DARK ENERGY
SURVEY

Photo-z Requirements for Self-Calibration of Cluster Dark Energy Studies

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Collaborators

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Hiroaki Oyaizu	University of Chicago
Ofer Lahav	University College London

Outline

- Cluster mass function
- Number counts and Covariance
- Mass-Observable relation
- Self-Calibration
- Results

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Mass function

- Cluster mass-function exponentially sensitive to linear density perturbations σ

$$\frac{d\bar{n}}{d\ln M} = 0.3\frac{\rho_m}{M}\frac{d\ln\sigma^{-1}}{d\ln M}\exp\left[-\left|\ln\sigma^{-1}+0.64\right|^{3.82}\right]$$

Jenkins et al. 2001

$\Rightarrow$ Cluster number counts sensitive to DE parameters.

Number Density

- Number density in bin i $(z,\ M,\ \text{angle, etc...})$

$$\bar{n}_i = \int_{M_i^{obs}}^{M_{i+1}^{obs}} d\ln M^{obs} \int d\ln M \frac{d\bar{n}}{d\ln M} p(M^{obs} \mid M)$$

where

$$p(M^{obs} \mid M) = \frac{1}{\sqrt{2\pi\sigma^2_{\ln M}(z)}} \exp\left[-\left(\frac{\ln M^{obs} - \ln M - \ln M^{bias}(z)}{\sqrt{2\sigma^2_{\ln M}(z)}}\right)^2\right]$$

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Number Counts

- Volume element $dV = \frac{D_A^2(z)}{H(z)} dz d\Omega$
- Number counts

$$\overline{N_i} = \Delta\Omega \int_{z_i^{phot}}^{z_{i+1}^{phot}} dz^{phot} \int dz \frac{D_A^2}{H} \bar{n}_i(z) p(z^{phot} \mid z)$$

where

$$p(z^{phot} \mid z) = \frac{1}{\sqrt{2\pi\sigma_z^2(z)}} \exp\left[-\left(\frac{z^{phot} - z - z^{bias}(z)}{\sqrt{2\sigma_z^2(z)}} \right)^2 \right]$$

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Sample Covariance

$$S_{ij} = \left\langle (N_i - \overline{N_i})(N_j - \overline{N_j}) \right\rangle$$

$$= b_i b_j \bar{n}_i \bar{n}_j \int \frac{d^3k}{(2\pi)^3} W_i^*(\vec{k}) W_j(\vec{k}) P(k)$$

where the window $W_i(\vec{k})$ is convolved with the photo-z distribution.

Mass-Observable Relation: Redshift Evolution

- Arbitrary (2 mass parameters per bin)
- Mean relation: Power law

$$\frac{M(z_i)}{M_{fid}} = e^{A}(1+z_i)^{n}\left(\frac{O}{O_{fid}}\right)^{p}$$

Assume p is known.

- Scatter: Polynomial (cubic)

$$\sigma^2_{\ln M}(z_i) = \sigma^2_{\ln M}(z_i)\Big|_{fid} + \sum_{k=0}^{3} B_k z_i^k$$

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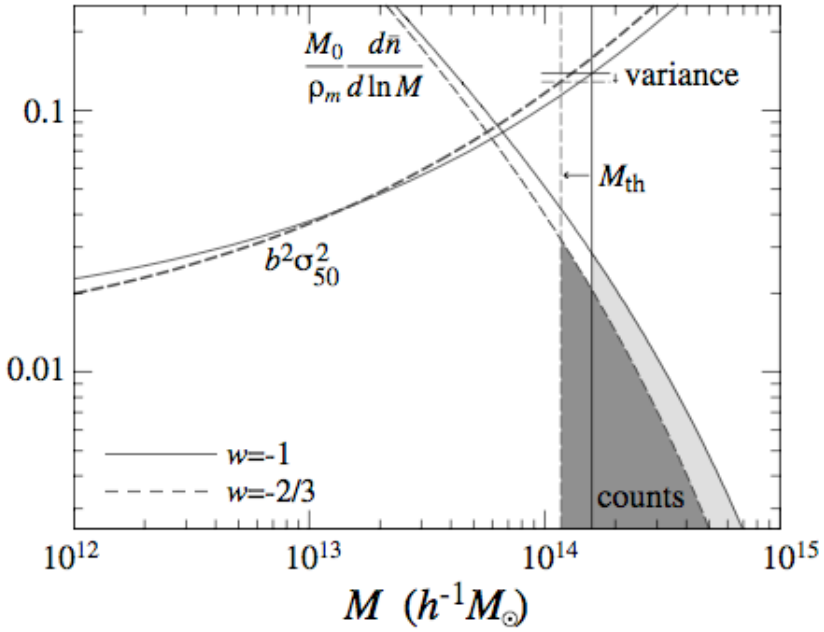
Uncertainties

- Mass and redshift uncertainties change the observed number counts and are degenerate with DE.



Lima & Hu 2004

Self-Calibration

- "Self-calibration" of mass-observable parameters: consistency between number counts and

1) clustering

Majumdar & Mohr 2004; Lima & Hu 2004

2) shape of observed mass function

Hu 2003; Lima & Hu 2005

3) follow up

Majumdar & Mohr 2003, 2004

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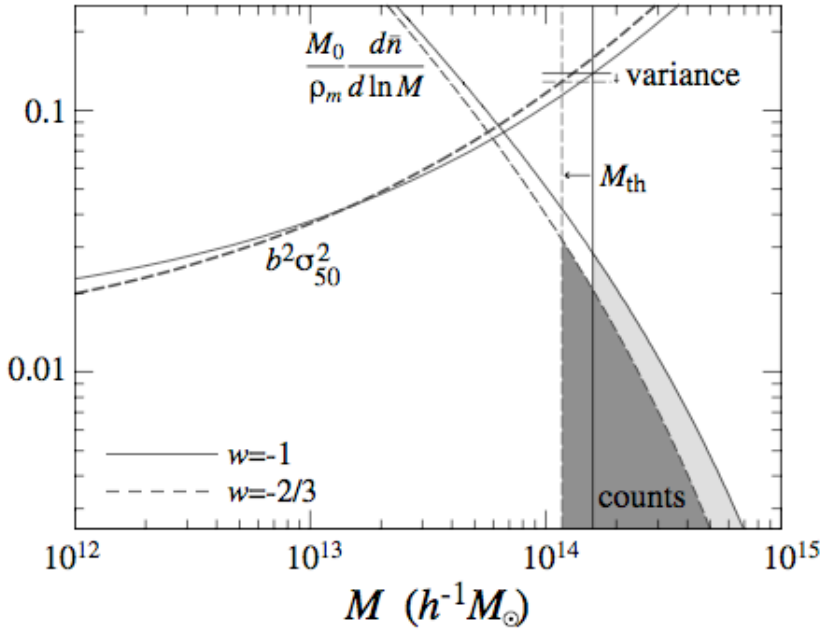
Self-Calibration

- Clustering: Requiring consistency between counts and sample variance breaks degeneracy between shifts in mass and DE variations .



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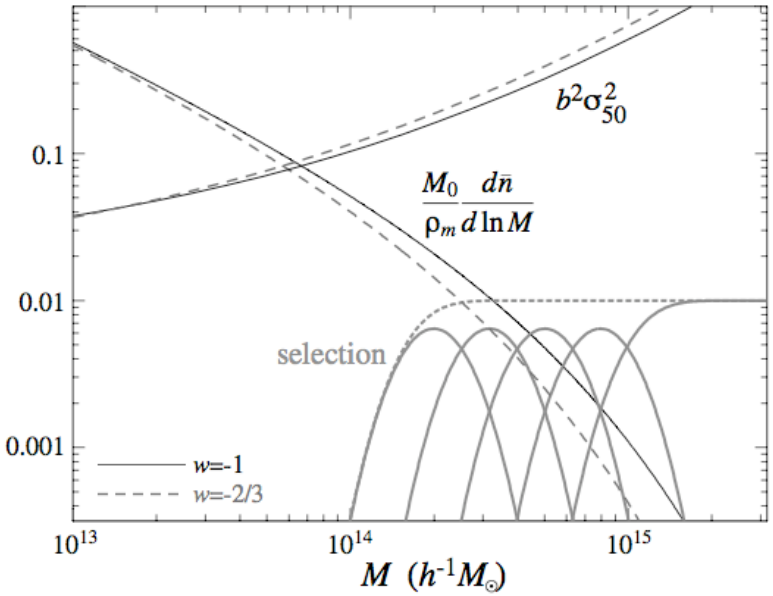
Self-Calibration

- Shape: Measuring number counts as a function of mass provides observed mass function. Consistency breaks degeneracy of DE with scatter in mass-observable.



