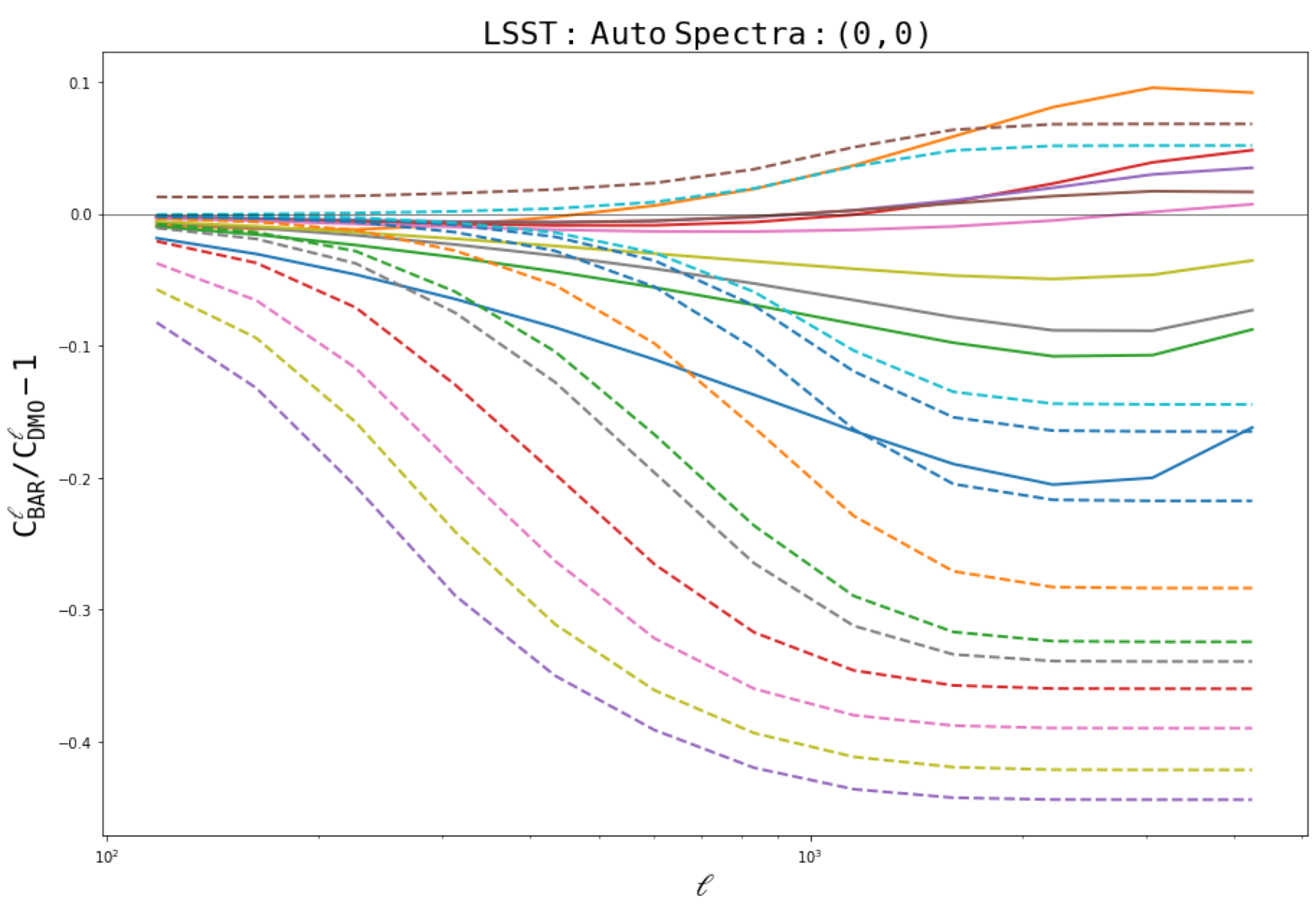
Emulating Baryonic Effects in Weak Lensing Measurements

Antigoni Georgiadou, Florida State University; Nick Gnedin, University of Chicago/Fermilab &
Brian Nord, University of Chicago/Fermilab

