Coronal Topology, Magnetic Field Reversal, and the Eternal Sun - III

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Abstract

This paper presents an extended formulation of the Eternal Sun Model (ESM), situating solar dynamics within a closed spacetime manifold of topology $S^3 \times S^1$. Building upon prior work addressing the solar neutrino problem and coronal heating anomaly, this paper develops a deeper analysis of the origin of solar magnetic fields, their periodic reversal, and the morphological features of the corona—namely, coronal holes and streamers. The hypothesis advanced here is that the magnetic and thermal anomalies of the solar atmosphere are best explained by radiation recurrence and energy looping in a cyclic spacetime, where returning solar radiation is partially blocked or re-routed by large-scale matter configurations in the universe. Coronal holes are interpreted as interruptions in the radiation-return topology, while streamers are viewed as coherent zones of returning energy. A complete thermodynamic and relativistic reformulation is proposed, incorporating flux balance, entropy closure, and causal loop geometry. The paper also suggests ways to reconcile magnetic field evolution with closed timelike curves and electromagnetic standing wave structures. This model has implications not only for solar physics but for broader questions of cosmology, energy conservation, and metaphysical time.

1 Introduction

The Sun remains one of the most enigmatic bodies in astrophysical inquiry. Despite extensive modeling of its internal fusion dynamics, the outermost regions—the corona and heliosphere—continue to challenge scientific understanding. The solar corona exhibits a counterintuitive thermal inversion, where the temperature increases with radial distance from the core, reaching over 1.5×10^6 Kelvin [5]. Simultaneously, the Sun undergoes magnetic polarity reversals approximately every eleven years, a process not fully understood

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despite the application of solar dynamo theory [2]. Moreover, the phenomenon of coronal holes—dark, cool regions of the corona where magnetic field lines open into interplanetary space—and streamers, bright plasma structures aligned with closed field lines, suggest a more complex topological and energetic structure than standard models allow.

The paper [3] presents the original formulation of the Eternal Sun Model. This work proposes that the high-temperature solar corona can be explained by closed spacetime topology, specifically invoking a universe of the form $S^3 \times S^1$. The author develops the idea that radiative flux from the Sun follows a causal loop, returning after a cosmic time delay and delivering energy to the corona. It ad. This implies a closed-loop system of energy exchange.

The second paper [4], extends the conceptual framework by formulating the mathematical infrastructure underpinning the Eternal Sun Model. It explores tensor fields and spacetime periodicity, presenting recurrence equations governing electromagnetic flux under topological constraints. The treatment also introduces causal loop energy balance, and reinterprets solar surface features such as sunspots and coronal hol. This implies a closed-loop system of energy exchange.

This paper builds upon the Eternal Sun Model (ESM), which proposes that solar energy is not solely generated by internal fusion but is instead sustained by radiation that loops back via closed spacetime geometries [7]. In such a framework, energy emitted from the solar surface returns after a cosmic loop, leading to equilibrium at the corona rather than requiring continuous internal generation. This paper further extends the ESM to account for solar magnetic field generation, cyclic reversal, and the morphology of coronal features. It proposes that coronal holes are indicative of absorption or scattering events along the returning radiation paths, effectively interrupting the loop and creating zones of flux depletion.

2 Closed Spacetime Topology and the Eternal Sun Model

The Eternal Sun Model finds mathematical structure in solutions to Einstein's field equations that admit closed timelike curves (CTCs). In particular, the Segal model with $S^3 \times S^1$ topology represents a universe with closed spatial and temporal dimensions [7]. In such a model, radiation emitted at a point on the Sun at time t returns after a finite delay N, forming a closed causal loop. The line element for such a spacetime may be defined as:

$$ds^2 = -dt^2 + R^2 \left(d\chi^2 + \sin^2 \chi (d\theta^2 + \sin^2 \theta d\phi^2) \right), \tag{1}$$

where R is the radius of curvature of the spatial 3-sphere S^3, and the time dimension is compactified such that $t \equiv t + N$.

The returning energy flux $F_r(t)$ can be modeled as a function of the outgoing flux $F_{out}(t - N)$ and a retention efficiency factor η that accounts for losses or redirection:

$$F_r(t) = \eta F_{out}(t - N), \tag{2}$$

with $\eta \leq 1$. In perfect equilibrium, $\eta \to 1$ and the returning flux matches the outgoing flux:

$$F_r(t) = F_{out}(t). \tag{3}$$

These conditions permit a radiation recycling model where net energy loss is zero:

$$Q_{net} = Q_{fusion} - Q_{return} \to 0. \tag{4}$$

This suggests that solar energetics can be self-sustaining in a thermodynamically closed universe.

3 The Solar Magnetic Field and Its Reversal: Beyond the Dynamo Hypothesis

The Sun's magnetic field is a dynamic and cyclic structure that undergoes a polarity reversal approximately every 11 years, forming the foundation of the solar activity cycle. According to the standard solar dynamo theory, this magnetic field originates from differential rotation and turbulent plasma motion in the convection zone. However, this theory remains incomplete in explaining several key aspects, including the coherence of global field reversals and the initial conditions required for sustained dynamo action [1, 2].

In the Eternal Sun Model, an alternative origin of the solar magnetic field is proposed. Within a closed spacetime geometry, electromagnetic radiation emitted by the Sun can loop back and re-interact with the outer plasma layers. These returning fluxes are not only thermal but may also include polarized electromagnetic modes, capable of inducing surface and subsurface current systems. If the spacetime curvature allows for the formation of quasi-standing electromagnetic wave modes, a large-scale field may emerge naturally.

Consider Maxwell's equations in curved spacetime. In the presence of a background metric $g_{\mu\nu}$, the field tensor $F^{\mu\nu}$ satisfies the covariant form:

$$\nabla_\nu F^{\mu\nu} = \mu_0 J^\mu, \tag{5}$$

where ∇_ν denotes the covariant derivative and J^μ is the four-current. In a compact spacetime, periodic boundary conditions apply:

$$F^{\mu\nu}(t + N) = F^{\mu\nu}(t). \tag{6}$$

These boundary conditions support the hypothesis of a field configuration that recurs identically over time, allowing the magnetic field to undergo smooth transitions and reversals. The feedback loop involving returning radiation modulated by the plasma conditions could act as a form of a self-regulating dynamo, where magnetic fields reverse due to phase interference in the returning electromagnetic field.

Furthermore, in this model, the magnetic cycle period T_{mag} can be linked to the geometric time loop period N via harmonic resonance:

$$T_{mag} = \frac{N}{k}, \tag{7}$$

where k is a small integer determined by the mode structure of the spacetime geometry. If $N = 5000$ years, as proposed in the Brahma Kumaris cosmology, then $k = 454$ yields a period of approximately 11 years, remarkably close to the observed solar magnetic cycle.

Thus, the Eternal Sun Model provides a coherent geometric basis for the solar magnetic field and its reversals, avoiding the need for deep convection zone turbulence as the primary cause.

4 Coronal Holes and Streamers: Thermodynamic and Geometric Interpretations

Coronal holes and streamers are large-scale features observed in the solar corona. In the standard model, coronal holes are regions where magnetic field lines are open, allowing solar wind to escape, whereas streamers are associated with closed magnetic loops trapping high-density plasma. These features are central to the understanding of solar wind generation and magnetic topology [5, 2].

In the Eternal Sun Model, we reinterpret these structures as thermodynamic and geometric manifestations of returning or disrupted radiation flux. Specifically, coronal holes are proposed to be regions where the closed spacetime radiation loop is broken or obstructed due to the presence of absorbing matter in the universe. In contrast, streamers represent successful reentry pathways for returning radiation, resulting in localized energy density enhancement.

Let the returning flux be direction-dependent, denoted $F_r(t, \theta, \phi)$. In regions where spacetime is perturbed by absorption or scattering (e.g., interstellar dust, plasma clouds), the local efficiency $\eta(\theta, \phi)$ drops below unity:

$$F_r(t, \theta, \phi) = \eta(\theta, \phi) F_{out}(t - N), \tag{8}$$

with $\eta(\theta, \phi) \ll 1$ in the direction of a coronal hole. Consequently, the equilibrium temperature in these regions is lower, as modeled by:

$$T_c(\theta, \phi) = \left(\frac{F_r(t, \theta, \phi)}{\sigma} \right)^{1/4}, \tag{9}$$

where σ is the Stefan-Boltzmann constant. In contrast, high-η zones lead to enhanced coronal brightness and streamer formation. Therefore, the spatial heterogeneity of the corona can be directly attributed to the topological and absorptive variations in the surrounding cosmic medium.

This interpretation also aligns with observational data showing that coronal holes are sources of fast solar wind, which in this model, correspond to radiative escape zones rather than magnetic leakages alone. The implications are profound: variations in the cosmic radiation-absorption field determine the morphology of solar coronal features, allowing a thermodynamic mapping of cosmic topology through coronal imaging.

5 Mathematical Formalization of Radiation Suppression and Feedback

In the Eternal Sun Model (ESM), the solar corona is proposed to be sustained not by ongoing thermonuclear reactions in the solar core, but through the continuous return of radiative energy via a closed spacetime topology. This hypothesis requires a mathematical framework to model both the recurrence of energy flux and the conditions under which this flux may be partially suppressed or absorbed by intervening cosmic media. In this section, we develop a quantitative model for such radiation dynamics.

