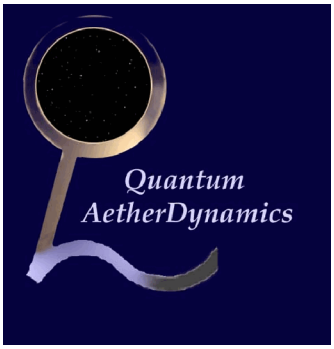

Quantum AetherDynamics Institute (QADI)

Aether Tomography: Residual Cosmic Birefringence as a Probe of Organized Five-Dimensional Chronogeometric Structure

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It develops the Aether Physics Model (APM)

Abstract

Paper 1 established a five-dimensional chronogeometric framework Thomson III [2026] in which cosmic birefringence arises from organized temporal-torque memory embedded within the Aether. The present work develops the concept of Aether tomography, wherein residual polarization rotation maps are interpreted as observational probes of hidden chronogeometric organization. A mathematical framework is developed for chronotorsional curl-organization density, harmonic decomposition, simulated residual birefringence maps, and observational reconstruction using present and future cosmic microwave background polarization surveys. The framework produces falsifiable predictions relating residual birefringence to galactic spiral organization, magnetic helicity, and filamentary large-scale structure.

1 Introduction

The Aether Physics Model (APM) proposes that cosmic organization arises from a five-dimensional chronogeometric manifold,

$$(x, y, z, \tau_v, \tau_t),$$

where

- τ_v represents forward-backward chronovibrational oscillation, and
- τ_t represents left-right chronotorsional orientation.

Within this framework, cosmic birefringence is interpreted Minami and Komatsu [2020a] as a measurable consequence of organized temporal-torque structure embedded throughout the Aether.

2 Review of Paper 1 and Definition of Aether Tomography

Paper 1 demonstrated Thomson III [2026] that the observed polarization rotation field may be decomposed into an isotropic component and a residual component,

$$\beta(\theta, \phi) = \beta_0 + \delta\beta(\theta, \phi),$$

where

$$\beta_0 = \frac{1}{16\pi^2}.$$

The residual field,

$$\delta\beta(\theta, \phi),$$

is interpreted as an observational projection of organized temporal-torque structure.

Accordingly, Aether tomography is defined as the inverse problem:

$$\delta\beta(\theta,\phi) \longrightarrow \chi_t(\mathbf{x}),$$

where χ_t denotes chronotorsional curl-organization density.

3 Mathematical Framework

3.1 Residual Birefringence Field

Residual birefringence is modeled as an accumulated temporal-torque effect along the photon propagation path,

$$\delta\beta = \kappa \int \chi_t(s)\, ds,$$

where s is propagation distance, χ_t is chronotorsional curl-organization density, and κ is an observational coupling coefficient.

In the present work, κ is treated as an observational coupling coefficient that converts accumulated chronotorsional curl-organization density into measurable polarization rotation. It is not assumed here to be instrument-dependent. Instead, κ is provisionally treated as a phenomenological bridge coefficient whose QMU-native origin remains to be derived. A later paper in this series will examine whether κ emerges as a universal chronogeometric coupling from QMU closure relations, Ledger One, and chronotorsional holonomy.

The complete birefringence field therefore becomes

$$\beta(\theta,\phi) = \frac{1}{16\pi^2} + \kappa \int \chi_t(s)\, ds.$$

This expression separates the universal topological component, β_0, from the residual component, $\delta\beta(\theta,\phi)$, which is treated as the observable projection of organized Aether structure.

The reconstruction problem is limited by projection degeneracy, foreground contamination, instrument polarization calibration, sky masking, and measurement noise. These limitations do not invalidate the tomographic framework, but they determine the level of statistical confidence that can be assigned to any reconstructed temporal-torque structure. Accordingly, the present paper treats χ_t reconstruction as a constrained inverse problem rather than a direct image of the hidden Aether domain.

