Stony Brook University

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Abstract

Exploring the Dark Universe with Cosmic Microwave Background and Optical Data

By
Mathew Syriac Madhavacheril

Over the past two decades, a standard cosmological model has emerged that supports the picture of an expanding Universe dominated by dark matter and dark energy. Understanding the nature of the dark Universe is a major open problem in cosmology. By making the first measurement of gravitational lensing of the CMB by dark matter halos and the first measurement of the ratio of this signal to the lensing signal from optical data, this dissertation develops new techniques to map dark matter and constrain the properties of dark energy.

Gravitational lensing is the phenomenon by which photons from a background source are deflected by the gravitational interaction with intervening matter as the photons travel to us. Using CMB maps from the Atacama Cosmology Telescope, we make the first measurement of lensing of the CMB by dark matter halos. This detection opens up a new way of measuring masses of dark matter halos, a crucial step in constraining dark energy through its effect on the growth of structure over cosmic time. Dark energy also affects the expansion history of the Universe and leaves an imprint on the relationship between cosmic distances and redshifts. We perform the first measurement that compares the lensing signal of the same dark matter halos using sources at two very different distances, the CMB (redshift ~ 1100) and background galaxies (redshift ~ 1), thus obtaining a purely geometric distance ratio that can be used to constrain dark energy. We also explore how dark matter can be mapped by measuring the lensing distortions in shapes of galaxies and develop a technique that can better reconstruct the fluctuations in the intervening matter density using these shapes. Finally, we investigate the particle properties of dark matter by examining its effect on fluctuations in the CMB, thereby setting the tightest constraints on the annihilation cross-section and mass of dark matter particles from the CMB.

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