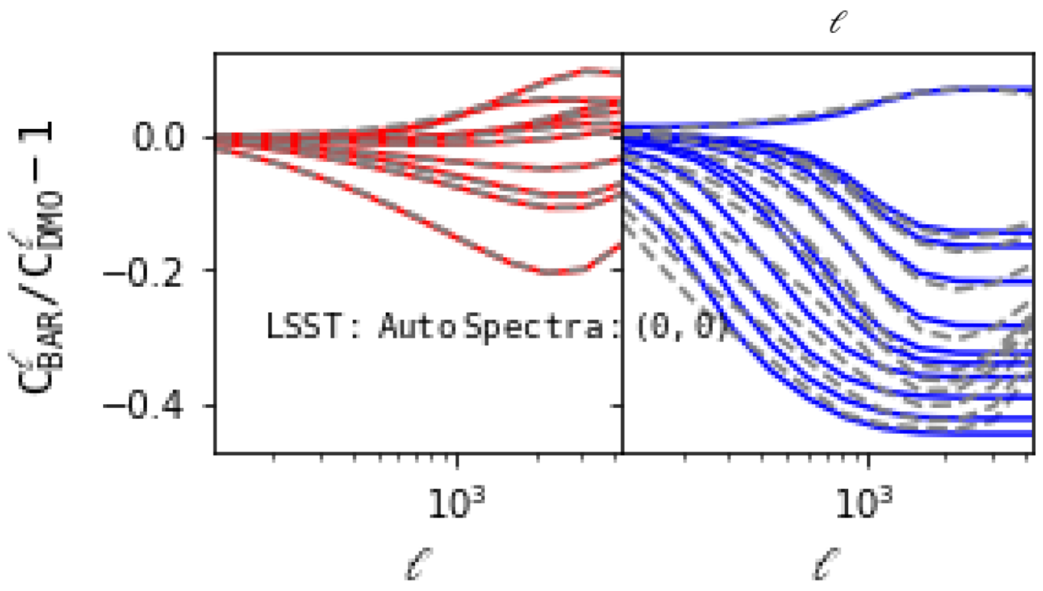
FERMILAB-POSTER-18-017-A

Gravitational Lensing

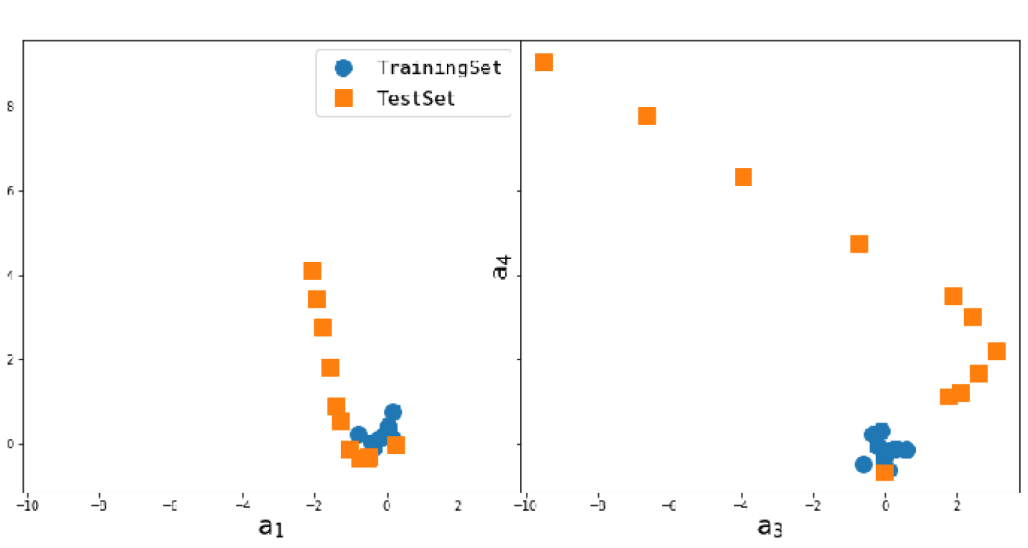
Baryonic effects are one of the most serious systematics to the tomographic analysis of weak lensing statistical measurements. We are working on a novel method for correcting cosmological observations for baryonic effects - a term used to label the fact that we observe galaxies, while theoretical modeling at present is only accurate enough for the dynamics of dark matter. Although modern cosmological simulations of dark matter (the "dark matter only", or DMO simulations) consistently reach the required 1% level of precision, the effect of baryonic physics on cosmological scales is expected to be a source of a much more severe systematic error in weak lensing measurements. In this analysis we apply a general framework to consistently include systematic effects into a likelihood analysis for cosmological surveys, such as the Dark Energy Survey (DES), and future Large Synoptic Survey Telescope survey (LSST).



Shear Spectra in the first redshift bin for LSST-like survey.



