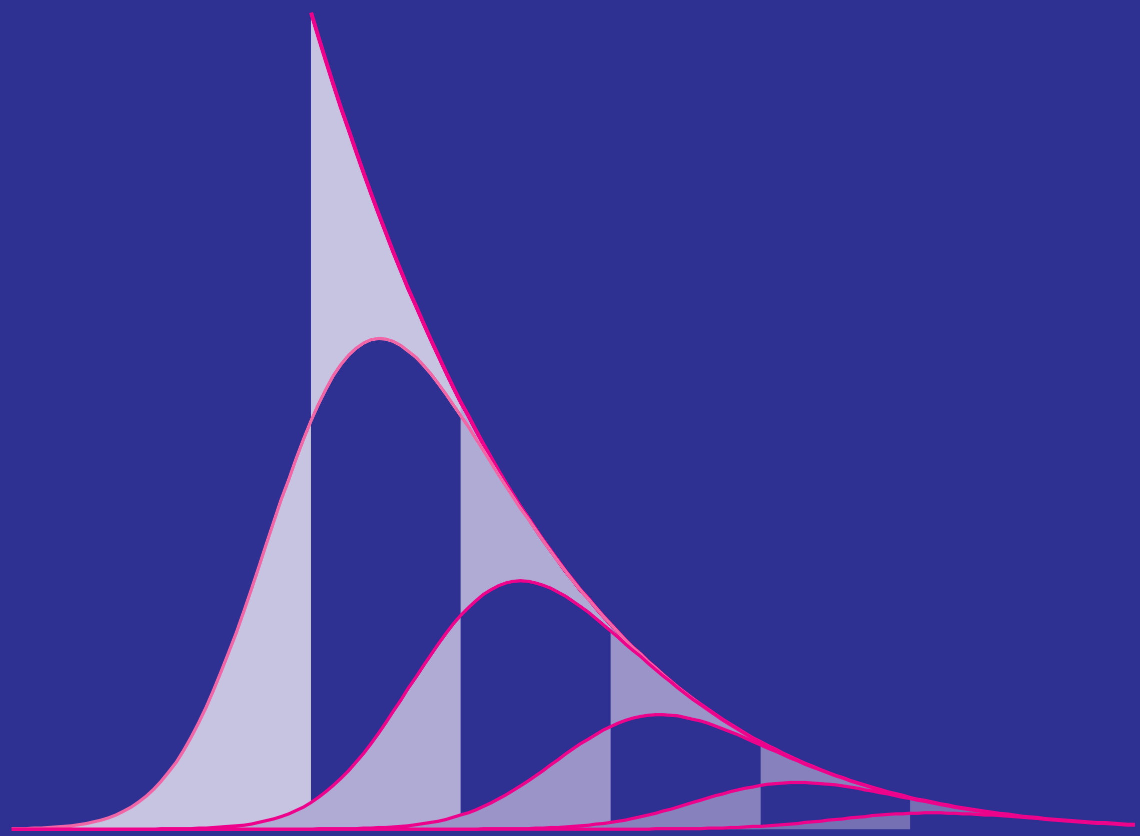
Calibration Issues for Cluster Counts:



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

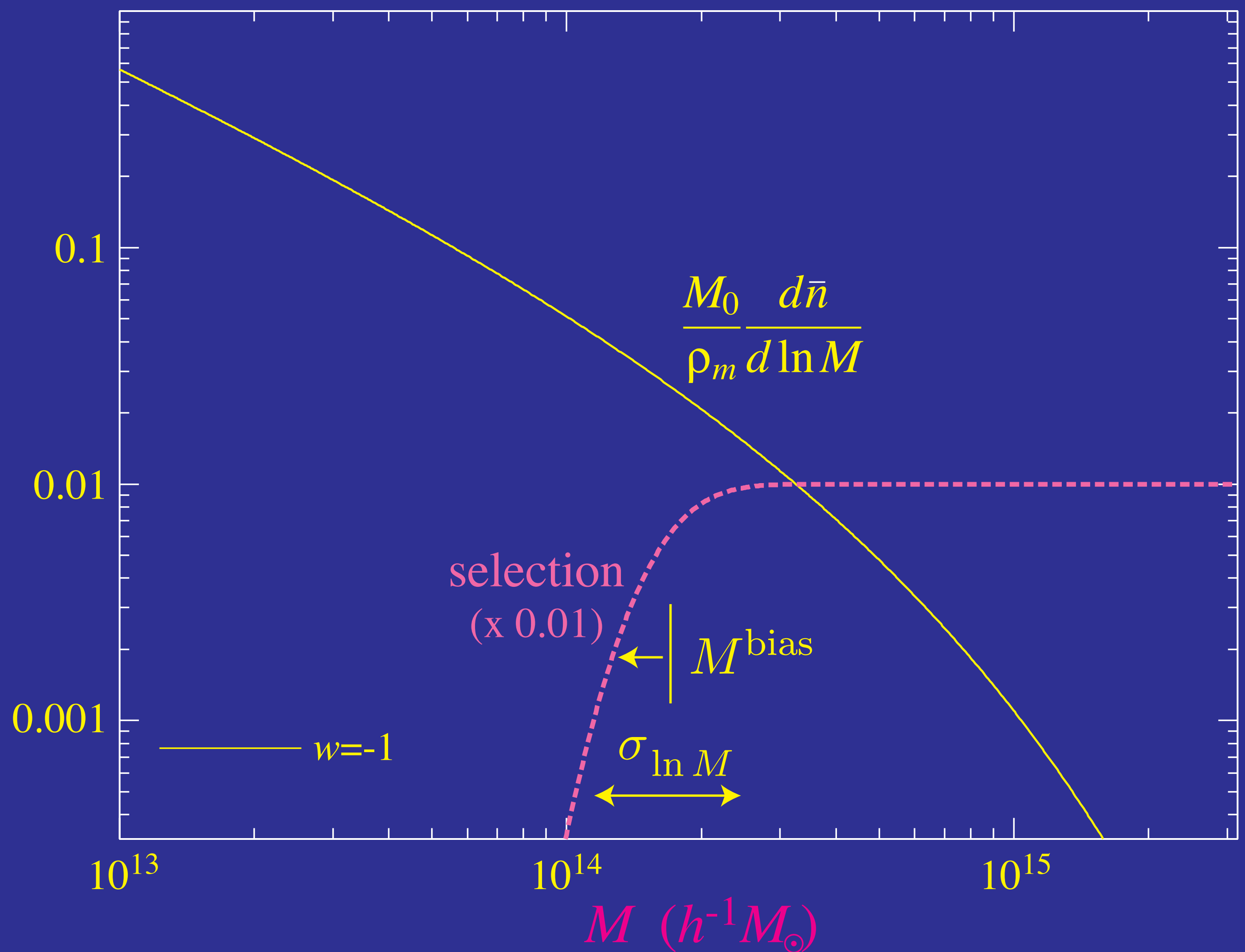
  prospects for self-calibration of a simple, Gaussian, mass independent distribution that evolves

  shape: Hu (2003); power: Majumdar & Mohr (2003)

Observable Mass Distribution

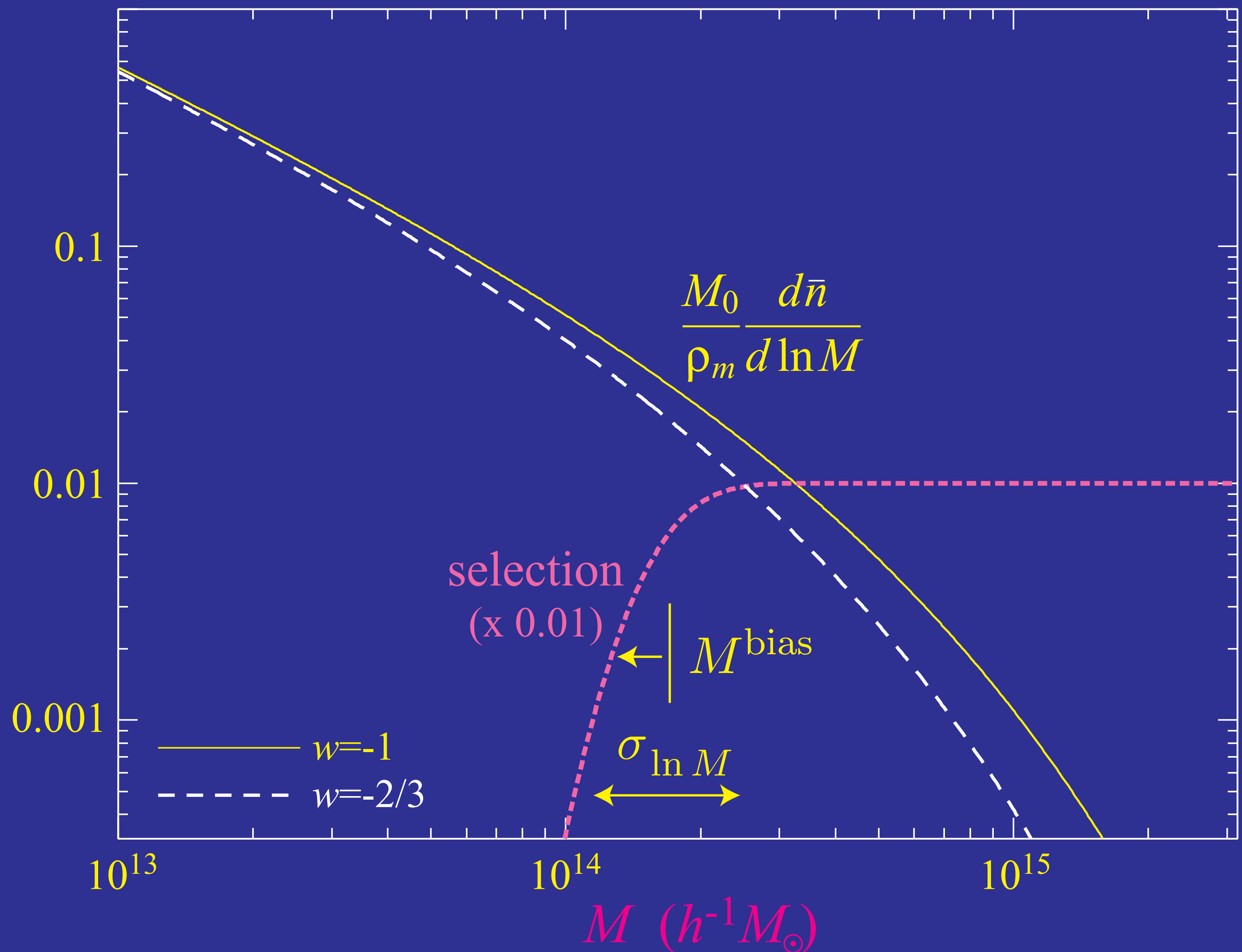
- Gaussian scatter and bias of a mass estimator