Let $F_{out}(t, \theta, \phi)$ represent the radiative flux emitted from the solar surface at time t in the direction specified by spherical coordinates (θ, ϕ). Due to the closed nature of spacetime in the $S^3 \times S^1$ topology [7], this flux returns to the Sun after a fixed cosmic loop time N, altered by absorption or scattering encountered in the intervening path. The returning flux can then be written as:

$$F_r(t, \theta, \phi) = \eta(\theta, \phi) F_{out}(t - N, \theta, \phi), \tag{10}$$

where $\eta(\theta, \phi)$ is the directional efficiency factor satisfying $0 \leq \eta(\theta, \phi) \leq 1$. This function encapsulates the suppression of energy due to cosmic dust, plasma interactions, and gravitational lensing along the closed geodesic. In regions where $\eta \to 0$, radiation fails to return, which in the ESM corresponds to the formation of coronal holes.

The energy balance at the solar surface then becomes:

$$F_{net}(t, \theta, \phi) = F_{out}(t, \theta, \phi) - F_r(t, \theta, \phi). \tag{11}$$

To maintain a thermodynamically stable corona, this net flux must vanish or be compensated by a dynamic field reconfiguration. Assuming steady-state recurrence in high-efficiency regions, one obtains the local equilibrium condition:

$$F_{out}(t, \theta, \phi) = \eta(\theta, \phi) F_{out}(t - N, \theta, \phi). \tag{12}$$

Iterating this expression yields a recurrence relation across multiple cosmic cycles:

$$F_{out}(t, \theta, \phi) = \eta^k(\theta, \phi) F_{out}(t - kN, \theta, \phi), \tag{13}$$

which implies exponential decay in radiative amplitude in low-η directions and stable periodic return in high-η domains.

This feedback process influences local coronal temperature through the Stefan-Boltzmann law. The temperature $T_c(\theta, \phi)$ of the coronal plasma shell is given by:

$$T_c(\theta, \phi) = \left(\frac{F_r(t, \theta, \phi)}{\sigma} \right)^{1/4}, \tag{14}$$

where σ is the Stefan-Boltzmann constant. This leads to significant latitudinal and longitudinal variations in coronal temperature, correlating with observed features such as coronal holes and streamers [5].

To model the suppression dynamically, we introduce a cosmic opacity field $\kappa(x^\mu)$ that affects the energy return along the spacetime geodesic γ from emission point P to reception point Q. Then η becomes a path-dependent exponential:

$$\eta(\theta, \phi) = \exp\left(-\int_\gamma \kappa(x^\mu)ds\right), \tag{15}$$

where ds is the line element along γ. This formulation allows κ to represent cosmological structures such as interstellar clouds, dark matter halos, or gravitational wells, which alter the return flux's amplitude and phase.

If we include polarization effects, the field tensor $F^{\mu\nu}$ undergoes transformation due to scattering:

$$F_r^{\mu\nu}(t) = \eta_{\alpha\beta}^{\mu\nu} F_{out}^{\alpha\beta}(t - N), \tag{16}$$

where $\eta_{\alpha\beta}^{\mu\nu}$ encodes tensorial suppression factors due to spacetime curvature and media anisotropy. The resulting structure influences not only intensity but also the vector orientation of returned electromagnetic fields, potentially leading to observed features in solar magnetic topology.

This mathematical formalization unifies radiation thermodynamics, cosmic geometry, and energy equilibrium in a single feedback model, offering a coherent alternative to the internal-fusion paradigm. The approach also links directly to topological cosmology, allowing predictions about cyclic energy recurrence that can be matched with coronal imaging data and solar activity cycles.

6 Brightness of the Night Sky as Diffused Returning Solar Radiation

One of the most enduring puzzles in astrophysical theory is the faint but measurable brightness of the night sky. While traditional cosmology resolves this through assumptions of an expanding universe and cosmic redshift, the Eternal Sun Model (ESM) offers a fundamentally different interpretation. In this model, the brightness of the night sky is not the accumulated light of distant galaxies but rather the redistributed and phase-diluted radiation originally emitted by the Sun. This radiation, having . This implies a closed-loop system of energy exchange.

In the standard cosmological framework, the darkness of the night sky is classically associated with Olbers' paradox, which asks: if the universe is infinite, eternal, and uniformly filled with stars, why is the sky not ablaze with light? The Big Bang model resolves this by asserting a finite age for the universe and a redshift of distant light beyond the visible spectrum [12]. However, the Eternal Sun Model offers an alternative explanation rooted in general relativistic topology. Here. This implies a closed-loop system of energy exchange.

Let $F_{out}(t, \theta, \phi)$ be the solar radiation emitted at time t in direction (θ, ϕ). After completing a closed loop through spacetime with duration N, this radiation returns with reduced intensity due to absorption and scattering. The observed sky brightness I_{sky} at any point on Earth can be described as an integral over the sky dome of all returning fluxes:

$$I_{sky} = \frac{1}{4\pi} \int_\Omega \eta(\theta, \phi) F_{out}(t - N, \theta, \phi) d\Omega, \tag{17}$$

where $\eta(\theta, \phi)$ is the cosmic transmission function and $d\Omega$ is the differential solid angle. This formulation implies that the night sky brightness is the averaged sum of solar radiation from all directions after a complete spacetime recurrence.

A critical implication of this hypothesis is that the brightness of the night sky should exhibit a low-level isotropy, with minor anisotropies reflecting variations in $\eta(\theta, \phi)$ caused by intervening matter and spacetime curvature. This aligns with the Cosmic Optical Background (COB) measurements, which reveal a residual isotropic background light [13]. In the ESM, the COB is thus reinterpreted as a thermodynamic remnant of prior solar radiation, rather than extragalacti. This implies a closed-loop system of energy exchange.

The spectral energy distribution of the night sky can also be analyzed in this framework. Let $\mathcal{S}_\lambda(\theta, \phi)$ represent the spectral flux density of returning radiation per unit wavelength. Then the observed spectral irradiance is given by:

$$I_\lambda = \frac{1}{4\pi} \int_\Omega \eta(\theta, \phi) \mathcal{S}_\lambda(t - N, \theta, \phi) d\Omega. \tag{18}$$

In a fully transparent universe $\eta = 1$, and the spectral irradiance would be comparable to solar values, leading to a visibly bright sky at night. However, given realistic values $\eta \ll 1$, the resulting I_λ corresponds to the faint glow observed in dark-sky environments. This explains the measured magnitude of sky brightness in deep-sky surveys without invoking hypothetical energy sources or requiring a cosmological redshift interpretation.

Moreover, this returning radiation could influence nocturnal biological rhythms, atmospheric chemistry, and even surface-level photonic interactions on Earth. Since this radiation is out of phase and spread across the celestial sphere, it escapes detection as direct sunlight, yet contributes an ambient photonic field. This background field may also interact with low-energy particles in Earth's magnetosphere, offering new interpretations for upper-atmosphere phenomena such as noctilucent clouds or weak. This implies a closed-loop system of energy exchange.

Finally, the ESM allows for the temporal mapping of sky brightness fluctuations across solar cycles. Because $F_{out}(t - N)$ varies cyclically, so too must I_{sky}. Observational campaigns could be designed to measure this low-level cyclic variation, providing a testable prediction distinct from the conventional cosmological model. The brightness of the night sky, then, becomes a dynamic indicator of temporal solar evolution under a closed geometric model.

In this framework, Olbers' paradox is not only resolved, but also transformed. The night sky is not dark because the universe is expanding or because light is redshifted into oblivion. It is dimly bright because radiation once emitted returns, redistributed, diluted, and softened by cosmic geometry. The night sky becomes a quiet echo of the Sun's prior self, offering insight not only into astrophysical dynamics but into the deep structure of time and causality.

7 Ionization through Colliding Solar Wind Streams in the Eternal Sun Model

The Eternal Sun Model (ESM), with its hypothesis of returning radiation and particle fluxes through closed spacetime geometries, introduces an unorthodox yet compelling explanation for the formation of highly ionized atomic species in the solar wind. Particularly, the abundant observation of ions such as Fe^{XII} and Fe^{XIII} in the outer corona and heliosphere can be naturally accounted for by the process of high-energy collisions between outgoing and returning solar wind particl. This implies a closed-loop system of energy exchange.

In conventional solar physics, ionization states of heavy ions like Fe are attributed to local heating, typically explained by wave dissipation, magnetic reconnection, or microflare activity. These mechanisms, while plausible, often fail to maintain the observed charge states over vast radial distances [5, 14]. The ESM offers a mechanism that is both distributed and persistent: the collision of solar wind ions with their returning counterparts along radial geodesics define. This implies a closed-loop system of energy exchange.

Let the velocity of the outgoing solar wind be denoted by v_{out} and the velocity of the returning flux by v_{in}. The relative velocity in the Earth's rest frame, assuming approximately equal magnitudes, becomes:

$$v_{\text{rel}} = v_{\text{out}} + v_{\text{in}} \approx 1000 \text{ km/s}. \tag{19}$$

Given the reduced mass μ of two colliding protons or a proton and Fe nucleus, the center-of-mass kinetic energy per collision is:

$$E_{\text{rel}} = \frac{1}{2}\mu v_{\text{rel}}^2. \tag{20}$$

For $\mu \sim m_p \approx 1.67 \times 10^{-27}$ kg, we obtain:

$$E_{\text{rel}} \approx \frac{1}{2} \cdot 1.67 \times 10^{-27} \cdot (1 \times 10^6)^2 \approx 8.35 \times 10^{-15} \text{ J} \approx 52 \text{ eV}. \tag{21}$$

When heavier ions like Fe^{+q} are involved, with reduced masses $\mu \gg m_p$, and velocities consistent with higher kinetic profiles (up to 1600 km/s), the resulting collision energies can exceed 300 eV. These values correspond closely with ionization potentials required for transitions to Fe^{XII} (285 eV) and Fe^{XIII} (330 eV) [15]. Therefore, the ESM inherently provides a continuous, geometry-enabled mechanism for such ion production.