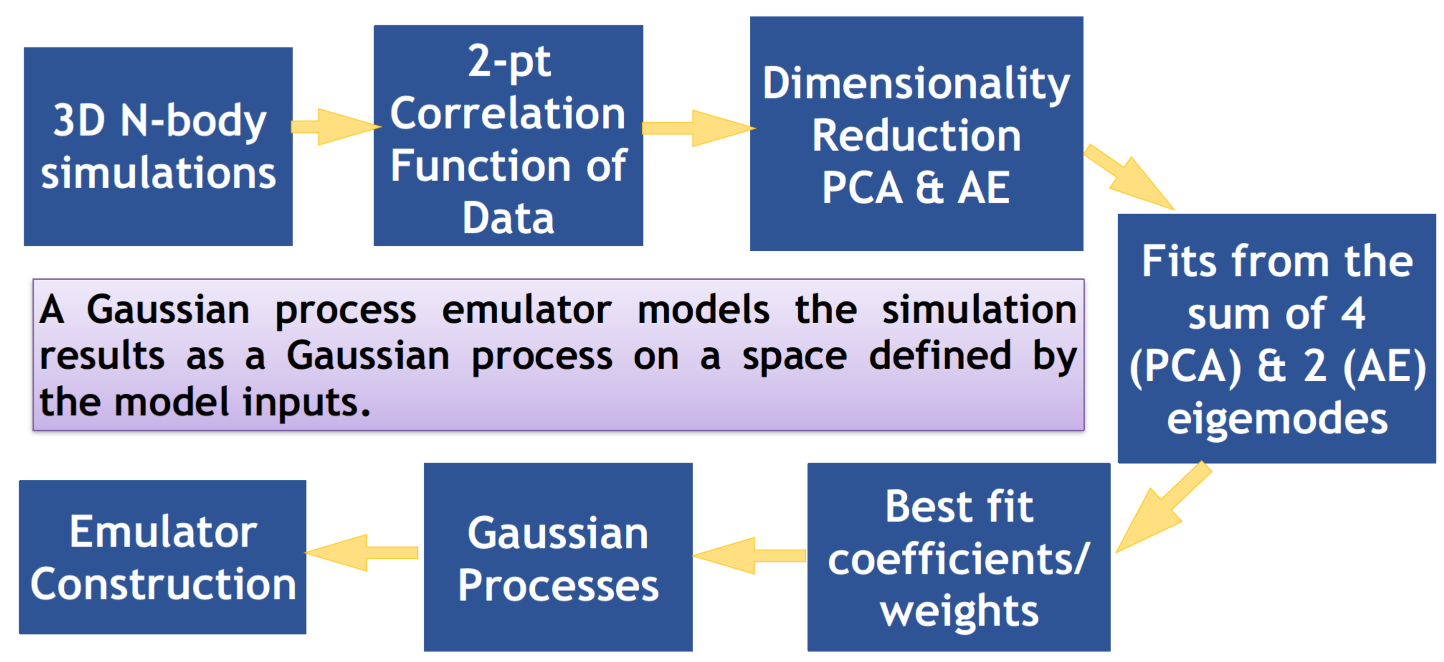
Fits to baryon contrasts after summing the first four eigenmodes for the training and test sets for LSST-like surveys (upper panel). Best fit coefficients for the training and test sets (lower panel).



We define baryons contrast for the weak lensing auto shear power spectra, which serve as the relative deviation from the DMO case. We split the cosmological simulation sets into training and test sets. The training set includes the subset of all baryonic scenarios used to compute the minimal set of principal components PCs. Outliers- most extreme baryonic scenarios- are included in the test set.

