\, P(z)\, U(r)}{V(r)}. \tag{8}$$

The numerical anchor that fixes the GRBMORS scale is the daily angular frequency

$$\omega_{\rm day} = \frac{2\pi}{86400 \text{ s}} = 7.2722052 \times 10^{-5} \text{ s}^{-1}, \tag{9}$$

which we identify with $|\Omega_U|$ in the maximally GRBMORS decomposition of the googly (1). The yearly modulation frequency entering $S(t)$ is

$$\nu_{\rm yr} = \frac{2\pi}{365.25 \times 86400 \text{ s}} = 1.9910213 \times 10^{-7} \text{ s}^{-1}, \tag{10}$$

and the small ratio $\nu_{\rm yr}/\omega_{\rm day} \simeq 2.74 \times 10^{-3}$ justifies treating the Obukhov-type yearly modulation as a slow drift relative to the daily rotational scale.

The full Christoffel, Ricci, and Einstein tensors of (3) will be presented in detail in separate work. For the EEERET chain developed below we need only (8) together with the volume element (7) and the inverse metric components

$$\begin{aligned} g^{00} &= \frac{V}{WP^2\Delta}, \qquad & g^{02} &= \frac{\sqrt{2}\, U}{WP\Delta}, \\ g^{11} &= -\frac{1}{WS^2}, \qquad & g^{22} &= -\frac{c^2}{W\Delta}, \\ g^{33} &= -1. \end{aligned} \tag{11}$$

3 EEERET: from relative rotation to torsion-induced current

We model the Earth as a localized rotating subsystem of angular velocity Ω_E embedded in the GRBMORS background, whose own angular velocity is denoted by Ω_U. The corresponding 4-velocities are

$$u^\mu = \frac{dx^\mu}{d\tau}, \qquad u^\mu u_\mu = -1, \tag{12}$$

and the angular-velocity tensor is

$$\Omega_{\mu\nu} = \nabla_\mu u_\nu - \nabla_\nu u_\mu, \tag{13}$$

with vorticity vector

$$\omega^\mu = \frac{1}{2}\epsilon^{\mu\nu\rho\sigma} u_\nu \Omega_{\rho\sigma}. \tag{14}$$

Following the Einstein–Cartan tradition [6, 7, 8, 9], we introduce a torsion tensor

$$T^\lambda{}_{\mu\nu} = \Gamma^\lambda{}_{\mu\nu} - \Gamma^\lambda{}_{\nu\mu}, \tag{15}$$

and posit that, in the EEERET regime, the dominant torsion contribution couples to the rotation of the localized subsystem through

$$T^\lambda{}_{\mu\nu} \simeq \kappa_S\, u^\lambda\, \Omega_{\mu\nu}, \tag{16}$$

with κ_S an effective coupling of dimension length. The corresponding torsion-induced current is

$$J_I^\mu \equiv \nabla_\nu T^{\mu\nu} = \kappa_S\, \nabla_\nu (u^\mu \Omega^\nu)\,. \tag{17}$$

For a rigidly rotating Earth, the relevant kinematic identity is $\Omega^{\mu\nu} = \epsilon^{\mu\nu\alpha\beta}\omega_\alpha u_\beta$, which reduces (17) to the effective form

$$J_I^\mu \approx \kappa_S\, I_E\, \Omega_{\rm rel}\, u^\mu, \tag{18}$$

with I_E the relevant moment of inertia of the rotating subsystem and $\Omega_{\rm rel}$ the relative angular velocity defined in (1). The crucial feature of (18) is that only the difference $\Omega_E - \Omega_U$ enters; an absolute rigid rotation of the universe and the Earth together produces no torsion-induced current. This is the geometric origin of the googly invariance quoted in Section 1.

3.1 Numerical anchor for J_I^μ

If GRBMORS is realized in the maximal sense, $\Omega_U = -\omega_{\rm day}$ and $\Omega_E \to 0$, then $|\Omega_{\rm rel}| = \omega_{\rm day} = 7.27 \times 10^{-5}\ {\rm s}^{-1}$. For $I_E \sim I_\oplus = 8.04 \times 10^{37}\ {\rm kg\,m^2}$ and a nominal coupling $\kappa_S \sim 10^{-30}\ {\rm m\,(kg\,m^2)^{-1}}$ chosen so that the resulting current density J_I^0/c in SI units is of geophysical magnitude $\sim 10^2\ {\rm A\,m^{-2}}$, one obtains

$$\kappa_S I_E \Omega_{\rm rel} \sim 5.85 \times 10^3\ {\rm m^{-2}\,s^{-1}} \sim 10^2\ {\rm A\,m^{-2}}/c, \tag{19}$$

which is suggestive of the current densities required to drive a global geodynamo [10, 11]. Equation (19) is phenomenological: κ_S is the dimensional parameter that must ultimately be constrained by data. For the cosmological version of EEERET the relevant moment of inertia is that of the rotating GRBMORS background, and the resulting current density is microscopic but coherent over Hubble volumes.

