Cosmic Walkers in Midway

Combined Probes Analysis with the Dark Energy Survey

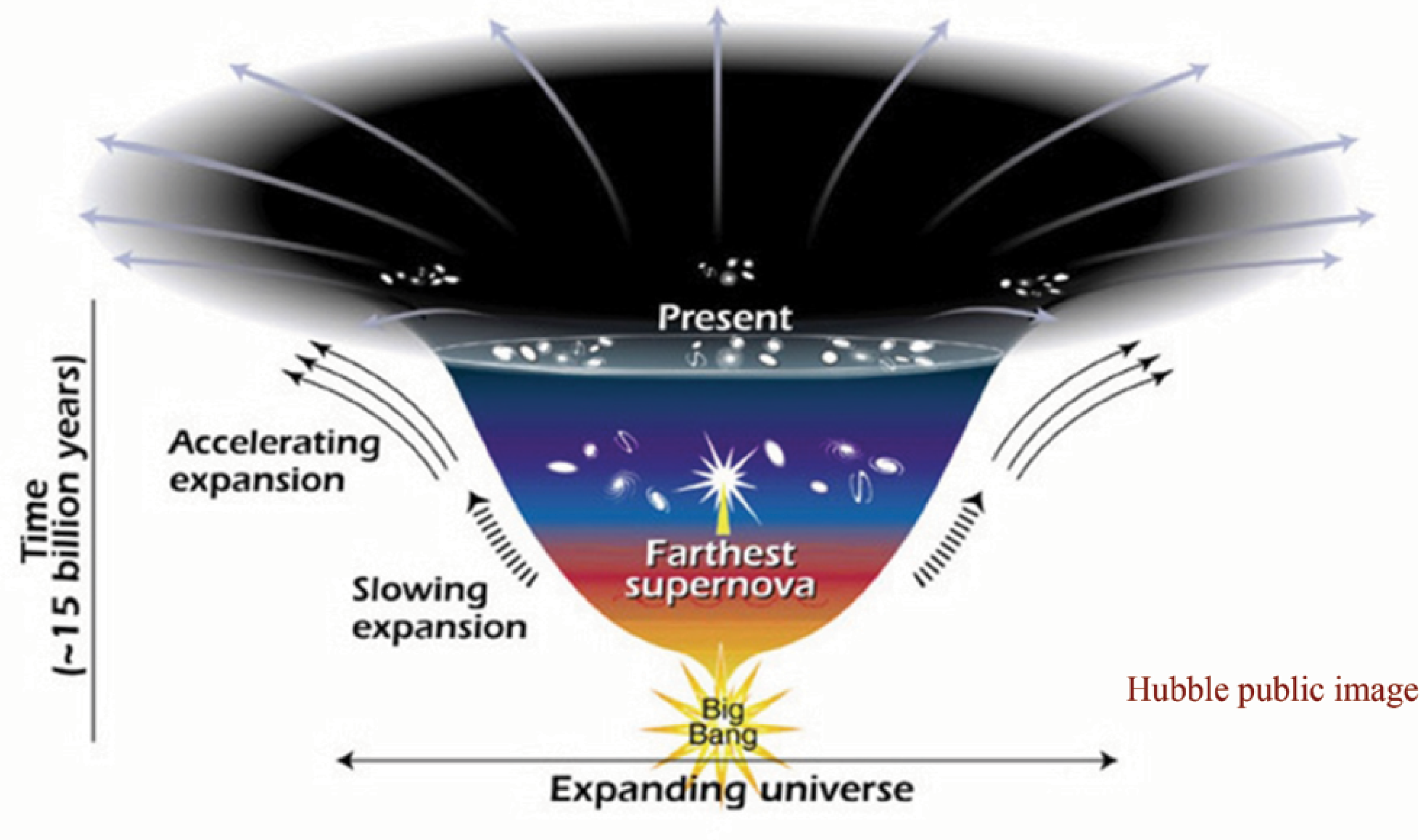
Youngsoo Park

KICP / Department of Physics, University of Chicago

Kavli Institute for Cosmological Physics AT THE UNIVERSITY OF CHICAGO

DARK ENERGY SURVEY

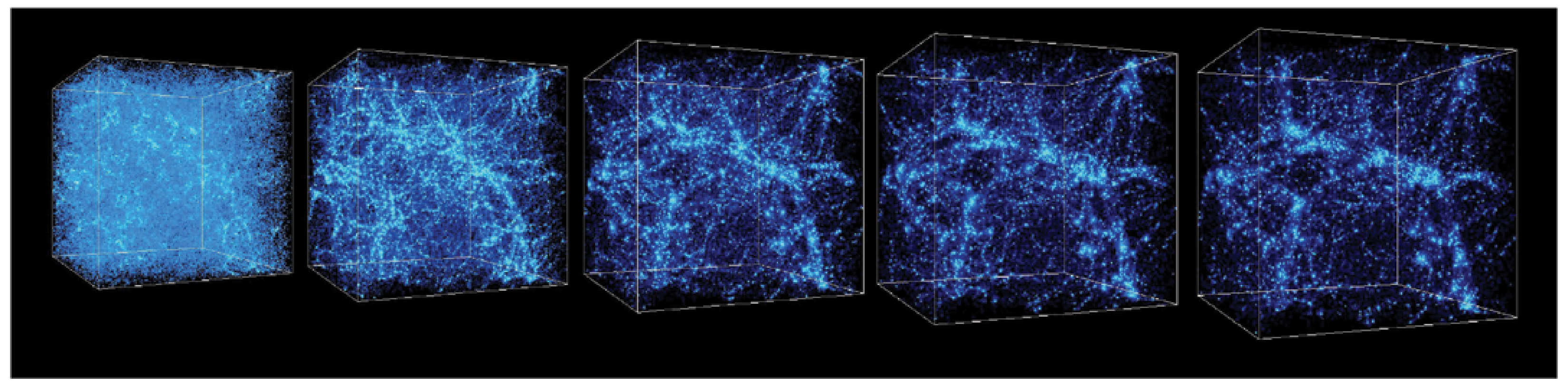
The Dark Side of the Universe



Hubble public image

A key discovery of modern cosmology is the accelerated expansion of our universe; something is strongly countering the effect of gravity. The source of this acceleration, commonly known as ***Dark Energy***, accounts for over 70% of the entire mass-energy content. However, the exact nature of Dark Energy is, somewhat fittingly, yet in the dark. Understanding how this cosmic ingredient acts and evolves has now become a central effort in cosmology. The Dark Energy Survey is an attempt to answer this critical question by observing an eighth of the sky, three billion years deep, taking a survey of over 300 million galaxies.

