Calibration Issues for Cluster Counts:

Observable-Mass Distribution

Wayne Hu
EFI, October 2005
Calibration Issues for Cluster Counts:

Observable-Mass Distribution

Wayne Hu
EFI, October 2005
There are known knowns; there are things that we know we know. We also know there are known unknowns; that is to say we know there are some things we do not know. But there are also unknown unknowns - the ones we don't know we don't know...

- Donald Rumsfeld
Scattered Forecasts

• Scatter, or a distribution in the observable mass, causes uncertainty in dark energy constraints at high z

• Related work:
  Holder et al (2000); Battye & Weller (2003): bias from scatter
  Levine et al (2002): marginalization of constant M-T bias & scatter

• This work:
  Lima & Hu (2005):

  abstract analysis of the impact of scatter and bias in the distribution

  prospects for self-calibration of a simple, Gaussian, mass independent distribution that evolves

• **Gaussian scatter and bias of a mass estimator**

\[
p(M^{\text{obs}} | M) = \frac{1}{\sqrt{2\pi\sigma_{\ln M}^2}} \exp \left[ -\frac{(\ln M^{\text{obs}} - \ln M - \ln M^{\text{bias}})^2}{2\sigma_{\ln M}^2} \right]
\]
Degeneracy

- Uncertainties in bias and scatter cause degeneracies with dark energy
Selection Bias

- Exponential tail of mass function
- Threshold cut in the observable mass
Selection Bias

- Clusters upscattered into threshold
Selection Bias

- Clusters *upscattered* into threshold
- Out number *downscattered* across threshold
Selection Bias

- Bias proportional to variance of distribution and mass function slope
- Introduces trend in redshift even if scatter is constant
Relative Importance of Scatter

- In the small scatter limit, relative importance of variance vs. bias proportional to local power law slope of mass function
- Increases with increasing mass or redshift
Sensitivity to Uncertainties

- A 25% bias would produce a ~100% change in high-z cluster counts
- A 25% scatter a ~50% change - but scales as variance

\[
\ln M_{\text{bias}} = 0.25
\]

\[
\sigma_{\ln M}^2 = (0.25)^2
\]

\[
M_{\text{obs}} \geq 10^{14.2} \, (h^{-1} M_\odot)
\]
Fully Calibrated

- Given a completely **known** observable-mass **distribution** dark energy constraints are quite **tight** (4000 sq deg, $z<2$)
- Marginalizing scatter (linear $z$ evolution) and bias (power law evolution) destroys all dark energy information.
Self-Calibration with Clustering

- Clustering bias as a function of mass is predicted in a cosmology
- Angular clustering of clusters or (co)variance of counts provides mass bias calibration but not jointly with scatter
Self-Calibration with Clustering

• Arbitrary evolution of bias and scatter in 20 bins of $\Delta z = 0.1$
Self-Calibration with Clustering

- Power law evolution of bias and arbitrary evolution of scatter in 20 bins of $\Delta z = 0.1$
Self-Calibration with Clustering

- Power law evolution of bias and cubic evolution of scatter in $z$
Observable MassBins

- Exploit knowledge by **breaking sample into observable mass bins**
- Demand **consistent count ratio** to solve for bias and scatter
Self-Calibration with Binning

- Arbitrary evolution of bias and scatter in 20 bins of $\Delta z = 0.1$
Self-Calibration with Binning

- Power law evolution of bias and arbitrary evolution of scatter in 20 bins of $\Delta z=0.1$
Self-Calibration with Binning

- Power law evolution of bias and cubic evolution of scatter in $z$
Joint Self-Calibration

- Both counts and their variance as a function of binned observable
- Many observables allows for a joint solution of a mass independent bias and scatter with cosmology
Joint Self Calibration

- Arbitrary evolution of bias and scatter in 20 bins of $\Delta z=0.1$
Joint Self Calibration

- Power law evolution of bias and arbitrary evolution of scatter in 20 bins of $\Delta z=0.1$
Joint Self Calibration

- Power law evolution of bias and cubic evolution of scatter in $z$
Prior Knowledge of Scatter

- Priors on the 20 independent scatter parameters of 10% each
- Or 2% on the evolution of scatter to $z \sim 1$ improves constraints $\chi^2$ beyond self-calibration
Forecasts: Scatters with Partial Clearing

- **Unknown scatter** at the 10% level at \( z > 1 \) will significantly degrade the cosmological utility of such clusters.
- **Self-calibration** from the power spectrum or clustering of clusters alone is insufficient to solve internally for both a bias and a scatter.
- Self-calibration from the **shape of the counts** in the observable can jointly provide for calibration with a sufficiently deep sample.
- **External calibration** will assist self calibration at the level of 2-10% scatter uncertainties at \( z \sim 1 \).
Forecasts: Scatters with Partial Clearing

- Unknown scatter at the 10% level at $z > 1$ will significantly degrade the cosmological utility of such clusters.
- Self-calibration from the power spectrum or clustering of clusters alone is insufficient to solve internally for both a bias and a scatter.
- Self-calibration from the shape of the counts in the observable can jointly provide for calibration with a sufficiently deep sample.
- External calibration will assist self calibration at the level of 2-10% scatter uncertainties at $z \sim 1$.

Caveats:
- Trends in the distribution versus the mass must be known and taken out.
- Non-Gaussian tails in the distribution must be understood.
- Self calibration $\leftrightarrow$ self consistency.
- Divide up data in as many ways as possible, check assumptions!