4 Covariant Maxwell sector and the secular growth of $\mathcal{I}_2$

The covariant Maxwell equations sourced by (18) are

$$\nabla_\mu F^{\mu\nu} = J_I^\nu, \qquad \nabla_{[\lambda} F_{\mu\nu]} = 0, \tag{20}$$

with field tensor $F_{\mu\nu} = \partial_\mu A_\nu - \partial_\nu A_\mu$. Using the volume element (7), the inhomogeneous equation may be rewritten as

$$\partial_\mu\Big(W^{3/2} SP\sqrt{\Delta}\, F^{\mu\nu}\Big) = W^{3/2} SP\sqrt{\Delta}\, J_I^\nu. \tag{21}$$

A plane-wave ansatz $\delta A_\mu \propto e^{ik_\alpha x^\alpha}$ around an arbitrary GRBMORS background field gives the modified dispersion relation

$$\omega^2 = c^2 k^2 - \frac{\sqrt{2}\, PU}{V}\, k_\phi + R^{00}, \tag{22}$$

where R^{00} is the relevant Ricci component. The off-diagonal term $-\sqrt{2} PU\, k_\phi / V$ is the geometric frame-dragging contribution (8), and is the GRBMORS origin of the parity-odd electromagnetic response.

The two Lorentz invariants of the electromagnetic field are

$$\mathcal{I}_1 = F_{\mu\nu} F^{\mu\nu}, \qquad \mathcal{I}_2 = F_{\mu\nu} \widetilde{F}^{\mu\nu}, \tag{23}$$

with dual tensor $\widetilde{F}^{\mu\nu} = (1/2\sqrt{-g})\epsilon^{\mu\nu\rho\sigma} F_{\rho\sigma}$. In locally inertial conventions

$$\mathcal{I}_1 = 2(B^2 - E^2), \qquad \mathcal{I}_2 = -4\, \mathbf{E}\cdot\mathbf{B}. \tag{24}$$

The first is parity-even and energetic; the second is parity-odd and chiral. Only $\mathcal{I}_2$ can carry the directional information needed to distinguish the two GRBMORS rotational chiralities, and only $\mathcal{I}_2$ couples naturally to the rotational order parameter introduced in Section 5.

The growth of the electromagnetic field is modelled by a single-mode growth law

$$\frac{dF_{\mu\nu}}{dt} = \Gamma_{\rm EM}\, F_{\mu\nu}, \tag{25}$$

where $\Gamma_{\rm EM}$ is the unstable-mode growth rate determined by the dispersion relation (22) together with the EEERET source (18) [10, 11, 12]. The solution is

$$F_{\mu\nu}(t) = F_{\mu\nu}(0)\, e^{\Gamma_{\rm EM} t}, \tag{26}$$

and because $\mathcal{I}_2$ is quadratic in $F_{\mu\nu}$ the pseudoscalar grows at twice the field-amplitude rate,

$$\mathcal{I}_2(t) = \mathcal{I}_2(0)\, e^{2\Gamma_{\rm EM} t}. \tag{27}$$

This secular accumulation of parity-odd electromagnetic content is the heart of the EEERET mechanism. It is the analogue, for a rotating GRBMORS background, of the chiral magnetic effect [13, 14, 15, 16] and of the anomaly-induced helicity injection [17, 18, 19] in non-rotating plasmas.

The growth of $\mathcal{I}_2$ is bounded below by the relative-rotation source (18) and bounded above by back-reaction on the GRBMORS metric. We discuss the metric back-reaction in Sec. 10; for the cusp analysis it suffices that $\mathcal{I}_2$ grows at a definite rate $\Gamma_{\rm EM}$ until the rotational reservoir is exhausted or the geometric back-reaction becomes important.

5 $\mathcal{I}_2$ as a chemical potential for rotational chirality

We introduce the GRBMORS rotational order parameter

$$R \equiv \langle \hat{\Omega} \rangle, \tag{28}$$

where the average is over a coarse-graining scale large compared with the local EEERET source size but small compared with the cosmological horizon. Positive and negative values of R correspond to the two rotational chiralities; in particular, the GRBMORS solution that fits the present apparent diurnal motion of the sky is one of these two values, while the opposite value corresponds to the post-reversal cosmological state.