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



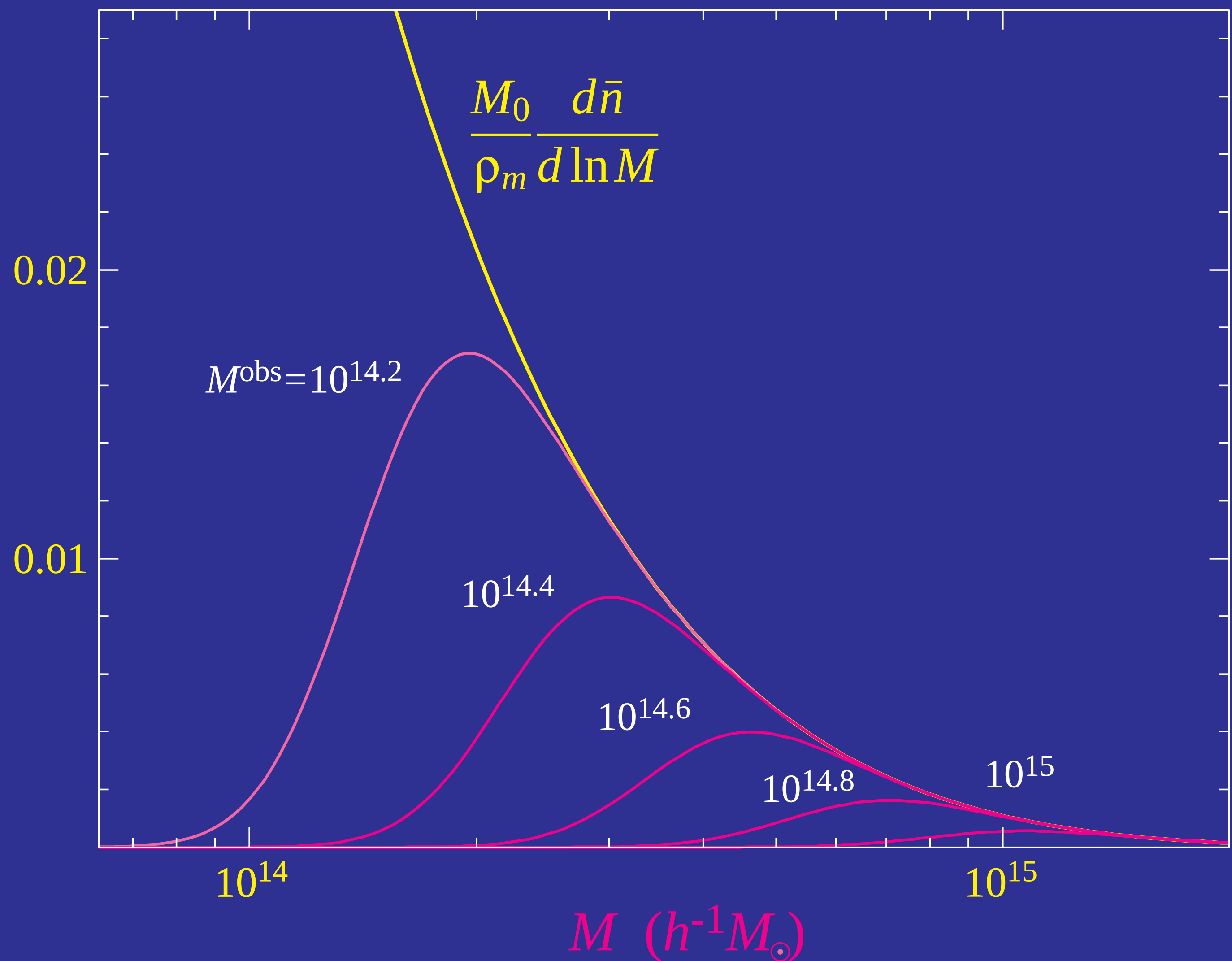
Degeneracy

- Uncertainties in bias and scatter cause degeneracies with dark energy



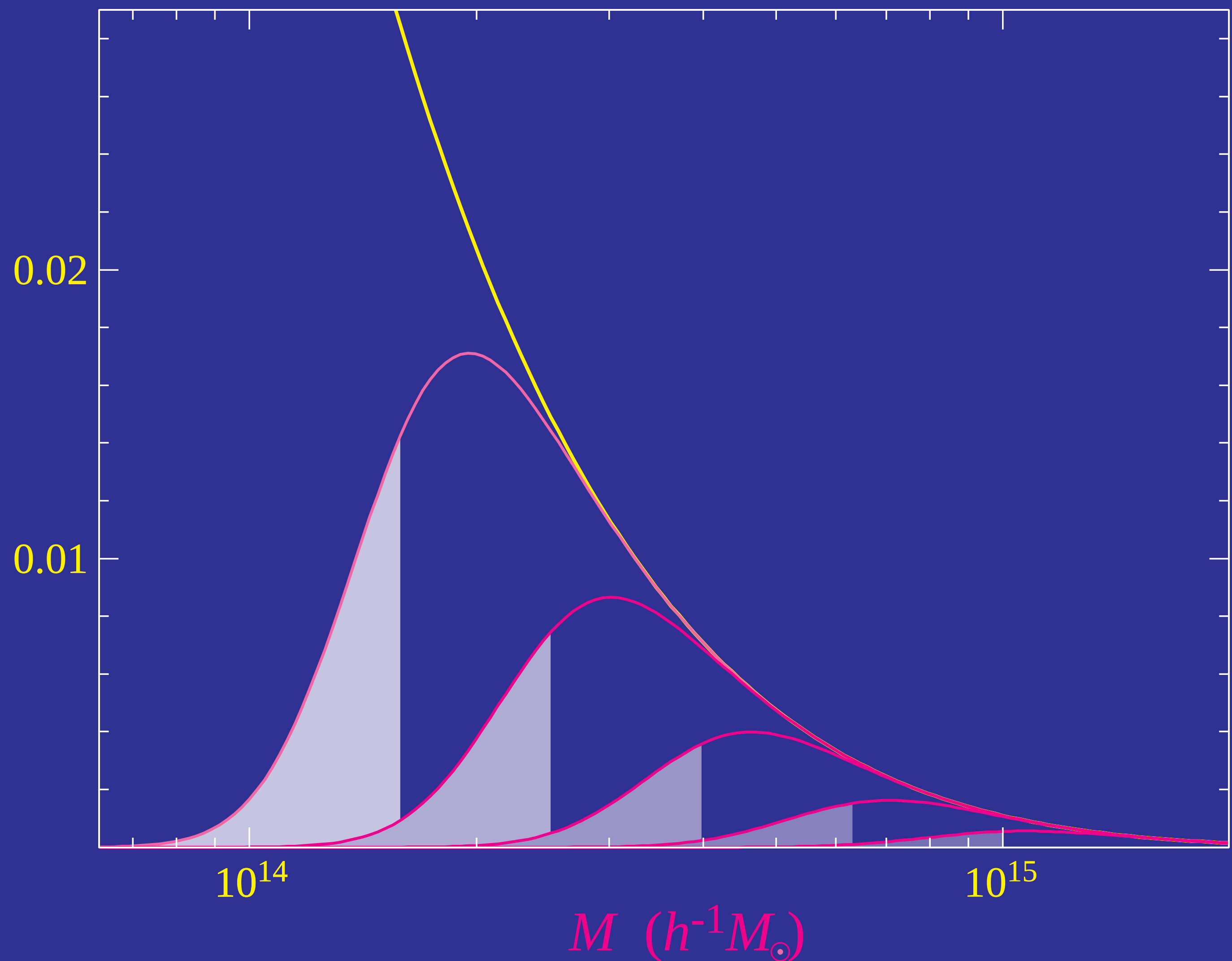
Selection Bias

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



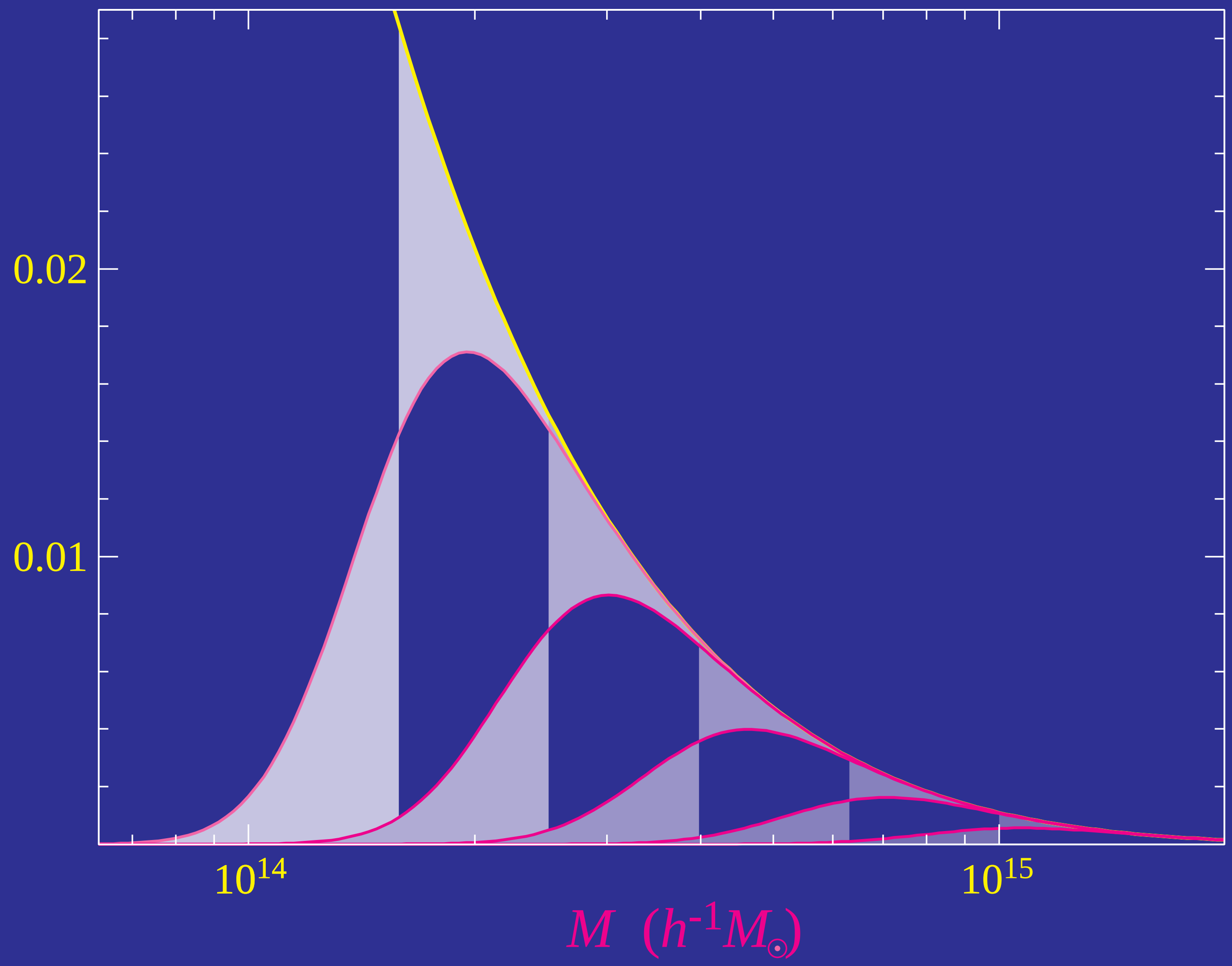
Selection Bias

- Clusters upscattered into threshold



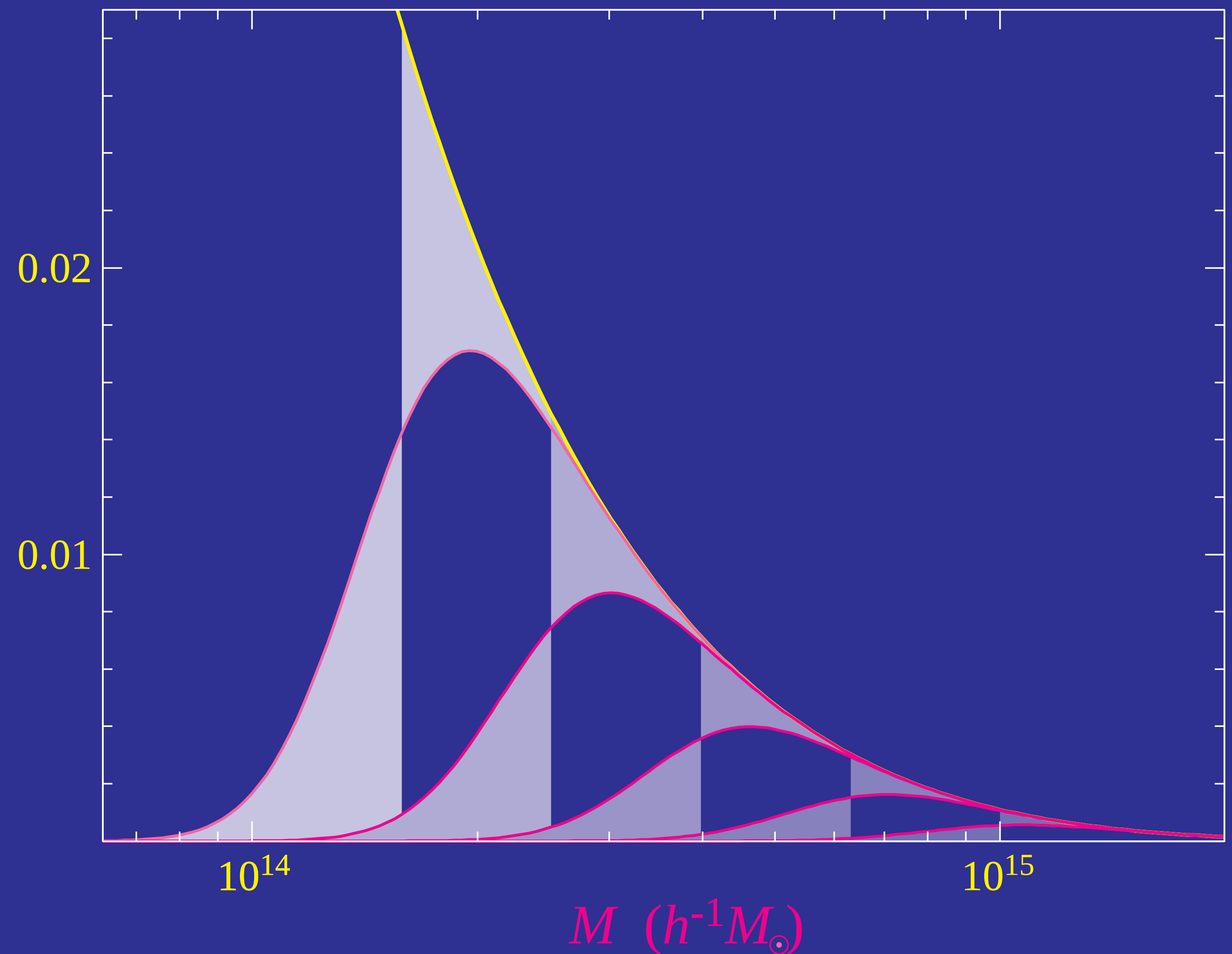
Selection Bias

- Clusters upscattered into threshold
- Out number downscattered across threshold