Moreover, this process is not localized to active regions but is instead distributed radially across the heliosphere, thus accounting for the presence of high-ionization states even in the fast solar wind emerging from polar coronal holes. This directly addresses a limitation in reconnection-based models, which struggle to account for uniformly observed charge states in both fast and slow solar wind flows [16].

Additionally, the resultant ions produced by such high-energy collisions may emit in extreme ultraviolet (EUV) and soft X-ray bands. Observations from instruments aboard SOHO and Hinode have repeatedly identified Fe^{XII} and Fe^{XIII} emission lines at 195 Å and 202 Å, respectively [17]. In the ESM, these lines emerge not from localized magnetic confinement heating but from an extended shell of interaction where returning and outgoing flows intersect.

We define the volumetric collision rate $\mathcal{R}$ as:

$$\mathcal{R} = n_{\text{out}} n_{\text{in}} \sigma(v_{\text{rel}}) v_{\text{rel}}, \tag{22}$$

where n_{out} and n_{in} are the number densities of outgoing and returning ions, and $\sigma(v_{\text{rel}})$ is the velocity-dependent ionization cross-section. The persistence of high ion densities in the solar wind can be maintained if $\mathcal{R}$ is significant in regions where returning flux density n_{in} is non-trivial.

In summary, the Eternal Sun Model naturally supports a collision-driven ionization process for heavy ions in the corona and solar wind. This mechanism not only aligns with the energy thresholds for known ionic species but also explains their spatial distribution and spectral signatures without invoking highly localized and fine-tuned reconnection events. Future missions like Solar Orbiter and Parker Solar Probe may be used to detect these head-on collision zones indirectly by mapping fine anisotropies in. This implies a closed-loop system of energy exchange.

8 Spicule Formation through Advanced–Retarded Solar Flux Interactions

In classical electrodynamics, the decomposition of fields into retarded and advanced potentials has long been a powerful tool in analyzing causal and acausal radiative interactions, most notably in the Wheeler–Feynman absorber theory and Dirac's time-symmetric formulation. Within the Eternal Sun Model (ESM), a similar division can be drawn between the outgoing solar radiation and wind, referred to as the "retarded flux," and the returning flux through topologically closed spacetime loops, dubbed the "a. This implies a closed-loop system of energy exchange.

Spicules are narrow, jet-like plasma ejections observed at the solar limb and within the chromosphere. They reach altitudes between 5,000 and 10,000 km and display lifetimes of several minutes [18]. Despite over a century of observation, their precise origin remains unresolved within standard solar models. The ESM introduces a novel mechanism rooted in the interaction between retarded and advanced fluxes, leading to a standing field or interference zone at chromospheric heights, from wh. This implies a closed-loop system of energy exchange.

We define the total radiative-kinetic field $\Phi(x^\mu)$ as a superposition of the retarded and advanced contributions:

$$\Phi(x^\mu) = \Phi_{\text{ret}}(x^\mu) + \Phi_{\text{adv}}(x^\mu), \tag{23}$$

where each Φ includes energy-momentum and plasma flow vectors. The interaction energy density U_{int} between the two fields, especially when their directions oppose, can be expressed as:

$$U_{\text{int}} = \epsilon_0 \Phi_{\text{ret}}(x^\mu) \cdot \Phi_{\text{adv}}(x^\mu), \tag{24}$$

assuming scalar product interactions in Minkowski-like local patches of curved spacetime. Regions where Φ_{ret} and Φ_{adv} are antiparallel will yield negative interaction energy densities, potentially leading to local plasma instabilities.

A further modeling layer can be introduced using pressure gradients. Let P_{ret} and P_{adv} be the pressure fields associated with the respective fluxes. Then the resulting vertical acceleration a_z of chromospheric plasma can be approximated by:

$$a_z = -\frac{1}{\rho}\frac{\partial}{\partial z}(P_{\text{ret}} + P_{\text{adv}}), \tag{25}$$

where ρ is the local mass density. At heights where constructive or destructive pressure interference occurs, plasma may be lifted rapidly into the upper chromosphere or low corona, forming a spicule.

This mechanism also provides a thermodynamic context. The effective temperature gradient created by overlapping fluxes enhances conductive and radiative instabilities. In regions of constructive flux overlap, localized heating can exceed chromospheric equilibrium, prompting vertical expulsion of ionized matter.

Observationally, spicules tend to align with magnetic field lines, indicating magnetohydrodynamic (MHD) coupling. The advanced–retarded flux model does not contradict this but rather complements it, suggesting that magnetic guidance can co-exist with flux-driven initiation. Indeed, MHD simulations with source-driven perturbations have reproduced spicule-like jets [19], but often require arbitrary velocity drivers. The ESM offers a physical origin for these drivers without ad hoc assumpti. This implies a closed-loop system of energy exchange.

Moreover, the spatio-temporal scales of spicules match well with the estimated interference length and time scales of advanced and retarded fluxes. For a closed loop recurrence time $T \sim 11$ years and chromospheric scale heights $H \sim 2,000$ km, a local phase interference condition could be achieved periodically, leading to cyclical increases in spicule activity. This may help explain why spicule density and occurrence rate vary over the solar cycle [20].

We may define a spicular formation criterion via a threshold condition on the energy density:

$$U_{\text{int}} > U_{\text{crit}}, \tag{26}$$

where U_{crit} is the local threshold needed to overcome gravitational binding and atmospheric stratification. When this criterion is satisfied in localized chromospheric regions, vertical jets form rapidly and decay as the advanced–retarded overlap phase subsides.

In summary, spicule formation in the ESM arises naturally from interaction zones between retarded (outgoing) and advanced (returning) solar fluxes. This mechanism offers a thermodynamically and geometrically grounded explanation that aligns with both high-resolution solar observations and numerical modeling. It avoids the need for finely-tuned magnetic reconnection or artificial boundary conditions and instead attributes spicule emergence to a broader topological structure of spacetime radiation flow.

9 Origin and Reversal of Solar Magnetic Fields in the Eternal Sun Model

The origin of the Sun's magnetic field and its periodic reversal every eleven years remains one of the most profound and unresolved questions in solar physics. Standard models attribute the magnetic field to a hydromagnetic dynamo operating within the tachocline—a shear layer between the radiative interior and the convective outer envelope [21]. This model invokes differential rotation and turbulent plasma motions to stretch and fold magnetic field lines, regenerating the field ove. This implies a closed-loop system of energy exchange.

However, these dynamo models struggle to explain several observations: the high regularity of the solar cycle, simultaneous polar reversals across hemispheres, and the global coherence of the process despite hemispheric asymmetries in sunspot migration. Moreover, they offer limited physical insight into the absolute orientation of the magnetic field and why reversals should occur with such temporal precision. Within the Eternal Sun Model (ESM), a new perspective arises, wherein the topology of spaceti. This implies a closed-loop system of energy exchange.

We begin by defining the net magnetic field at any point in the solar interior or atmosphere as a combination of a forward-in-time "retarded" component and a returning "advanced" component:

$$\vec{B}(t, \vec{x}) = \vec{B}_{\text{ret}}(t, \vec{x}) + \vec{B}_{\text{adv}}(t - N, \vec{x}), \tag{27}$$

where $N \approx 11$ years corresponds to the phase delay due to a full spacetime recurrence loop. These fields represent the contributions of outgoing and incoming charged plasma flows within a closed manifold geometry. The advanced magnetic field $\vec{B}_{\text{adv}}$ carries not just energy but also helicity and orientation from the Sun's past state.

The magnetic helicity, a conserved quantity in ideal magnetohydrodynamics (MHD), is given by:

$$\mathcal{H}(t) = \int_V \vec{A}(t, \vec{x}) \cdot \vec{B}(t, \vec{x}) \, d^3x, \tag{28}$$

where $\vec{A}$ is the vector potential such that $\vec{B} = \nabla \times \vec{A}$. In the ESM, the helicity evolves as an interference term between advanced and retarded components:

$$\mathcal{H}(t) = \int_V \left[\vec{A}_{\text{ret}} + \vec{A}_{\text{adv}} \right] \cdot \left[\vec{B}_{\text{ret}} + \vec{B}_{\text{adv}} \right] d^3x. \tag{29}$$

This expansion introduces cross-terms that can constructively or destructively interfere, causing periodic reversals in the net helicity and hence the global magnetic orientation. When the returning flux is approximately antiparallel to the outgoing flux, the resulting net magnetic field diminishes and flips its sign.

Observations confirm that the polar magnetic field weakens significantly before a reversal and then reestablishes with opposite polarity [22]. This phenomenon aligns with the ESM, in which destructive interference between $\vec{B}_{\text{ret}}$ and $\vec{B}_{\text{adv}}$ would momentarily drive the net field toward zero before inverting. Additionally, the simultaneous reversal across solar

hemispheres, despite the spatial separation of sunspot activity, suggests a globally coherent mechani. This implies a closed-loop system of energy exchange.

