Redshift Calibration with CMB+LSS Cross-Correlations

Eric Baxter
The University of Pennsylvania

Redshift Estimation

Accurate galaxy redshifts are needed for future optical surveys like LSST

- For LSST, mean z of galaxy bins must be known to ~0.002 (Zhan, Knox 2006, Newman et al. 2013)

Standard photo-z methods

Templates

- Match observed galaxy colors to library of redshifted template spectra
- Problem: templates don't necessarily match real galaxies

Machine learning

- Obtain spectroscopic z for set of "training" galaxies, then use machine learning techniques to predict z for photometric galaxies
- Problem: it is difficult to obtain training set at high-z

Fundamental problem: degeneracies in color-redshift space

"Correlation methods"

- Correlate photometric galaxy sample with spectroscopic galaxy sample (Newman 2008, McQuinn & White 2010)
- Correlate galaxy sample with CMB lensing maps

Photometric Redshift Calibration with CMBxLSS 2pt functions

Three observables from optical imaging survey + CMB

γ : galaxy shears	**g** : galaxy positions	**κ** : CMB lensing

Two Point Functions:

CMB x LSS	**LSS-only**	**CMB-only**
g x κ, γ x κ	γ x γ, g x g, g x γ	κ x κ

CMB x LSS 2pt functions depend on galaxy redshifts distributions

- g x k depends on redshifts of lens galaxies
- γ x k depends on redshifts of source galaxies

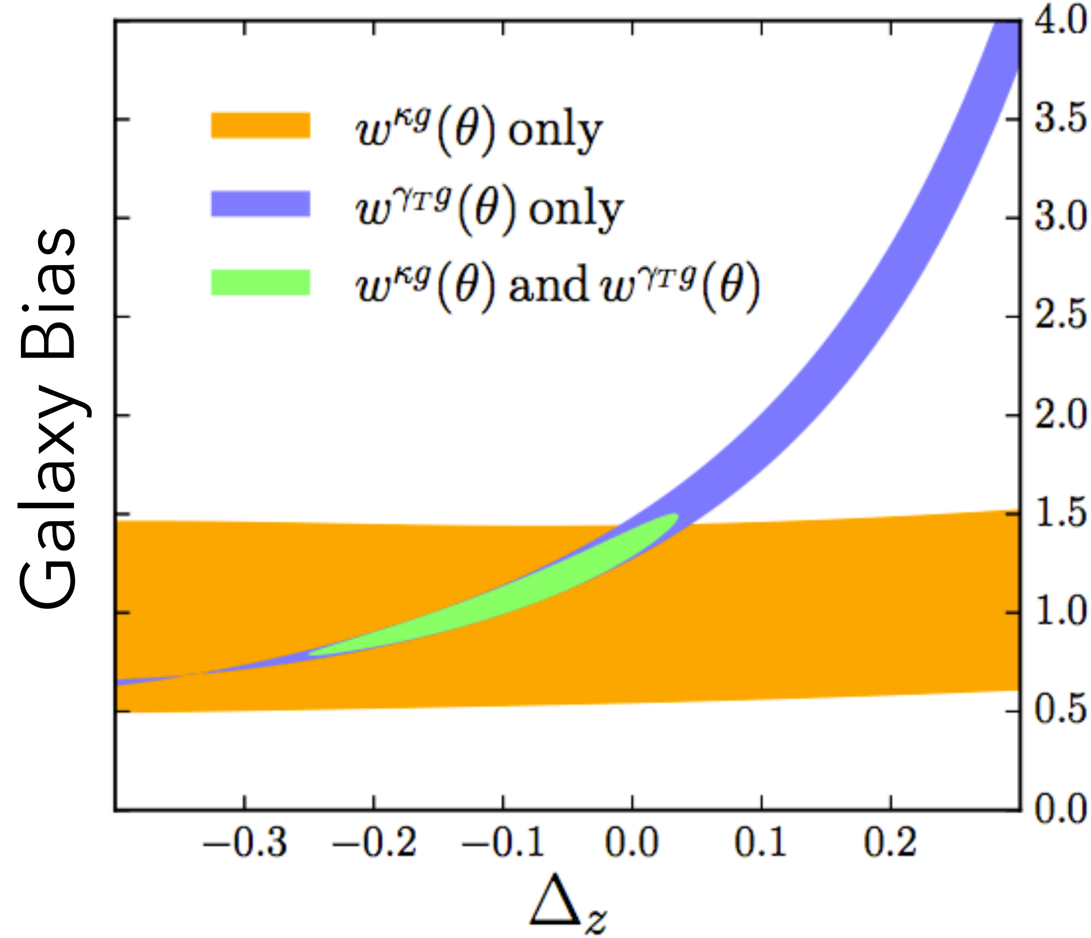
Broad CMB lensing weight means g x κ and γ x κ aren't very sensitive to small shifts in N(z)