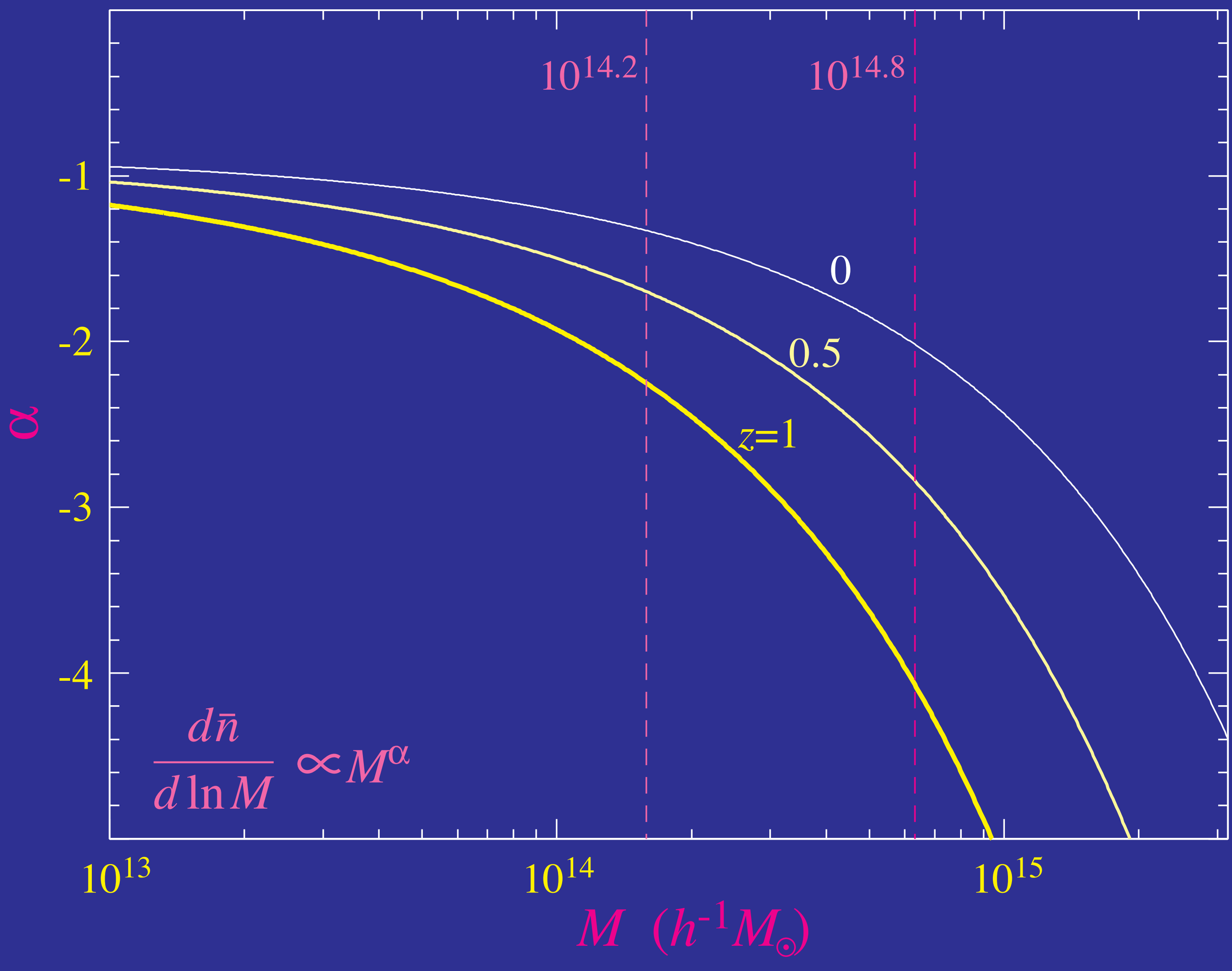
Selection Bias

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



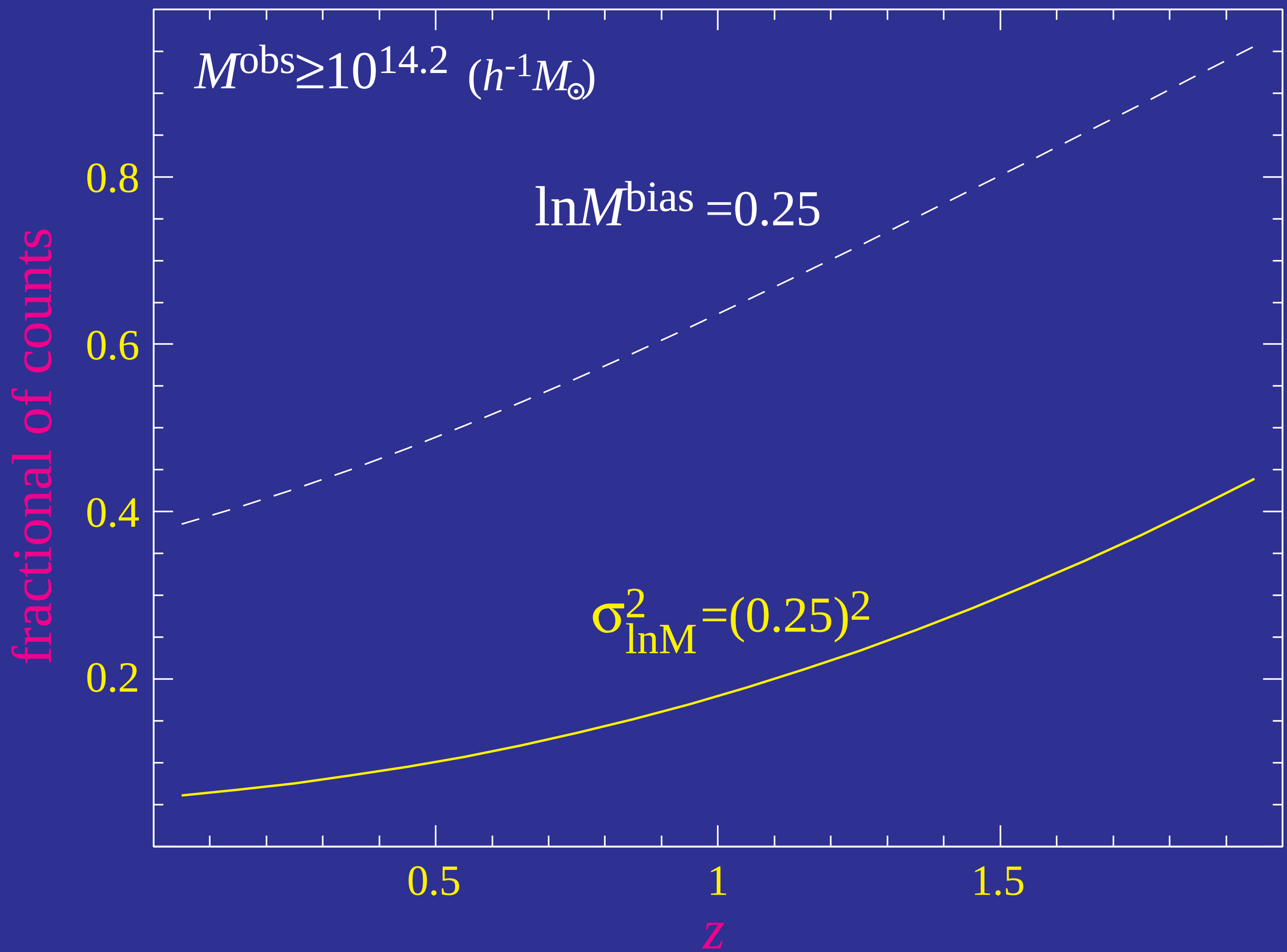
Relative Importance of Scatter

- 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



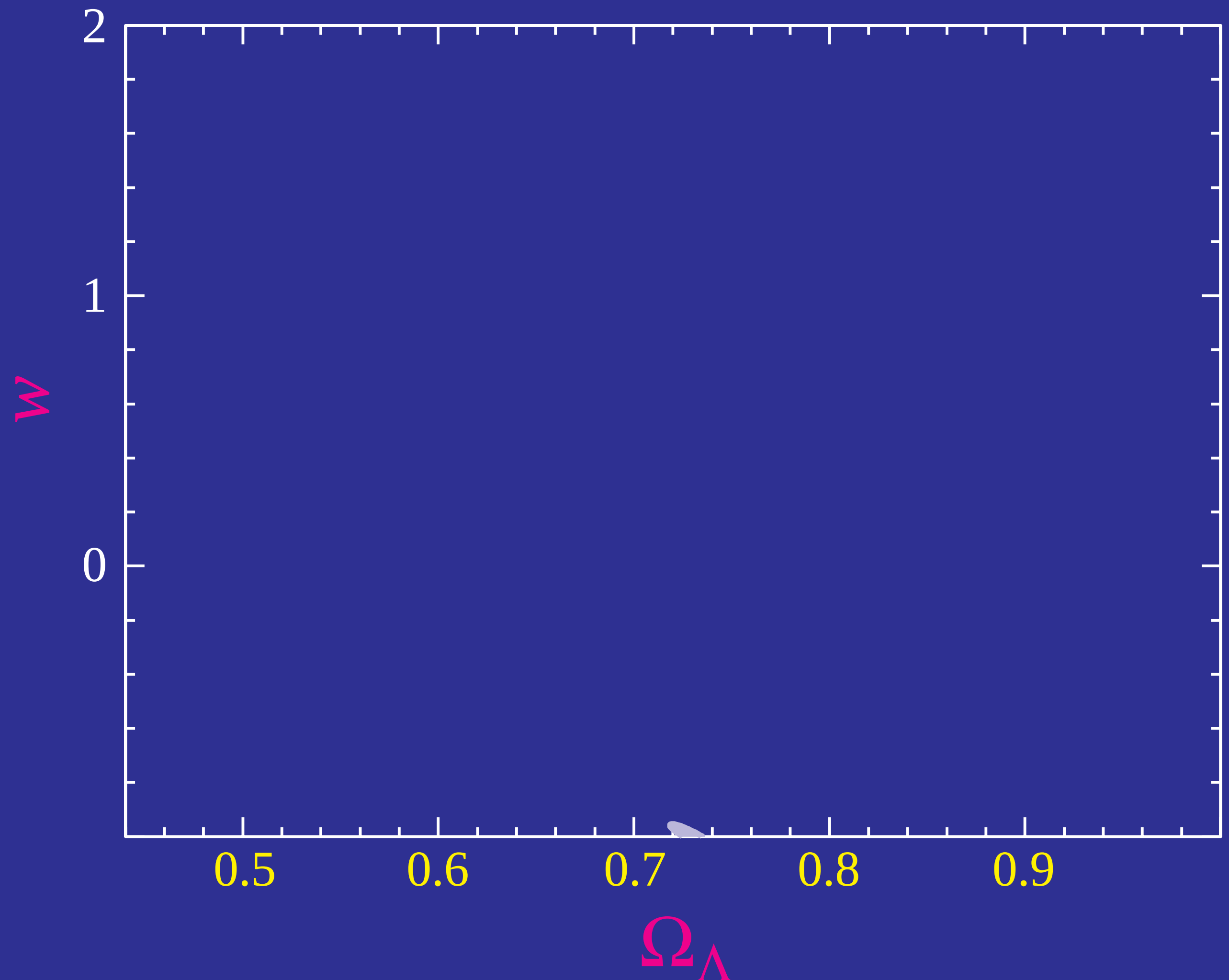
Sensitivity to Uncertainties

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