A central postulate of the EEERET construction is that the secularly growing pseudoscalar (27) couples linearly to R as an effective chemical potential,

$$\mu_{\rm EM} = \chi_{\rm EM}\, F_{\mu\nu}\widetilde{F}^{\mu\nu} = -4\chi_{\rm EM}\,\mathbf{E}\cdot\mathbf{B}, \tag{29}$$

where $\chi_{\rm EM}$ is an effective susceptibility of dimension energy per parity-odd invariant density [13, 14, 15]. The susceptibility is fixed in principle by integrating out the matter sector that mediates the R–$\mathcal{I}_2$ coupling, just as the chiral magnetic susceptibility is fixed by the axial anomaly in QED.

The symmetric rotational potential is the standard Mexican-Hat,

$$\Phi_0(R) = \lambda\,(R^2 - R_0^2)^2, \qquad \lambda > 0, \tag{30}$$

with minima at $R = \pm R_0$ and a barrier of height λR_0^4 at $R = 0$. The electromagnetic chemical potential tilts this potential according to

$$\Phi_{\rm eff}(R) = \lambda\,(R^2 - R_0^2)^2 - \mu_{\rm EM} R. \tag{31}$$

The extrema of (31) satisfy

$$\frac{d\Phi_{\rm eff}}{dR} = 4\lambda R(R^2 - R_0^2) - \mu_{\rm EM} = 0, \tag{32}$$

and the local curvature is

$$\frac{d^2\Phi_{\rm eff}}{dR^2} = 4\lambda(3R^2 - R_0^2). \tag{33}$$

For small $\mu_{\rm EM}$, the two minima are shifted from $\pm R_0$ by

$$\delta R_\pm = \frac{\mu_{\rm EM}}{8\lambda R_0^2}, \tag{34}$$

and to leading order the well energies are

$$\Phi_{\rm eff}(R_\pm) \simeq \mp \mu_{\rm EM} R_0. \tag{35}$$

The asymmetry between the two wells is

$$\Delta\Phi_{\rm asym} = \Phi_{\rm eff}(R_-) - \Phi_{\rm eff}(R_+) = 2\mu_{\rm EM} R_0, \tag{36}$$

showing that one rotational chirality is energetically preferred according to the sign of $\mu_{\rm EM}$. This is the precise sense in which EEERET produces *directed* rather than symmetric rotation reversal. The analogy with ferromagnetism is exact: R plays the role of magnetization, and $\mu_{\rm EM}$ that of an external magnetic field,

$$V_{\rm mag}(M) = aM^2 + bM^4 - HM, \tag{37}$$

with $R \leftrightarrow M$, $\mu_{\rm EM} \leftrightarrow H$. The directional bias of rotation reversal is thus the analogue of magnetization alignment in an applied field.

6 Cusp catastrophe: barrier collapse and the RR/RRR boundary

The cusp catastrophe associated with (31) is the simultaneous vanishing of the first and second derivatives,

$$\frac{d\Phi_{\rm eff}}{dR} = 0, \qquad \frac{d^2\Phi_{\rm eff}}{dR^2} = 0. \tag{38}$$

Using (32) and (33), the critical inflection point satisfies

$$R_c^2 = \frac{R_0^2}{3}. \tag{39}$$

Substituting back into (32) gives the critical chemical potential

$$|\mu_c| = \frac{8}{3\sqrt{3}}\,\lambda R_0^3, \qquad \mu_c^2 = \frac{64}{27}\,\lambda^2 R_0^6. \tag{40}$$

The two regimes of EEERET-driven rotation reversal are therefore

$$\begin{aligned} \text{RR:}&\quad |\mu_{\rm EM}| < |\mu_c|, &&\text{barrier finite,}\\ \text{RRR:}&\quad |\mu_{\rm EM}| \ge |\mu_c|, &&\text{barrier collapsed.} \end{aligned} \tag{41}$$

In the RR regime, reversal proceeds by thermal activation

$$\Gamma_{-\to+} = \Gamma_0\,\exp\left[-\frac{\Delta\Phi_-}{k_B T_{\rm eff}}\right], \tag{42}$$

or, in the cosmological regime in which thermal activation is negligible, by quantum tunneling [20, 21]

$$\Gamma_{\rm q}^{(\pm)} = \Omega_{\rm pref}\,\exp\left[-\frac{2S_E^{(\pm)}}{\hbar}\right], \tag{43}$$

with WKB action

$$S_E^{(\pm)} = \int_{R_{\rm in}^{(\pm)}}^{R_{\rm out}^{(\pm)}} \sqrt{2M_R[\Phi_{\rm eff}(R) - E_\pm]}\,dR. \tag{44}$$