However: including CMBxLSS 2pt functions breaks degeneracies between N(z) and e.g. galaxy bias ➔ improved constraints on N(z)

An Example from DES + SPT

Data:
- DES Science Verification (roughly 150 sq. deg.)
- SPT-SZ

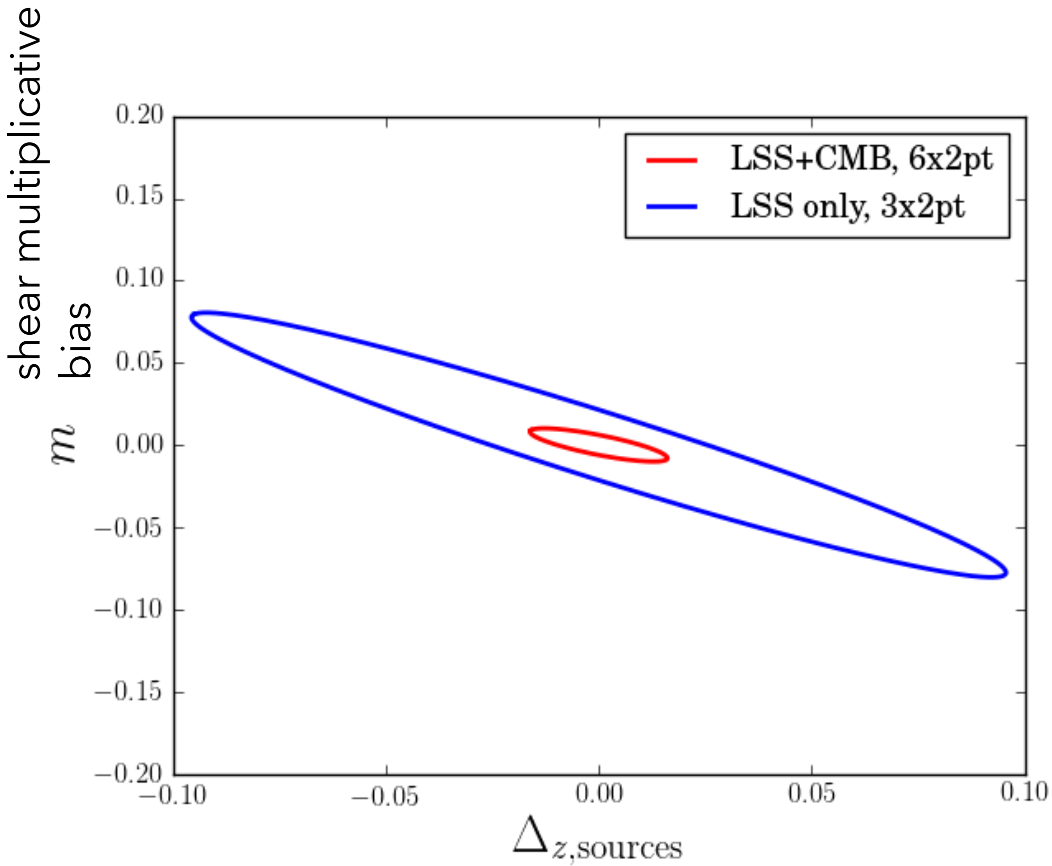
N(z) bias parameterization:
- Use standard photo-z methods to estimate N(z)
- Use cross-correlation to constrain bias parameter
  Δz = shift in N(z)
- Only considering Δz for lenses here



