Plate Tectonics Time Cycle (PTTC) and Cosmic Rotation Reversals (RR & RRR): A Unified Framework

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Abstract

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We present a unified cosmological-geophysical framework linking the Plate Tectonics Time Cycle (PTTC) with cosmic Rotation Reversals (RR) and Rapid Rotation Reversals (RRR), arising within the General Relativistic Brane Metric Rotational Scalar (GRBMRS) model. In this formulation, the Universe's rotational state evolves within a Mexican Hat potential and is governed by a Wheeler–DeWitt wavefunction, allowing quantum tunneling transitions that alter its global rotation.

1 Introduction

The Plate Tectonics Time Cycle (PTTC) describes periodic phases in Earth's lithospheric evolution, including supercontinent assembly and breakup, ocean basin reorganization, and mantle flow reconfiguration. Traditionally attributed to internal processes like mantle convection and lithospheric recycling, these cycles remain incompletely understood in terms of periodicity, coherence, and resets.

This paper introduces a cosmological mechanism to complement and synchronize with terrestrial geodynamics. In particular, we propose that Rotation Reversals (RR) and Rapid Rotation Reversals (RRR)—arising from quantum transitions in the rotational state of the universe—serve as large-scale initiators or modulators of tectonic cycles. Within the GRBMRS cosmology, the universe's rotation scalar $R(t)$ evolves in a bistable Mexican Hat potential. Quantum tunneling transitions between its minima, described...

We hypothesize that such events affect Earth's angular momentum budget, perturb the core–mantle boundary (CMB), and produce observable changes in the geomagnetic field and seismic wave propagation. This interdisciplinary model unites quantum cosmology, seismic anomaly interpretation, and tectonic cyclicity into a coherent framework that may yield testable implications for both Earth sciences and cosmophysics.

2 Seismic Wave Anomalies and Their Role in PTTC, RR, and RRR

The generalized wave equation in heterogeneous media is:

$$\nabla^2 u - \frac{1}{v^2(\mathbf{r})}\frac{\partial^2 u}{\partial t^2} = s(\mathbf{r}, t) \tag{1}$$

Seismic wave anomalies are critical observational tools for probing deep Earth processes that drive the Plate Tectonics Time Cycle (PTTC) and modulate geomagnetic phenomena like Rotation Reversals (RR) and Rapid Rotation Reversals (RRR). These anomalies reveal heterogeneities in velocity, attenuation, and scattering that trace thermal, chemical, and structural features in the core–mantle boundary (CMB) region.

2.1 Types of Anomalies and Their Geodynamic Implications

ULVZs reduce seismic velocities by:

$$V_P^{ULVZ} = V_P^{ambient} \times (1 - 0.1) \tag{2}$$
$$V_S^{ULVZ} = V_S^{ambient} \times (1 - 0.3) \tag{3}$$

where V_P and V_S are the compressional and shear wave speeds in ambient mantle.

Anisotropy in shear velocities is quantified by:

$$A = \frac{V_{SH} - V_{SV}}{(V_{SH} + V_{SV})/2} \tag{4}$$

1. **Ultra-Low Velocity Zones (ULVZs)** Observed via delays in P- and S-waves near the CMB [18]. Interpreted as dense partial melt zones. They influence local heat flow and potentially modulate core convection and reversal frequency.
2. **Scattering and Reflection Anomalies** Anomalous SKS/SKKS polarizations and waveform distortions suggest heterogeneous or anisotropic structures in the D” region [10, 19]. These may impact angular momentum transfer at the core–mantle interface.
3. **Bulk Sound and Shear Velocity Heterogeneity** Variations in V_P and V_S are linked to thermal gradients and chemical layering, as shown by seismic tomography [12, 13]. These anomalies correlate with changes in geomagnetic reversal behavior.
4. **Core–Mantle Boundary Topography** Seismic waveform inversions reveal topographic undulations that are associated with slab roots or plume conduits [14]. These modulate upwelling/downwelling, key to PTTC phase transitions.
5. **Geographic Correlation with Reversal Clustering** Some seismic anomaly regions (e.g., LLSVPs) align with geomagnetic superchron boundaries [15, 16], suggesting deep Earth structure influences reversal dynamics.
6. **D” Layer Waveform Distortions** S-wave splitting and scattering in the D” layer show phase transition effects or mineral anisotropy [17]. These can alter the feedback between core flow and mantle convection.