The EEERET bias (29) changes $S_E^{(+)}$ and $S_E^{(-)}$ unequally, turning the symmetric tunneling process into a directed one. The forward and backward Kramers/Coleman rates therefore obey

$$\frac{\Gamma_{-\to+}}{\Gamma_{+\to-}} = \exp\left[\frac{2\mu_{\rm EM}R_0}{k_B T_{\rm eff}}\right]. \tag{45}$$

In the RRR regime the barrier disappears and the dynamics reduce to a deterministic roll-down of R from the disfavored well into the favored well. Combining (27) with (40) gives the explicit onset time

$$t_{\rm RRR} = \frac{1}{2\Gamma_{\rm EM}}\,\ln\left[\frac{8\lambda R_0^3}{3\sqrt{3}\,|\mu_{\rm EM}(0)|}\right]. \tag{46}$$

Equation (46) is the central quantitative prediction of EEERET: the time required for a small initial pseudoscalar electromagnetic content to grow into a full rotation reversal is logarithmic in the initial bias and inversely proportional to twice the EEERET-driven instability rate.

6.1 Time-scale hierarchy for RR and RRR

Let

$$t_{\rm grow} = \Gamma_{\rm EM}^{-1}, \quad t_{\rm spin} = \frac{I|\Omega|}{\kappa B^2}, \quad t_{\mathcal{T}} = \lambda_{\mathcal{T}}^{-1}, \tag{47}$$

be the EM growth, the spin-down by Maxwell stress, and the torsion-relaxation times respectively. Then

$$\text{RR} \;:\; t_{\rm grow} \lesssim t_{\rm spin} \sim t_{\mathcal{T}}, \tag{48}$$

$$\text{RRR} \;:\; t_{\rm grow} \ll t_{\rm spin} \ll t_{\mathcal{T}}. \tag{49}$$

RR is the regime in which the system slowly crosses the bifurcation threshold; RRR is the regime in which the unstable electromagnetic mode grows so quickly that the rotational reservoir is dumped before the torsion background has time to readjust.

7 Frame-equivalence: the googly stated precisely

We now formalize the statement that EEERET-driven rotation reversal is robust under the choice of absolute rotation between the Earth and the cosmological background. Let $\Omega_{\rm inertial}$ denote the angular velocity of the local inertial frame at the Earth, as determined by the GRBMORS vorticity (14),

$$\Omega_{\rm inertial} = \sqrt{\omega^\mu \omega_\mu}. \tag{50}$$

We parametrize the Machian content of GRBMORS by a single dimensionless number $\xi \in [0,1]$,

$$\Omega_{\rm inertial} = \xi\,\Omega_U, \tag{51}$$

so that $\xi = 1$ is the maximally Machian regime in which the local inertial frame co-rotates exactly with the cosmological matter, while $\xi = 0$ is the maximally anti-Machian regime in which the local inertial frame is independent of cosmological rotation. The apparent angular velocity of the sky relative to the Earth-fixed frame is

$$\Omega_{\rm app} = \xi\,\Omega_U - \Omega_E. \tag{52}$$

The observed sidereal day fixes $\Omega_{\rm app} \equiv \omega_{\rm day}$. The googly is the statement that the pair $(\xi\Omega_U, \Omega_E)$ is determined by the single observable $\Omega_{\rm app}$ only up to the gauge (2), so that an entire one-parameter family of $(\xi, \Omega_U, \Omega_E)$ triplets reproduces the same apparent diurnal motion. In particular, the Newtonian convention is

$$(\xi, \Omega_U, \Omega_E)_{\rm New} = (0,\,0,\,-\omega_{\rm day}), \tag{53}$$

the maximally Machian GRBMORS convention is

$$(\xi, \Omega_U, \Omega_E)_{\rm GRBMORS} = (1,\,\omega_{\rm day},\,0), \tag{54}$$

and any convex combination is allowed.

The crucial observation is that the EEERET source current (18) depends on $\Omega_E - \Omega_U$, while *the only observable that fixes this combination is precisely* (52). Therefore

$$\Omega_{\rm rel} = \Omega_E - \Omega_U = -\Omega_{\rm app}/(1-\xi), \tag{55}$$

which is invariant under the gauge (2) for each fixed ξ. For $\xi = 0$ (Newtonian), $\Omega_{\rm rel} = -\Omega_{\rm app}$; for $\xi = 1$ (maximally Machian) the relative rotation diverges, which is the formal way of saying that in the maximally Machian limit the EEERET coupling $\kappa_S\Omega_{\rm rel}$ must be re-interpreted as a finite combination $\kappa_S\Omega_{\rm rel} \to \tilde{\kappa}_S\Omega_{\rm app}$. We adopt $\xi \in [0,1)$ for the rest of the paper, where the relation (55) is finite and unambiguous.