The standard Parker dynamo wave model introduces the idea of magnetic field belts drifting toward the equator, but it offers no definitive reason for the periodicity. In contrast, the ESM treats this as a fundamental outcome of the spacetime geometry itself. Let T_{rev} denote the reversal period, and T_{loop} the spacetime recurrence time. Then the model implies:

$$T_{\text{rev}} \approx T_{\text{loop}} = \oint_{\gamma} d\tau, \tag{30}$$

where the integral is taken over a closed geodesic γ in spacetime and τ is the proper time of the field-bearing plasma. This suggests that the field reversal is not simply a product of local plasma dynamics, but a manifestation of global geometric recurrence.

Additionally, the interaction between advanced and retarded magnetic field lines could give rise to observed phenomena such as magnetic field line tangling, reconnection, and the appearance of twisted loops or sigmoid structures in the corona. These may be understood as interference fringes or phase nodes in the vector field configuration arising from this dual-component structure.

The Eternal Sun Model therefore offers a compelling alternative to classical dynamo theories. It unifies the periodicity, global coherence, and spatial simultaneity of magnetic reversals under a geometric and topological principle. Moreover, it predicts that the field reversal must be linked to all solar processes coupled to flux return, including solar flares, coronal mass ejections, and solar cycle modulation of solar irradiance. Future studies may test these predictions using helioseismology and ne. This implies a closed-loop system of energy exchange.

10   Comparative Analysis of Solar and Terrestrial Magnetic Field Reversals

The magnetic fields of both the Sun and the Earth undergo polarity reversals, yet the timescales, mechanisms, and regularities associated with these reversals differ significantly. Understanding these differences not only deepens insight into their respective internal dynamics but also illuminates the influence of global geometry and feedback structures. In this section, we present a comparative analysis of solar and terrestrial magnetic reversals from both classical and Eternal Sun Model (ESM) persp. This implies a closed-loop system of energy exchange.

The solar magnetic field is widely attributed to a dynamo process in the tachocline, the shear zone between the Sun's radiative and convective layers [21]. The key drivers include differential rotation, meridional circulation, and turbulent convection. This system generates toroidal and poloidal magnetic field components that undergo regular transformation and regeneration. Observations demonstrate that the solar field reverses its polarity approximately every 11 years, corresponding. This implies a closed-loop system of energy exchange.

In contrast, the Earth's magnetic field is sustained by the geodynamo within the fluid outer core, composed primarily of iron and nickel. The flow of electrically conductive material under the influence of Coriolis forces and thermal gradients produces a persistent but

fluctuating dipolar field. Unlike the Sun, the Earth's magnetic reversals are not periodic. Instead, they occur stochastically over timescales ranging from 100,000 to several million years [23]. The causes behind these reve. This implies a closed-loop system of energy exchange.

In terms of dynamics, solar magnetic field reversals are synchronized globally, with both poles flipping within a short temporal window. The Sun's magnetic field also exhibits clear pre-reversal weakening, followed by a complete inversion of the polar field. The entire cycle is highly reproducible. In the Earth's case, the reversal process often involves transitional states with low field intensity and multipolarity. The geomagnetic field can even exhibit temporary excursions—partial, aborted reversa. This implies a closed-loop system of energy exchange.

From a modeling perspective, the Earth's dynamo is treated through numerical magnetohydrodynamic simulations, which show irregular reversal behavior depending on boundary conditions and flow patterns [24]. On the solar side, the Babcock-Leighton model, which emphasizes surface magnetic flux transport and subsurface shearing, underpins many modern solar dynamo models. However, these explanations often invoke complex, parameter-sensitive feedback systems to maintain periodicity.

In the Eternal Sun Model, the solar reversal is explained as a topological phenomenon. The Sun emits retarded magnetic flux $\vec{B}_{\mathrm{ret}}(t)$, which propagates outward. Due to the closed geometry of spacetime, this flux returns as an advanced field $\vec{B}_{\mathrm{adv}}(t - N)$ after a cycle of duration $N \approx 11$ years. The superposition of these fields is given by:

$$\vec{B}_{\mathrm{net}}(t) = \vec{B}_{\mathrm{ret}}(t) + \vec{B}_{\mathrm{adv}}(t - N), \tag{31}$$

and the global field reverses when $\vec{B}_{\mathrm{adv}}$ overtakes $\vec{B}_{\mathrm{ret}}$ in phase and orientation. This creates a periodic field inversion without requiring stochastic or chaotic inputs. In this framework, the regularity of the solar cycle arises naturally from spacetime geometry.

No such mechanism is evident for the Earth. The planet does not participate in closed-loop flux propagation in the same geometric sense, and hence lacks a built-in recurrence. As a result, its reversal behavior must emerge from the internal dynamics of the fluid core, making it inherently more random and variable. The magnetic helicity $\mathcal{H}$, defined as:

$$\mathcal{H}(t) = \int_V \vec{A}(t, \vec{x}) \cdot \vec{B}(t, \vec{x}) \, d^3x, \tag{32}$$

evolves smoothly in the solar case due to interference effects between the two flux components. For the Earth, the evolution of $\mathcal{H}(t)$ is more chaotic and driven by thermal and compositional convection within the outer core.

The implications of this comparison are profound. The solar magnetic cycle is a predictable, global, and geometrically grounded process. The terrestrial magnetic reversal is emergent, stochastic, and dependent on complex fluid behavior. The ESM offers a novel lens to understand solar regularity, while emphasizing the fundamentally different nature of planetary dynamo systems.

11 Structure and Extension of the Solar Corona in the Eternal Sun Model

One of the most enduring puzzles in solar astrophysics concerns the anomalous nature and extraordinary extent of the solar corona. The corona is an ionized plasma atmosphere that extends outward from the solar surface up to two to three solar radii, often even more under the influence of solar wind acceleration and heliospheric structures. With temperatures exceeding one million Kelvin, the solar corona presents a paradox: it is far hotter than the underlying photosphere, which maintains a temperatu. This implies a closed-loop system of energy exchange.

In the conventional solar model, the coronal heating problem has attracted various theoretical proposals. These include the dissipation of Alfvén waves, magnetic reconnection events, and the accumulation of energy through nanoflares [25]. Alfvén waves are capable of transporting energy from the solar interior into the corona, where it may dissipate via viscosity or nonlinear interactions. Magnetic reconnection involves the realignment of field lines in current sheets, releasing potentia. This implies a closed-loop system of energy exchange.

However, these mechanisms do not inherently explain the corona's radial extent or why its temperature profile remains elevated over such distances. The standard MHD models offer limited insight into how the energy delivery is sustained at multiple solar radii without falling off sharply due to geometrical spreading and radiative cooling. Moreover, while magnetic structures such as streamers and loops are clearly observed, their origin and coherence remain challenging to simulate at full coronal scal. This implies a closed-loop system of energy exchange.

In the Eternal Sun Model (ESM), a different mechanism is proposed—one that stems not from local plasma instabilities, but from the global geometric topology of spacetime. In this view, the solar output is not radiating into an infinite empty vacuum, but instead propagates through a closed manifold where energy fluxes loop and return. These returning fluxes, described as "advanced" fields, interact with the outgoing "retarded" fluxes, forming an extended zone of interference.

We denote the total local energy density in the corona as $U_{\mathrm{cor}}(r,t)$, which is the sum of contributions from retarded and advanced components:

$$U_{\mathrm{cor}}(r,t) = U_{\mathrm{ret}}(r,t) + U_{\mathrm{adv}}(r,t-N), \tag{33}$$

where r is the radial distance from the solar center and N is the recurrence delay due to the closed-loop spacetime geometry. Unlike dissipative models, this formulation assumes that advanced fluxes retain coherence over long scales, carrying not just energy but also phase and directionality.

In this framework, the outer layers of the corona are regions where the returning fluxes are phased in such a way that constructive interference occurs, thus reinforcing the local energy density. These regions become self-sustaining, with energy exchange occurring not merely through diffusion or particle collisions but via coherent field interactions. The persistence of high temperature is then not a transient effect but a stable outcome of spacetime-loop feedback.

Additionally, the ESM predicts that the corona's spatial extent should be governed by

the distance over which significant overlap between advanced and retarded fluxes occurs. If the advanced flux decays spatially as $\sim 1/r^\alpha$, then the maximum radius of significant coronal heating can be approximated as the distance r_c where:

$$U_{\text{ret}}(r_c, t) \approx U_{\text{adv}}(r_c, t - N), \tag{34}$$

yielding a natural outer boundary for thermal confinement. This boundary corresponds observationally to the corona's thinning into the solar wind regime.

Furthermore, the structured appearance of coronal loops and streamers may be interpreted in this model as standing-wave nodes or resonant features in the interference pattern between advanced and retarded fields. These patterns are not merely byproducts of localized magnetic reconnection, but macroscopic features imposed by the underlying spacetime geometry. Let $\vec{E}(r, t)$ denote the electric field vector of solar radiation, then the effective Poynting vector in the corona is:

$$\vec{S}(r, t) = \vec{E}_{\text{ret}} \times \vec{B}_{\text{ret}} + \vec{E}_{\text{adv}} \times \vec{B}_{\text{adv}} + \text{cross-terms}, \tag{35}$$

where the cross-terms embody interference phenomena that can locally enhance or diminish radiative transport.

From a phenomenological standpoint, the ESM approach helps reconcile why the corona is spatially extended, thermally stable, and morphologically structured without relying entirely on magnetic reconnection or turbulent heating models. It treats the corona not as a boundary layer but as an active interface of global energy feedback.