Lima & Hu 2005

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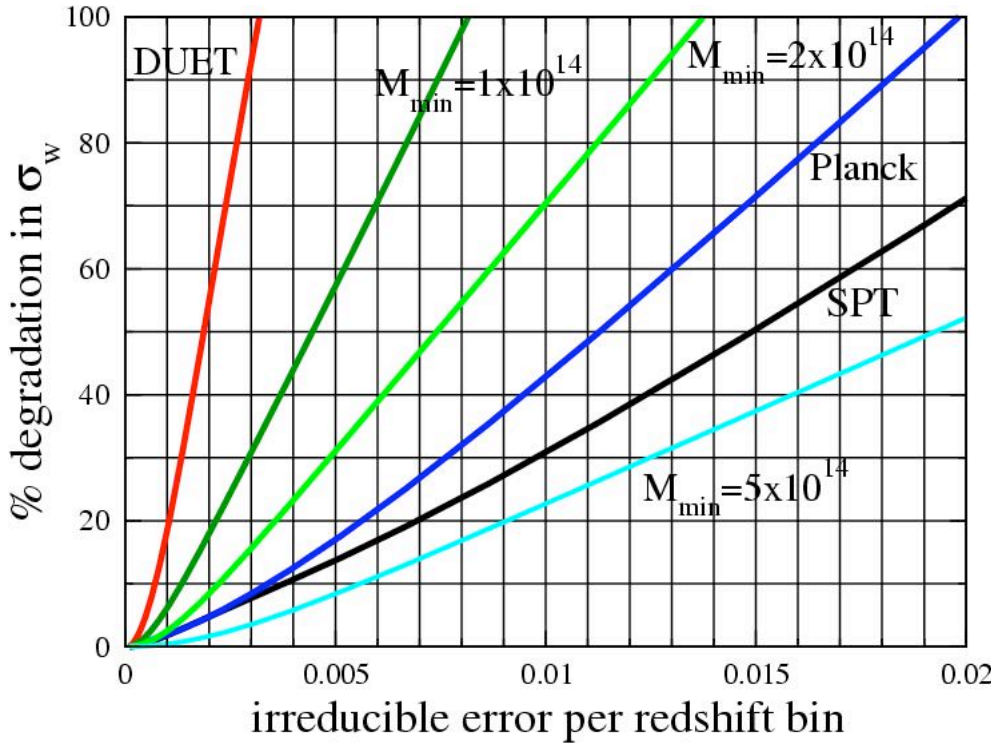
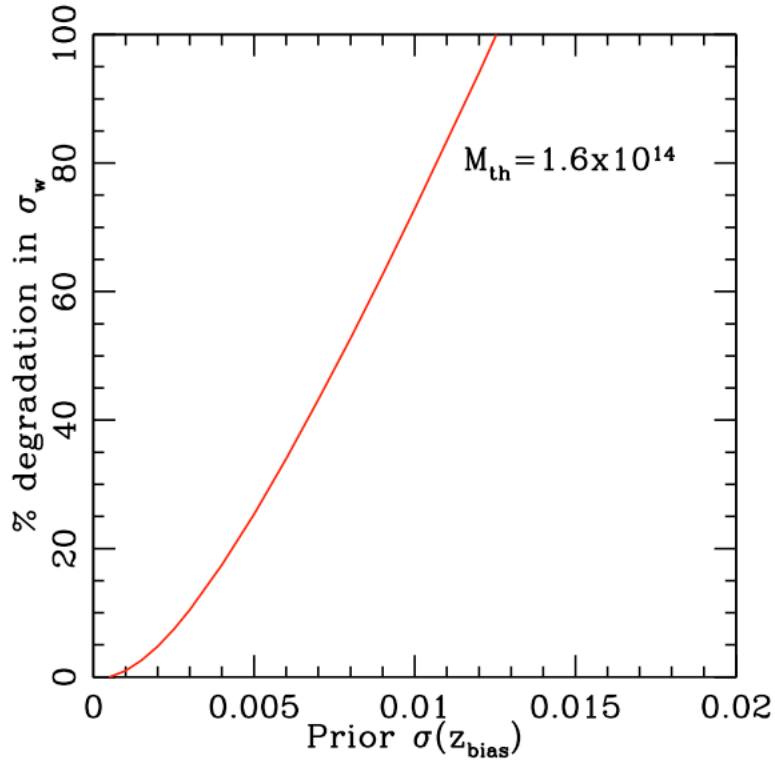
Previous studies

- Fixed mass-observable. No z scatter. Priored z bias.
- Counts only



Huterer et al. 2004



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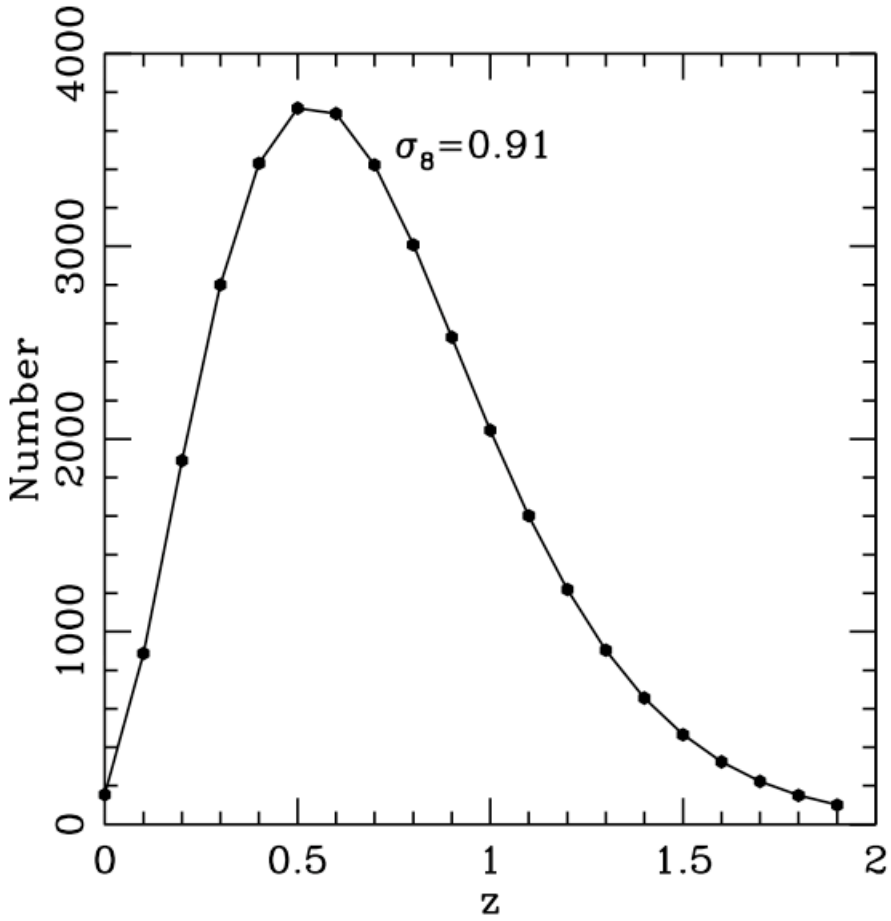
Number Counts

SPT like

$4000\ \mathrm{deg}^2$

$\Delta z = 0.1$ bins

WMAP 1yr



DARK ENERGY SURVEY

Number Counts

SPT like

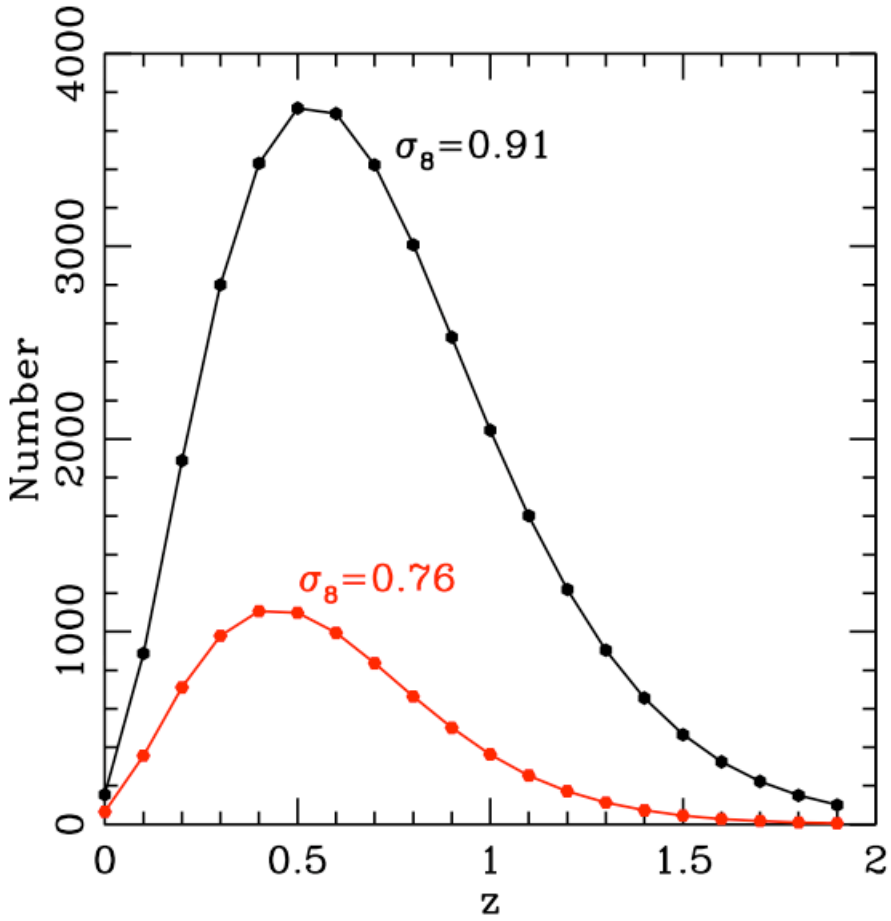
$4000\ \mathrm{deg}^2$

$\Delta z = 0.1$ bins

WMAP 1yr

WMAP 3yr

(4 x less!)



