New Nuisance Tests for a Cosmic Power Spectra Analysis of Subaru Hyper Suprime-Cam data

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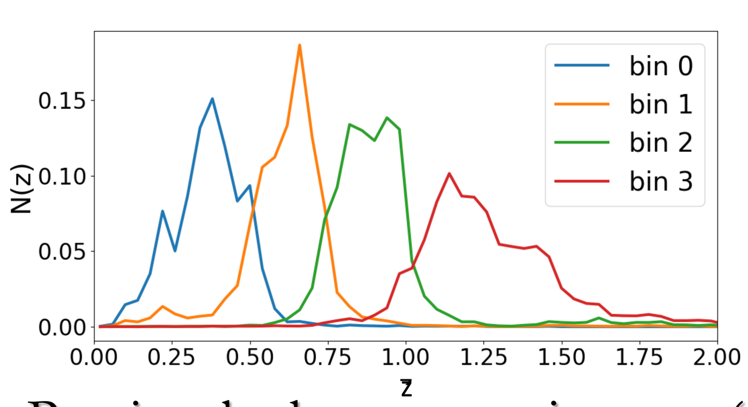
Abstract:

The Hyper Suprime-Cam (HSC) Subaru Strategic Program gave us a large catalog of galaxies and galaxy clusters[1]. We use a fiducial analysis of our galaxy clustering catalog with a specific set of parameters produced by modern astrophysics and cosmology. The catalog from the HSC contains measurements of galaxy positions and approximate redshifts sorted in 4 tomographic redshift bins. Because the calculations used in the process of sorting do have error bars, we add shifts of the same magnitude to the redshift bins in the positive or negative direction to marginalize over systematic uncertainty (nuisance). We now add 4 new parameters which will increase or decrease the width of these 4 bins in addition to the shifts. After adding the new width parameter, we find that it does not have a significant effect on the model.

Acknowledgements:

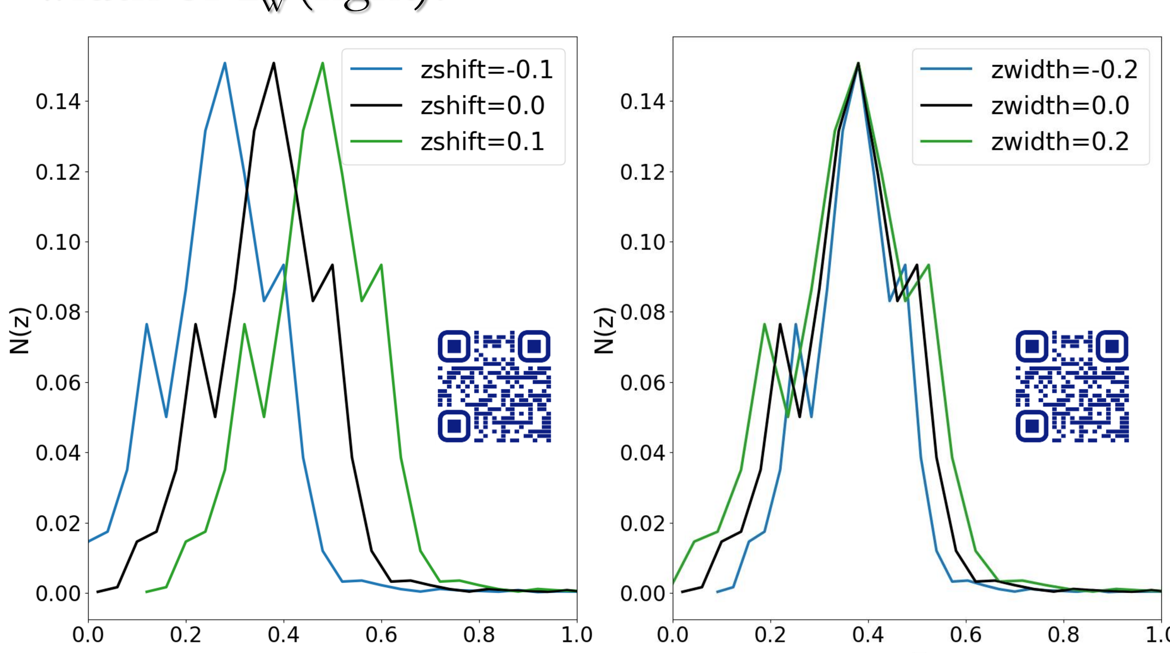
This project was supported in part by the U.S. Department of Energy, Office of Science, Office of Workforce Development for Teachers and Scientists (WDTS) under the Science Undergraduate Laboratory Internships Program (SULI).