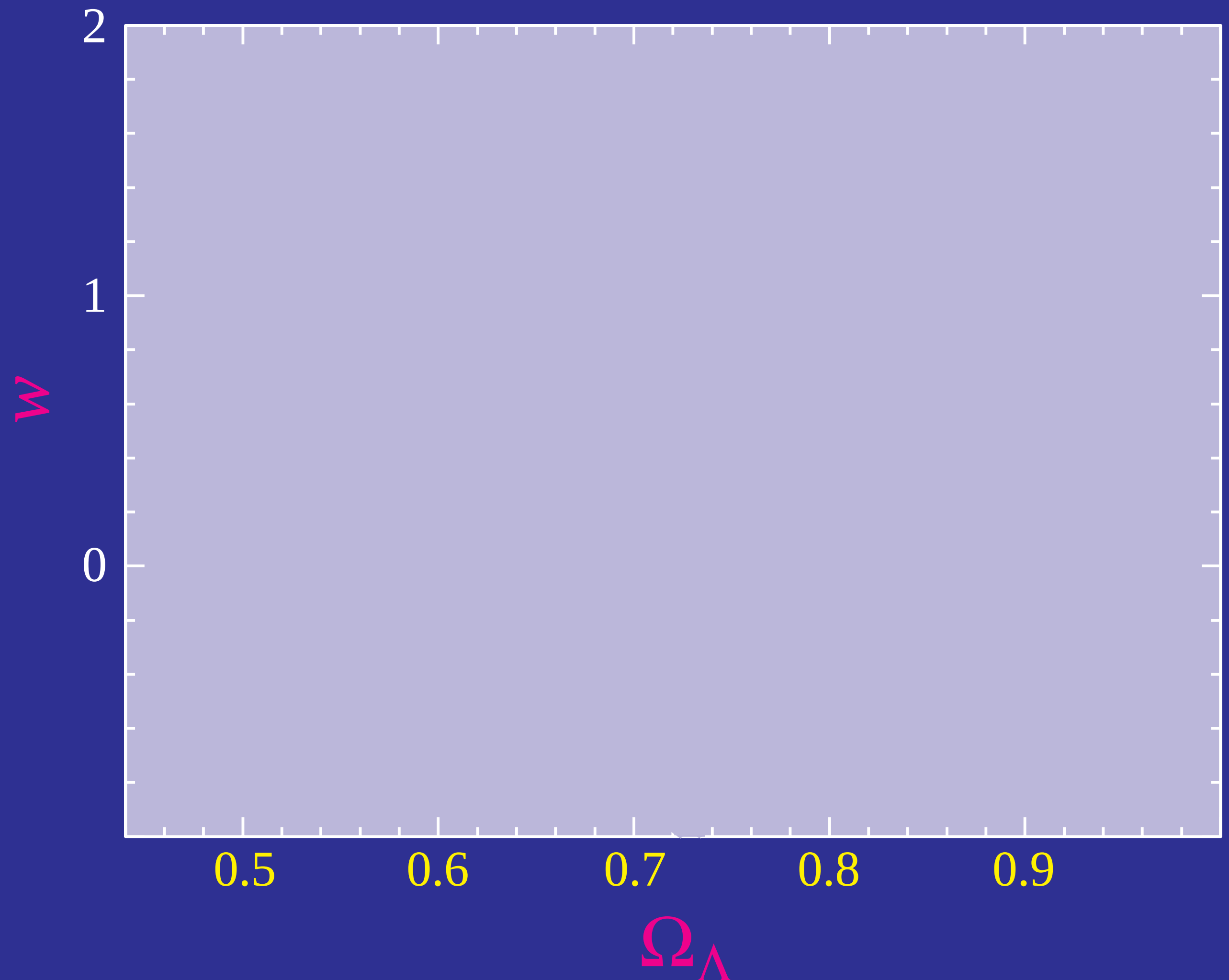
Fully Calibrated

- Given a completely known observable-mass distribution dark energy constraints are quite tight (4000 sq deg, $z<2$)



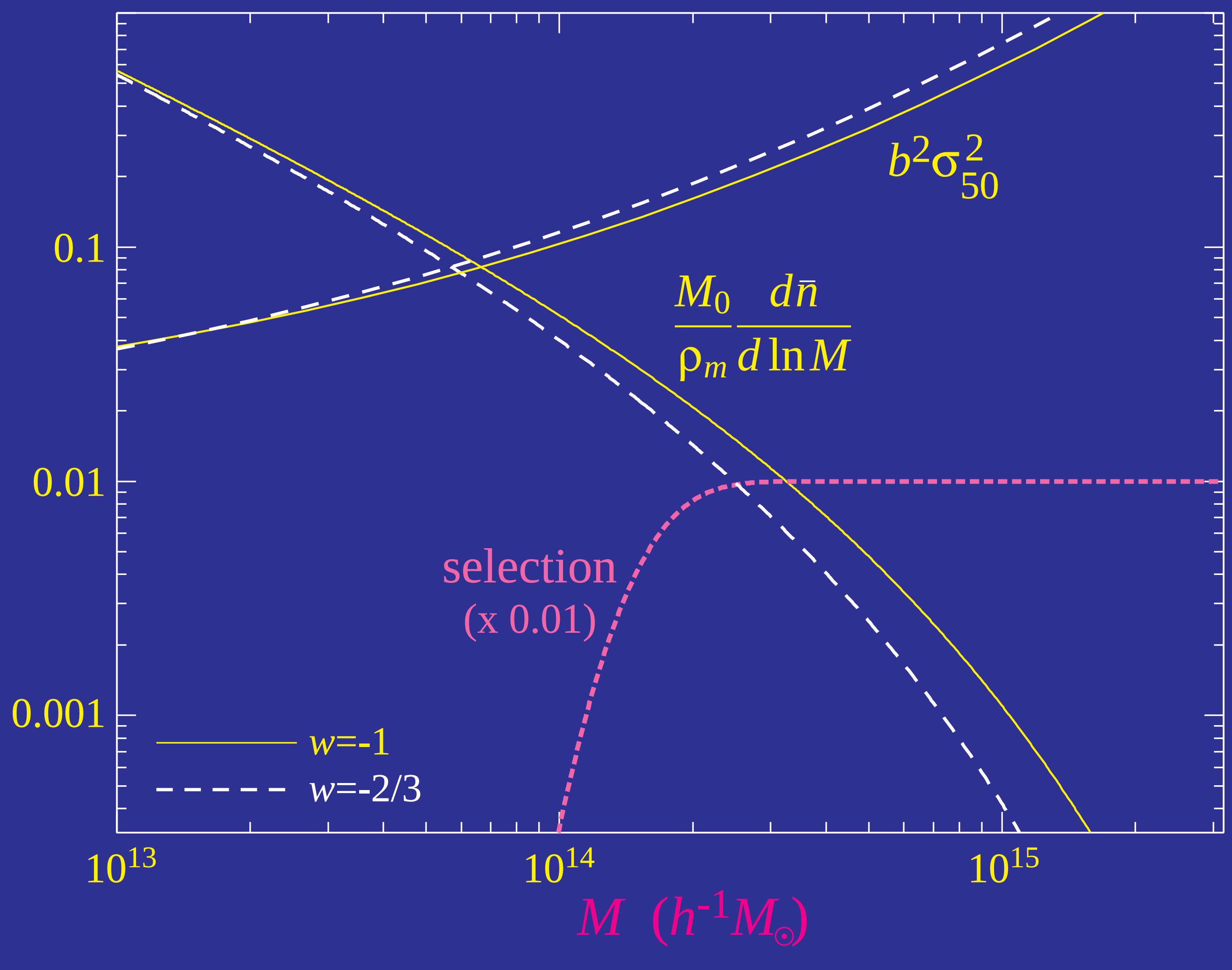
Un-Calibrated

- Marginalizing scatter (linear *z* evolution) and bias (power law evolution) destroys all dark energy information