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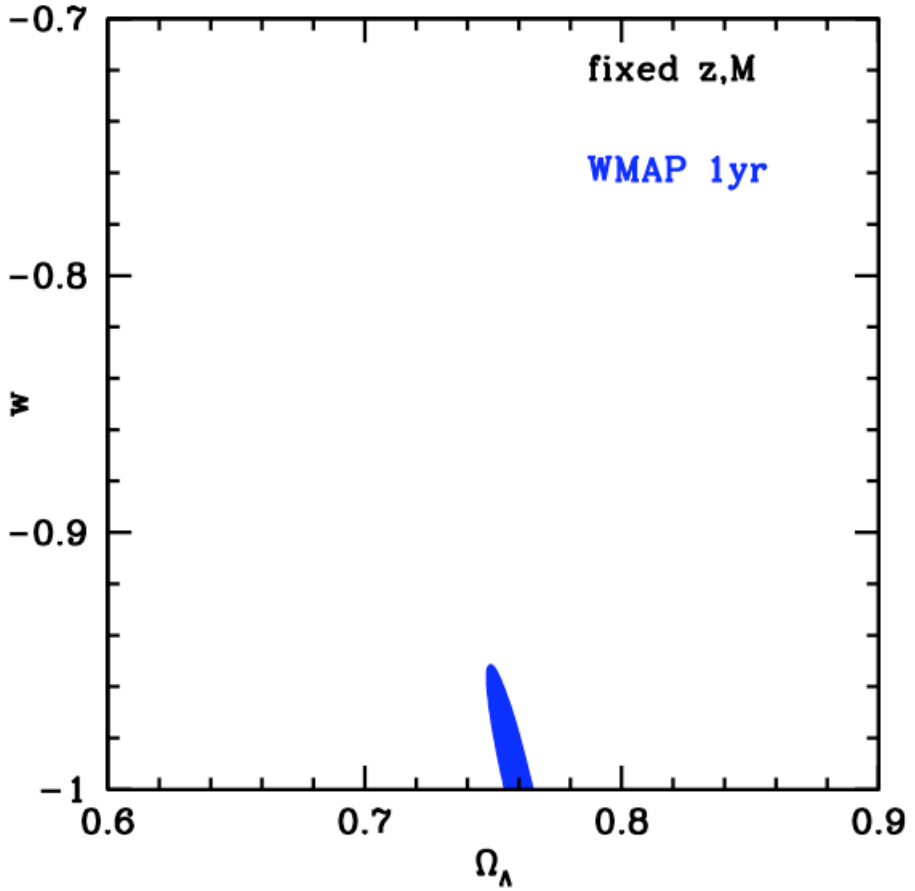
Baseline constraints

Fixed Mass, Redshifts.

WMAP 1yr



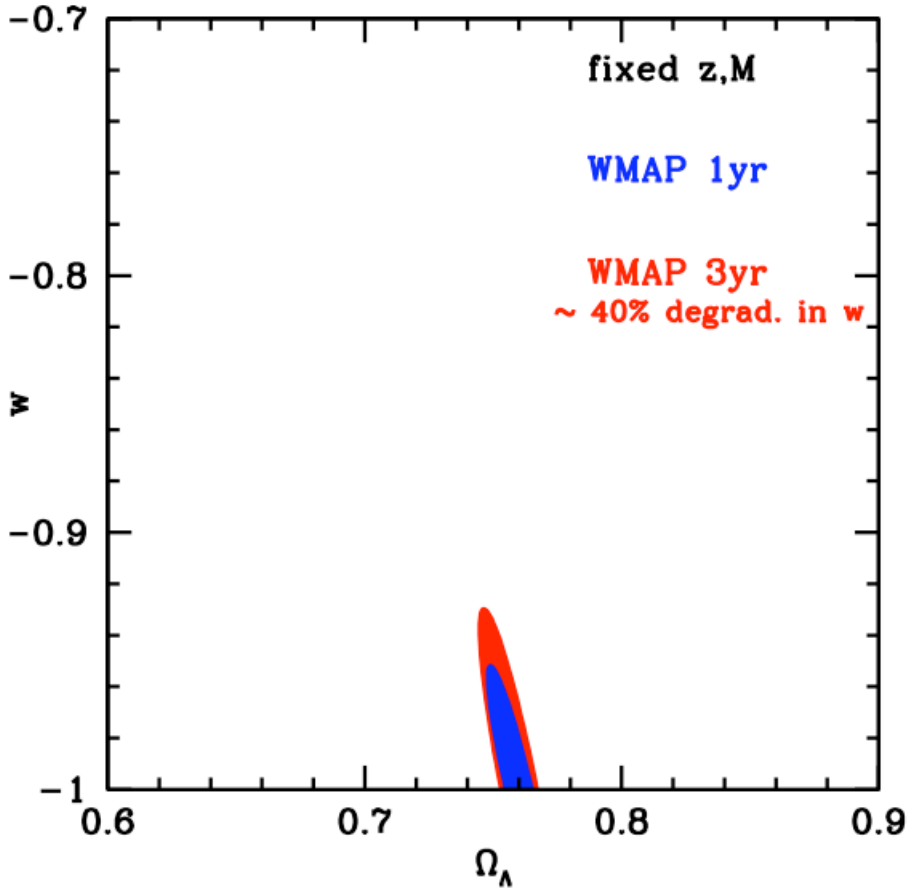
DARK ENERGY
SURVEY

Baseline constraints

Fixed Mass, Redshifts.

WMAP 1yr

WMAP 3yr



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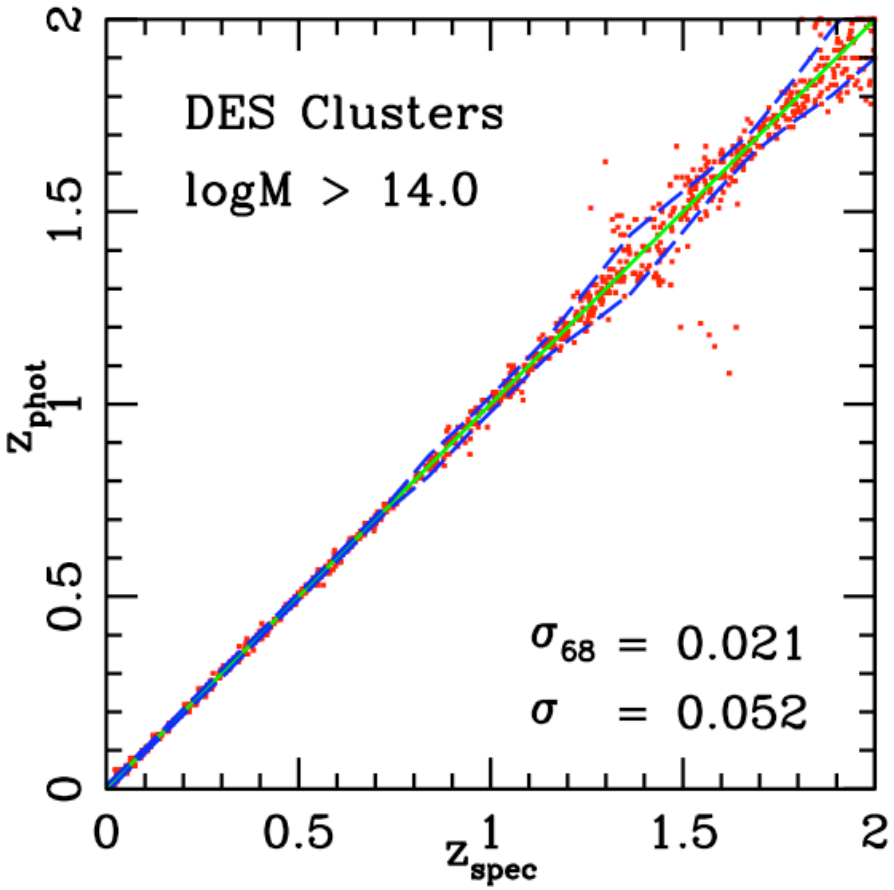
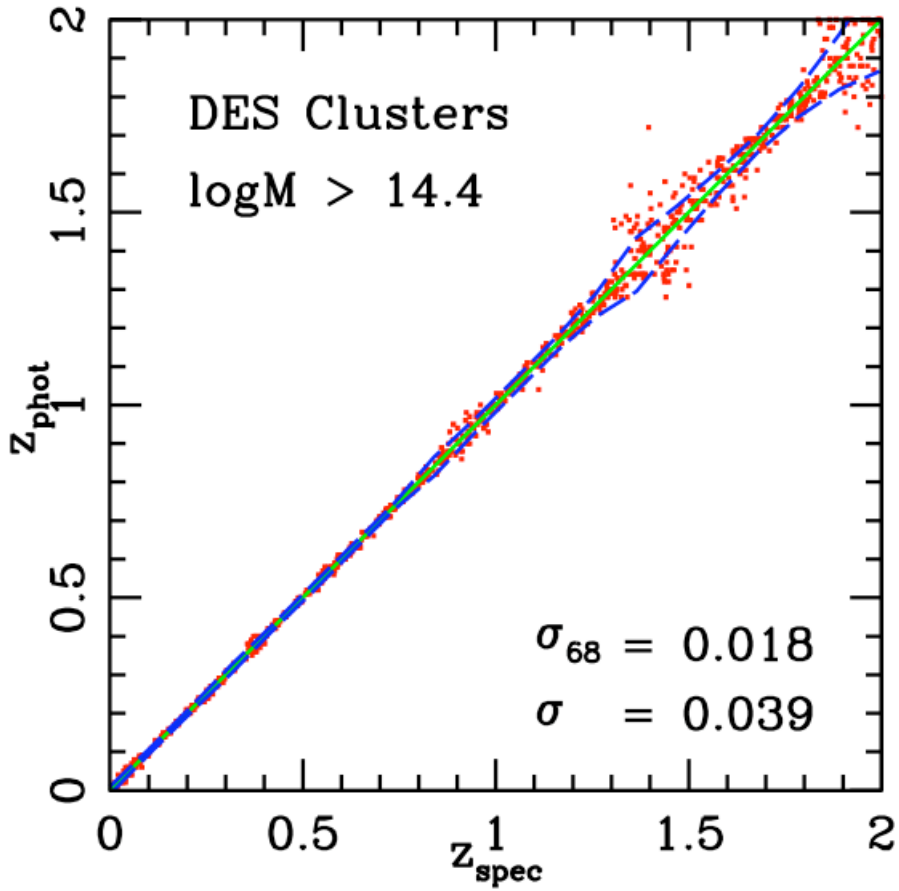
Cluster Photo-z's