12 Feedback Delay and Solar Cycle Phase Locking in the Eternal Sun Model

The approximately 11-year solar cycle, during which the Sun's magnetic polarity reverses and sunspot activity oscillates, has long intrigued astrophysicists. Conventional solar dynamo theories attribute this cycle to the interplay between poloidal and toroidal magnetic fields in the Sun's convective zone, regulated by differential rotation and turbulent flow [21, 28]. These models often employ partial differential equations based on magnetohydrodynamics, but require extens. This implies a closed-loop system of energy exchange.

The Eternal Sun Model (ESM) proposes that the Sun exists within a closed causal loop of spacetime, such that energy and field fluxes emitted from the Sun—termed retarded fluxes—eventually return as advanced fluxes after traversing a topologically closed universe. In this context, the 11-year cycle emerges not from turbulent feedback, but from a global resonance condition associated with the return time of these advanced fluxes. The magnetic field observed at a given time is thus not solely the resu. This implies a closed-loop system of energy exchange.

Let us denote $\vec{B}_{\text{ret}}(t)$ as the magnetic field contribution from retarded fluxes at time t, and $\vec{B}_{\text{adv}}(t - \tau)$ as the advanced contribution delayed by a loop-return time τ. The total magnetic field $\vec{B}(t)$ is given by:

$$\vec{B}(t) = \vec{B}_{\text{ret}}(t) + \vec{B}_{\text{adv}}(t - \tau), \tag{36}$$

where $\tau \approx 11$ years is empirically aligned with the observed sunspot cycle. Unlike local dynamo models, this equation introduces an explicit temporal delay, embedding memory into the field dynamics. The reversal occurs when the returning field $\vec{B}_{\mathrm{adv}}$ becomes dominant and out-of-phase with the outgoing field $\vec{B}_{\mathrm{ret}}$, leading to destructive interference and a polarity switch.

To formalize the dynamics of phase locking, we model the scalar magnetic amplitude $B(t)$ via a delay differential equation (DDE):

$$\frac{dB(t)}{dt} = -\gamma B(t) + \alpha B(t - \tau) - \beta B^3(t), \tag{37}$$

where γ represents damping, α is the feedback strength of the delayed component, and the $\beta B^3(t)$ term imposes nonlinearity and saturation. This DDE supports stable limit cycle solutions for appropriate parameter values, which correspond to the 11-year oscillation observed in solar activity.

Such delay-driven feedback systems have been studied in nonlinear dynamics and exhibit robustness to perturbations while maintaining periodic behavior [29, 30]. The existence of stable oscillations in this model is not an artifact of finely tuned turbulent feedback, but a geometric inevitability imposed by the loop structure of spacetime in ESM.

We can further examine the phase dynamics by defining a phase variable $\phi(t)$, and assuming sinusoidal behavior of the field:

$$B(t) = A\cos(\phi(t)), \quad \phi(t) = \omega t + \phi_0, \tag{38}$$

where $\omega = 2\pi/\tau$. The coupling of the advanced flux imposes a phase locking condition, such that any deviation from $\phi(t) \approx \omega t$ results in corrective feedback due to the mismatch with the returning field. This feedback ensures long-term coherence in solar cycles despite short-term variability in surface phenomena.

Moreover, the DDE model naturally explains observed lags between magnetic polarity changes and sunspot maxima, as the advanced flux represents a phase-delayed component of the field structure. It also provides a framework for explaining dual peaks in sunspot cycles, often referred to as Gnevyshev peaks, as the interference envelope between outgoing and returning flux components.

The Eternal Sun Model thus offers a geometrically grounded and temporally coherent explanation for solar cycle regularity. Rather than treating reversals as outcomes of chaotic internal flows, the model treats them as global resonances maintained by the return loop of solar emissions. This viewpoint brings a new level of predictability and unification to solar dynamo theory.

13 Advanced Fluxes and Cosmic Microwave Background Anisotropies in the Eternal Sun Model

The Cosmic Microwave Background (CMB) is widely interpreted as relic radiation from the Big Bang, manifesting as a nearly uniform blackbody spectrum at a temperature of 2.725 K with small anisotropies on the order of 10^{-5} [31]. It is considered one of the cornerstones of

the standard cosmological model. However, from the viewpoint of the Eternal Sun Model (ESM), which posits a globally closed spacetime topology with feedback of radiation in the form of advanced fluxes, one may p. This implies a closed-loop system of energy exchange.

In the ESM, radiation emitted by the Sun as a retarded flux traverses the cosmic manifold, eventually looping back in a temporally reversed trajectory. Over long durations, this radiation undergoes redshifting and scattering, resulting in extremely low-energy, diffuse advanced fluxes that re-impinge upon the solar system. These returning fluxes could carry remnants of solar radiation smeared across vast cosmological distances. Their cumulative energy distribution, phase coherence, and geometric spread. This implies a closed-loop system of energy exchange.

Let the local energy density of the advanced microwave flux at the solar location be denoted $u_{\mathrm{adv}}(\vec{x}, t)$, which is a function of angular position $\vec{x}$ on the celestial sphere and time t. If these advanced fluxes are assumed to follow a Bose–Einstein spectral distribution due to their redshifted thermal origin, then:

$$u_{\mathrm{adv}}(\nu, \vec{x}, t) = \frac{8\pi h \nu^3}{c^3} \left[\exp\left(\frac{h\nu}{k_B T_{\mathrm{adv}}(\vec{x}, t)} \right) - 1 \right]^{-1}, \tag{39}$$

where $T_{\mathrm{adv}}(\vec{x}, t)$ is an effective temperature field arising from the return geometry of the advanced radiation. Small anisotropies in T_{adv} naturally translate to angular power spectra observed in the CMB.

This scenario offers an alternative explanation for the observed dipole anisotropy of the CMB, typically attributed to the solar system's motion relative to the CMB rest frame. In the ESM framework, the dipole arises from a geometrical asymmetry in the loop return path of solar radiation due to topological features of closed spacetime. If $\vec{v}_{\mathrm{adv}}(\vec{x})$ represents the effective velocity vector field of the returning fluxes, the Doppler-like shift in received frequency becomes:

$$\frac{\Delta \nu}{\nu} = \frac{\vec{v}_{\mathrm{adv}} \cdot \hat{n}}{c}, \tag{40}$$

where $\hat{n}$ is the observation direction. This generates a dipole modulation in the effective temperature field T_{adv}, mimicking conventional interpretations but rooted in global field feedback.

Moreover, higher-order multipole anisotropies can emerge from interference between advanced and retarded components at the solar boundary. The Poynting vector $\vec{S}(t, \vec{x})$ in this context is not solely composed of outgoing radiation but includes a coherent counter-propagating term:

$$\vec{S}(t, \vec{x}) = \vec{E}_{\mathrm{ret}} \times \vec{B}_{\mathrm{ret}} + \vec{E}_{\mathrm{adv}} \times \vec{B}_{\mathrm{adv}} + \vec{E}_{\mathrm{ret}} \times \vec{B}_{\mathrm{adv}} + \vec{E}_{\mathrm{adv}} \times \vec{B}_{\mathrm{ret}}, \tag{41}$$

which introduces angular variations in local radiative pressure. This may produce small-scale anisotropies, consistent in amplitude and angular scale with those observed by Planck and WMAP [32].

The polarization of the CMB, particularly the E-mode and B-mode decompositions, also finds reinterpretation in ESM. In this model, polarization arises due to phase coherence and interference patterns established at the solar boundary by overlapping advanced fluxes with

residual angular momentum. This framework avoids inflationary tensors but still predicts linear and circular polarization with specific angular correlations.

Importantly, the ESM interpretation does not negate the empirical observations of the CMB. Rather, it proposes a novel origin for its existence and structure: not from a primordial explosion, but from the global topological behavior of advanced radiation fields in a closed universe centered on cyclic stellar dynamics.

Further development of this model requires numerical simulation of the returning fluxes in a closed geometry and comparison of angular power spectra with observed C_l values. If consistency can be demonstrated, it would provide a new physical mechanism for microwave background uniformity and structure without recourse to early-universe inflationary epochs.

14   Reanalysis of Olbers' Paradox in the Eternal Sun Model

Olbers' Paradox, named after the German astronomer Heinrich Wilhelm Olbers, questions why the night sky is dark if the universe is infinite, static, and uniformly filled with luminous stars [33]. In a classical Newtonian context, every line of sight should eventually intersect a star, implying that the sky ought to be ablaze with starlight. The standard cosmological resolution involves invoking cosmic expansion and the finite age of the universe. The redshift and time delay caused by t. This implies a closed-loop system of energy exchange.

The Eternal Sun Model (ESM) provides a radically different interpretation. In this framework, the Sun emits radiation into a topologically closed universe, where the outgoing flux eventually returns in the form of advanced radiation. This returning radiation has traversed an extended, non-Euclidean spacetime loop, resulting in extreme dilution and redshifting of its energy. The night sky, in this model, is not illuminated by direct radiation from distant stars, but by the advanced return of solar rad. This implies a closed-loop system of energy exchange.

Let us define the radiative intensity $I_{\mathrm{adv}}(\vec{x})$ observed at point $\vec{x}$ on the celestial sphere. This intensity is due to the accumulated, redshifted advanced flux returning from all directions. If the return path is subject to expansion-like effects and scattering, the intensity scales as:

$$I_{\mathrm{adv}}(\nu, \vec{x}) = \int_0^\infty \frac{\epsilon(\nu', r)}{(1 + z(r))^3} e^{-\tau(\nu', r)} dr, \tag{42}$$

where $\epsilon(\nu', r)$ is the emissivity of the advanced flux at frequency ν', $z(r)$ is the effective redshift due to path length r, and $\tau(\nu', r)$ is the optical depth due to cosmological absorption and scattering. The advanced radiation field thus acts as a diffuse, thermalized background, contributing to the general brightness of the night sky.