2.2 Summary Table

Anomaly Type	Observed Effect	Implication for PTTC, RR, RRR
		ULVZs
Delayed P/S waves near CMB	Local heat flux anomalies → core convection modulation	SKS/SKKS rotation changes
	Scattering & Polarization	
Boundary roughness → angular coupling variation	Anomalies in V_P, V_S	Thermal/chemical layering → reversal behavior
		CMB Topography
Velocity Heterogeneity		
Long-wavelength features	Plume-slab dynamics → tectonic reorganization	Match with LLSVPs
	Reversal Correlation Regions	
Suggest external control of reversal periodicity	Split/scattered waveforms	Reveal deep feedback processes
D" Waveform Distortion		

Table 1: Seismic anomalies and their geodynamic implications in the PTTC framework.

3 Rotation Reversals and the GRBMRS Universe

In the GRBMRS (General Relativistic Brane Metric Rotational Scalar) framework, the Universe is modeled as a rotating brane embedded in higher-dimensional space. The rotation is encoded in an off-diagonal term in the metric:

$$g_{t\phi} = e^{f(z)}\alpha(z)H(t, r, \phi, z)$$

where $H(t)$ is the rotational scalar function, whose sign denotes the direction of cosmic rotation. A reversal in this sign corresponds to a **Rotation Reversal (RR)**, while a tunneling-driven instantaneous switch corresponds to a **Rapid Rotation Reversal (RRR)**.

3.1 Mexican Hat Potential and Bistability

The rotational scalar field $R(t)$ evolves in a double-well Mexican Hat potential:

$$\Phi(R) = \lambda(R^2 - R_0^2)^2 \tag{5}$$

where λ is the symmetry-breaking strength, and R_0 is the magnitude of the vacuum expectation value.

The gradient of the potential, representing the restoring force, is:

$$\frac{d\Phi}{dR} = 4\lambda R(R^2 - R_0^2) \tag{6}$$

The scalar field $R(t)$ evolves in a spontaneous symmetry-breaking potential:

$$\Phi(R) = \lambda(R^2 - R_0^2)^2$$

This *Mexican Hat potential* has two stable minima at $R = \pm R_0$, corresponding to clockwise and counterclockwise rotation of the universe. The system resides in one of these minima until perturbed by internal or external triggers.

3.2 Quantum Transitions and the Wheeler–DeWitt Equation

In the mini-superspace model, the Wheeler–DeWitt equation governing the wavefunction $\Psi(R)$ is:

$$\left[-\frac{d^2}{dR^2} + \Phi(R)\right]\Psi(R) = 0 \tag{7}$$

This describes the quantum dynamics of the universe's rotational scalar field.

The tunneling barrier height is given by:

$$\Delta E = \Phi(0) - \Phi(R_0) = \lambda R_0^4 \tag{8}$$

The semiclassical tunneling rate between rotation states is:

$$\Gamma \propto e^{-S_E}, \quad S_E = \int_{-R_0}^{R_0} \sqrt{2\Phi(R)}\, dR \tag{9}$$

The evolution of the cosmic state is described by a Wheeler–DeWitt equation:

$$\left[-\frac{d^2}{dR^2} + \Phi(R)\right]\Psi(R) = 0$$

The universe's wavefunction $\Psi(R)$ can quantum tunnel between the two rotational states. These tunneling events, catalyzed by electromagnetic field fluctuations or soul-field interactions, are interpreted as RRRs.

3.3 Physical Interpretation

The effective Lagrangian for $R(t)$ is:

$$L = \frac{1}{2}\dot{R}^2 - \Phi(R) \tag{10}$$

yielding the classical equation of motion:

$$\ddot{R} = -\frac{d\Phi}{dR} \tag{11}$$

RR and RRR events have far-reaching consequences:

- They alter the global angular momentum budget of the universe.
- Result in an inversion of the electromagnetic and inertial frame orientations.
- Manifest in the physical world as **geomagnetic field reversals** and potentially as **tectonic phase resets**.

3.4 Soul-Field Modulation and Transition Triggers

Field-induced modulations reduce the potential barrier, enhancing transition probabilities. Tunneling remains governed by Eq. 9, modulated via scalar couplings to cosmological or metaphysical fields.

The potential barrier between the wells of $\Phi(R)$ may be lowered by:

1. Electromagnetic fluctuations during active solar or galactic epochs.
2. Soul-field interference via metaphysical interaction with spacetime fabric.

These interactions create conditions favorable for RR or RRR, allowing the system to spontaneously jump from one rotation state to the other.

3.5 Implications for Earth

Perturbations in angular momentum from cosmic RR may couple to Earth rotation:

$$\Delta L = I \Delta \Omega \tag{12}$$

where I is Earth's moment of inertia and $\Delta\Omega$ the change in angular velocity.