- Huan Lin's catalog. Template Fitting photo-z's





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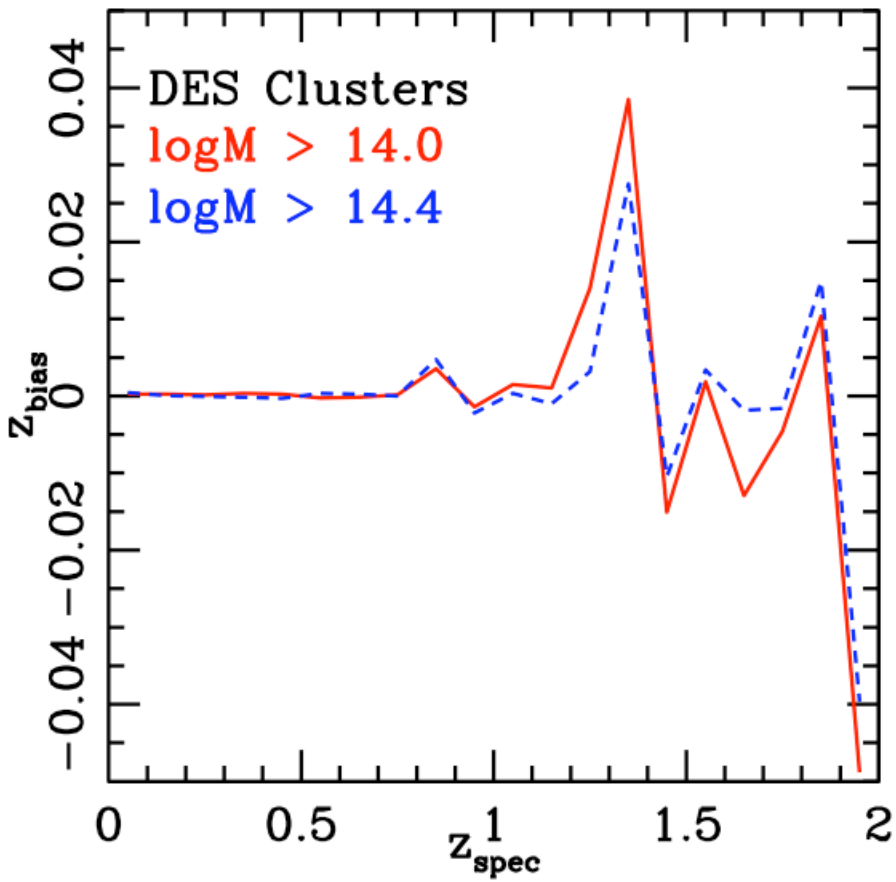

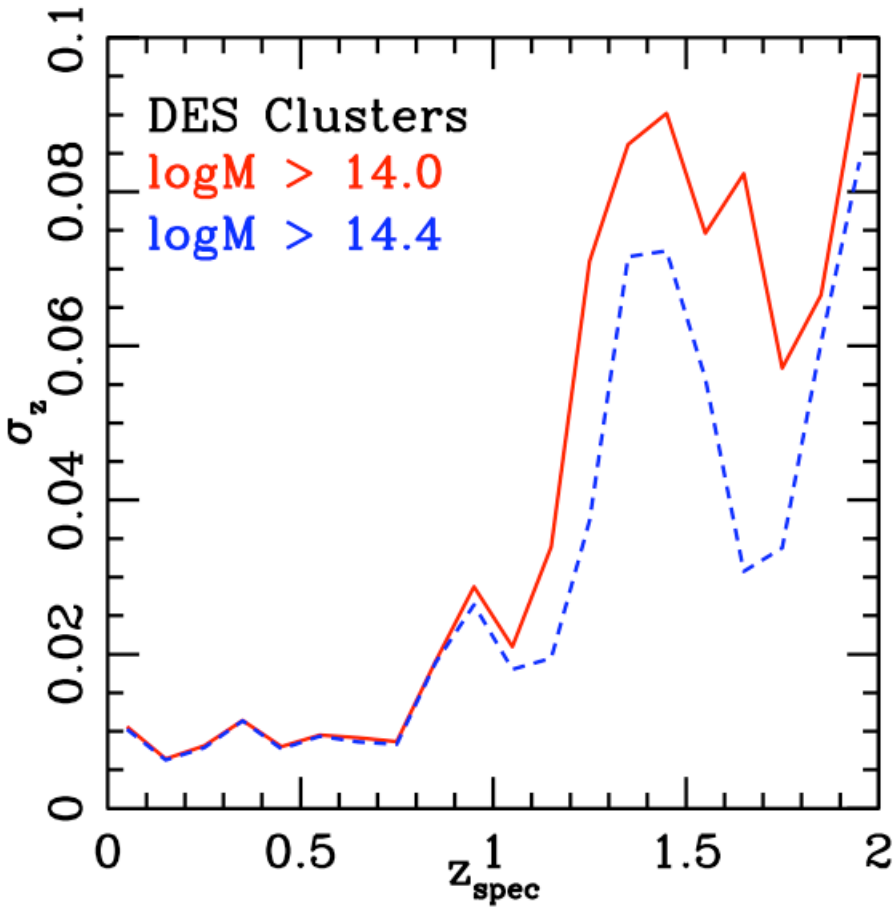

Constraints

- SPT like, $4000\ \mathrm{deg}^2$, $z_{\mathrm{max}} = 2$, $\Delta z = 0.1$
  $M_{\mathrm{th}} = 10^{14.2}$ solar masses
- Flat universe
- WMAP 3yr cosmology
- Other cosmological parameters (not DE): priors of ~1%
- Constant w

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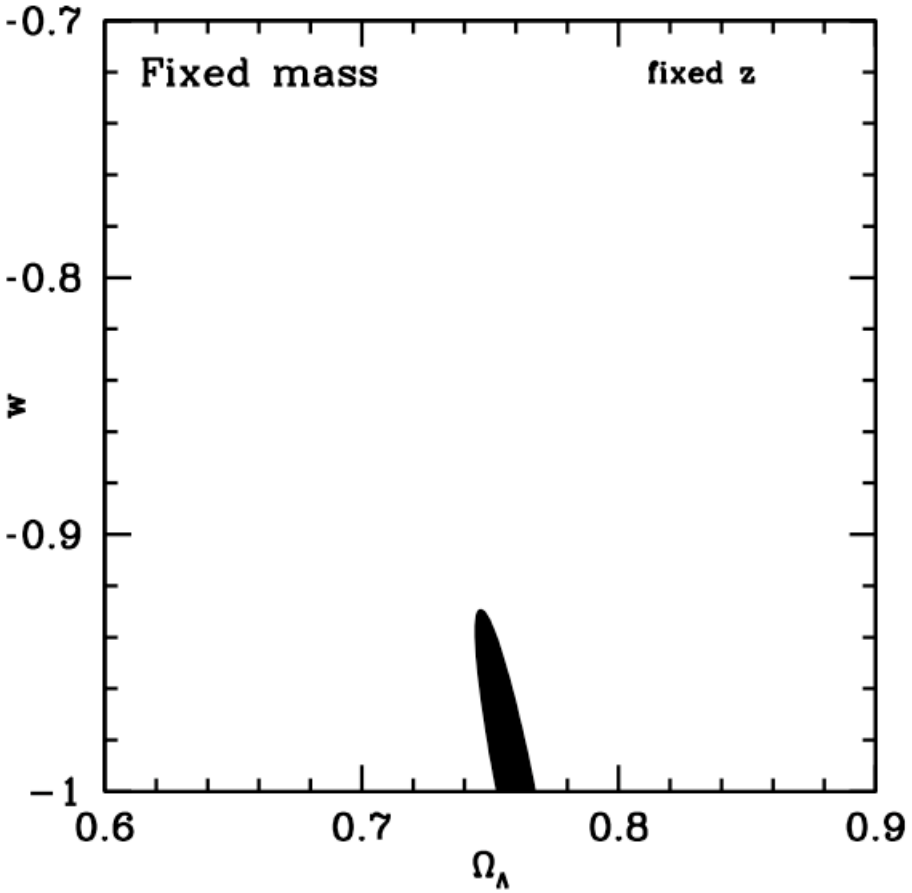
Fixed Mass-Observable