3.2 Forward Modeling of Residual Birefringence

The central hypothesis of Aether tomography is that organized temporal-torque structure within the Aether produces observable residual polarization rotation. Let $\chi_t(\mathbf{x})$ denote the hidden chronotorsional curl-organization density field throughout space. The observable residual birefringence field is modeled as the line-of-sight projection,

$$\delta\beta(\theta,\phi) = \kappa \int_{\mathrm{LOS}} \chi_t(\mathbf{x})\, ds,$$

where s denotes propagation distance along the photon trajectory.

This formulation establishes a forward modeling procedure:

1. Specify an organized Aether distribution, $\chi_t(\mathbf{x})$.
2. Project the chronotorsional organization field along the photon line of sight.
3. Produce a predicted residual birefringence map, $\delta\beta(\theta,\phi)$.
4. Compare the predicted map with observed polarization rotation data.

The forward model therefore establishes a direct connection between hidden chronogeometric organization and observable cosmic birefringence.

3.3 The Inverse Tomographic Problem

The converse problem is the reconstruction of organized Aether structure from residual birefringence observations. Define the forward projection operator,

$$\mathcal{T} : \chi_t(\mathbf{x}) \longrightarrow \delta\beta(\theta,\phi).$$

Aether tomography is then defined as the inverse problem,

$$\chi_t(\mathbf{x}) = \mathcal{T}^{-1}[\delta\beta(\theta,\phi)]\,.$$

This inverse structure introduces three distinct observational layers. The directly measured layer is the residual sky field, $\delta\beta(\theta,\phi)$. The intermediate analysis layer is the harmonic representation, $a_{\ell m}$. The hidden source layer is the chronotorsional curl-organization density field, $\chi_t(\mathbf{x})$. Aether tomography therefore proceeds through the chain

$$\delta\beta(\theta,\phi) \longrightarrow a_{\ell m} \longrightarrow \chi_t(\mathbf{x}).$$

This chain is the operational core of the present paper. Measurements produce residual maps, residual maps produce harmonic coefficients, and harmonic coefficients constrain the organized chronotorsional organization domains that generated the observed birefringence structure.

The objective of Aether tomography is not merely the measurement of polarization rotation, but the reconstruction of the underlying temporal-torque organization that generated the observed residual field.

The present paper does not attempt a unique inversion procedure. Instead, it establishes the mathematical framework necessary for future reconstruction techniques, including harmonic inversion, maximum-likelihood methods, Bayesian reconstruction procedures, and numerical simulation pipelines.

The resulting observational sequence may be summarized as

$$\chi_t(\mathbf{x}) \longrightarrow \delta\beta(\theta,\phi) \longrightarrow a_{\ell m} \longrightarrow \chi_t(\mathbf{x}),$$

where the final reconstruction is constrained by the measured harmonic coefficients.

4 Candidate Chronotorsional Organization Operators

Several candidate operators for the hidden chronotorsional organization field are considered. These definitions are phenomenological at this stage and are intended to organize observational tests. Paper 3 audits their QMU dimensions and identifies $\chi_t = \eta_4\,\mathrm{curl/volm}$ specifically as curl-organization density rather than native QMU torque density.

A curl-gradient formulation is

$$\chi_t = \eta_1 \nabla(\mathrm{curl}),$$

where η_1 is a coupling coefficient relating curl-gradient structure to chronotorsional curl-organization density. This form associates residual birefringence with spatial gradients in rotational participation. Large-scale astrophysical systems are known to exhibit coherent angular-momentum organization generated by tidal torques Peebles [1969].

A chronotorsional holonomy formulation is

$$\chi_t = \eta_2 \frac{d\mathcal{H}}{ds},$$

where $\mathcal{H}$ represents accumulated chronotorsional holonomy along the photon path. This form associates residual birefringence with path-dependent temporal orientation memory.

A loxodromic organization model is

$$\chi_t = \eta_3 \chi_L,$$

where χ_L represents a loxodromic organization parameter. This form associates residual birefringence with persistent spiral or helical organization.

A QMU-native density candidate is

$$\chi_t = \eta_4 \frac{\mathrm{curl}}{\mathrm{volm}},$$

which may also be written as

$$\chi_t = \eta_4 \frac{{e_{emax}}^2}{m_e {\lambda_C}^4}.$$

This final expression treats chronotorsional curl-organization density as curl participation per quantum volume.