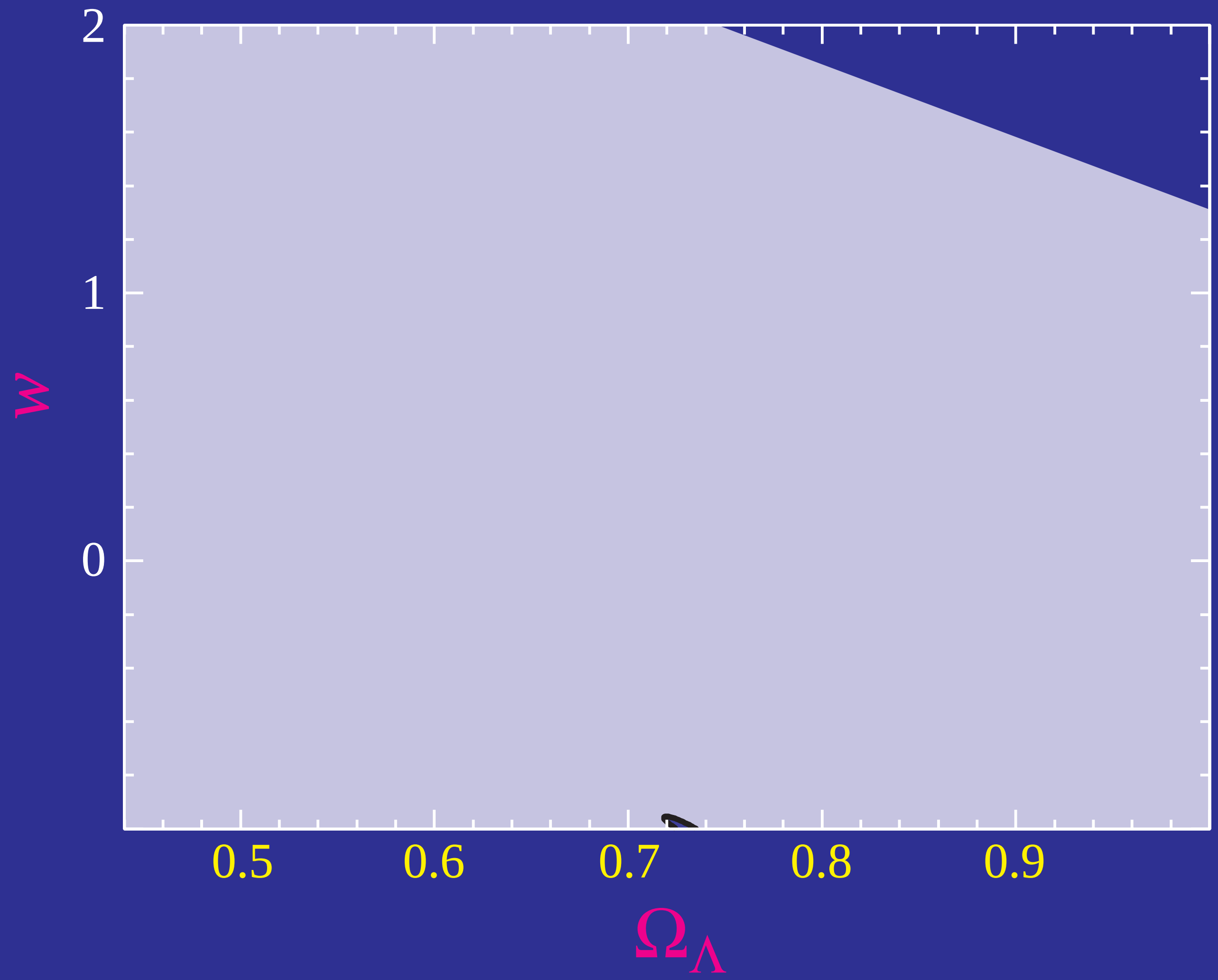
Self-Calibration with Clustering

- 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



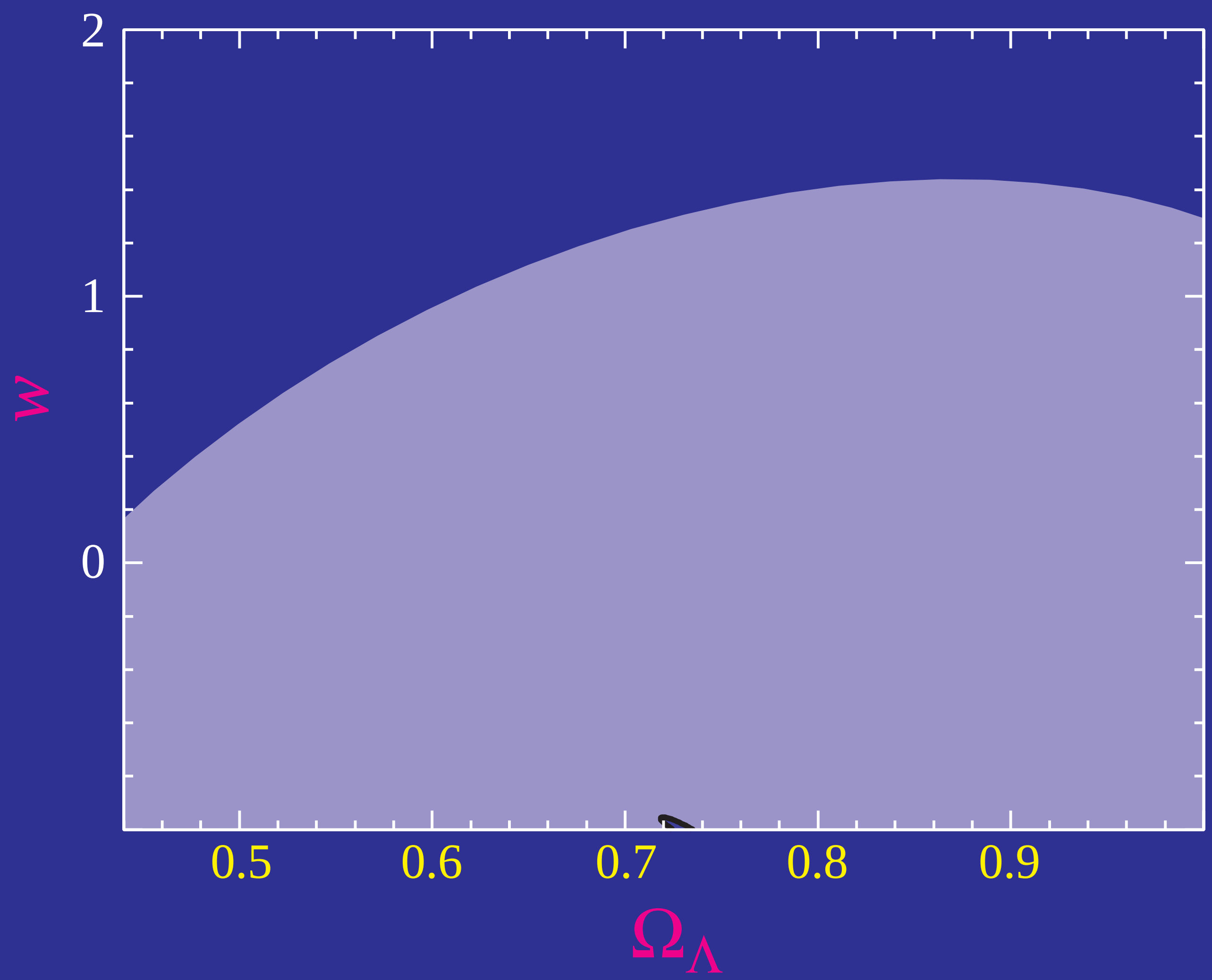
Self-Calibration with Clustering

- Arbitrary evolution of bias and scatter in 20 bins of Δz=0.1



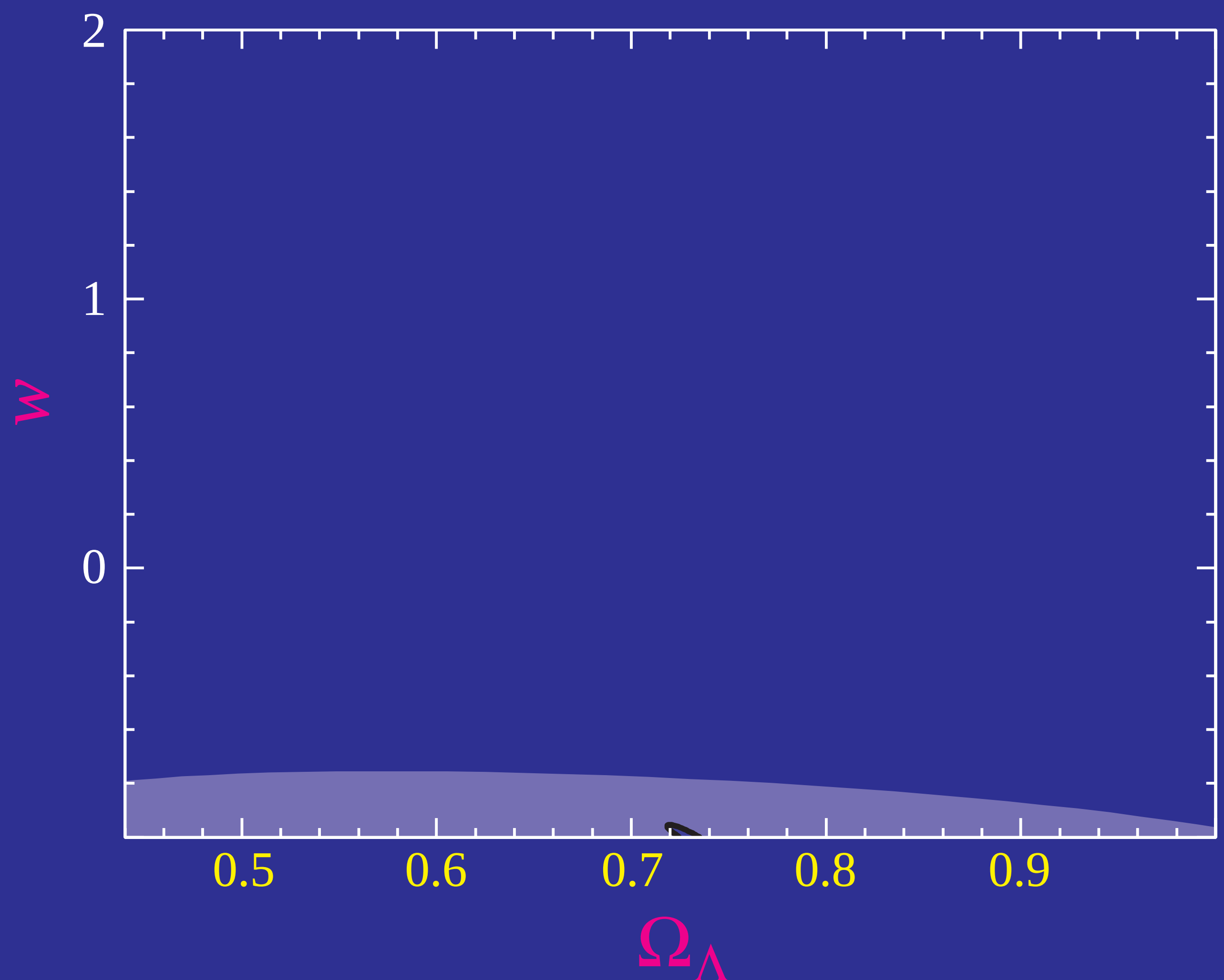
Self-Calibration with Clustering

- Power law evolution of bias and arbitrary evolution of scatter in 20 bins of Δz=0.1