- Fixed z bias
- Fixed z scatter

- Counts

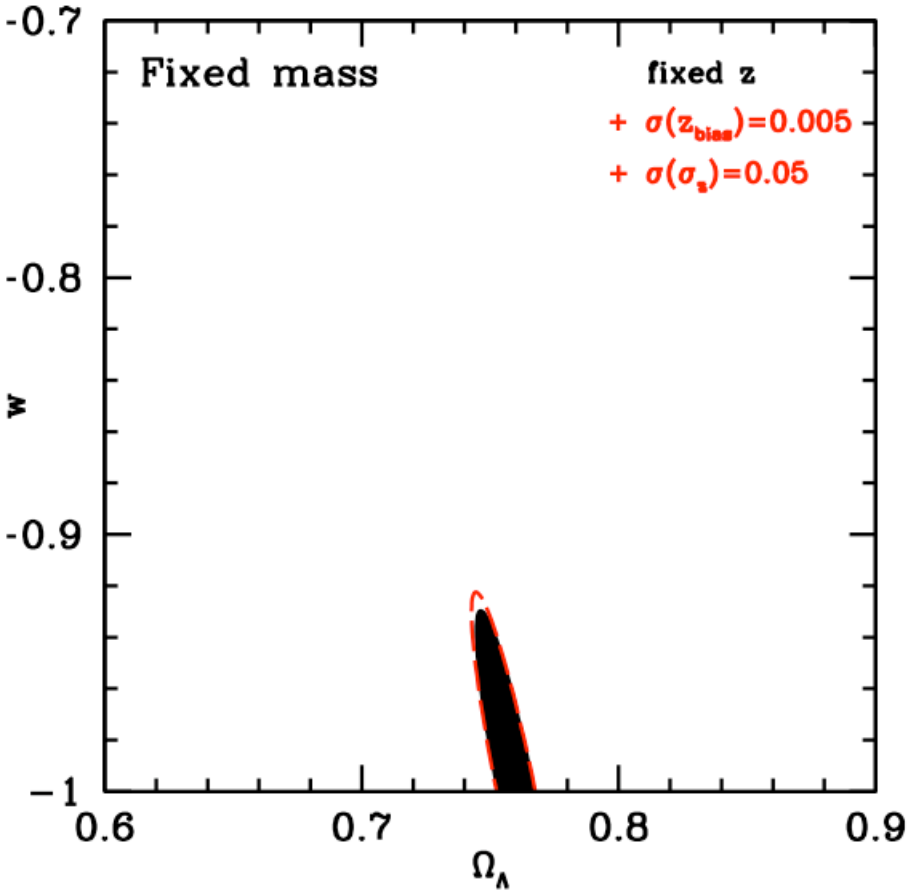


DARK ENERGY SURVEY

Fixed Mass-Observable

- Priored z bias
- Priored z scatter

- Counts



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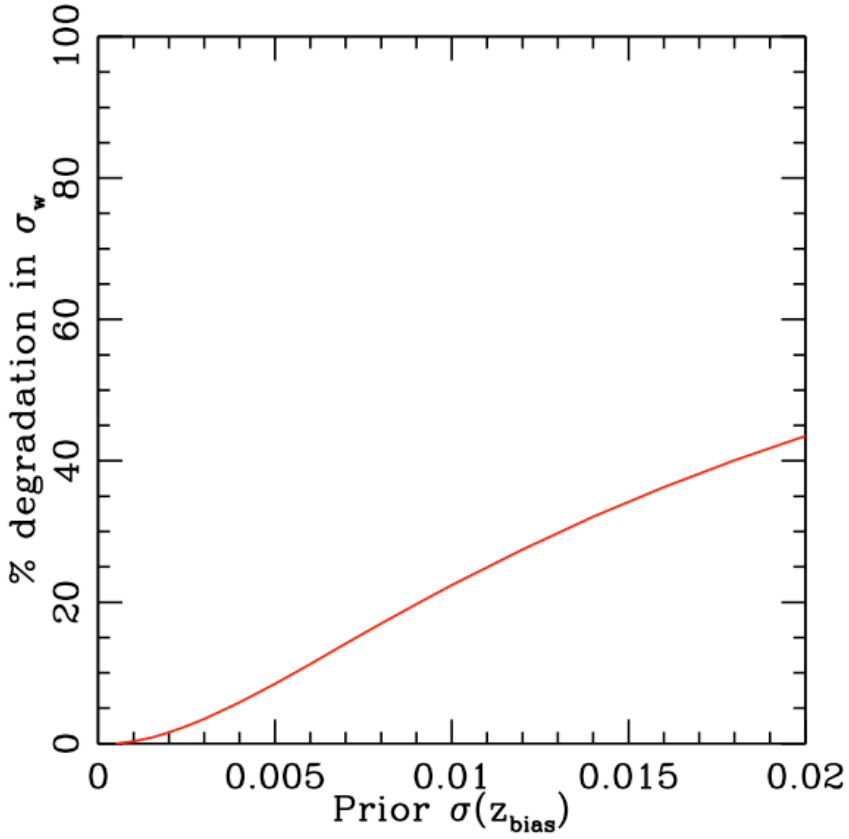
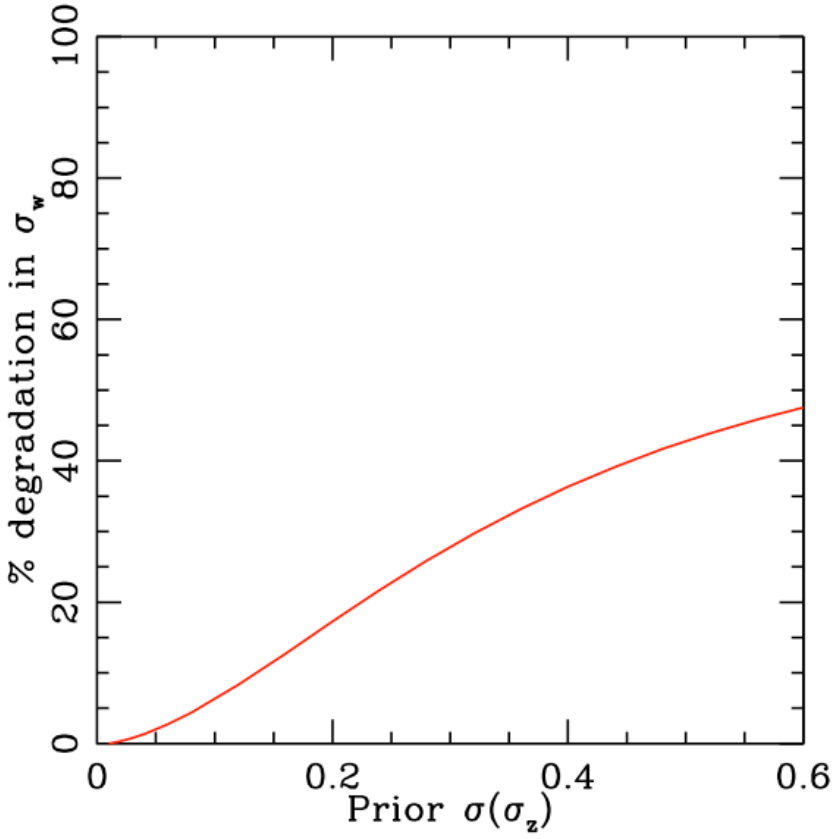
Fixed Mass-Observable: Degradation in w