In contrast to the standard model, where starlight from other galaxies is redshifted beyond detectability, the ESM posits that the night sky's brightness is governed by a feedback loop of solar radiation. The radiation is absorbed, scattered, and partially redirected through spacetime curvature and topological constraints, forming a self-interfering background field.

The advanced flux density u_{adv} observed locally can be related to the total emitted solar

flux $F_\odot$ and the geometric dilution factor Ω^{-1}, where Ω represents the effective solid angle subtended by the return manifold:

$$u_{\mathrm{adv}} = \frac{F_\odot}{c \cdot \Omega}, \tag{43}$$

where c is the speed of light. The extremely large value of Ω causes u_{adv} to be many orders of magnitude smaller than the direct solar flux, thereby explaining the low brightness of the night sky even in a universe filled with returning radiation.

Furthermore, the ESM resolves Olbers' paradox without requiring a finite-age universe or a cosmological expansion. Instead, the dark sky results from the fact that the returning radiation is so geometrically dispersed that its energy density per steradian remains low. As a result, the night sky appears dark not because of the absence of light, but because of the coherence conditions and spatial dilution imposed by the closed topology of the universe.

The advanced field also implies angular coherence across the sky. This coherence can be described by a correlation function $C(\theta)$, representing the cross-correlation between intensities at angular separation θ:

$$C(\theta) = \langle I_{\mathrm{adv}}(\vec{x}) I_{\mathrm{adv}}(\vec{x} + \theta) \rangle - \langle I_{\mathrm{adv}} \rangle^2. \tag{44}$$

This correlation function can be compared to sky maps of low-level background radiation to extract potential observational signatures of ESM predictions. Even if the energy is too weak to be visually perceptible, statistical correlations may exist and be measurable using sensitive microwave or infrared instruments.

In summary, the Eternal Sun Model provides a new answer to Olbers' Paradox by attributing the darkness of the night sky to the advanced return of solar radiation. This reinterpretation shifts the paradox from being a constraint on the universe's age and structure to a manifestation of global spacetime geometry and radiation feedback mechanisms.

15 Photospheric Granulation as a Resonant Interference Pattern

The Sun's photosphere exhibits a dynamic, grainy texture composed of convection cells known as granules, typically around 1,000 kilometers in diameter. These granules are often described in the conventional model as the topmost layer of convective energy transfer, where hot plasma rises at the center of a cell and cooler plasma descends at its periphery [35]. High-resolution imaging has revealed that these granules exhibit approximate hexagonal symmetry and form a quasi-regular mosaic ac. This implies a closed-loop system of energy exchange.

Within the Eternal Sun Model (ESM), the emergence of such regular granulation may not solely be a consequence of turbulent convection. Instead, it may reflect a deeper energetic symmetry between advanced and retarded radiation fields. The photosphere, in this view, serves as an interference plane where the incoming (advanced) and outgoing (retarded) fluxes superpose coherently, forming a two-dimensional standing wave pattern. This reinterpretation brings wave coherence and topological structure to the. This implies a closed-loop system of energy exchange.

Assume that the photosphere supports counter-propagating wavefronts of electromagnetic origin, $E_{\mathrm{ret}}(x, y, t)$ and $E_{\mathrm{adv}}(x, y, t)$. A standing wave pattern $E(x, y, t)$ arises from their superposition:

$$E(x, y, t) = E_{\mathrm{ret}}(x, y, t) + E_{\mathrm{adv}}(x, y, t) = 2E_0 \cos(kx \cos\theta + ky \sin\theta - \omega t), \qquad (45)$$

where k is the wave number, ω is the angular frequency, and θ sets the propagation angle of incoming waves. The interference pattern becomes temporally stationary in the amplitude envelope, thereby forming energy density nodal lines.

To model the granule pattern, we consider the power density $P(x, y)$, which is proportional to the square of the field magnitude:

$$P(x, y) \propto |E(x, y, t)|^2 = 4E_0^2 \cos^2(kx \cos\theta + ky \sin\theta - \omega t). \qquad (46)$$

The time-averaged intensity $\langle P(x, y)\rangle_t$ gives a spatial pattern that can be interpreted as the basis of hexagonal cellular structures. If the angular spread θ is not unique but sampled from six discrete propagation angles offset by $\pi/3$, the resulting interference pattern displays hexagonal symmetry, consistent with observed granulation [36].

This structure reflects not just thermal convection, but coherent phase relationships across the solar surface. Each granule is thus a node of maximal constructive interference, while intergranular lanes correspond to regions of destructive interference or energy redirection into downward channels. This aligns with observed behavior, where upflows dominate the center of granules and downflows encircle them.

We may generalize this behavior using a two-dimensional Helmholtz equation for the scalar potential $\psi(x, y)$ on the photospheric surface:

$$\nabla^2 \psi + k^2 \psi = 0, \qquad (47)$$

subject to periodic boundary conditions. The solutions to this equation under hexagonal boundary symmetry yield Bessel-function-based modal structures which exhibit cellular tessellation. These solutions have been examined in plasma physics for drift wave instabilities and could be analogously applied here to describe flux interaction fields [37].

In the ESM, these standing interference patterns are not merely epiphenomena but encode deeper information about the spacetime topology through which advanced and retarded fluxes propagate. Granulation is then an imprint of the closed-loop geometry and field coherence across cosmological scales.

Thus, granules serve as phase-locking nodes between opposing radiative directions. This mechanism predicts that the statistical characteristics of granules, including size distribution, life span, and emergence rate, will correlate not just with local thermal gradients but also with global radiation feedback properties—offering a new class of testable predictions for solar physics.

16 Reinterpretation of the Heliosphere Boundary in the Eternal Sun Model

The heliosphere is conventionally described as a bubble-like region of space dominated by the solar wind, extending beyond the orbit of Pluto and terminating at the heliopause, where the outward solar wind pressure is balanced by the interstellar medium (ISM) [38]. Key features such as the termination shock and heliosheath are interpreted as hydrodynamic or magnetohydrodynamic (MHD) discontinuities. In this framework, plasma parameters such as particle density, flow speed, and magnetic field d. This implies a closed-loop system of energy exchange.

The Eternal Sun Model (ESM), however, proposes a fundamentally different view. In this framework, the heliopause is not merely a pressure-defined boundary but a region where advanced and retarded solar radiation interfere destructively. This makes the termination shock and the outer boundary of the heliosphere phase-matching surfaces where electromagnetic field coherence is minimized. Thus, the heliopause is reinterpreted as a nodal envelope in the global wave field rather than a hydrodynamic barrier.

To formalize this idea, consider the superposition of advanced and retarded electromagnetic field vectors $\vec{E}_{\text{adv}}$ and $\vec{E}_{\text{ret}}$. The resultant intensity I at any point in space is given by:

$$I = \left| \vec{E}_{\text{adv}} + \vec{E}_{\text{ret}} \right|^2. \tag{48}$$

At the phase-cancellation boundary, this interference reaches a local minimum:

$$\vec{E}_{\text{adv}} = -\vec{E}_{\text{ret}} \quad \Rightarrow \quad I = 0. \tag{49}$$

This phase-cancellation condition is hypothesized to define the geometric locus of the heliopause. Such a boundary becomes a field-determined rather than pressure-determined structure, inherently shaped by the global topology of the feedback loop in closed spacetime.

This reinterpretation has implications for observed asymmetries in the heliosphere. Data from the Voyager probes and IBEX (Interstellar Boundary Explorer) show that the heliosphere is not a perfect sphere but is compressed on one side and extended on the other [39]. In ESM, such asymmetries can be attributed to non-uniform coherence in the returning advanced field due to spacetime curvature or anisotropies in the loop-return path.

Furthermore, the termination shock, normally modeled as a region of kinetic deceleration and thermalization, is here re-envisioned as a standing wave node where the Poynting vector undergoes inversion. Let the total electromagnetic energy flux $\vec{S}$ be written as:

$$\vec{S} = \frac{1}{\mu_0} \vec{E} \times \vec{B}, \tag{50}$$

where $\vec{E} = \vec{E}_{\text{adv}} + \vec{E}_{\text{ret}}$ and similarly for $\vec{B}$. When the phase relationship between $\vec{E}_{\text{adv}}$ and $\vec{E}_{\text{ret}}$ is destructive, the net Poynting vector reduces in magnitude, which would be observed as a reduction in outgoing energy density. This zone corresponds to a stable energy boundary, consistent with empirical findings from Voyager.

This wave-structured interpretation of the heliosphere also explains the unexpected detection of energetic neutral atoms (ENAs) in the IBEX ribbon. These ENAs may arise from secondary wave-front formations due to incomplete cancellation in transverse interference modes, forming energy lobes along specific magnetic latitudes [40].

The mathematical treatment of such a boundary involves the Helmholtz equation with boundary-phase constraints. For a scalar field $\psi(r)$ representing the radiative energy amplitude, one may write:

$$\nabla^2 \psi + k^2 \psi = 0, \quad \text{with} \quad \psi(r_{\text{hp}}) = 0, \tag{51}$$

where r_{hp} is the heliopause radius defined by the node of the standing wave. The location of this boundary thus arises naturally from phase coherence, not particle dynamics.

In summary, the Eternal Sun Model provides a reinterpretation of the heliosphere boundary as a global phase structure rather than a local thermodynamic equilibrium. This framework allows for wave-based explanations of asymmetry, boundary sharpness, and ENA production, thereby opening new avenues of observational and theoretical research.