Introduction & Hypothesis:



In this project, we focus on the four tomographic redshift bins that the galaxies are sorted into (top).

Previously the systematic error (nuisance) was accounted for in a displacement of redshift or Δz (left). The new error parameter will change the width or z_w (right).



If we account for these possible errors described above, then we will see an effect in the fiducial model of the HSC first year data.

Methods:

HOD

The Halo Occupation Distribution (HOD) describes the relationship between galaxies and dark matter halos[2]. The parameters seen in the first figure of Results are from a method of describing the HOD that uses a Fourier transform of matter density correlation function called power spectra.

MCMC Sampler

Markov Chain Monte Carlo is a method for sampling probability distributions. It explores the likelihood surface by performing steps in a way that ensures that distribution of samples converges to an unbiased sampling from the underlying likelihood surface[3]. We use the MCMC Sampler to determine how likely our model fits the data with the given parameters.

Bin Width

We account for the error by modifying the input redshift bins using these equations.

Δz only: $z_{i,\text{modified}} = z_i + \Delta z_i$

Δz and z_w: $z_{i,\text{modified}} = (z_i - z_{i,\max})(1 + z_{i,w}) + z_{i,\max} + \Delta z_i$

When z_w is zero, then the new equation simplifies to the same equation as before. These adjustments can be visualized here:

Benefits of this method:

- works for high dimensional problems
- less computation time
- versatile results

QR Codes?

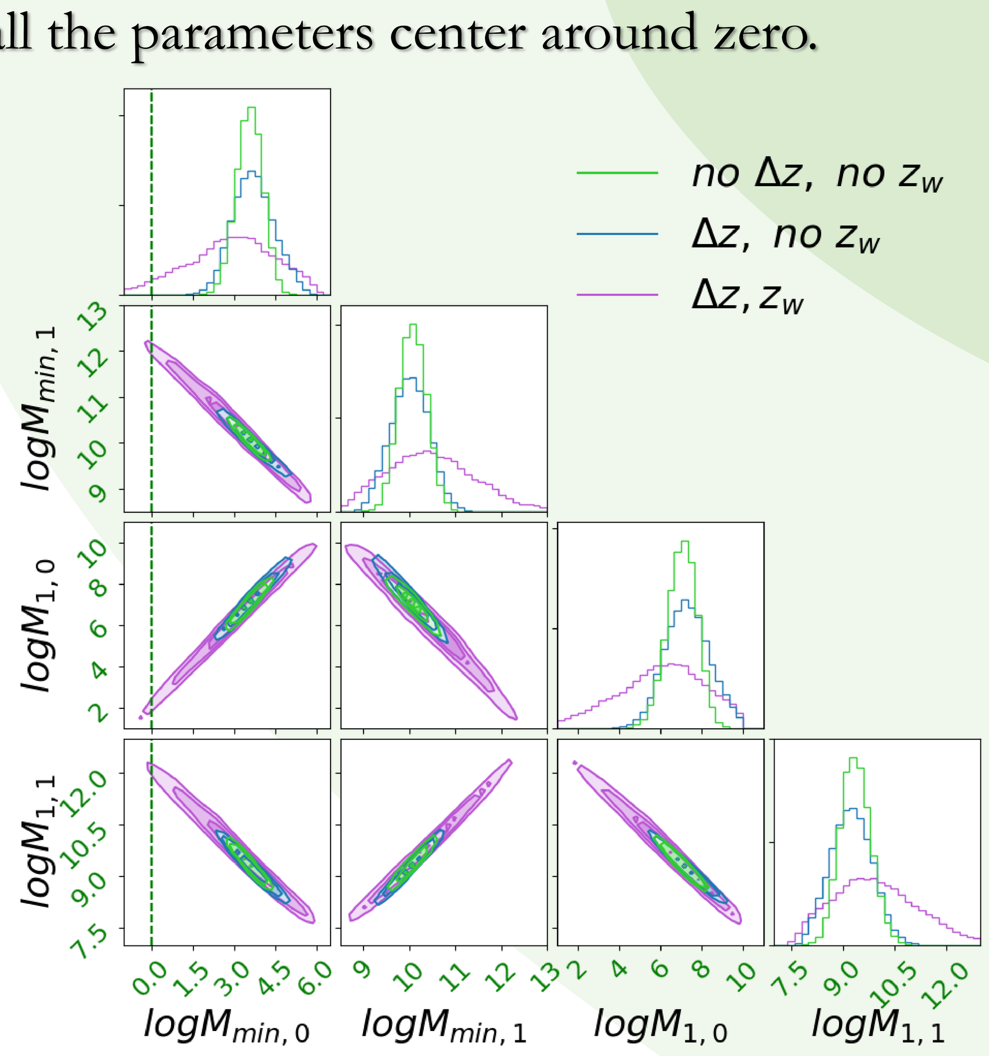
The QR codes you see will take you to a series of external gifs to better visualize what the nuisance parameters do.