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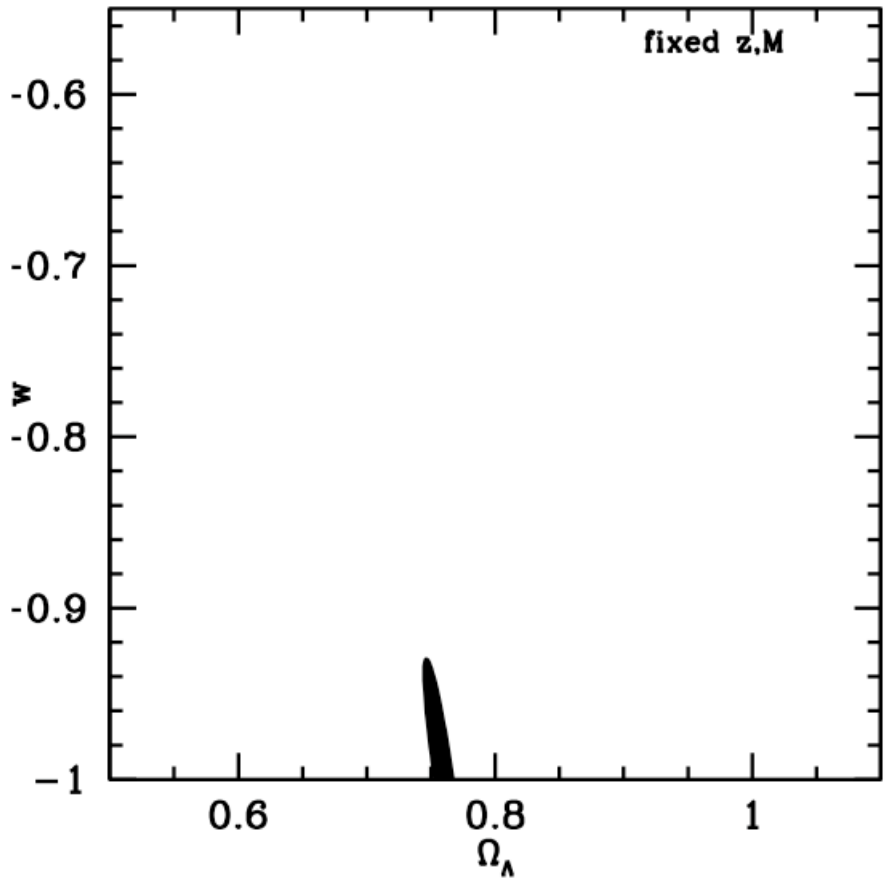
Self-Calibration: Mean + Scatter in Mass-Observable

- Fixed z bias
- Fixed z scatter

- Fixed M bias
- Fixed M scatter

- Counts



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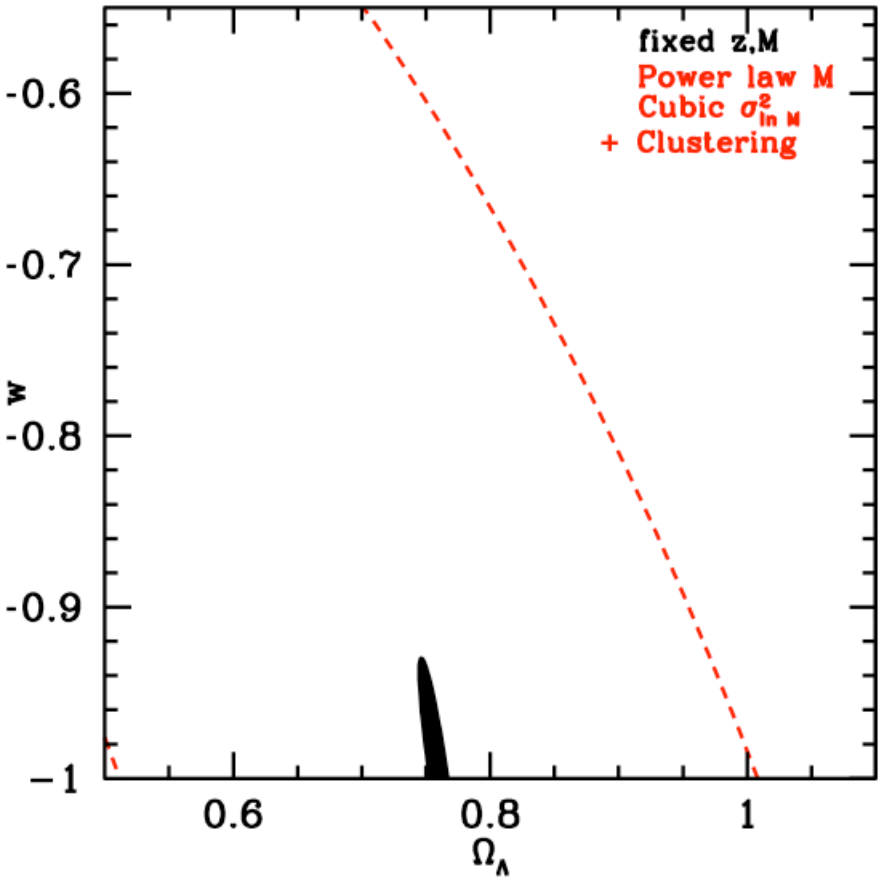
Self-Calibration: Mean + Scatter in Mass-Observable