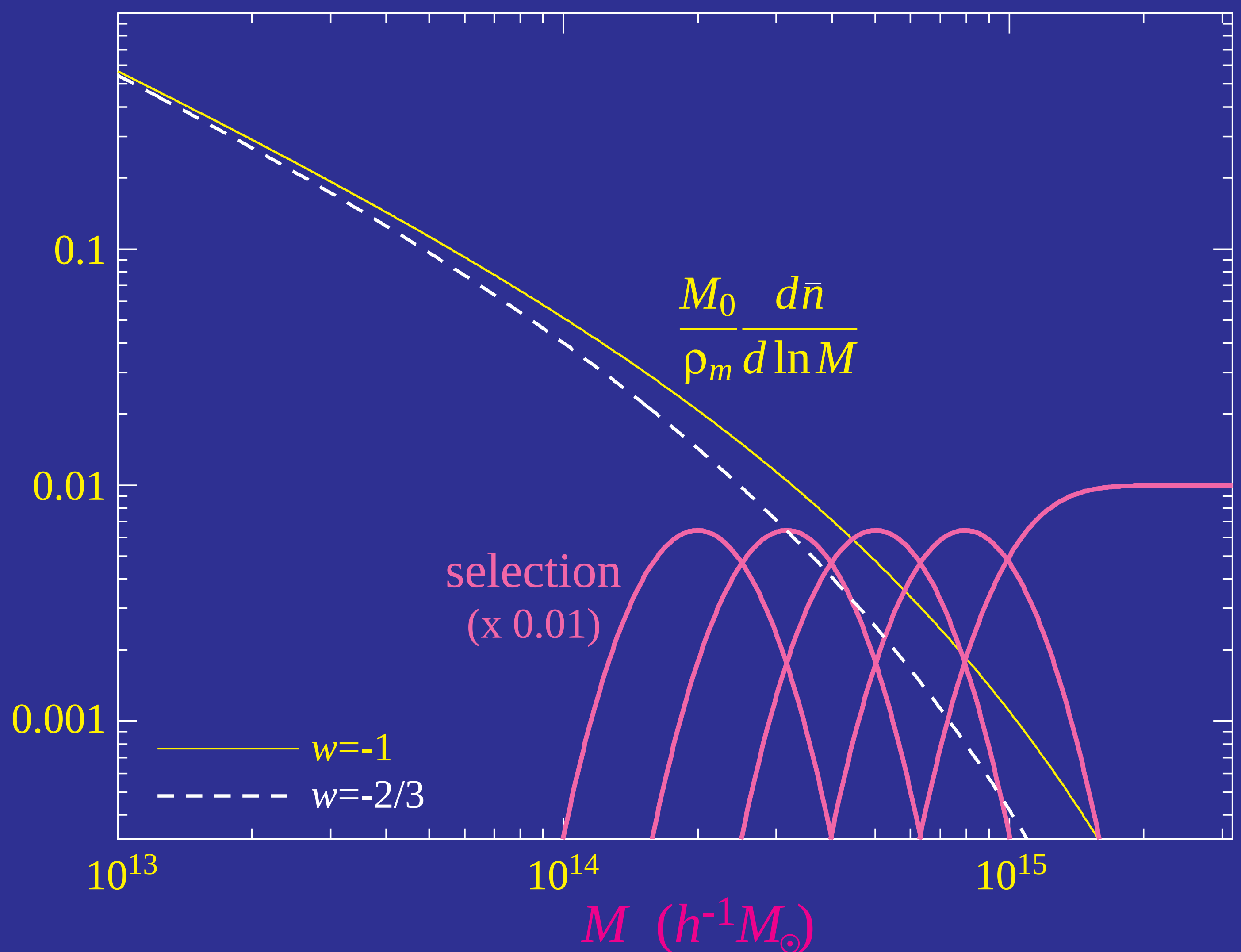
Self-Calibration with Clustering

- Power law evolution of bias and cubic evolution of scatter in *z*



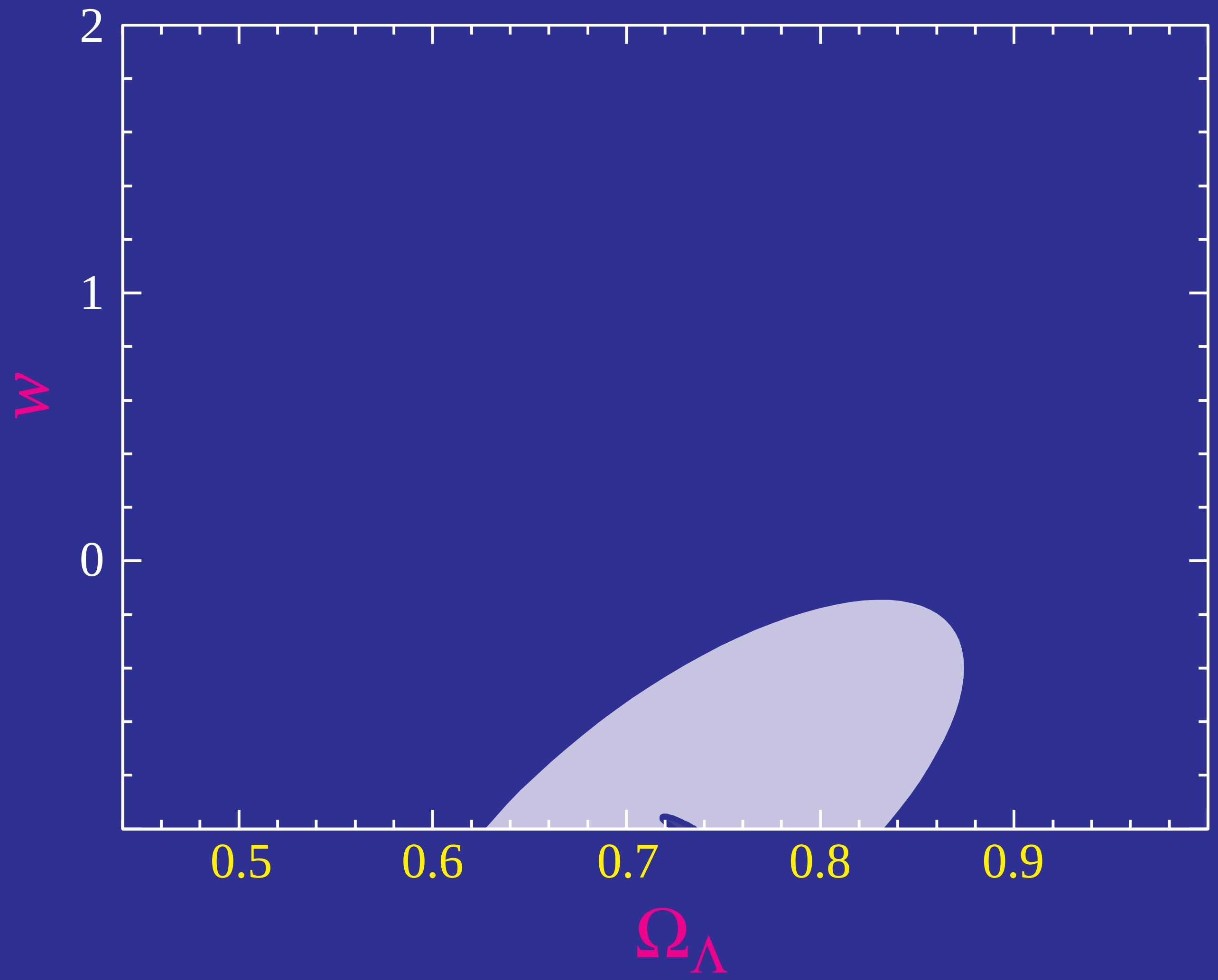
Observable Mass Bins

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