Results:

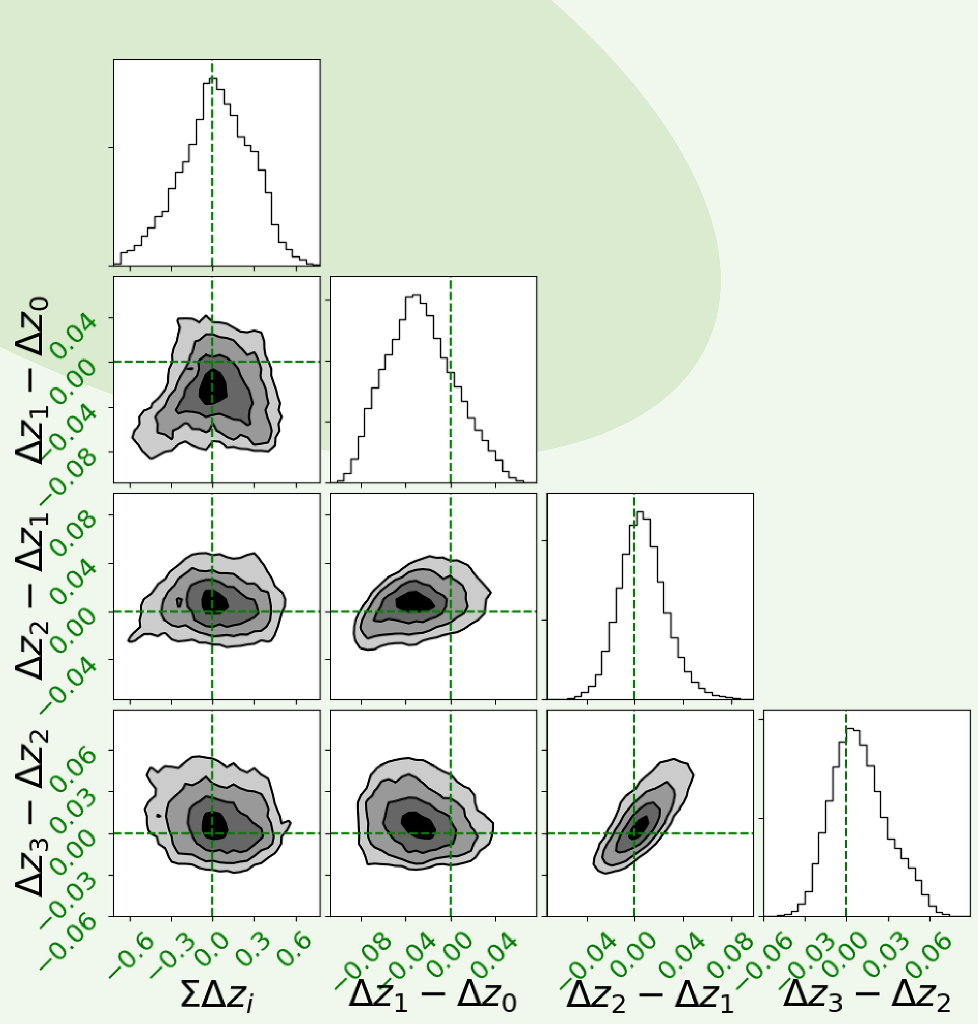
To see if a nuisance parameter such as the bin width has any effect on the model, we plot the likelihood distribution for each parameter.