- Fixed z bias
- Fixed z scatter

- Power Law M bias
- Cubic M scatter

- Counts
+ Clustering

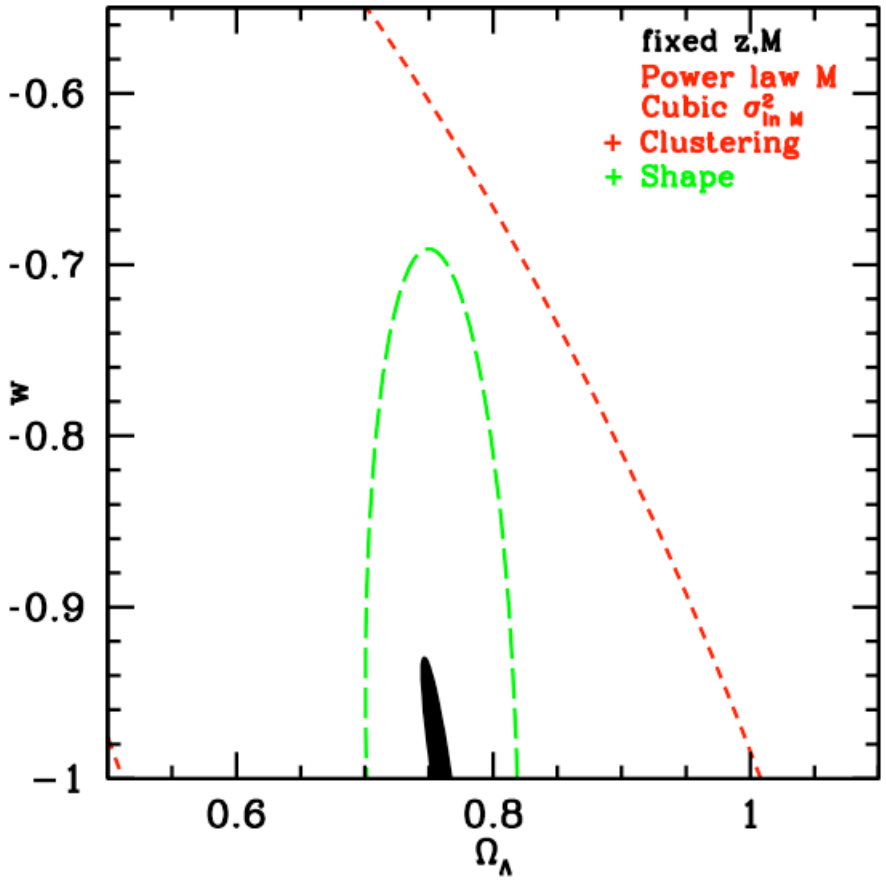


Self-Calibration: Mean + Scatter in Mass-Observable

- Fixed z bias
- Fixed z scatter

- Power Law M bias
- Cubic M scatter

- Counts
  + Clustering
  + Shape

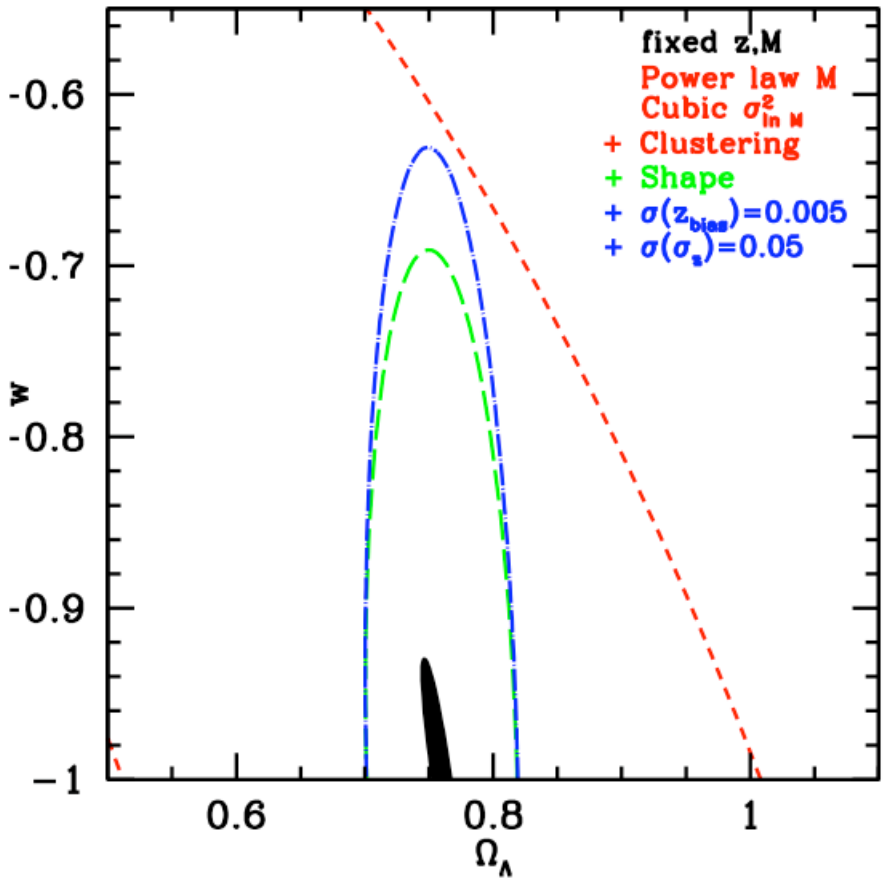


Self-Calibration: Mean + Scatter in Mass-Observable

- Priored z bias
- Priored z scatter

- Power Law M bias
- Cubic M scatter

- Counts
  + Clustering
  + Shape



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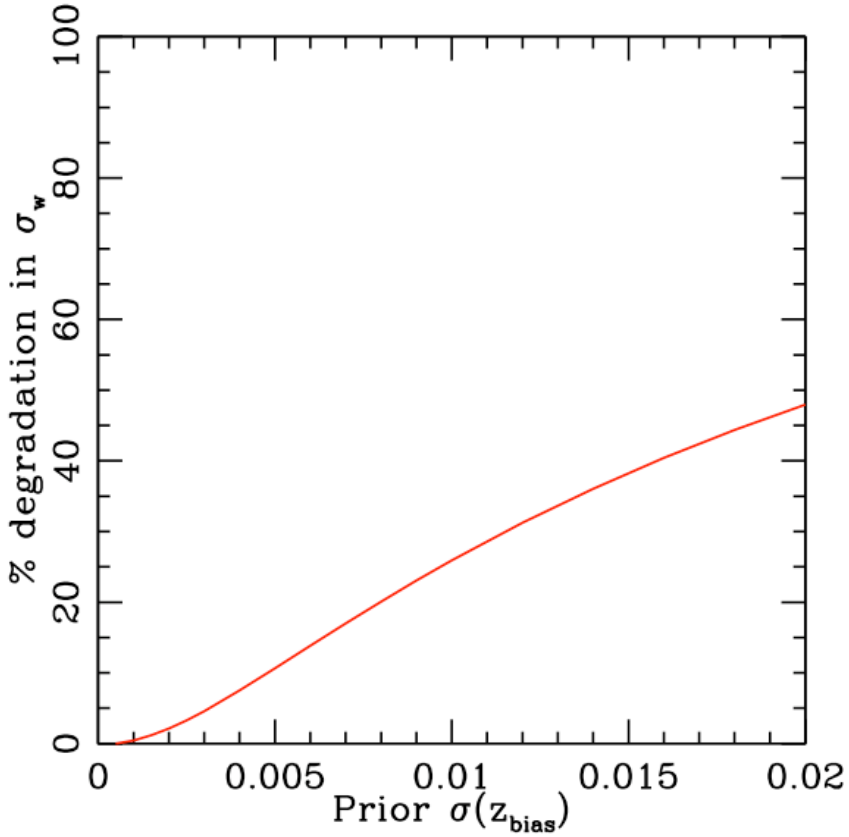
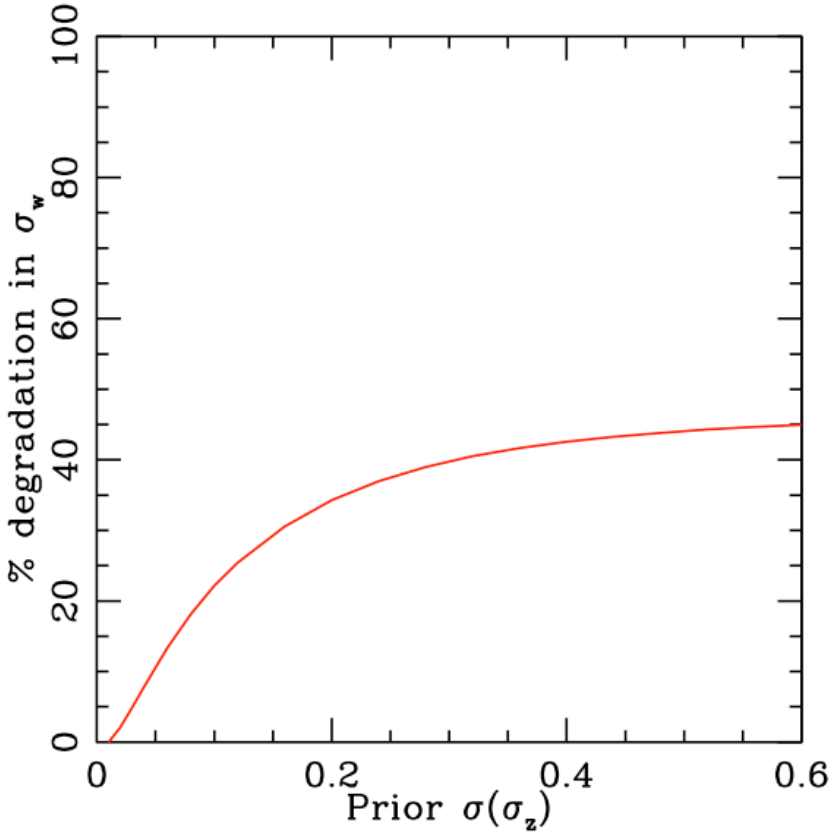
Mean + Scatter in Mass-Observable: Degradation in w





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Another case: n fixed

- Mean relation: Power law

$$\frac{M(z_i)}{M_{fid}} = e^{A}(1+z_i)^{n}\left(\frac{O}{O_{fid}}\right)^{p}$$

Assume p fixed.

Assume n fixed.

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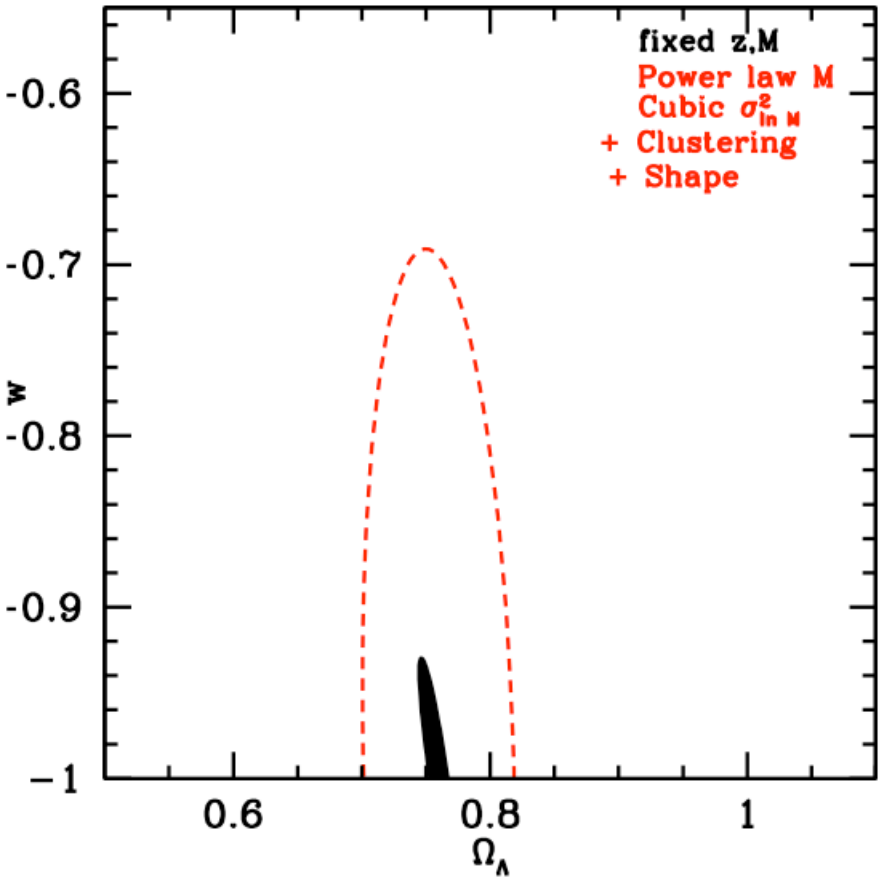
Another case: n fixed