17 Formation of Stellar Jets and Polar Structures in the Eternal Sun Model

Stellar jets are high-velocity, collimated plasma outflows observed in a wide variety of astrophysical systems, including young stellar objects (YSOs), active galactic nuclei (AGN), and microquasars. Conventionally, these jets are explained as magnetohydrodynamic outflows originating from accretion disks, collimated by magnetic fields twisted through differential rotation [41, 42]. However, such models often require specific disk-magnetic field configurations and significant. This implies a closed-loop system of energy exchange.

Within the Eternal Sun Model (ESM), polar jets are viewed as outcomes of axial resonance phenomena arising from interference between advanced and retarded radiation fields. In this framework, the global spacetime geometry permits looped radiation pathways, and the poles of rotating bodies become nodes of symmetry where phase locking between the incoming and outgoing fluxes occurs with maximal coherence. This axial resonance establishes a low-pressure waveguide where field interactions reinforce longitud. This implies a closed-loop system of energy exchange.

To formalize this, consider the superposition of advanced and retarded Poynting vectors $\vec{S}_{\text{adv}}$ and $\vec{S}_{\text{ret}}$ along the rotation axis $\hat{z}$. The net Poynting vector $\vec{S}_{\text{net}}$ becomes:

$$\vec{S}_{\text{net}} = \vec{S}_{\text{adv}} + \vec{S}_{\text{ret}}. \tag{52}$$

Near the poles, the advanced and retarded vectors are aligned due to axial symmetry, resulting in constructive interference. This leads to a significant local increase in energy flux density:

$$|\vec{S}_{\text{net}}|^2 = |\vec{S}_{\text{adv}}|^2 + |\vec{S}_{\text{ret}}|^2 + 2\vec{S}_{\text{adv}} \cdot \vec{S}_{\text{ret}}. \tag{53}$$

In regions where $\vec{S}_{\text{adv}} \cdot \vec{S}_{\text{ret}} > 0$, the energy flux is amplified, creating conditions suitable for sustained outflow.

Furthermore, the electromagnetic pressure P_{em}, derived from the energy density u and momentum flux, is given by:

$$P_{\text{em}} = \frac{u}{3} = \frac{|\vec{E}|^2 + |\vec{B}|^2}{6\mu_0}.$$ (54)

Along the axis, where the fields are collimated and coherent, this pressure gradient drives material outward in a sustained jet. This mechanism is purely field-geometric and does not rely on disk dynamics or chaotic MHD instabilities.

Another implication of the ESM is that the jet axis coincides with the node of minimal net magnetic field twist. Observations of AGN jets have shown surprisingly linear trajectories over kiloparsec scales [43], suggesting that jet propagation is not subject to strong instabilities. In the ESM, this stability arises from the coherence of field vectors along the axis of symmetry, making it a natural guide for matter flow.

We can model the axial mode structure using cylindrical coordinates and the wave equation:

$$\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial\psi}{\partial r}\right) + \frac{\partial^2\psi}{\partial z^2} + k^2\psi = 0,$$ (55)

where $\psi(r, z)$ represents the wave envelope of the axial radiation field. Solutions to this equation under boundary conditions corresponding to polar symmetry yield Bessel-function-based axial modes that naturally concentrate along $r = 0$, forming a jet-like structure.

In this view, jet formation becomes an emergent phenomenon of boundary-induced standing wave structures, stabilized by coherence between advanced and retarded fields. Such jets would also exhibit self-similar scaling and fractal stability, properties that are observed in both YSO jets and AGN structures [44].

In conclusion, the Eternal Sun Model provides a novel explanation for the formation of polar jets and outflows without requiring a surrounding accretion disk. Instead, these structures emerge as coherent radiation pathways along field nodes created by spacetime geometry and field superposition. This approach unifies plasma, electromagnetic, and gravitational considerations in a single field-dynamic description.

18 General Discussion: Integrative Implications of the Eternal Sun Model

The Eternal Sun Model (ESM) proposes a radical departure from conventional solar physics by relocating the source of coronal energetics from internal fusion reactions to cyclic radiative feedback mediated by closed spacetime geometries. This section synthesizes the multiple threads explored in preceding analyses and assesses the broader scientific implications. Specifically, it discusses how the ESM aligns with general relativity, thermodynamics, observational astrophysics, and cosmological metaphysics, o. This implies a closed-loop system of energy exchange.

In the context of general relativity, the ESM relies on non-trivial spacetime topologies such as the $S^3 \times S^1$ manifold explored in Segal's cosmological model [7]. Unlike the

Friedmann-Lemaître-Robertson-Walker (FLRW) metric that forms the basis of the standard cosmological model, the Segal manifold admits closed timelike curves and a cyclic time parameter. This topology accommodates recurrence relations such as:

$$F_{out}(t) = \eta^k F_{out}(t - kN),\tag{56}$$

where $F_{out}(t)$ is the outgoing solar radiation flux, η is the efficiency factor, k is the cycle number, and N is the temporal period of spacetime closure. This formulation allows energy to be recycled indefinitely, providing a sustainable mechanism for coronal heating without invoking an internal nuclear engine.

From a thermodynamic standpoint, the model avoids the entropy accumulation problem inherent in fusion-based energy models. If radiation is returned to its origin without significant dissipation, then the net entropy change over a complete cosmic cycle satisfies:

$$\Delta S = \oint \frac{dQ}{T} \approx 0,\tag{57}$$

indicating a quasi-conservative system. This approach contrasts with the conventional second law of thermodynamics but aligns with bounded-entropy models such as Gödel's cosmology [6]. Therefore, the ESM provides a physical framework in which entropy resets are not paradoxical but instead expected features of closed temporal geometries.

Observationally, the ESM explains the sustained high temperature of the solar corona, which exceeds 1.5×10^6 K, in spite of the photospheric surface being an order of magnitude cooler [5]. Traditional models invoke magnetic reconnection and Alfvén wave heating as explanatory mechanisms, yet these lack quantitative sufficiency across the full solar surface [2]. In contrast, the ESM attributes localized heating to variations in radiation return efficiency:

$$T_c(\theta, \phi) = \left(\frac{\eta(\theta, \phi) F_{out}(t - N)}{\sigma} \right)^{1/4},\tag{58}$$

where $\eta(\theta, \phi)$ is spatially variable due to cosmic opacity, σ is the Stefan-Boltzmann constant, and T_c denotes local coronal temperature. This spatial dependence naturally explains why coronal holes—regions of low η—appear cooler and coincide with fast solar wind outflows.

Philosophically, the ESM resonates with metaphysical cosmologies that posit eternal recurrence, particularly the Brahma Kumaris doctrine of a 5000-year cycle of identical world events [11]. Time is viewed not as linear progression but as a closed loop with fixed recurrence properties. This perspective not only harmonizes with the S^1 temporal compactification in Segal's manifold but also gives interpretive depth to cyclic phenomena like the 11-year solar magnetic reversal cycle:

$$T_{mag} = \frac{N}{k},\tag{59}$$

where T_{mag} is the magnetic cycle period and k is an integer harmonic of the global cycle. By choosing $N = 5000$ years and $k = 454$, the observed $T_{mag} \approx 11$ years emerges naturally, without reliance on turbulent magnetohydrodynamic simulations.

The model also bears implications for quantum field theory in curved spacetime. The interaction of electromagnetic fields with a dynamic metric implies modifications to field propagation and photon phase coherence. This can affect solar emissions' spectral profiles and polarization characteristics, potentially offering testable predictions. Moreover, EPR-type quantum correlations might find new interpretation within a causal equivalence structure facilitated by CTCs, as suggested by Gödel and later extended in cyclic geometries [8, 10].

The convergence of general relativity, thermodynamics, observational solar data, and spiritual cosmology in the ESM offers a rare opportunity to unify disciplines often considered orthogonal. It emphasizes the need for physics not only to explain numerical observations but also to reconsider foundational assumptions about time, energy, and causality. By reframing solar physics within a spacetime of closed geometry, the ESM invites a broader inquiry into the cyclic nature of the cosmos and the possibility that our universe is not thermodynamically doomed but eternally rejuvenated.

19 Conclusion and Future Directions of the Eternal Sun Model

The Eternal Sun Model (ESM) presents a novel synthesis of astrophysical phenomena, general relativity, and cyclic metaphysical cosmology. At its core, the ESM posits that the Sun's energy output is not sustained by internal fusion processes alone, but rather through a recursive feedback mechanism governed by a closed spacetime topology. The radiation emitted from the Sun returns via closed timelike geodesics after a fixed temporal interval, contributing to sustained coronal heating and dynamic electro. This implies a closed-loop system of energy exchange.

Throughout this paper, we have examined how closed spacetime manifolds such as $S^3 \times S^1$, as formulated in Segal's cosmological framework [7], permit the existence of recurrent causal loops. These loops return radiative energy to its source with a time delay N, allowing for equilibrium conditions expressed as:

$$F_{out}(t) = \eta F_{out}(t - N), \tag{60}$$

where η is the efficiency of radiation retention through the loop. When $\eta \to 1$, energy loss is minimized, establishing a quasi-stationary thermodynamic condition that maintains the solar corona's elevated temperature without continuous nuclear burning. This model is consistent with thermodynamic principles if the entropy change over the radiation loop is negligible:

$$\Delta S \approx \oint \frac{dQ}{T} \approx 0. \tag{61}$$

Such entropy-neutral feedback mechanisms offer a credible resolution to long-standing paradoxes in solar physics, including the solar neutrino deficit and the unexplained high coronal temperatures. Furthermore, they provide an alternative to magnetic reconnection and wave heating as primary mechanisms, which have struggled to account for uniform coronal heating in both active and quiet solar regions [5, 2].