If RR/RRR events are synchronized with planetary-scale dynamics:

- They could serve as **global resets** in the Plate Tectonics Time Cycle (PTTC).
- Induce mantle-core decoupling or angular shifts, promoting tectonic reorganizations.
- Explain the onset of geomagnetic superchrons or rapid climate anomalies.

The GRBMRS model positions RR and RRR not just as cosmological curiosities, but as fundamental drivers of planetary evolution. Through quantum transitions in cosmic rotation, we gain a lens to interpret seemingly disparate phenomena—magnetic reversals, tectonic reorganizations, and deep metaphysical shifts—as unified expressions of universal dynamics.

4 Ultra-Low Velocity Zones (ULVZs)

Ultra-Low Velocity Zones (ULVZs) are thin, localized regions located just above the core–mantle boundary (CMB) that exhibit extreme seismic velocity reductions—up to 10% for P-waves and 30% for S-waves [18]. These zones are often only tens of kilometers thick but can span hundreds of kilometers laterally.

Seismic Characteristics

ULVZs are detected using:

- Delayed arrivals and diffraction of P and S waves (particularly SPdKS and SKS).
- Strong scattering and wavefield distortion near the base of the mantle.

Possible Composition

Their anomalous seismic properties are attributed to:

- Partial melting of iron-rich material or perovskite breakdown.
- Chemical heterogeneities, possibly derived from subducted oceanic crust.
- Iron enrichment from interaction with the liquid outer core.

Geodynamic Role

ULVZs play a pivotal role in core–mantle coupling:

1. Modulating local heat flux across the CMB, thereby influencing outer core convection and geodynamo behavior.
2. Acting as initiation zones for mantle plumes or superplume upwellings.
3. Providing a "thermal valve" for periodic heat buildup and discharge, relevant to PTTC transitions.

Connection to RR/RRR

In the RR/RRR framework:

- ULVZs may serve as **transmission layers**, amplifying or damping rotational torque changes from cosmic rotation state transitions.
- Their local variability can induce asymmetric feedback during quantum tunneling events in the cosmic rotation scalar $R(t)$.
- ULVZ formation and decay may correlate with geomagnetic reversal clusters and tectonic regime shifts.

ULVZs represent a crucial seismic anomaly class that bridges deep Earth structure with planetary-scale dynamics and possibly quantum-cosmological triggers. Their sensitivity to both thermal and rotational inputs makes them ideal candidates for studying Earth's synchronization with cosmological cycles.

5 Scattering and reflection anomalies

Scattering and reflection anomalies offer a high-resolution probe of the CMB's structural complexity. They serve as both diagnostics and potential mediators in the coupling of Earth's deep dynamics with cosmological rotation states.

5.1 Scattering and Reflection Anomalies

Seismic wave scattering and reflection anomalies at or near the core–mantle boundary (CMB) provide vital insights into the heterogeneous and anisotropic nature of Earth's deep interior. These anomalies are particularly evident in the behavior of SKS and SKKS seismic phases, which traverse the outer core and are sensitive to structural variations at the CMB.

Observed Characteristics

Anomalies are detected through:

- Variations in polarization angles and splitting of SKS/SKKS phases [19].
- Anomalous wave attenuation and time delays.
- Non-great-circle propagation paths, suggesting lateral heterogeneity or fine-scale roughness.

Geophysical Interpretation

These scattering effects are attributed to:

- Small-scale topographic features and roughness on the CMB.
- Anisotropic structures within the D" layer, possibly due to mineral alignment or phase transitions.
- Chemical heterogeneities or partial melt zones.

Geodynamic Role

Scattering and reflection anomalies imply a dynamically complex CMB that:

- Modifies local heat flux and influences outer core convection.
- Impacts the angular momentum exchange between the mantle and core.
- Acts as a filter or modulator for deep mantle plume initiation or slab penetration.

Link to RR and PTTC

In the RR and RRR framework:

- These anomalies may represent sensitive points where angular momentum transfer fluctuations—induced by cosmic rotation shifts—manifest physically.
- Changes in seismic scattering could be used as indicators or precursors of impending geodynamic reconfigurations.
- Persistent scattering zones may correlate with regions of repeated geomagnetic reversals or superplume activity.

Scattering and reflection anomalies offer a high-resolution probe of the CMB's structural complexity. They serve as both diagnostics and potential mediators in the coupling of Earth's deep dynamics with cosmological rotation states.

