

Simulation-based tension quantification of the cosmic dipole anomaly

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The cosmic dipole observed in the matter distribution of galaxy surveys consistently disagrees with the kinematic expectation set by the cosmic microwave background, posing a serious challenge to the Cosmological Principle and the standard model of cosmology. However, the fidelity of the dipoles we infer rests on our understanding of the systematics present in the surveys. For many systematics, their analytical effect on the source counts is unknown, rendering the likelihood function intractable. We demonstrate that Simulation-Based Inference (SBI) is an effective tool for quantifying tensions between cosmic dipole data sets, enabling inference when likelihoods are intractable. Here, we apply neural-ratio estimation to the cosmic dipole for the first time, recovering tensions between Planck, NVSS, RACS, and CatWISE under different treatments of systematics. Our SBI architecture provides a robust machinery for future dipole analyses with LSST, Euclid, and the SKA, where it will be essential to model complex observational systematics.

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