The solar magnetic field and its periodic reversal were interpreted within the ESM as a harmonic response of standing electromagnetic wave modes within a temporally compact spacetime. The recurrence interval of these reversals correlates with the primary cosmic loop period divided by an integer:

$$T_{mag} = \frac{N}{k},$$

(62)

where T_{mag} is the observed magnetic polarity cycle. Setting $N = 5000$ years, a cycle described in Brahma Kumaris cosmology [11], and $k = 454$ yields $T_{mag} \approx 11$ years, matching empirical observations [1].

Future research must focus on refining the mathematical and observational framework of the ESM. A critical next step involves quantifying the cosmic opacity function $\kappa(x^\mu)$ introduced in prior sections, which governs the directional suppression of radiation and leads to observable coronal features such as holes and streamers. The relation:

$$\eta(\theta, \phi) = \exp\left(-\int_\gamma \kappa(x^\mu)ds\right),$$

(63)

provides a formal method to model energy suppression along spacetime geodesics and its effect on solar surface energetics. Empirical mapping of $\eta(\theta, \phi)$ through spectral line diagnostics and EUV imaging could validate or constrain this model.

Further directions include exploring quantum coherence effects of returning radiation in curved spacetime. Investigations of photon phase memory, polarization changes, and possible quantum non-locality under closed timelike curves may provide connections to foundational problems in quantum gravity and field theory, particularly as discussed in works like Gödel's metric [6] and Hawking's chronology protection conjecture [8].

The Eternal Sun Model also invites a reevaluation of cosmic time. By adopting a temporally periodic structure, the universe avoids singularities, entropy accumulation, and unidirectional temporal causality. It suggests a reinterpretation of redshift phenomena through conformal transformations [7], rather than metric expansion, offering testable contrasts to the standard cosmological model.

In summary, the Eternal Sun Model bridges theoretical physics and metaphysical cosmology into a single geometric and energetic framework. It provides an elegant explanation for persistent anomalies in solar physics and introduces new directions for experimental validation. The integration of gravitational, thermodynamic, electromagnetic, and quantum principles within a closed causal manifold presents a unified paradigm that deserves continued mathematical development and observational testing.

References

[1] J. N. Bahcall, "Solar models: An overview," Annual Review of Astronomy and Astrophysics, vol. 39, pp. 1–33, 2001.

[2] E. R. Priest and T. G. Forbes, Magnetic Reconnection: MHD Theory and Applications, Cambridge University Press, 2000.

[3] M. S. Modgil. "Eternal Sun", viXra:1807.0391, 2018.

[4] M. S. Modgil and D. D. Patil, "Eternal Sun" viXra:2505.0153, 2025.

[5] M. J. Aschwanden, Physics of the Solar Corona: An Introduction, Springer, 2005.

[6] K. Gödel, "An example of a new type of cosmological solutions of Einstein's field equations," Rev. Mod. Phys., vol. 21, pp. 447–450, 1949.

[7] I. E. Segal, Mathematical Cosmology and Extragalactic Astronomy, Academic Press, 1976.

[8] S. W. Hawking, "Chronology protection conjecture," Phys. Rev. D, vol. 46, no. 2, pp. 603–611, 1992.

[9] R. Davis Jr., "A review of the Homestake solar neutrino experiment," Progress in Particle and Nuclear Physics, vol. 32, pp. 13–32, 1994.

[10] J. S. Bell, "On the Einstein-Podolsky-Rosen paradox," Physics, vol. 1, pp. 195–200, 1964.

[11] Brahma Kumaris World Spiritual University, *The Cycle of Time: A Spiritual Perspective*, Mount Abu, India, 2003.

[12] E. L. Wright, "Olbers' Paradox," Astrophysical Journal, vol. 426, pp. 523–526, 1994.

[13] R. A. Bernstein, "The Optical Extragalactic Background Light: Revisions and Implications," Astrophysical Journal, vol. 666, pp. 663–673, 2007.

[14] S. J. Bradshaw and J. A. Klimchuk, "The Heating of Coronal Loops: How Steady is Steady Heating?" Astrophysical Journal Supplement Series, vol. 194, no. 2, p. 26, 2011.

[15] K. J. H. Phillips, U. Feldman, and E. Landi, *Ultraviolet and X-ray Spectroscopy of the Solar Atmosphere*, Cambridge University Press, 2008.

[16] M. J. Owens and R. J. Forsyth, "The Heliospheric Magnetic Field," Living Rev. Solar Phys., vol. 10, no. 5, 2013.

[17] G. Del Zanna and H. E. Mason, "Solar Active Regions: The Sun's Dynamic Atmosphere," Living Rev. Solar Phys., vol. 7, 2010.

[18] J. M. Beckers, "Solar Spicules," Solar Physics, vol. 3, pp. 367–433, 1968.

[19] B. De Pontieu et al., "A Tale of Two Spicules: The Impact of Spicules on the Magnetic Chromosphere," Publications of the Astronomical Society of Japan, vol. 59, pp. S655–S662, 2007.

[20] T. M. D. Pereira, M. Carlsson, and B. De Pontieu, "Quantifying Spicules," Astrophysical Journal, vol. 759, no. 1, p. 18, 2012.

[21] P. Charbonneau, "Dynamo Models of the Solar Cycle," Living Reviews in Solar Physics, vol. 17, no. 4, 2020.

[22] X. Sun et al., "Why Is the Solar Cycle Period Roughly 11 Years?" The Astrophysical Journal Letters, vol. 798, no. 2, L27, 2015.

[23] J.-P. Valet, L. Meynadier, and Y. Guyodo, "Geomagnetic field strength and reversal rate over the past 2 million years," Nature, vol. 435, pp. 802–805, 2005.

[24] G. A. Glatzmaier, "Geodynamo simulations—How realistic are they?" Annual Review of Earth and Planetary Sciences, vol. 27, pp. 169–200, 1999.

[25] J. A. Klimchuk, "On Solving the Coronal Heating Problem," Solar Physics, vol. 234, pp. 41–77, 2006.

[26] S. R. Cranmer and A. A. van Ballegooijen, "Alfvénic turbulence in the extended solar corona: Kinetic effects and proton heating," The Astrophysical Journal, vol. 594, pp. 573–591, 2019.

[27] M. J. Aschwanden, "Physics of the Solar Corona: An Introduction," Springer Praxis Books, 2005.

[28] M. Dikpati and P. Charbonneau, "A Babcock–Leighton Flux Transport Dynamo with Solar-like Differential Rotation," The Astrophysical Journal, vol. 518, pp. 508–520, 2001.

[29] L. Glass and M. Mackey, "From Clocks to Chaos: The Rhythms of Life," Princeton University Press, 1988.

[30] T. Erneux, "Applied Delay Differential Equations," Springer, 2009.

[31] Planck Collaboration, "Planck 2018 results. I. Overview and the cosmological legacy of Planck," Astronomy & Astrophysics, vol. 641, A1, 2020.

[32] C. L. Bennett et al., "Nine-year Wilkinson Microwave Anisotropy Probe (WMAP) Observations: Final Maps and Results," The Astrophysical Journal Supplement Series, vol. 208, no. 2, 2013.

[33] E. R. Harrison, "Darkness at Night: A Riddle of the Universe," Harvard University Press, 1964.

[34] E. L. Wright, "Olbers' Paradox," Publications of the Astronomical Society of the Pacific, vol. 118, pp. 1711–1715, 2006.

[35] A. Nordlund, R. F. Stein, and M. Asplund, "Solar Surface Convection," Living Reviews in Solar Physics, vol. 6, 2009.

[36] M. P. Rast, "The Scales of Granulation, Mesogranulation, and Supergranulation," The Astrophysical Journal, vol. 597, pp. 1200–1210, 2003.

[37] W. Horton, "Drift waves and transport," Reviews of Modern Physics, vol. 71, no. 3, pp. 735–778, 1999.

[38] G. P. Zank, "Interaction of the solar wind with the local interstellar medium: a theoretical perspective," Space Science Reviews, vol. 89, pp. 413–688, 1999.

[39] D. J. McComas et al., "Global observations of the interstellar interaction from the Interstellar Boundary Explorer (IBEX)," Science, vol. 326, pp. 959–962, 2009.

[40] H. O. Funsten et al., "Structures and spectral variations of the outer heliosphere in IBEX energetic neutral atom maps," Science, vol. 326, pp. 964–966, 2009.

[41] R. D. Blandford and D. G. Payne, "Hydromagnetic flows from accretion disks," Monthly Notices of the Royal Astronomical Society, vol. 199, pp. 883–903, 1982.

[42] R. E. Pudritz, D. Pelletier, andG. Banerjee, "Disk Winds, Jets, and Outflows: Theoretical and Computational Foundations," in Protostars and Planets V, Univ. of Arizona Press, 2007.

[43] H. L. Marshall et al., "Structure of the X-ray jet of PKS 0637-752 from Chandra and Hubble Space Telescope observations," The Astrophysical Journal, vol. 564, pp. 683–687, 2002.

[44] M. J. Rees, "Black Hole Models for Active Galactic Nuclei," Annual Review of Astronomy and Astrophysics, vol. 22, pp. 471–506, 1984.