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Exploiting the cosmic web in DESI for enhanced cosmological constraints

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Modern spectroscopic surveys operate at a scale where cosmological inference benefits from both statistical precision and wide coverage. The Dark Energy Spectroscopic Instrument (DESI) is mapping the large-scale structure of the Universe through high-throughput multi-object spectroscopy, assembling tens of millions of galaxy and quasar spectra across a redshift range from $z \sim 0$ to $z \sim 3.5$ over 14,000 deg^2. While baryon acoustic oscillations (BAO) and redshift-space distortions (RSD) from two-point correlation functions remain central pillars for constraining the expansion history $H(z)$ and growth rate $f\sigma_8(z)$, DESI's unprecedented depth, volume ($\sim$ 20 Gpc^3), and target diversity enable complementary analyses that access non-Gaussian information in the matter distribution.

I will show how perspectives sensitive to the cosmic web, characterizing voids, filaments, and their topological organization, naturally complement power spectrum and correlation function summaries.
These approaches capture environment-dependent clustering, probe the full probability distribution function of density fluctuations beyond Gaussian predictions, and provide independent constraints on survey systematics such as target selection effects and observational incompleteness.

Specifically, I will outline how cosmic-web-based statistics such as void size function, filament size function, void autocorrelations, filament autocorrelations, and void-filament cross-correlations encode complementary constraints on fundamental parameters including the dark energy equation of state (w_0, w_a), matter density Ω_m, amplitude of matter fluctuations σ_8, and neutrino masses m_ν. These summary statistics exploit different cosmological dependencies than standard clustering: voids are particularly sensitive to dark energy and modified gravity through the Alcock-Paczyński effect and void-galaxy cross-correlations, while filamentary structures trace the anisotropic collapse history sensitive to σ_8 and growth.

Finally, I will show how the ASTRA algorithm can be leveraged to identify and characterize the cosmic web in DESI data. I will present preliminary results of cosmic web structures extracted using ASTRA on DESI's EDR and public DR1 data releases.

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