Large(st) Scale Structures

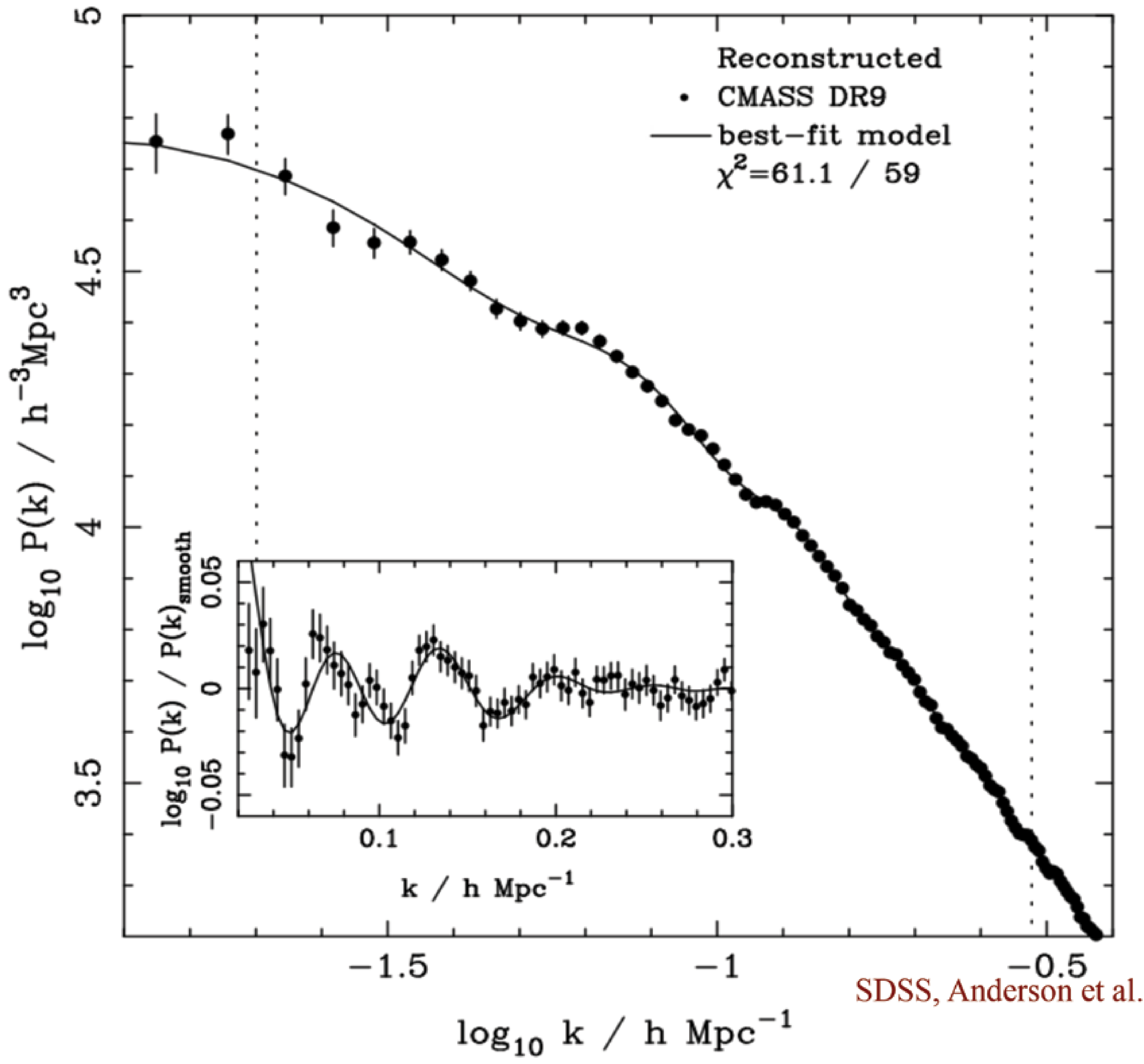


Kravtsov et al. (2004)

The Large Scale Structure of the universe consisting of galaxies and galaxy clusters, arguably the largest scale structures mankind has ever seen, is assumed to have ***grown*** from small initial perturbations in the distribution of matter across the universe. This growth is dictated by the composition and expansion history of the universe, both exhibiting strong dependences on dark energy contribution. Thus, it is natural to consider measurements of structure growth, such as the sample of galaxies observed by Dark Energy Survey, as a probe of dark energy.

What We Can See, What We Cannot

Growth of structure affects the matter distribution itself, and thus would ideally be measured directly from the matter distribution of the universe. However, with most of it being dark matter that does not interact with light, we can only observe dense objects that emit light – galaxies and galaxy clusters. The clustering of these objects is our best observable, measured by the Fourier space ***galaxy power spectrum***. The power spectrum, calculated from the two-point function of galaxies, can be predicted theoretically with a number of well-calibrated assumptions drawn from N-body simulations, allowing for an MCMC likelihood analysis.



SDSS, Anderson et al.

Combine and Conquer

While galaxy clustering traces the underlying clustering of matter, galaxies tend to clump stronger than matter; they are biased tracers. In particular, the more massive a galaxy is, the stronger its tendency to cluster with other galaxies will be. Therefore, galaxy mass information is crucial in correctly predicting galaxy clustering. Since clustering measurements do not contain this information, we combine a different probe, namely the ***weak lensing signal*** of galaxies, to this end. The gravitational potential of a galaxy bends light that travels around it, and if we assume a universal density profile for galaxies we can fully describe its lensing signal with its mass. Thus, combining these two observables provides a way to correctly predict the galaxy power spectrum, and ultimately the clustering of matter.