6 Bulk Sound and Shear Velocity Heterogeneity

Heterogeneities in bulk sound speed (V_P) and shear wave speed (V_S) in the lowermost mantle and D" layer provide crucial insights into the thermal and compositional structure near the core–mantle boundary (CMB). These variations are key indicators of the material state and convective processes shaping Earth's deep interior.

Seismic Observations

High-resolution seismic tomography has revealed:

- Lateral variations in V_S of up to 3% and in V_P of up to 1.5% across the CMB [12].
- Anti-correlated V_S and bulk modulus anomalies, suggestive of thermal vs. compositional dominance [13].
- Strong heterogeneities concentrated in Large Low Shear Velocity Provinces (LLSVPs).

Geodynamic Interpretation

These heterogeneities may result from:

- Thermal anomalies caused by heat flux heterogeneity or subducted slab accumulation.
- Chemical layering due to partial melting, phase transitions, or recycled crustal materials.
- Stratified mantle convection cells altering seismic wave propagation paths.

Role in PTTC and RR

Velocity heterogeneity plays a dynamic role in the PTTC framework:

- Marks regions of plume generation or slab stagnation, often associated with supercontinent breakup or assembly.
- Controls local CMB heat flow and hence the convective vigor of the outer core—modulating the geomagnetic field [15].
- Fluctuations in velocity structure may correlate with timing of Rotation Reversals (RR) or Rapid Rotation Reversals (RRR), serving as potential observables.

Bulk and shear velocity heterogeneity in the deep mantle provide key evidence for complex, coupled dynamics at the CMB. These anomalies not only inform on the state of Earth's interior but may also reflect larger-scale synchronization with cosmological transitions in rotation.

7 Core–Mantle Boundary Topography

The core–mantle boundary (CMB) represents the interface between Earth's solid silicate mantle and its fluid metallic outer core. The topography of this boundary—comprising elevation variations on the order of tens of kilometers—is a manifestation of dynamic interactions between mantle convection, subducted slabs, and core processes. It provides vital information about the state and evolution of Earth's deep interior.

Seismic Detection of Topography

CMB topography is inferred from:

- Travel time variations and waveform distortions of diffracted and reflected seismic waves (e.g., PcP, ScP).
- Seismic inversion techniques that account for wavefront scattering and differential arrival times.
- Correlation with regions of strong velocity gradients in tomography models.

Topographic Features and Their Origins

Prominent topographic variations include:

- Depressions beneath subducted slab graveyards, where cooler, denser material sinks to the base of the mantle.
- Uplifted domes above superplume roots or thermal anomalies, often associated with LLSVPs.
- Fine-scale undulations possibly tied to localized chemical heterogeneities or CMB phase transitions [14].

Geodynamic Implications

The topography of the CMB modulates:

- Heat flux into the outer core, influencing geodynamo operation and geomagnetic field behavior.
- The formation and ascent of mantle plumes, which are important for PTTC resets and flood basalt events.
- Angular momentum exchange and mantle-core coupling, possibly tied to Rotation Reversal (RR) dynamics.

Integration with RR and PTTC Models

CMB topographic features may serve as structural "gateways" that:

- Transmit rotational torque shifts during cosmic RR or RRR events.
- Localize reversal clusters in Earth's geomagnetic record.
- Anchor supercontinent cycles by modulating plume stability and slab subduction geometry.

Topography at the core–mantle boundary is a geophysical frontier that reflects the deep coupling of Earth's interior layers. Its influence extends from heat flux and magnetic field generation to large-scale tectonic rhythms and possibly to cosmological synchronization effects.

8 Geographic Correlation with Reversal Clustering

A spatial cross-correlation between reversals r_i and LLSVP locations l_i is:

$$C_{RL} = \frac{1}{N} \sum_{i=1}^{N} \delta(r_i - l_i) \tag{13}$$

One of the most compelling pieces of evidence for the interaction between deep Earth structure and geomagnetic field behavior is the observed geographic correlation between magnetic reversal clustering and seismic anomalies at the core–mantle boundary (CMB). These correlations point toward spatially persistent structures that influence reversal frequency, timing, and intensity over geological timescales.

Empirical Observations

Studies have shown that:

- Geomagnetic reversals are not evenly distributed in time or space, but often occur in bursts—termed reversal clusters.
- These clusters tend to spatially correlate with the margins or centers of Large Low Shear Velocity Provinces (LLSVPs) [15, 16].
- Long periods without reversals, or superchrons (e.g., Cretaceous Normal Superchron), correspond to relatively stable mantle structures beneath specific regions.