- Fixed z bias
- Fixed z scatter

- Power Law M bias
- Cubic M scatter

- Counts
  + Clustering
  + Shape



DARK ENERGY SURVEY

Another case: n fixed

- Fixed z bias
- Fixed z scatter

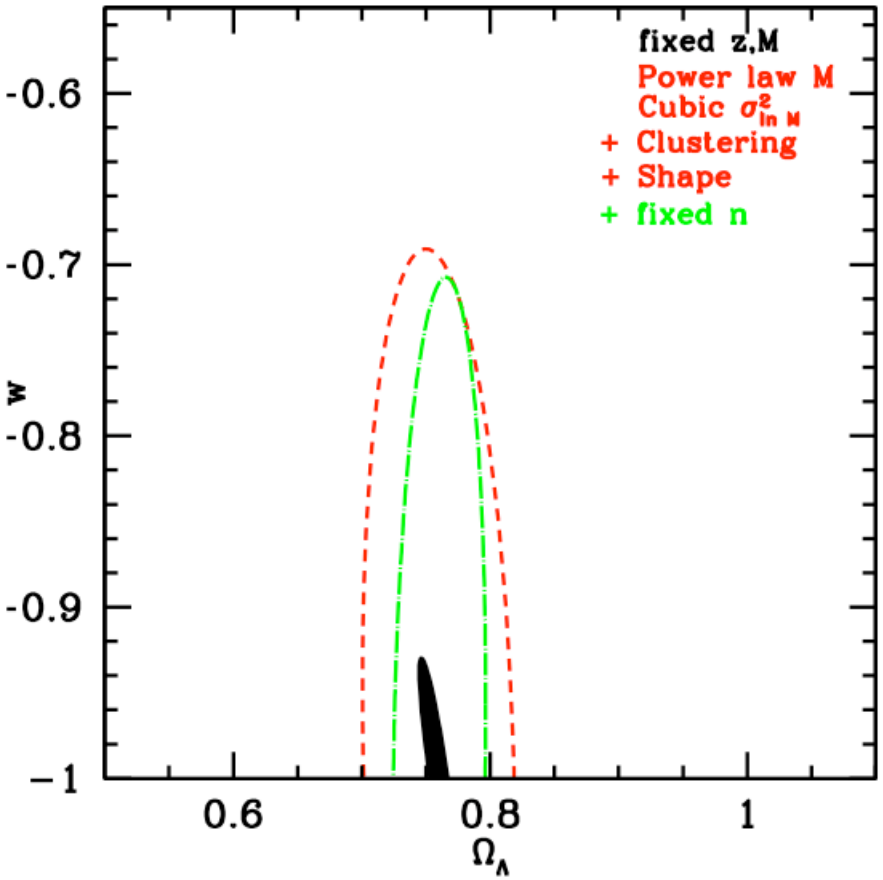
- Power Law M bias
- Cubic M scatter

- Counts

+ Clustering

+ Shape

+ n fixed



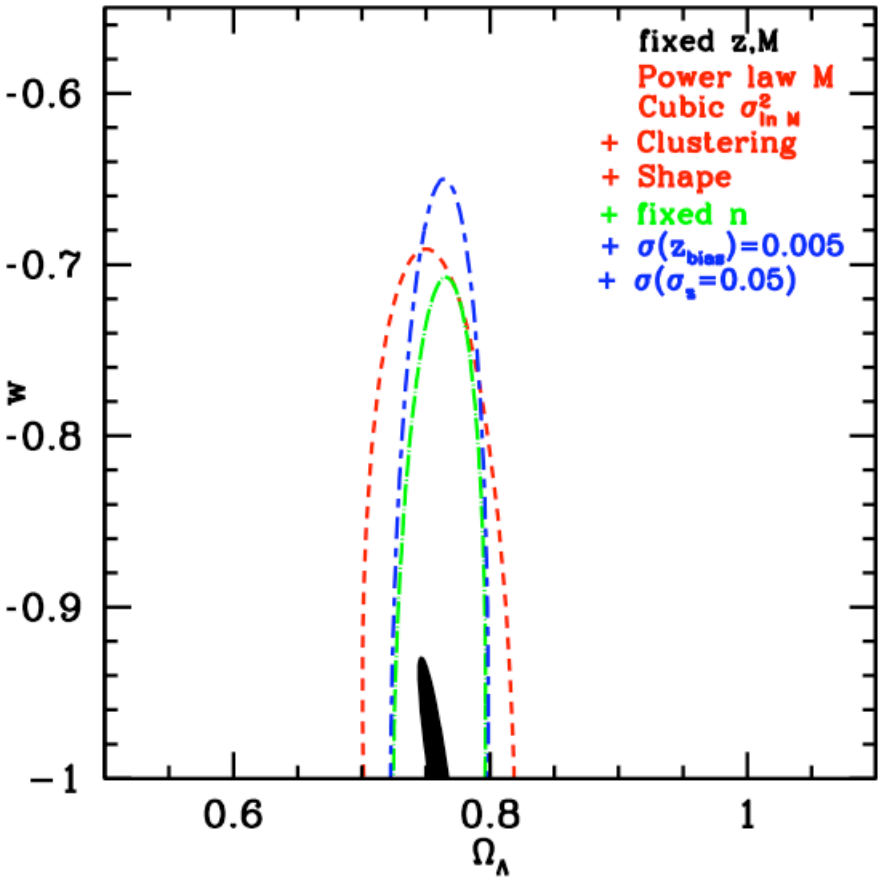
DARK ENERGY SURVEY

Another case: n fixed

- Priored z bias
- Priored z scatter

- Power Law M bias
- Cubic M scatter

- Counts
  + Clustering
  + Shape
  + n fixed



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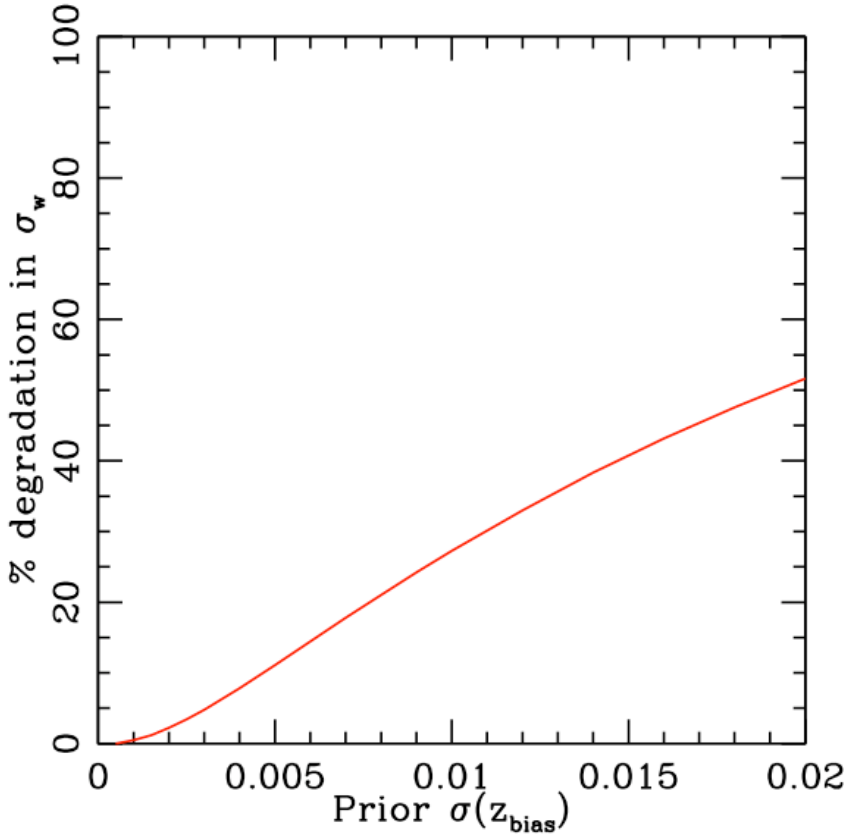
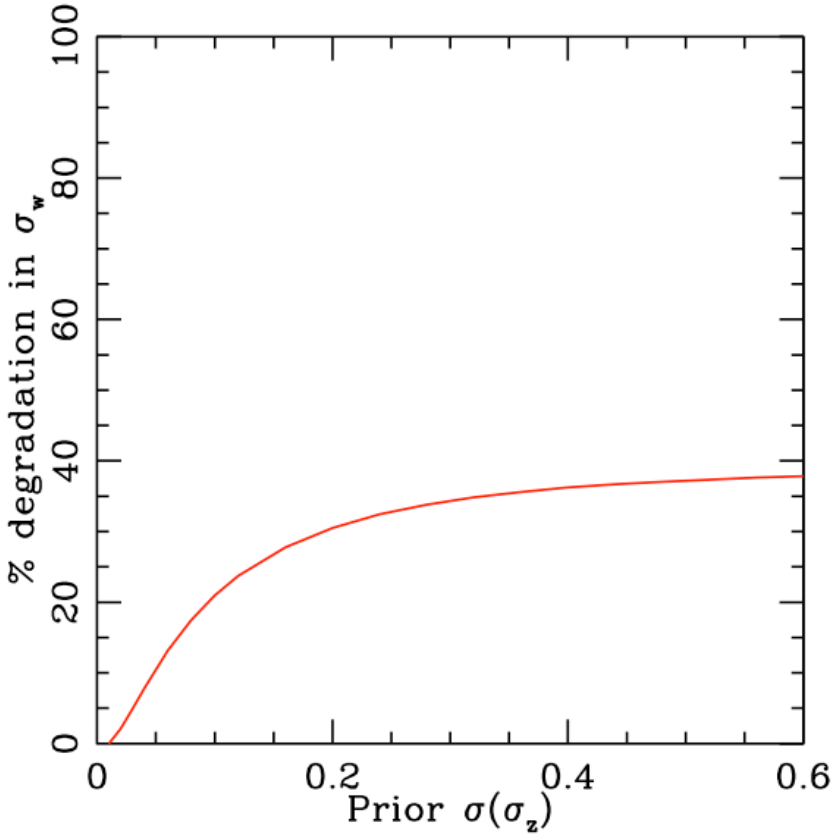
Another case: n fixed





Summary

- WMAP 3yr: 4 times less clusters
  ~ 40% degradation in baseline.
  Up to ~ 100% in self-calibration.
- Photo-z requirements: ~ 0.005 for z bias,
  ~ 0.05 for z scatter.
- Future: - Improve uncertainty in z bias and scatter requirement to be a function of z.
  - Calculations with CatSim1 cluster catalog.