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Department of Theoretical Physics

Cosmology and Astroparticle Physics

Highlights

A novel survey design, with combination of wide plus deep components, was proposed and shown to lead to precision cosmology even with a much smaller yield of clusters.

Galaxy clusters observed jointly in X-ray and Sunyaev-Zel'dovich surveys were used to construct an ensemble of cosmic rulers. It was shown from cosmological distance estimates that these 'rulers' can give tighter constraints on Dark Energy.

A top-down, phenomenological model for the intra-cluster medium was built yielding the cluster gas pressure profile and the cluster Sunyaev-Zel'dovich scaling relations in excellent agreement with observations.

A 'universal entropy injection' prescription was proposed, and its properties studied, for galaxy clusters having the recently observed universal pressure profile.

Text

Research was carried out mainly in the areas of structure, energetics and evolution of galaxy clusters, galaxy cluster surveys and Dark Energy.

Cosmology with a combination of deep and wide surveys

The advantages of a wedding-cake design for Sunyaev-Zel'dovich cluster surveys were demonstrated. It was shown that by dividing up a cluster survey into a wide and deep survey, one can essentially recover the cosmological information that would be diluted in a single survey of the same duration due to the uncertainties in our understanding of cluster physics. The parameter degeneracy directions of the deep and wide surveys are slightly different, and combining them breaks these degeneracies effectively. A variable depth survey with a few thousand clusters is as effective at constraining cosmological parameters as a single depth survey with a much larger cluster sample. [Subhabrata Majumdar with Satej Khedekar (DAA)].

Using clusters in Sunyaev-Zel'dovich effect plus X-ray surveys as an ensemble of rulers to constrain cosmology

Ongoing and upcoming surveys in X-rays and Sunyaev-Zel'dovich Effect (SNE) are expected to jointly detect many clusters due to the large overlap in sky coverage. These clusters were shown to form an ensemble of rulers to estimate the angular diameter distance, dA(z). It was shown that this comes at no extra observational cost, as these clusters form a subset of a much larger sample, assembled to build cluster number counts dN/dz. On using this dA(z) the dark energy constraints can be improved by factors of 1.5-4 over those from just dN/dz. Even in the presence of a mass follow-up of 100 clusters (done for mass calibration), the dark energy constraints can be further tightened by factors of 2-3. Adding dA(z) from clusters was shown to be similar to adding luminosity distance dL(z) from the SNE observations. [Subhabrata Majumdar with Satej Khedekar

(DAA)].

Sunyaev-Zel'dovich scaling relations from a simple phenomenological model for galaxy clusters

A simple, top-down model for the gas density and temperature profiles for galaxy clusters has been built. The gas is assumed to in hydrostatic equilibrium along with a component of non-thermal pressure taken from simulations and the gas fraction approaches the cosmic mean value only at the virial radius or beyond. The model has few free parameters which have been fixed from X-ray and lensing observations. The gas pressure profiles were compared with the recently proposed "Universal" pressure profile and found to be in very good agreement. The SZE scaling relations between the integrated SZE flux Y, the cluster gas temperature T, the cluster mass M_{total} and the gas mass M_{gas} were also shown to be in excellent agreement with the recently observed SZE scaling relations. The gas mass fraction was found to be increase with cluster mass and within 10% of observations at 2/3 the virial radius. It was argued that the consistency between the global properties of clusters detected in X-rays and SZE shows that observations are looking at a common population of clusters as a whole, and there is no deficit of SZE flux relative to expectations from X-ray scaling properties. Thus, it makes it easier to compare and cross-calibrate clusters from upcoming X-ray and SZE surveys. [Subhabrata Majumdar with Anya Chaudhuri (DAA)].

A universal entropy injection prescription and gas pressure in galaxy clusters

The effect of entropy injection in the Intra-Cluster Medium (ICM) was studied in light of the recent observationally determined universal pressure profile of the ICM. It was shown that a simple universal prescription of entropy injection results in the final, observed universal pressure profile. This simple prescription has two components, one associated with an overall increase in entropy and another associated with injection in the central parts of the cluster. This is indicative of a need of both preheating the ICM as well *in situ* AGN/SNe heating. The usefulness of the method was demonstrated by extending the calculations to clusters at high redshift, and predicting redshift evolution of cluster scaling relations that can be tested against data. It was shown that the current observational data are indicative of entropy injection decreasing with redshift. [Subhabrata Majumdar with Biman B. Nath (RRI)]