The EEERET-driven rotation-reversal phenomenon is therefore controlled by the single Machian parameter ξ and the observed sidereal day $\Omega_{\rm app}$, and is not sensitive to the absolute decomposition into "Earth rotates" and "cosmos rotates." This is the precise content of the googly.

8 Superconducting EEERET loop as a coherent realization

The simplest coherent laboratory realization of EEERET is a superconducting loop of inductance L in the presence of a torsion-induced electromotive force $\mathcal{E}_T$. Because the ohmic resistance vanishes ($R_{\rm sc} = 0$ [22, 23]), the loop equation is

$$L\,\frac{dI_{\rm sc}}{dt} = \mathcal{E}_T, \tag{56}$$

with persistent-current solution

$$I_{\rm sc}(t) = I_{\rm sc}(0) + \frac{1}{L}\int_0^t \mathcal{E}_T(t')\,dt'. \tag{57}$$

The London relation gives the covariant supercurrent

$$J^\mu_{\rm sc} = -\frac{n_s q^2}{m_s}\,A^\mu, \tag{58}$$

and the magnetic-flux quantization,

$$\Phi_B + L_k I_{\rm sc} = n\Phi_0, \quad \Phi_0 = \frac{h}{2e} = 2.0678 \times 10^{-15}\ \text{Wb}, \tag{59}$$

forces the EEERET drive to advance the current in discrete fluxoid units. For a circular loop of radius a, the axial magnetic field is $B_{\rm loop} \simeq \mu_0 I_{\rm sc}/(2a)$ and the torsion-induced electric field around the loop is $E_T \simeq \mathcal{E}_T/(2\pi a)$. The pseudoscalar invariant evaluated on this configuration is

$$F_{\mu\nu}\widetilde{F}^{\mu\nu} \simeq -\frac{\mu_0}{\pi a^2}\,\mathcal{E}_T I_{\rm sc}\cos\theta, \tag{60}$$

with θ the angle between the effective electric and magnetic fields. Substituting (56) into (60) gives

$$F_{\mu\nu}\widetilde{F}^{\mu\nu} \simeq -\frac{\mu_0 L}{\pi a^2}\, I_{\rm sc}\,\frac{dI_{\rm sc}}{dt}\cos\theta. \tag{61}$$

For an exponentially growing supercurrent $I_{\rm sc} = I_0 e^{\Gamma_I t}$, the loop-induced electromagnetic chemical potential is

$$\mu_{\rm EM}(t) \propto \Gamma_I I_0^2\, e^{2\Gamma_I t}, \tag{62}$$

which has growth rate $\Gamma_\mu = 2\Gamma_I$ as in (27).

The superconducting loop is therefore a concrete table-top analogue of EEERET: once a relative-rotation drive is established, the loop integrates the torsion-induced emf coherently, generates a parity-odd pseudoscalar $F_{\mu\nu}\widetilde{F}^{\mu\nu} \propto I_{\rm sc}\dot{I}_{\rm sc}$, and feeds that pseudoscalar into the GRBMORS chemical potential $\mu_{\rm EM}$. The cusp threshold (40) then determines whether the laboratory analogue is in RR (no full reversal, only a directional bias) or in RRR (deterministic flip).

For a typical superconducting solenoid with $L \sim 1$ H, $a \sim 0.1$ m, $I_{\rm sc} \sim 100$ A, $\Gamma_I \sim 10^{-6}$ s^{-1}, and $\cos\theta \sim 1$, the loop-generated pseudoscalar density is

$$|F_{\mu\nu}\widetilde{F}^{\mu\nu}| \sim 10^{-3}\ {\rm T}^2, \tag{63}$$

which is at the level required to detect parity-odd effects in precision laboratory tests of rotational chirality [24, 25, 26]. A dedicated EEERET–superconductor experiment would modulate Ω_E at the lab frame and search for the resulting $\mathcal{E}_T \propto \Omega_{\rm rel}$ signature in a SQUID-coupled loop, as a direct test of the coupling κ_S.

9 Observational and laboratory signatures

9.1 Geomagnetic reversals as RR events

The geomagnetic record contains $\sim 10^2$ polarity reversals over the past 160 Myr, with mean recurrence time $\bar{\tau}_{\rm rev} \sim 2\times 10^5$ to 5×10^6 years and reversal duration $\Delta t_{\rm rev} \sim 10^3$–$10^4$ years [27, 28, 29]. The standard geodynamo explanation [27] regards each reversal as a chaotic excursion of the magnetohydrodynamic state of the outer core. The EEERET interpretation is complementary: in addition to the geodynamo, the torsion-induced current (18) provides a global, frame-equivalent source whose pseudoscalar response (27) contributes to the chemical potential (29).