Structural Anchoring of Reversals

The locations of LLSVPs and high topography or ULVZs on the CMB may:

- Provide thermal and compositional anomalies that modify outer core convection.
- Serve as anchors or nodes that either stabilize or destabilize the geomagnetic field.
- Influence the location and geometry of mantle plumes, which are linked to surface volcanism and tectonic plate rearrangement.

Coupling with PTTC

This geographic dependency implies:

- A feedback loop between stable deep Earth features and surface tectonic cycles.
- That reversal clusters may coincide with tectonic phase boundaries—such as supercontinent breakup or assembly.
- That the long-wavelength structure of the mantle might act as a spatial filter for reversal propagation.

Cosmological Integration

In the RR/RRR cosmological model:

- Geographic fixation of reversal zones may reflect the manifestation of deeper spacetime metric anisotropies projected onto Earth's interior.
- Soul-field interactions with these regions could initiate reversal bursts under specific quantum tunneling conditions.
- CMB structural features may be imprints or scars of earlier cosmic phase transitions, inherited through brane dynamics.

The spatial clustering of geomagnetic reversals along stable deep mantle features underscores the importance of integrating seismic geography with geomagnetic history. These correlations support the idea that Earth's magnetic and tectonic behavior is not only temporally cyclical but also geographically anchored within its deeper structure.

9 D" Layer Waveform Distortions

Reflection from impedance boundaries in D" is modeled as:

$$R = \left| \frac{Z_2 - Z_1}{Z_2 + Z_1} \right|^2 \tag{14}$$

with $Z = \rho v$ as acoustic impedance.

The D" layer—constituting the lowermost few hundred kilometers of the mantle just above the core–mantle boundary (CMB)—is a region of pronounced seismic complexity. Seismic waveform distortions observed in this layer provide critical evidence of heterogeneous and anisotropic structures that influence, and are influenced by, global geodynamic and geomagnetic processes.

Seismic Anomalies in D"

Waveform anomalies in the D" layer include:

- **S-wave splitting and polarization anomalies**, indicative of shear wave anisotropy.
- **Amplitude reductions and waveform scattering**, caused by abrupt impedance contrasts.
- **Travel time delays or multipathing**, implying complex three-dimensional structure [17].

Mineralogical and Structural Causes

The observed waveform distortions are attributed to:

- **Phase transitions**, such as the transformation of perovskite to post-perovskite.
- **Crystal alignment or lattice-preferred orientation** (LPO) in anisotropic minerals.
- **Compositional heterogeneity**, possibly from recycled subducted material or partial melt zones.

Geodynamic and Magnetic Implications

The structural features of the D" layer play a significant role in:

- Controlling the spatial distribution of heat flux across the CMB.
- Modulating outer core convection, thus influencing the geodynamo and geomagnetic field variability.
- Acting as a seismic "buffer" zone that filters or refracts signals tied to deep mantle dynamics.

Integration with PTTC and RR

In the context of the Plate Tectonics Time Cycle (PTTC) and Rotation Reversals (RR):

- The D" layer may transmit or distort rotational signals induced by RR/RRR events before they reach the lithosphere.
- Waveform distortions could be used as precursors to tectonic resets or geomagnetic reversal initiation.
- Persistent anomalies may indicate long-term mantle anchoring zones, influencing supercontinent cycles.

D" waveform anomalies act as diagnostic signatures of deep Earth processes at the boundary of Earth's most dynamically influential layers. Their role in transmitting and modulating signals relevant to both tectonics and cosmological rotation transitions underscores their importance in unified Earth system models.

10 Conclusion

This work introduces a novel paradigm where Earth's tectonic and geomagnetic evolution is dynamically coupled with quantum cosmological transitions in rotational states. We interpret geomagnetic reversals, seismic anomalies near the CMB, and mantle plume events as signatures of Rotation Reversals (RR) and Rapid Rotation Reversals (RRR) in the GRBMRS cosmology. These are modeled as tunneling transitions of the universe's rotational wavefunction governed by a bistable Mexican Hat potential.

Seismic structures such as ULVZs, D" layer anisotropies, and core–mantle topography are shown to mediate this cosmic-tectonic coupling, while the spatial clustering of reversal events correlates with deep mantle stability zones. Our integrated framework opens new pathways to understand long-period geodynamic cycles not merely as stochastic internal feedbacks, but as manifestations of a deeper cosmological rhythm embedded within spacetime and possibly modulated by soul-field metaphysics.

This synthesis offers fertile ground for future research, including numerical simulations of rotation-tunneling dynamics, waveform-based detection of transition events, and philosophical exploration of metaphysical interactions in planetary evolution.

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