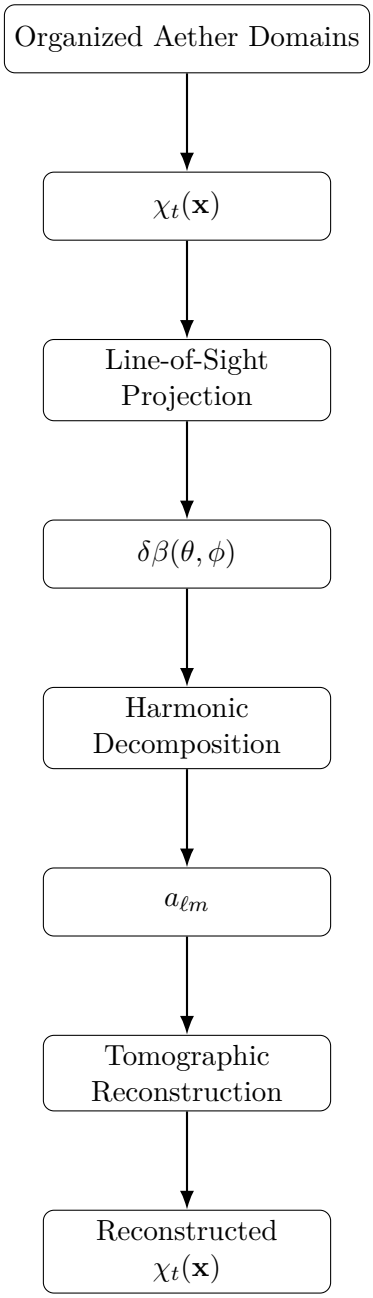


Figure 1: Aether tomography as a forward and inverse observational procedure. Organized temporal-torque structure produces a residual birefringence sky map, which may be decomposed into harmonic coefficients and used to reconstruct the hidden chronogeometric source field.

Table 1: Candidate chronotorsional curl-organization density formulations and their expected observational signatures.

Form	APM motivation	Expected sky signature	Falsification handle
$\chi_t = \eta_1 \nabla(\text{curl})$	Curl-gradient organization	Dipole and low-order gradients	No correlation between residual maps and modeled curl gradients
$\chi_t = \eta_2 d\mathcal{H}/ds$	Chronotorsional holonomy	Path-dependent quadrupole and parity structure	No stable path-dependent residual pattern
$\chi_t = \eta_3 \chi_L$	Loxodromic spiral organization	Spiral harmonics and handedness asymmetry	No preferred spiral phase or handedness statistic
$\chi_t = \eta_4 \text{curl/volm}$	QMU-native curl density	Hierarchical residual structure across angular scales	No scale-persistent residual hierarchy

5 Residual Harmonic Decomposition

Residual birefringence is expanded using spherical harmonics, a standard representation for full-sky CMB analyses Durrer [2008].

$$\delta\beta(\theta, \phi) = \sum_{\ell,m} a_{\ell m} Y_{\ell m}(\theta, \phi).$$

The coefficients $a_{\ell m}$ encode the angular organization of the residual field. Dipole modes, $\ell = 1$, represent large-scale directional temporal-torque gradients. Quadrupole modes, $\ell = 2$, represent opposing organized domains. Higher-order modes describe increasingly complex hierarchical structure.

A handedness observable may be defined as

$$H = \sum_{m} m \left| a_{\ell m} \right|^2 .$$

Under a parity-symmetric null model, the handedness statistic H should vanish statistically after accounting for sky masks, foreground residuals, and instrumental noise. A persistent nonzero value of H across independent surveys would therefore provide a direct test for chronotorsional asymmetry. In this framework, the key observational question is not merely whether residual birefringence exists, but whether its harmonic structure carries a preferred orientation or handedness.

6 Simulated Residual Sky Maps

6.1 Simulation Protocol

The simulated sky maps developed in this work follow a common procedure.