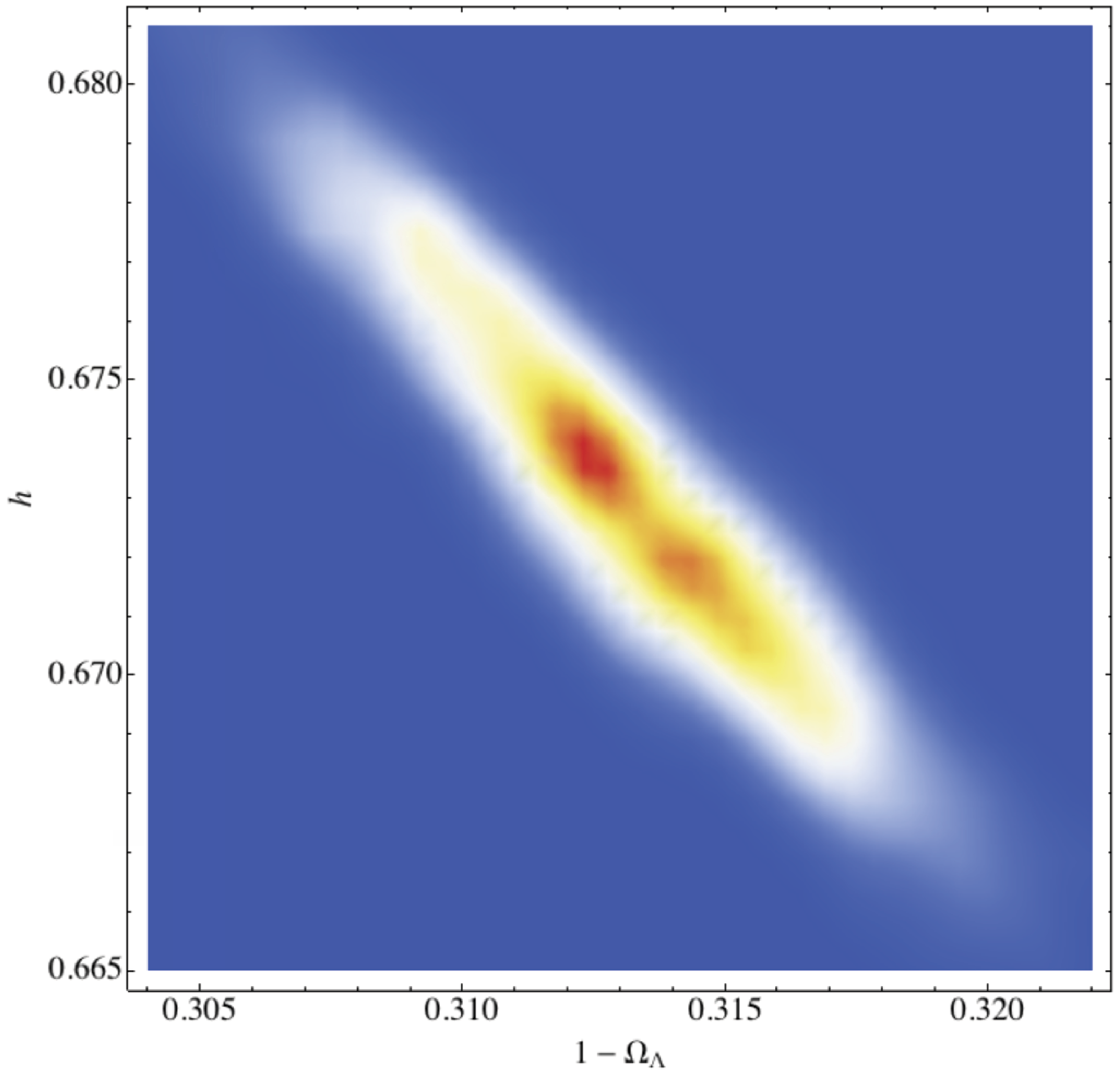
Exploring the Parametrized Universe

The "holy grail" of our analysis is a set of constraints on six parameters that enter the current best theory of our universe:

Ω_b, Ω_c, A_s, n_s, τ, and H_0.

In addition to these six, however, at least 20 different model nuisance parameters have to be included in the likelihood analysis even at the preliminary level, due to the combined modeling of different probes. This number could reach up to 100 for a full-scale analysis. At Midway, we tackle this challenge of probing a vast and degenerate parameter space by using the ***emcee*** sampler (Foreman-Mackey et al.), an implementation of the affine-invariant ensemble sampling algorithm (Goodman and Weare) that is capable of an efficient sampling of our parameter space as well as a straightforward parallelization of ensemble walkers at the OpenMP level. A modular analysis framework developed by the collaboration, CosmoSIS, is used to streamline the entire analysis process.

Below is an example of the chain kernel density, obtained by running our analysis with 96 cores on measurements from N-body simulations. With the recently finished first-year data streaming in, we are inches away from a new understanding of the cosmos.



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