In this picture, each geomagnetic reversal is an RR event of the EEERET dynamics: $\mu_{\rm EM}$ slowly drifts due to the secular growth of $\mathcal{I}_2$; when it crosses a fraction of $|\mu_c|$, thermally activated transitions across the Kramers barrier reorient the dipole. The rare events with $\mu_{\rm EM} \to \mu_c$ are RRR events, in which the geomagnetic dipole flips on a time-scale shorter than the diffusive geodynamo time. The geomagnetic "superchron" epochs (the Cretaceous Normal Superchron, 84–121 Myr ago, of duration ~ 40 Myr) correspond to extended periods in which $\mu_{\rm EM}$ remains pinned in one well; a transition from a superchron to a high-reversal-rate epoch is, in EEERET language, a slow drift of $\mu_{\rm EM}$ from one side of the cusp boundary to the other.

The EEERET interpretation makes one definite prediction beyond the geodynamo model: the asymmetry (45) between forward and backward reversal rates should be *directional*, i.e. correlated with the sign of $\mathbf{E}\cdot\mathbf{B}$ averaged over the outer-core dynamo state. This is a parity-odd observable that distinguishes EEERET from a chaotic geodynamo.

9.2 Length-of-day modulation

A subdominant signature is the secular modulation of the length-of-day (LOD) by the back-reaction of $\mu_{\rm EM}$ on the rotational order parameter R. The Langevin dynamics of R,

$$\frac{dR}{dt} = -\Gamma_R\,\frac{d\Phi_{\rm eff}}{dR} + \xi(t), \tag{64}$$

imply that the local rotational velocity $\Omega_E \propto R$ undergoes a slow drift on the time-scale $t_{\rm RRR}$ of (46). This contributes a small secular component to the observed LOD, in addition to the well-known tidal and core-mantle coupling contributions [30, 31]. A correlation between geomagnetic reversal epochs and millisecond-scale LOD jumps would be a positive signal for EEERET, and is in principle detectable in the modern atomic-clock and VLBI LOD records.

9.3 Apparent solar motion at RRR onset

At the instant of an RRR transition, R passes through zero before settling into the opposite well. From the proportionality $\Omega_E \propto R$, this implies that $\Omega_{\rm app}$ momentarily vanishes,

$$\Omega_{\rm app}(t_{\rm RRR}) = 0, \tag{65}$$

and then reverses sign,

$$\lim_{t\to t_{\rm RRR}^+}\Omega_{\rm app} = -\Omega_{\rm app}(t_{\rm RRR}^-). \tag{66}$$

The kinematic prediction is therefore that during an RRR event the apparent diurnal motion of the sun first slows to zero ("the sun appears stationary") and subsequently reverses ("the sun rises from the opposite direction"). The GRBMORS framework predicts that such an event would be a once-per-aeon geophysical singularity; on shorter time-scales, only the RR regime is realized, manifest as the geomagnetic reversal record discussed in Section 9.1. The kinematic statement (65)–(66) is the strongest observable possible: it provides a falsifiable kinematic prediction unique to the EEERET mechanism and cannot be produced by the conventional MHD geodynamo.

9.4 Laboratory test: torsion-coupled SQUID array

The coupling κ_S in (18) is the parameter that controls the entire EEERET chain. The most direct laboratory test is a SQUID-coupled superconducting loop mounted on a high-precision rotation platform, modulated at frequency $\Omega_{\rm mod} \ll \omega_{\rm day}$. The signature is a modulation of the persistent current $I_{\rm sc}$ at the drive frequency, with amplitude

$$\delta I_{\rm sc} \simeq \frac{\kappa_S I_E \Omega_{\rm mod}}{L\,\Omega_{\rm mod}} = \frac{\kappa_S I_E}{L}. \qquad (67)$$

The Earth-frame baseline drift of $I_{\rm sc}$, in contrast, scales as $\kappa_S I_E \omega_{\rm day}/L$ and would correspond to a constant drift rate. Comparing modulated to constant components of $I_{\rm sc}$ at a SQUID sensitivity of $\sim 10^{-15}$ T Hz$^{-1/2}$ would constrain κ_S at the level required for cosmological relevance.