1. Define an organized chronotorsional organization field, $\chi_t(\mathbf{x})$.
2. Project the field along all sky directions to generate $\delta\beta(\theta, \phi)$.
3. Expand the resulting residual map into spherical harmonics,

$$\delta\beta(\theta, \phi) = \sum_{\ell,m} a_{\ell m} Y_{\ell m}(\theta, \phi).$$

4. Compare the harmonic coefficients with observational measurements.
5. Apply inverse reconstruction techniques to estimate the underlying temporal-torque organization.

This procedure permits direct comparison between theoretical chronogeometric models and observed cosmic polarization rotation maps while simultaneously providing a framework for reconstructing organized Aether domains from future high-precision polarization surveys. Future implementations may employ HEALPix-based sky discretization and harmonic inversion techniques commonly used in CMB analyses G'orski et al. [2005].

6.2 Isotropic Baseline

The isotropic baseline is

$$\delta\beta = 0.$$

This case represents a sky in which only the universal birefringence component, β_0, is present. It provides the null residual model against which all organized Aether models are compared.

6.3 Galactic Spiral Organization

A spiral organization model is represented by

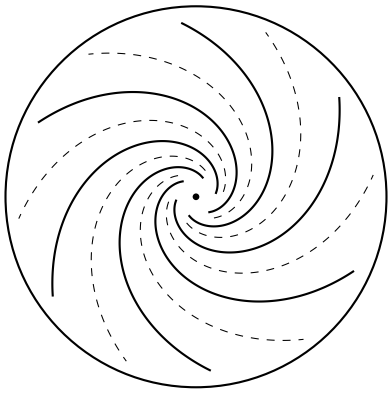
$$\chi_t = \Omega_0 \cos(m\phi - k \ln r)\,,$$

where Ω_0 is the temporal-torque amplitude, m is the spiral mode number, and k controls the radial winding rate. This form models loxodromic organization associated with persistent spiral structure.

6.4 Filamentary Organization

A filamentary organization model is represented by

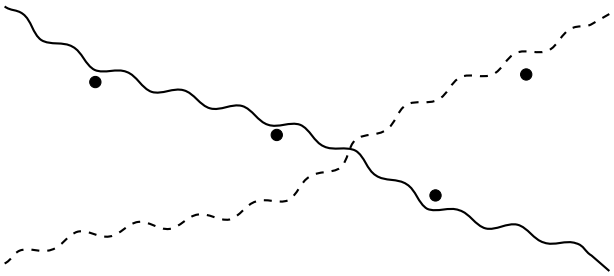
$$\chi_t = \sum_i \Omega_i \exp\left(-\frac{d_i^2}{2\sigma_i^2}\right),$$



$$\chi_t = \Omega_0 \cos(m\phi - k \ln r)$$

Figure 2: Schematic spiral temporal-torque organization. Alternating solid and dashed arms represent opposite residual birefringence orientation associated with loxodromic Aether structure.

where Ω_i is the temporal-torque strength of the ith filament, d_i is distance from the filament axis, and σ_i is the transverse width of the filamentary domain. The phenomenological form is motivated by the observed filamentary organization of the cosmic web Bond et al. [1996].



$$\chi_t = \sum_i \Omega_i \exp\left(-\frac{d_i^2}{2\sigma_i^2}\right)$$

Figure 3: Schematic filament-induced residual birefringence pattern. Filamentary Aether organization produces elongated corridors of temporal-torque accumulation along preferred large-scale structures.

6.5 Mixed Hierarchical Organization

A hierarchical model combines local, spiral, and filamentary contributions,

$$\chi_t = \Omega_{\text{spiral}} + \Omega_{\text{filament}} + \Omega_{\text{local}}.$$

This model predicts that residual birefringence maps should contain superposed signatures: low-order multipoles from large-scale organization, spiral harmonics from galactic structure, and elongated corridors from filamentary Aether domains.

7 Observational Program

Recent CMB polarization analyses provide the observational motivation for Aether tomography. Planck 2018 analyses reported $\beta = 0.35^\circ \pm 0.14^\circ$ Minami and Komatsu [2020b]. Planck PR4 analyses reported $\beta = 0.30^\circ \pm 0.11^\circ$ while emphasizing the role of polarized foreground uncertainty Diego-Palazuelos et al. [2022a]. ACT DR6 reported $\beta = 0.215^\circ \pm 0.074^\circ$ and noted unresolved systematics that prevent strong cosmological conclusions Diego-Palazuelos and Komatsu [2025]. LiteBIRD forecasts indicate that a 0.3° isotropic birefringence signal could be detected with a statistical significance of approximately 5–13σ, depending on pipeline and systematic treatment de la Hoz et al. [2025].