The first figure depicts likelihood distributions the base parameters describing the dark matter density functions. We see that as we add more nuisance parameters, they become less precise, but the maxima location does not vary.

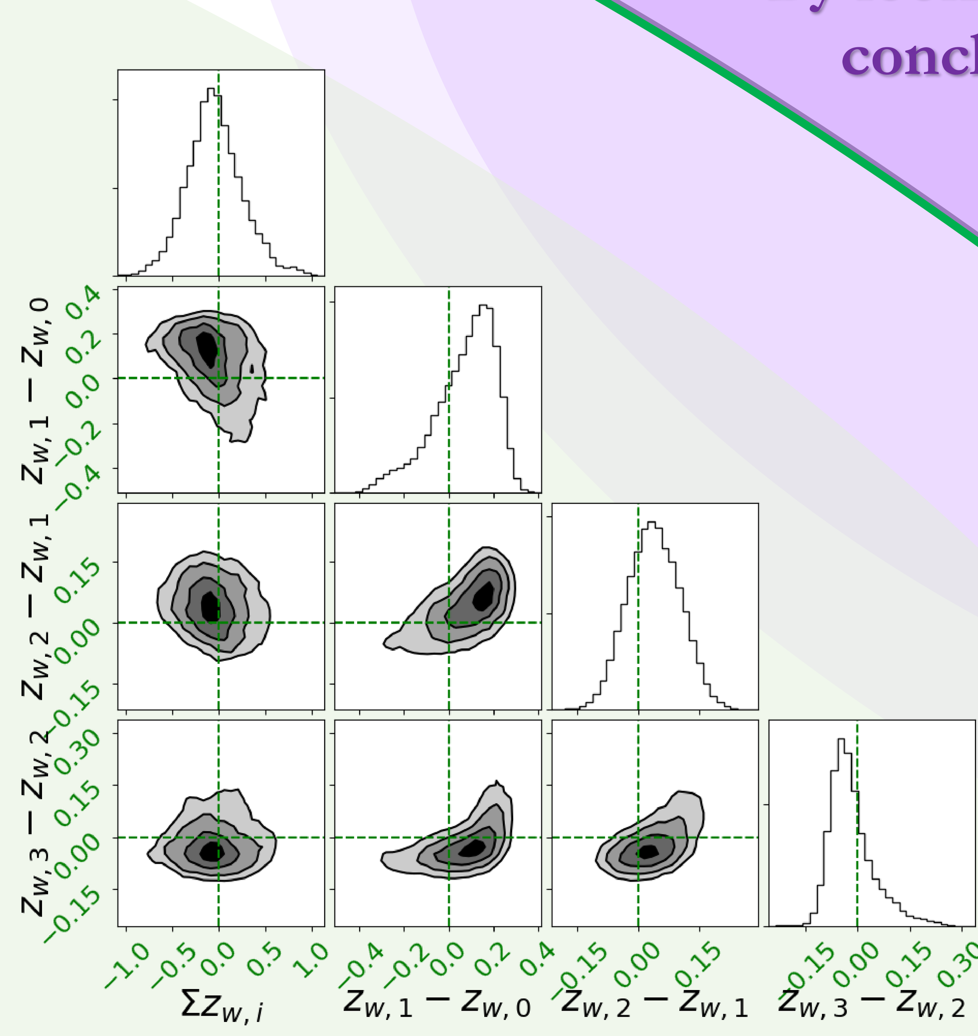
The second and third figure depicts likelihood distribution comparisons of the Δz parameters and z_w parameter (respectively) for all four bins. In these plots, we do see relative shifts between the first and second bins, but overall the parameters center around zero.



Likelihood distributions of halo density parameters with and without the presence of Δz and z_w.



Sum of likelihood distributions for Δz and differences between consecutive Δz likelihood distributions.



Sum of likelihood distributions for z_w and differences between consecutive z_w likelihood distributions.

Discussion and Conclusion:

Two important factors in these results:

- the locations of maxima likelihood in the halo model mass density parameter do not vary with the addition of nuisance parameters
- each of the nuisance parameters' maxima are centered around zero

By looking at these findings, we conclude that Δz and z_w have an insignificant effect on the model.

References:

1. Aihara, arXiv:1702.08449 (2017)
2. Wechsler, arXiv:1804.03097 (2018)
3. https://github.com/LSSTDESC/LSSLike
4. Background Images sourced from European Southern Observatory