CET Diagnostic Pipeline for Cosmic Voids: Methodological Overview and Application to the Eridanus Supervoid

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Abstract

This document provides a structured overview of the diagnostic pipeline used to analyze the Eridanus Supervoid under the Cosmic Elastic Theory (CET) framework. The pipeline integrates topological persistence, density estimation via wavelet-SPH, causal relaxation computation, redshift distortion analysis, cosmic Poisson ratio calculation, and observational validation with DES data. Each phase is modular and reproducible, forming a complete toolkit for evaluating elastic signatures in large-scale cosmic structures.

1 1. Introduction

The Eridanus Supervoid represents a promising environment to test predictions from the Cosmic Elastic Theory (CET), which posits that cosmic acceleration can emerge from elastic deformation of spacetime in underdense regions. To rigorously evaluate this, we designed a six-phase pipeline capable of extracting structural, physical, and spectral features from void datasets.

This paper outlines the logic, implementation, and outputs of each phase, consolidating the pipeline as a standalone methodology.

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2 2. Pipeline Overview

The pipeline consists of the following phases:

- **Phase 1: Persistent Topology** — Identifies the topological boundary of the void using persistent homology.
- **Phase 2: Density Estimation** — Applies a wavelet-enhanced SPH method to compute the 3D density field.
- **Phase 3: Elastic Relaxation** — Integrates elastic strain across the void using the CET framework.
- **Phase 4: Redshift Distortion** — Measures Δz between observed and CET-predicted values.
- **Phase 5: Cosmic Poisson Ratio** — Estimates ν using radial vs. transverse deformation.
- **Phase 6: Observational Validation** — Compares κ predicted by CET with data from the DES survey.

3 3. Methodological Notes

Each phase was implemented independently using Python-based modules. The modular structure enables the pipeline to be applied to other voids with minimal adaptation.

The integration of multiple data modalities (topology, density, redshift) allows a comprehensive evaluation of elastic signatures. This distinguishes CET diagnostics from purely geometric or statistical void analyses.

4 4. Reproducibility and Availability

All scripts used in the Eridanus case are archived and available as part of the public release under the CET project. Each figure produced corresponds to a direct output of a given phase, ensuring full transparency.

5 5. Discussion and Future Extensions

This pipeline can be extended in multiple directions:

- Incorporating lensing data to assess shear patterns;
- Applying the protocol to voids in hydrodynamical simulations;
- Refining the topological segmentation using TDA clustering techniques.

Its modularity also allows integration with other theories that rely on structural deformation or tension-based metrics.

Conclusion

The Eridanus pipeline serves as a concrete implementation of the CET diagnostic framework. It is adaptable, reproducible, and grounded in observational data. As such, it sets the foundation for future large-scale applications and comparative void studies.