The APM prediction for the universal component is

$$\beta_0 = \frac{1}{16\pi^2} \approx 0.3628^\circ.$$

The comparison between β_0 and observationally inferred birefringence angles motivates separating the measured field into an isotropic component and a residual component suitable for tomography.

Table 2: Representative observational context for isotropic cosmic birefringence. Values are included to motivate residual-map analysis and should be interpreted with the systematic qualifications stated in the cited works.

Source	Reported or forecast value	Relevance to Aether tomography
APM universal component	$\beta_0 \approx 0.3628^\circ$	Predicted isotropic reference component
Planck 2018	$\beta = 0.35^\circ \pm 0.14^\circ$	Early observational comparison
Planck PR4	$\beta = 0.30^\circ \pm 0.11^\circ$	Foreground-sensitive full-sky comparison
ACT DR6	$\beta = 0.215^\circ \pm 0.074^\circ$	Independent high-resolution comparison
LiteBIRD forecast	0.3° detectable at about 5–13σ	Future full-sky precision test

The present framework may be tested using Planck, ACT DR6, LiteBIRD, Simons Observatory, BICEP/Keck-class polarization calibration programs, and CMB-S4-class or successor surveys. The essential observational products are calibrated polarization maps, EB and TB spectra, multi-frequency foreground separation, Galactic masks, and residual birefringence maps suitable for harmonic decomposition Minami and Komatsu [2020a], Diego-Palazuelos et al. [2022b].

The principal observational objective is the reconstruction,

$$\delta\beta(\theta, \phi) \longrightarrow \chi_t(\mathbf{x}),$$

thereby establishing the observational discipline of Aether tomography.

8 Predictions and Falsification Criteria

The framework predicts:

1. an isotropic birefringence component,

$$\beta_0 = \frac{1}{16\pi^2},$$

2. statistically significant low-order residual harmonics,
3. spiral and filamentary organization signatures,
4. nonzero handedness observables, and
5. correlations with large-scale magnetic organization.

The framework is falsified if residual birefringence maps remain statistically isotropic and exhibit no persistent organization correlated with chronogeometric structure.

9 Discussion and Future Directions

The principal contribution of this paper is the formalization of residual cosmic birefringence as an inverse problem. The residual field, $\delta\beta(\theta, \phi)$, is not treated merely as an angular correction to the universal birefringence component. It is treated as an observable projection of hidden chronogeometric organization. This shifts the role of cosmic birefringence from signal detection to structural reconstruction.

Aether tomography provides a method for interpreting residual cosmic birefringence as an observational probe of organized five-dimensional chronogeometric structure. In this framework, the universal component β_0 represents the isotropic topological contribution, while $\delta\beta(\theta, \phi)$ represents the residual sky projection of hidden temporal-torque organization.

The present paper develops the forward and inverse structure of the method but treats the candidate definitions of χ_t phenomenologically. This is intentional. The observational framework must first identify which forms of organized Aether structure produce distinguishable residual maps before a unique QMU-native derivation of chronotorsional curl-organization density is imposed.

Paper 3 in this sequence will focus on a first-principles QMU derivation of χ_t. Paper 4 may then develop numerical reconstruction pipelines, including HEALPix-based sky simulations, Bayesian inversion, and machine-learning-assisted classification of spiral, filamentary, and hierarchical residual patterns. A later experimental paper may also examine whether optical or plasma analog systems can model temporal-torque gradients in a controlled laboratory setting.

Acknowledgments

The Quantum AetherDynamics Institute (QADI) is a private 501(c)(3) research institute developing the Aether Physics Model (APM) and Quantum Measurement Units (QMU) Thomson III [2025]. Publications and data are archived with DOIs in the AetherPhysics Zenodo community: zenodo.org/communities/aetherphysics.

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