

# The Kavli-IPMU focus week workshop on Cosmology with Small Scale Structure

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The Kavli IPMU focus week workshop on “Cosmology with Small Scale Structure” was held from July 22 to July 26 and brought together participants from all over the world interested in probing cosmological parameters of the Universe and modifications to gravity from small scale astrophysical observations of weak lensing, galaxy clustering, redshift space distortions, and galaxy clusters.

The main challenge in realizing the true potential of these probes is our limited understanding of galaxy formation. The focus of the workshop was to discuss ways to best marginalize over these uncertainties and tease out the cosmologically interesting information from these observables.

The workshop was held as a moderated round table discussion on the current developments in the field and challenges that lie ahead. The discussion on the first day revolved around designing sensitivity tests to identify a combination of observables that could be used to learn about galaxy formation phenomenologically, and simultaneously learn about the cosmological parameters. Numerical simulations of cold dark matter are the workhorse for cosmological studies from small-scale structure. The second day focused on the accuracy and large volume requirements on numerical simulations. The

third day was devoted to the topic of redshift space distortions, which reflect our inability to measure the exact positions of galaxies due to their motions. There was a discussion on the progress in modelling these distortions. The fourth day examined how baryonic processes can cause a back-reaction on the dark matter and understanding parameters that can capture these processes. This is essential to exploit the statistical power of measurements of cosmic shear which several ongoing and large upcoming surveys will provide. There was also a discussion on modifications to gravity, novel probes on large scales, and the ensemble of simulations of specific modifications to gravity currently available. The last day was devoted to identification of galaxy clusters in large imaging surveys, and their use as probes of cosmological parameters.

The last day also featured two summaries of the workshop, an optimist’s summary delivered by Frank van den Bosch and a skeptic’s summary delivered by Martin White. The optimist’s summary presented some of the difficulties in modeling of small scale structure that were discussed during the workshop, but also showed that these small scale probes are significantly constraining even after marginalization over a large number of galaxy formation and

modeling uncertainties. It also highlighted the current tension between cosmological parameters obtained from the cosmic microwave background experiment Planck, and a number of small-scale structure probes on the matter density and the amplitude of density fluctuations in the Universe. The skeptic's summary included a parallel to collider experiments in particle physics. The suggestion was that precision measurements of cosmological parameter should perhaps be left to clean probes such as baryon acoustic oscillation experiments or CMB experiments (analogous to electron machines in particle physics), while small scale structure probes (analogous to

proton machines) are excellent tools for discovery than precision. It highlighted the importance of demonstrating the resilience of small scale probes to uncertainties in galaxy formation physics. It also suggested the need to perform sensitivity studies (some ideas discussed during the workshop), to help design observational campaigns in the future.

The topics discussed during the workshop are central to guide the research directions necessary to exploit the potentials of the upcoming Hyper Suprime-Cam survey and the Prime Focus Spectrograph survey.