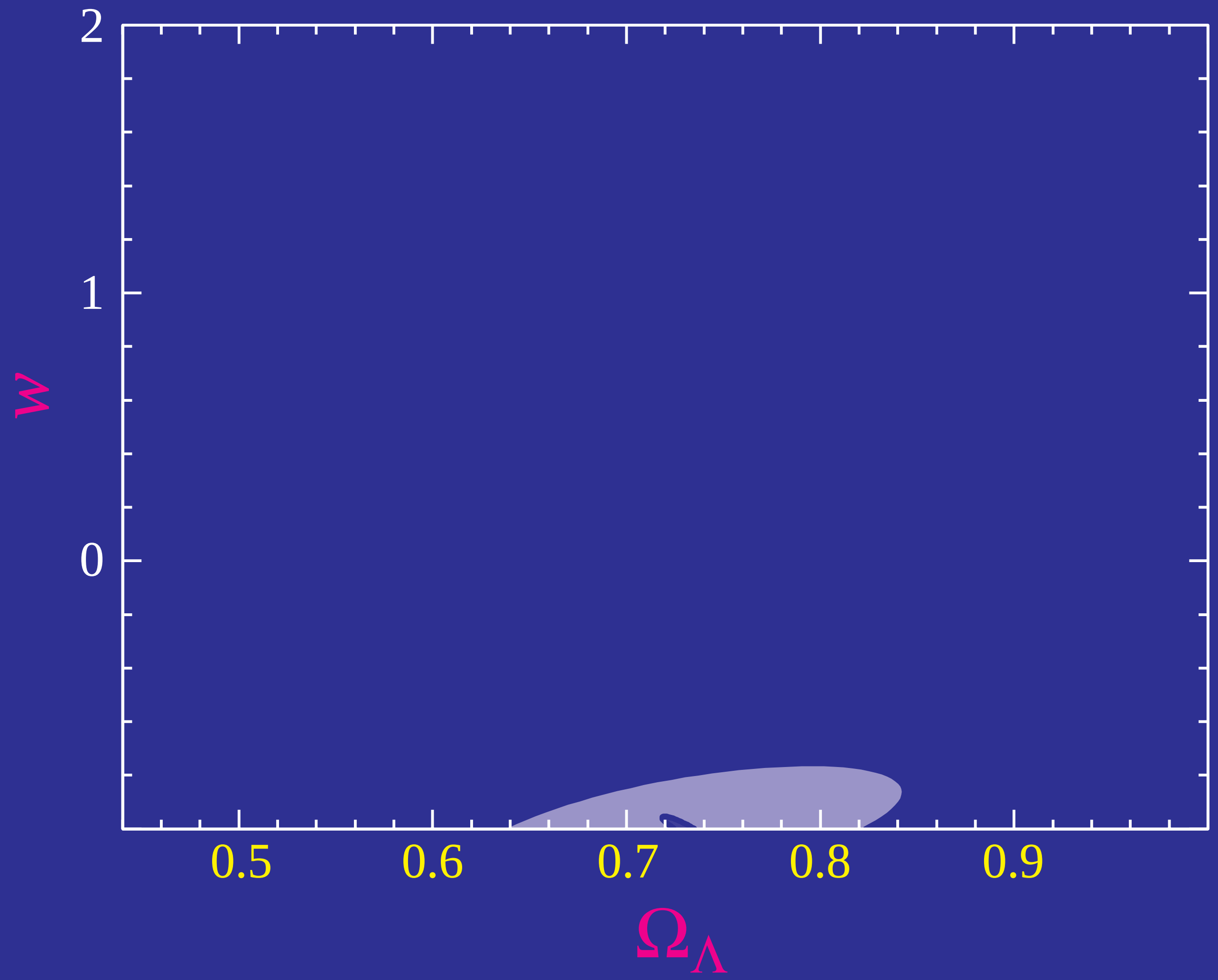
Self-Calibration with Binning

- Arbitrary evolution of bias and scatter in 20 bins of Δz=0.1



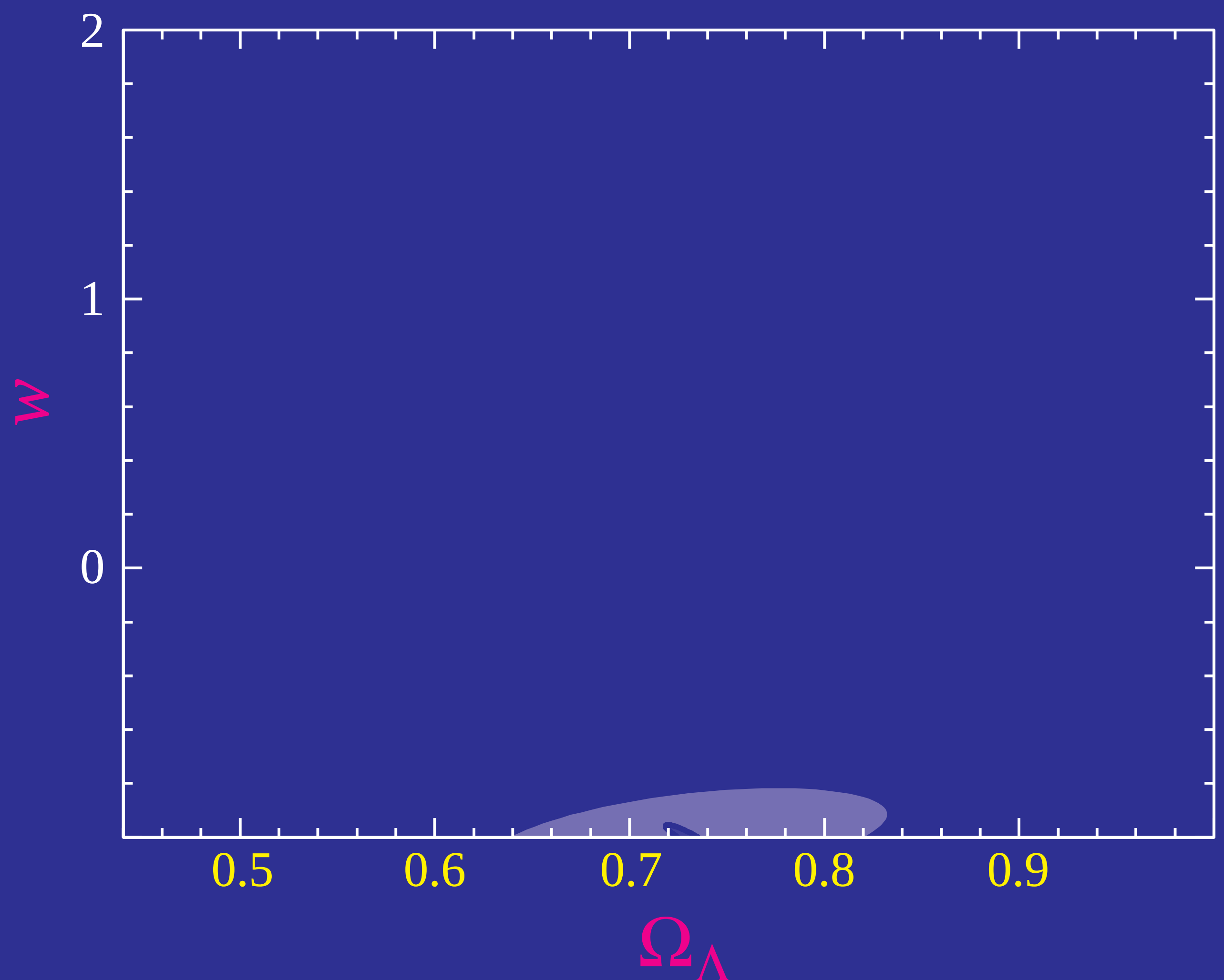
Self-Calibration with Binning

- Power law evolution of bias and arbitrary evolution of scatter in 20 bins of Δz=0.1