Workflow: Constructing the emulator

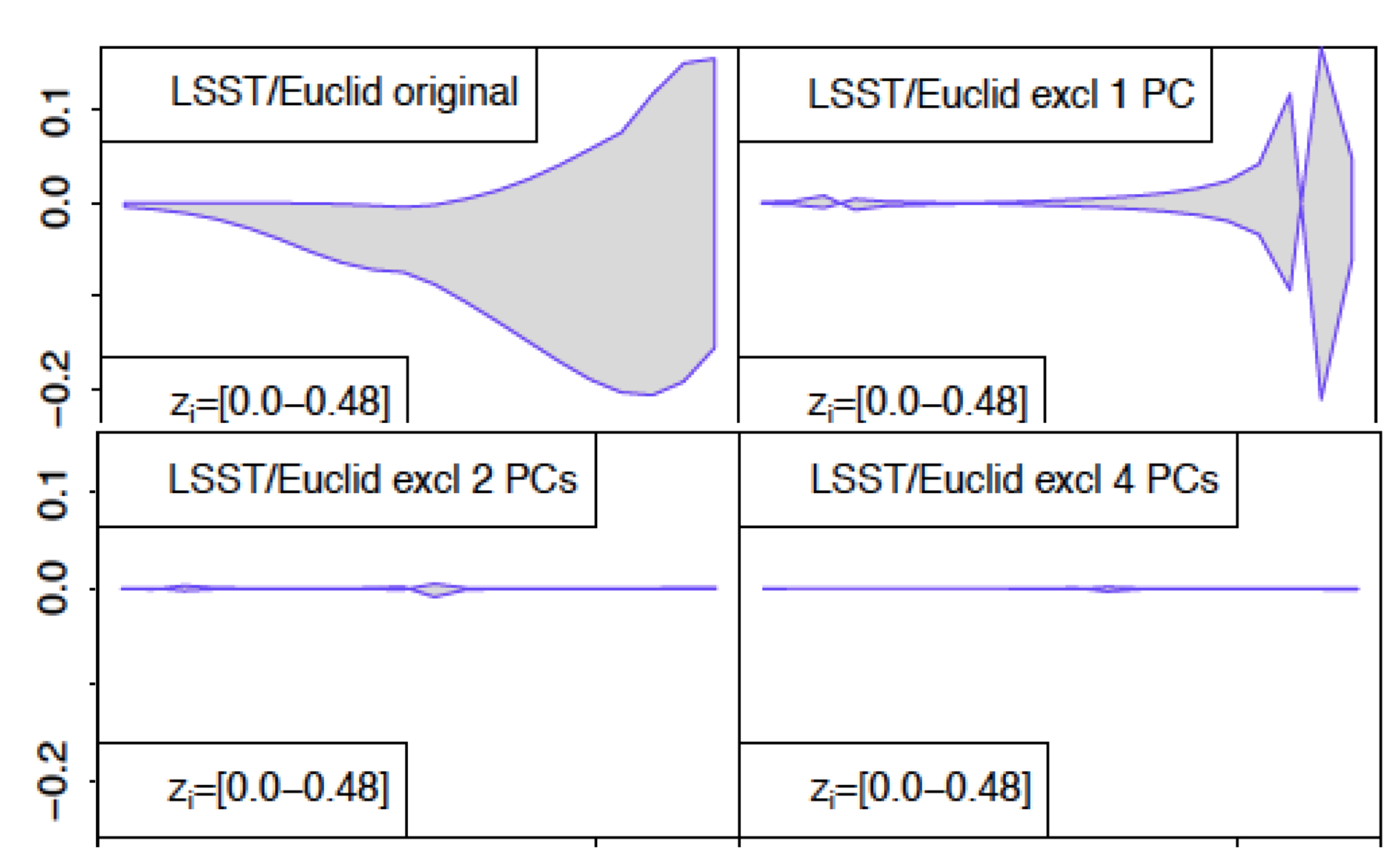
Baryonic effects are parameterized as the coefficients of principle components, with a Principal Component Analysis (PCA) and the Variational Autoencoder (AE) and should be marginalized over the cosmological parameter space.



Baryonic Effects in Simulations

We used various cosmological simulations to study different baryonic corrections on the tomographic analysis of the weak lensing shear power spectra for a LSST-like survey. Numerical simulations are computationally expensive so we need to approximate them. The basic idea is to build a statistical model, an emulator. Our approach for mitigating "baryonic effects" is based on using numerical simulations (a forward step from theory to observations) together with "emulating" techniques such as Gaussian Process modeling (a reverse step from observations to theory).

Tomographic autocorrelation power spectra for LSST/Euclid. Uncertainty intervals defined by the baryonic scenarios, centralized around the DMO case when excluding one (second panel on the top), two (first panel below) and four PCs (second panel below) compared to the initial uncertainty range.



Discussion

The discrepancy between what theorists can model well and what the real world offers us to see is rapidly becoming the most severe systematic bias for modern cosmological surveys, such as the Dark Energy Survey, and future Large Synoptic Survey Telescope survey. We will use Gaussian Processes modeling to mark parts of the baryonic effects parameter space that need additional simulations to enhance the emulator accuracy. Ultimately we will continue the process until the precision of the emulator is aligned with the observational probes of interest.

Fermi National Accelerator Laboratory

Fermilab U.S. DEPARTMENT OF ENERGY

This manuscript has been authored by Fermi Research Alliance, LLC under Contract No. DE-AC02-07CH11359 with the U.S. Department of Energy, Office of Science, Office of High Energy Physics.