Baxter et al. 2016

Projection: source galaxy redshifts

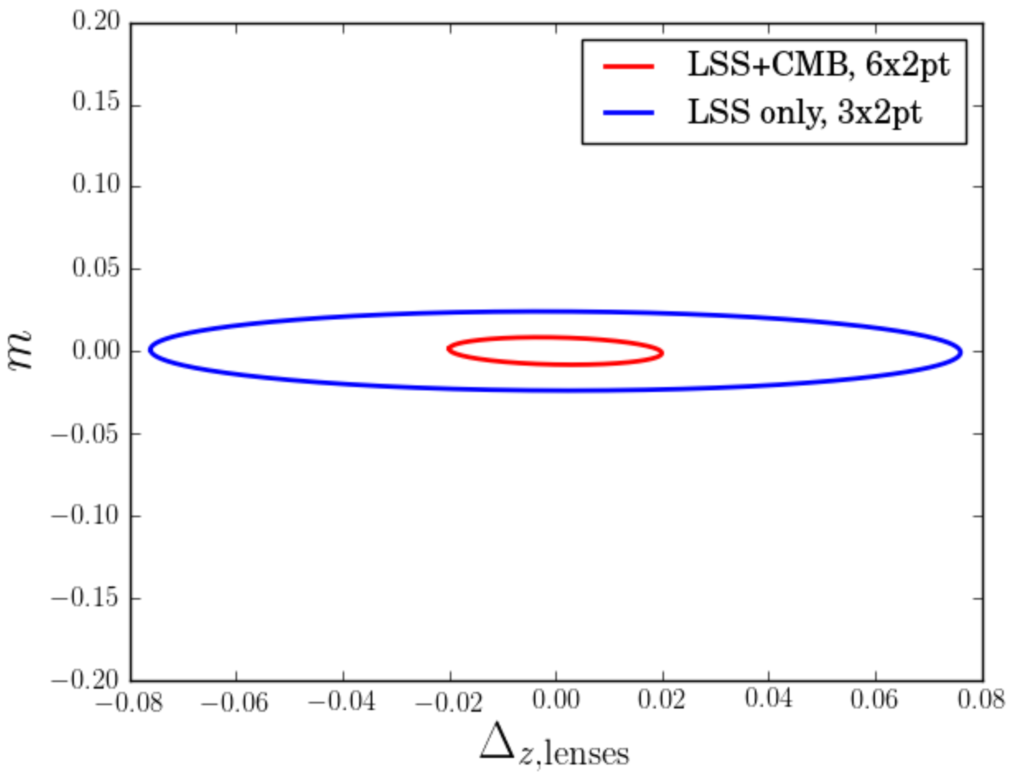
Calibrating photo-z of source galaxies is exciting because it is hard to obtain spectroscopic training sets for high-z objects



- Roughly S4 noise level for CMB lensing
- LSST-like source density
- Assumes relatively low density lens galaxies with very accurate photo-z
- Single lens and source bin
- Planck priors on cosmological parameters

Projection: lens galaxy redshifts

CMB lensing can also be used to constrain redshifts of “lens” galaxy sample



- Assume high density lens galaxies
- Marginalize over source galaxy photo-z bias with σ =0.01 prior
- Lens galaxy N(z) bias not degenerate with m
  - Consistent with findings of Schaan et al. 2016

Summary

- Future optical surveys need very accurate redshifts

- CMB 2pt functions provide additional information in joint analyses that can be used to constrain N(z)