9.5 CMB and binary-pulsar constraints

The strongest extant bounds on cosmic rotation, $\omega_0/H_0 < 7 \times 10^{-10}$ [2] and the Planck 2018 isotropy analysis [3], constrain the time-averaged value of $|\Omega_U|$ at the last-scattering surface. The recent multi-probe assessment of the cosmological principle [4] surveys the current state of empirical anomalies and their compatibility with isotropic-cosmology hypotheses. In the GRBMORS interpretation, the diurnal $|\Omega_U| \sim \omega_{\rm day}$ is reconciled with these bounds through the local geometric averaging implicit in CMB polarization analyses; the present paper does not re-derive this reconciliation, which is the subject of separate work in preparation. Binary-pulsar timing bounds on Lorentz/CPT-violating effects [32, 33] similarly constrain the EEERET susceptibility $\chi_{\rm EM}$, providing a complementary upper bound on the parity-odd response of the EEERET-generated electromagnetic sector.

10 Discussion: backreaction, falsifiability, and limitations

10.1 Back-reaction on the GRBMORS metric

The EEERET chain treats the GRBMORS background as fixed and the rotational order parameter R as a coarse-grained variable that evolves under $\mu_{\rm EM}$. Self-consistency requires that the back-reaction of the growing electromagnetic stress tensor on $g_{\mu\nu}$ remains small until the RRR transition. Schematically, the off-diagonal Einstein equation (8) requires

$$\rho_{\rm EM} \ll \frac{c^4 \Omega_{\rm geom}^2}{8\pi G}, \qquad (68)$$

which gives an upper bound on $|F_{\mu\nu}|$ that may be imposed self-consistently as a cut-off on the growth law (25). For the daily GRBMORS scale $\Omega_{\rm geom} \sim \omega_{\rm day}$, the bound is $\rho_{\rm EM} \ll 10^{-3}$ J m^{-3}, well above any laboratory electromagnetic energy density, so the back-reaction cut-off is operative only on cosmological scales. A complete self-consistent treatment requires a detailed back-reaction analysis, which we leave to future work.

10.2 Energy budget

The EEERET extraction is bounded by the rotational reservoir of the rotating subsystem. For the Earth as the subsystem, the rotational kinetic energy is $E_{\rm rot} \simeq (1/2) I_\oplus \omega_{\rm day}^2 \simeq 2.1 \times 10^{29}$ J, and the corresponding angular momentum is $L_\oplus \simeq 5.9 \times 10^{33}$ kg m^2 s^{-1}. A complete reversal of Ω_E requires extraction of $E_{\rm rot}$ over the time-scale (46), giving the time-averaged EEERET power

$$P_{\rm EEERET} \simeq \frac{E_{\rm rot}}{t_{\rm RRR}}. \qquad (69)$$

For the geomagnetic-reversal time-scale $\bar{\tau}_{\rm rev} \sim 10^5$ yr, $P_{\rm EEERET} \simeq 7 \times 10^{16}$ W, which is six orders of magnitude larger than the geodynamo dissipation rate $\sim 5 \times 10^{10}$ W [27]. This discrepancy is the reason why the EEERET interpretation of geomagnetic reversals requires that the reversal is not a complete reversal of the Earth's rotation but a much smaller reorientation of the rotational order parameter at a coarse-grained level: a complete RRR of the Earth would dissipate vastly more energy than the geodynamo can produce. The cosmological version of EEERET, in which the rotational reservoir is that of the entire GRBMORS background, has access to a much larger energy budget and can in principle support a full sign-flip of Ω_U on aeon-length time-scales. A more complete discussion of the cosmological energy budget is left to future work.

10.3 Falsifiability

The EEERET framework makes three falsifiable predictions:

1. A parity-odd correlation between the forward and backward geomagnetic reversal rates, signalled by the asymmetry (45).

2. A SQUID-coupled superconducting loop, mounted on a rotation platform and modulated at $\Omega_{\rm mod}$, exhibits a persistent-current response of magnitude (67), with the coupling κ_S at the level required for cosmological relevance.

3. During an RRR event, the apparent diurnal motion of the sun first vanishes and then reverses, as in (65)–(66).

The first prediction is testable now using the existing geomagnetic record; the second is a feasible decadal-time-scale laboratory programme; the third is a once-per-aeon kinematic signature.

10.4 Limitations

The EEERET construction is intentionally phenomenological. The coupling κ_S of (16), the susceptibility χ_{EM} of (29), and the Mexican-Hat parameters λ and R_0 of (30) are not derived from a microscopic theory in this paper. They are the empirical knobs that an Einstein–Cartan completion of GRBMORS, together with a chiral wave-function formulation of the rotational sector, must ultimately fix. Likewise, the back-reaction of the EEERET electromagnetic sector on the GRBMORS geometry is treated only to leading order. Finally, the relation between the geophysical RR (geomagnetic reversals) and the cosmological RR (sign-flip of Ω_U) is at present phenomenological: the EEERET framework asserts that both phenomena are controlled by the same Mexican-Hat dynamics, but they operate on very different energy budgets and time-scales.

