P8 From CMB maps and galaxy catalogs to (early) dark energy constraints

Background

Cosmic expansion history is a sensitive probe of the properties of dark energy across cosmic time. However, our interpretation of expansion history measurements can be affected by parameter degeneracies and priors, which can skew the widely used Bayesian parameter inference. Frequentist statistics provides a complementary perspective on parameter measurements through profile likelihoods.

Project Goal

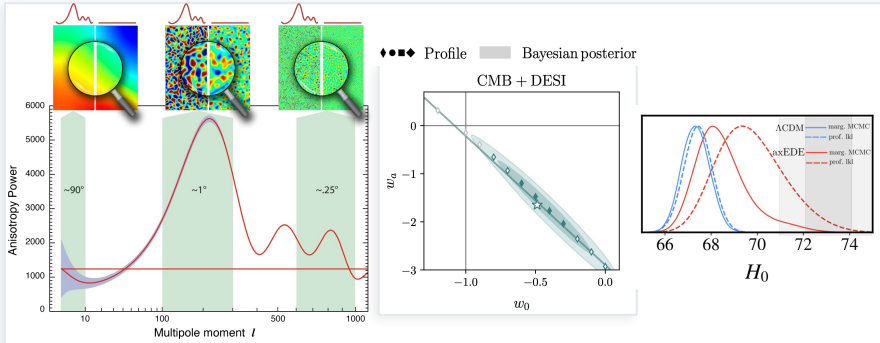
In this project, you will measure cosmic microwave background (CMB) power spectra from temperature maps and baryonic acoustic oscillations (BAO) from galaxy catalogs, and build intuition for their sensitivity to different fundamental physics.
We will then develop Bayesian inference (i.e., MCMC) and frequentist profile likelihood analyses to constrain properties of (early and late time) dark energy from these expansion history measurements, and explore the degeneracy-breaking power of combining measurements. If time permits, we will also incorporate supernovae into our analyses to familiarize ourselves with state-of-the-art dynamic dark energy constraints.

Necessary Concepts

- cosmological background evolution
- Bayesian statistics and Markov chain Monte Carlo (MCMC) methods
- proficiency with Cobaya, MontePython, python
- familiarity with HPCs

Computing Need

Initial measurements and parameter explorations can be carried out on a laptop. Full-parameter space inferences require HPC access, ca. 2000 CPU hours per inference.



*Left: CMB power spectrum and corresponding spatial scales of fluctuations. This is one of the two data sets that you will use in this project to characterize dark energy. **Center:** Bayesian and frequentist constraints on CPL dark energy from CMB + BAO data. **Right:** Bayesian and frequentist constraints on Hubble in LCDM and early dark energy cosmologies*

Background Resources

- High-level introduction to the CMB
  https://background.uchicago.edu/~whu/Papers/HuWhi04.pdf
- Frequentist parameter constraints with Procoli
  https://arxiv.org/pdf/2401.14225
- Bayesian Inference with Cobaya
  https://cobaya.readthedocs.io
- Bayesian Inference in Cosmology (Sections 2,3, and 5)
  https://arxiv.org/pdf/0803.4089


Anoma Ganguly
University of Arizona
anomaganguly@arizona.edu


Tanvi Karwal
University of Chicago
karwal@uchicago.edu


Elisabeth Krause
University of Arizona
krausee@arizoan.edu