11 Conclusion

We have constructed an explicit chain in which the relative daily rotation between the Earth and the GRBMORS cosmological background sources a torsion-induced electromagnetic four-current, drives an instability whose pseudoscalar invariant grows secularly, acts as a chemical potential for rotational chirality, tilts the symmetric Mexican-Hat potential governing the rotational order parameter, and triggers either gradual rotation reversal (RR) or rapid rotation reversal (RRR) depending on whether the chemical potential remains below or above the cusp-catastrophe threshold $|\mu_c| = (8/3\sqrt{3})\lambda R_0^3$. The construction is frame-equivalent under the googly transformation that interchanges "Earth rotates" and "cosmos rotates," because only the relative angular velocity $\Omega_{\mathrm{rel}} = \Omega_E - \Omega_U$ enters the EEERET source current. The mechanism admits a coherent superconducting-loop realization in which the loop integrates the torsion-induced emf into a parity-odd electromagnetic pseudoscalar, opening a feasible laboratory test of the coupling κ_S. Observational signatures include a parity-odd asymmetry in the geomagnetic reversal record, secular LOD modulation, and, in the once-per-aeon RRR limit, an apparent stationarity followed by reversal of the diurnal motion of the sun. EEERET is intentionally phenomenological in its couplings and is to be regarded as a falsifiable extension of, rather than a replacement for, conventional geodynamo and cosmic-rotation frameworks. The chiral wave-function and conformally compactified Romano–Goebel vacuum-energy questions on which the EEERET chain rests are subjects of separate work in preparation; the full tensor calculation of the GRBMORS metric, the brane-source origin of the torsion-induced current, and a more exhaustive treatment of the superconducting realization will be presented elsewhere.

The "googly" framing of this paper is intended as a serious conceptual proposal: that the asymmetric attribution of diurnal rotation to the Earth rather than to the cosmos is a convention rather than an observable fact, and that EEERET provides a frame-equivalent dynamical mechanism whose empirical consequences do not depend on which side of the googly one chooses. The same mechanism, with the same critical chemical potential, predicts geomagnetic reversals (the geophysical RR limit), once-per-aeon cosmological sign flips (the cosmological RRR limit), and a SQUID-based laboratory signature (the table-top analogue). Whether the universe is actually realizing the maximally Machian GRBMORS branch of the googly is a question that can ultimately be settled only by the empirical programme sketched in Section 9.

Methods note: use of artificial intelligence and large language models

In accordance with the COPE position statement on the use of artificial intelligence (AI) and AI-assisted technology in scholarly publishing, and with the Preprints.org policy on disclosure of AI use, the authors document below the role of AI tools in the preparation of this manuscript.

The authors used Anthropic's Claude family of large language models (LLMs), accessed through a desktop assistant interface, during the preparation of this manuscript for the following purposes: (i) drafting and copy-editing of expository English prose connecting the technical derivations to the established literature; (ii) suggestions on LaTeX structure, equation typesetting, and bibliographic consolidation in a REVTeX 4-2 source; (iii) generation of trial wordings for the abstract, section headings, and figure captions; (iv) cross-checking of dimensional consistency and algebraic manipulations against the authors' independent derivations.

The conceptual content of this manuscript – including the identification of the relative-rotation source current as the EEERET mechanism, the chemical-potential interpretation of the parity-odd electromagnetic invariant, the formulation of the cusp-catastrophe RR/RRR transition in terms of the critical value $|\mu_c| = (8/3\sqrt{3})\lambda R_0^3$, the frame-equivalence ("googly") reformulation under the Machian parameter ξ, and all predictions for geomagnetic reversals, length-of-day modulation, apparent solar motion, and the superconducting-loop signature – is due to the authors. LLM-generated text was reviewed, edited, and verified by the authors against primary sources before inclusion. No LLM was assigned, or could have been assigned, authorship; LLMs do not meet authorship criteria as set out by COPE and Preprints.org. The authors take full responsibility for the accuracy, completeness, and integrity of the final text, and have checked for any factual or referencing errors that may have been introduced by LLM assistance.

Author contributions

In the CRediT taxonomy: M.S.M. – conceptualization, methodology, formal analysis, investigation, writing – original draft, writing – review & editing, project administration. D.D.P. – methodology, formal analysis, investigation, writing – review & editing. Both authors have read and agreed to the posted version of the manuscript.

Data availability statement

This is a theoretical paper. No new experimental, observational, or simulation data were created or analyzed in the course of this study. All quantitative estimates quoted in the text are derived from the equations presented and from cited primary literature; the corresponding numerical inputs are stated in-line. Data sharing is therefore not applicable to this article.

Conflicts of interest

The authors declare no conflicts of interest.

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