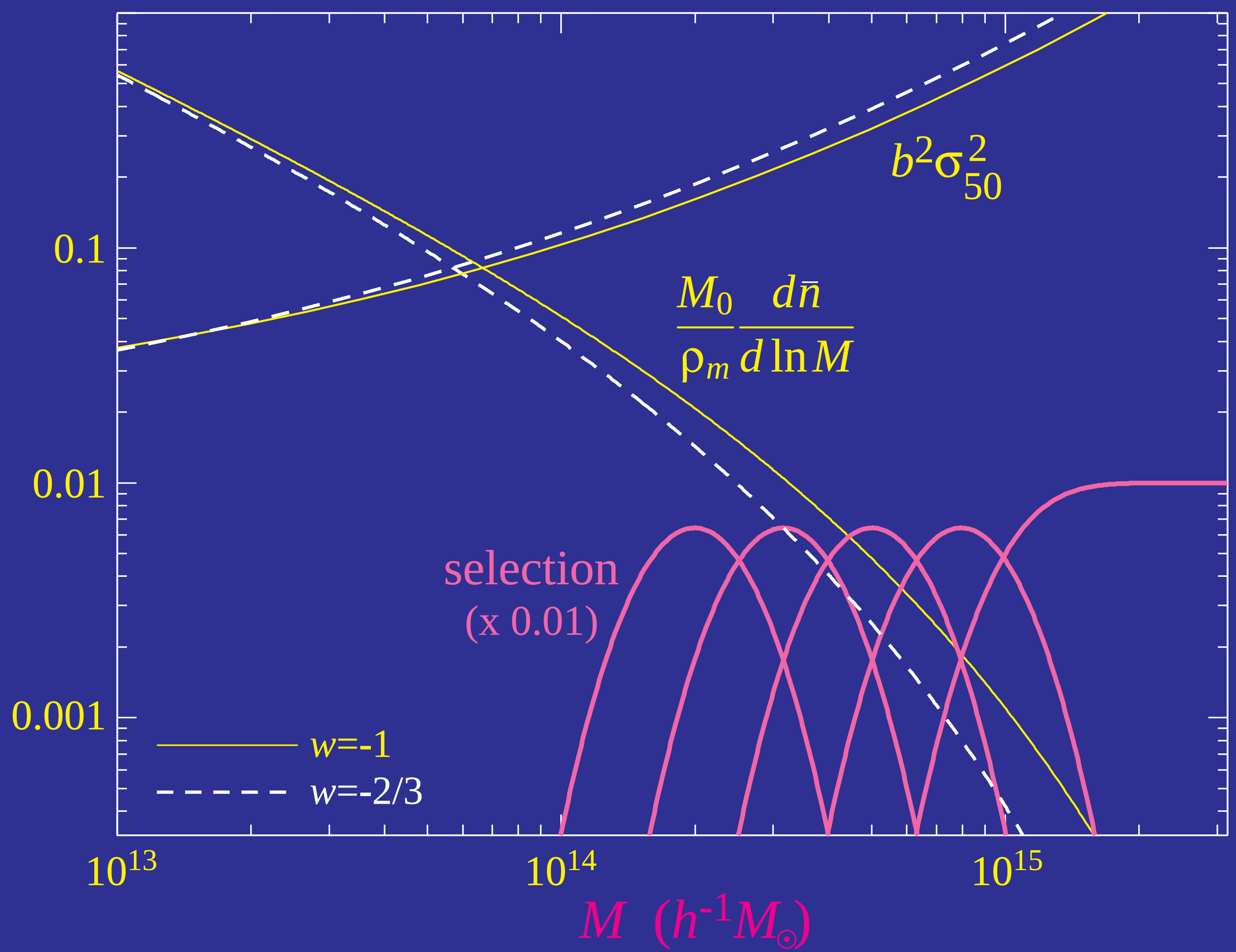
Self-Calibration with Binning

- Power law evolution of bias and cubic evolution of scatter in z



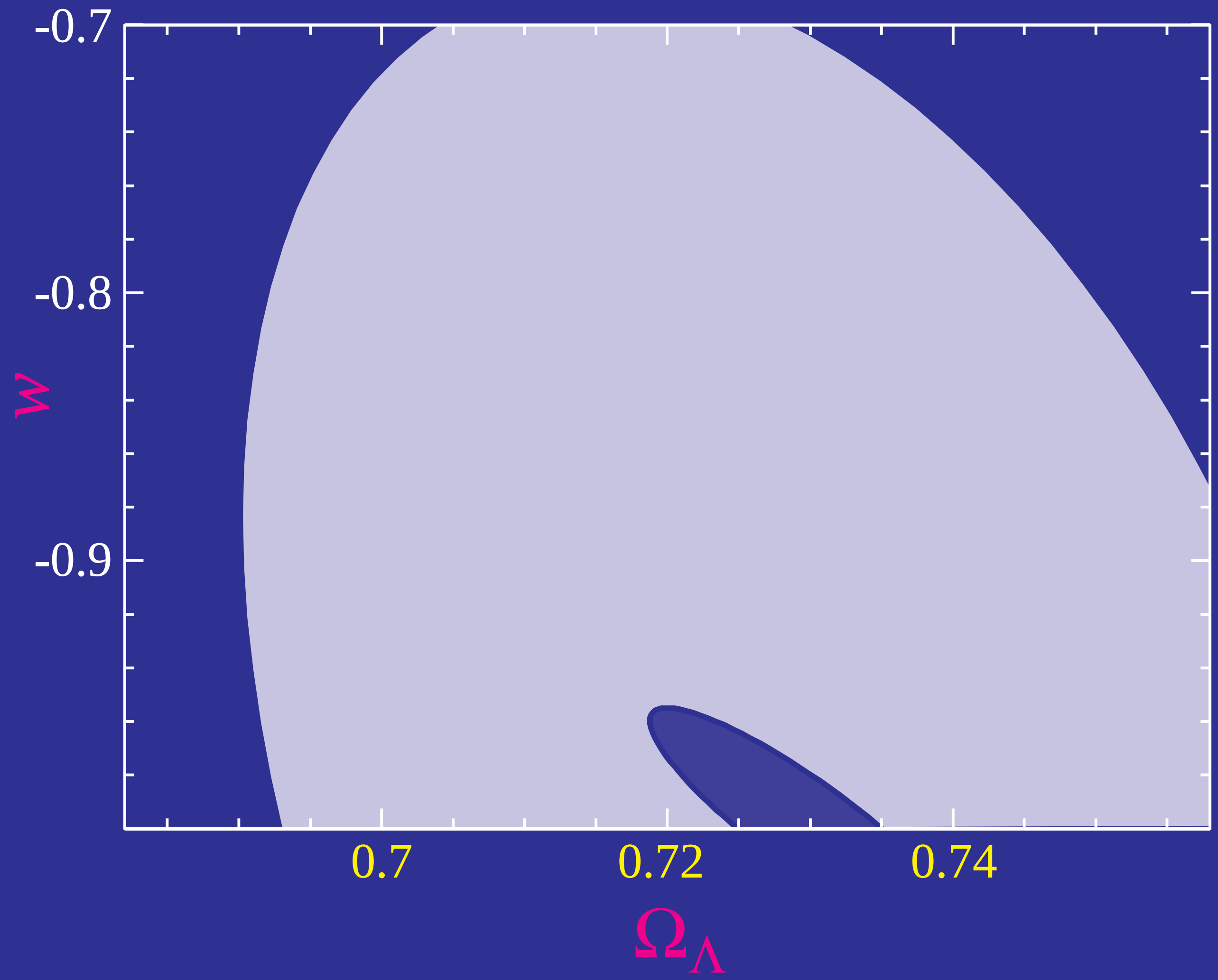
Joint Self-Calibration

- 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



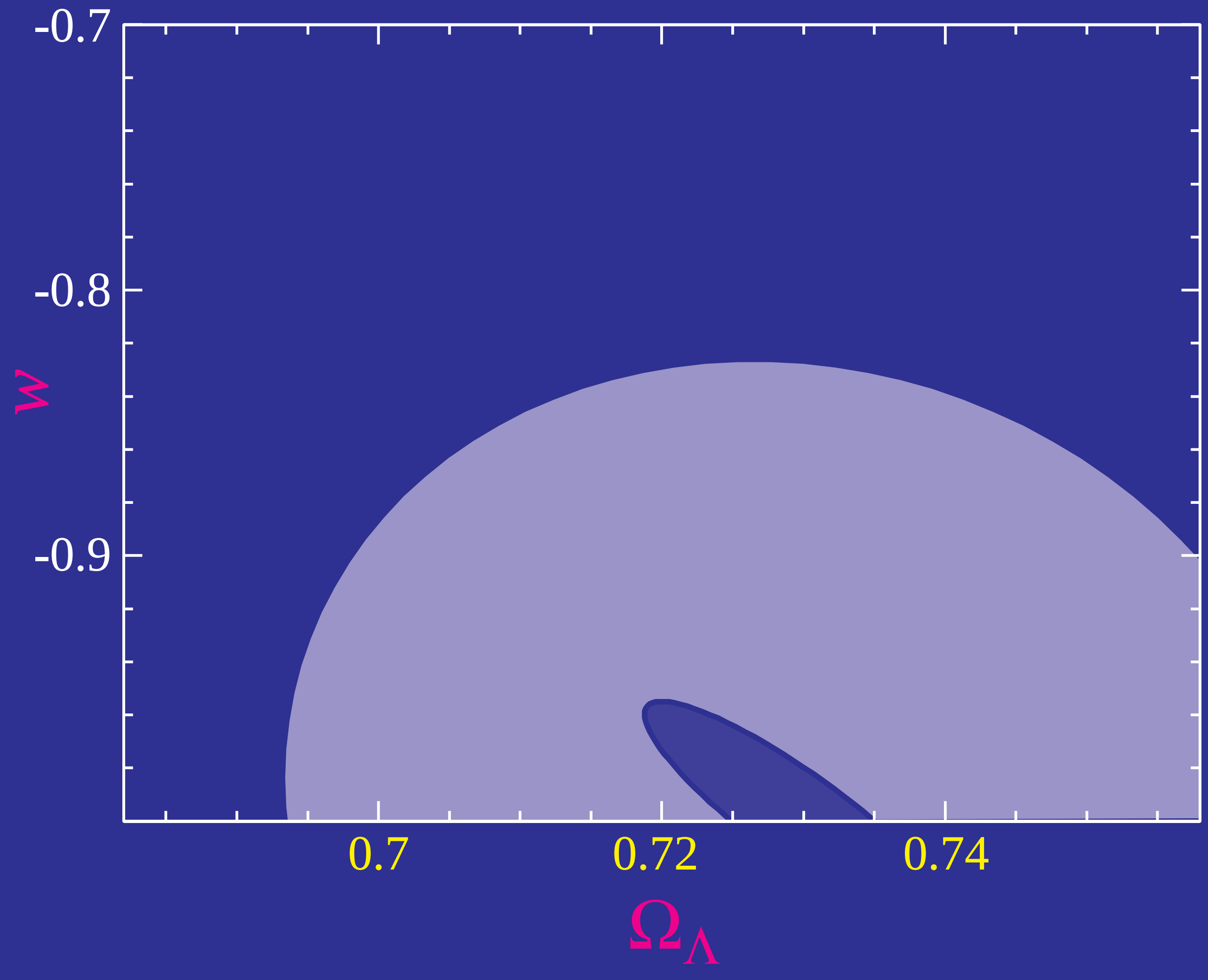
Joint Self Calibration

- Arbitrary evolution of bias and scatter in 20 bins of Δz=0.1



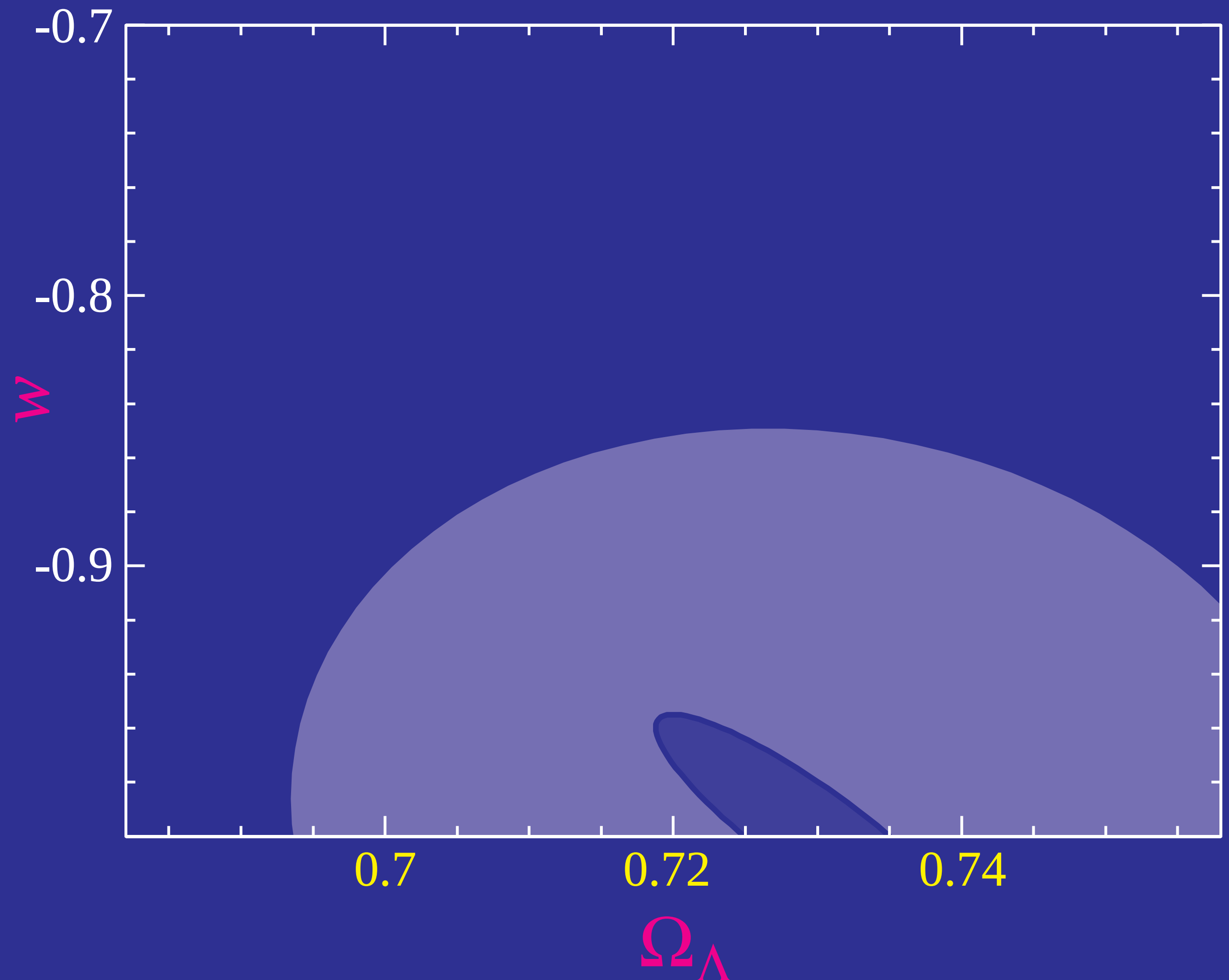
Joint Self Calibration

- Power law evolution of bias and arbitrary evolution of scatter in 20 bins of Δz=0.1



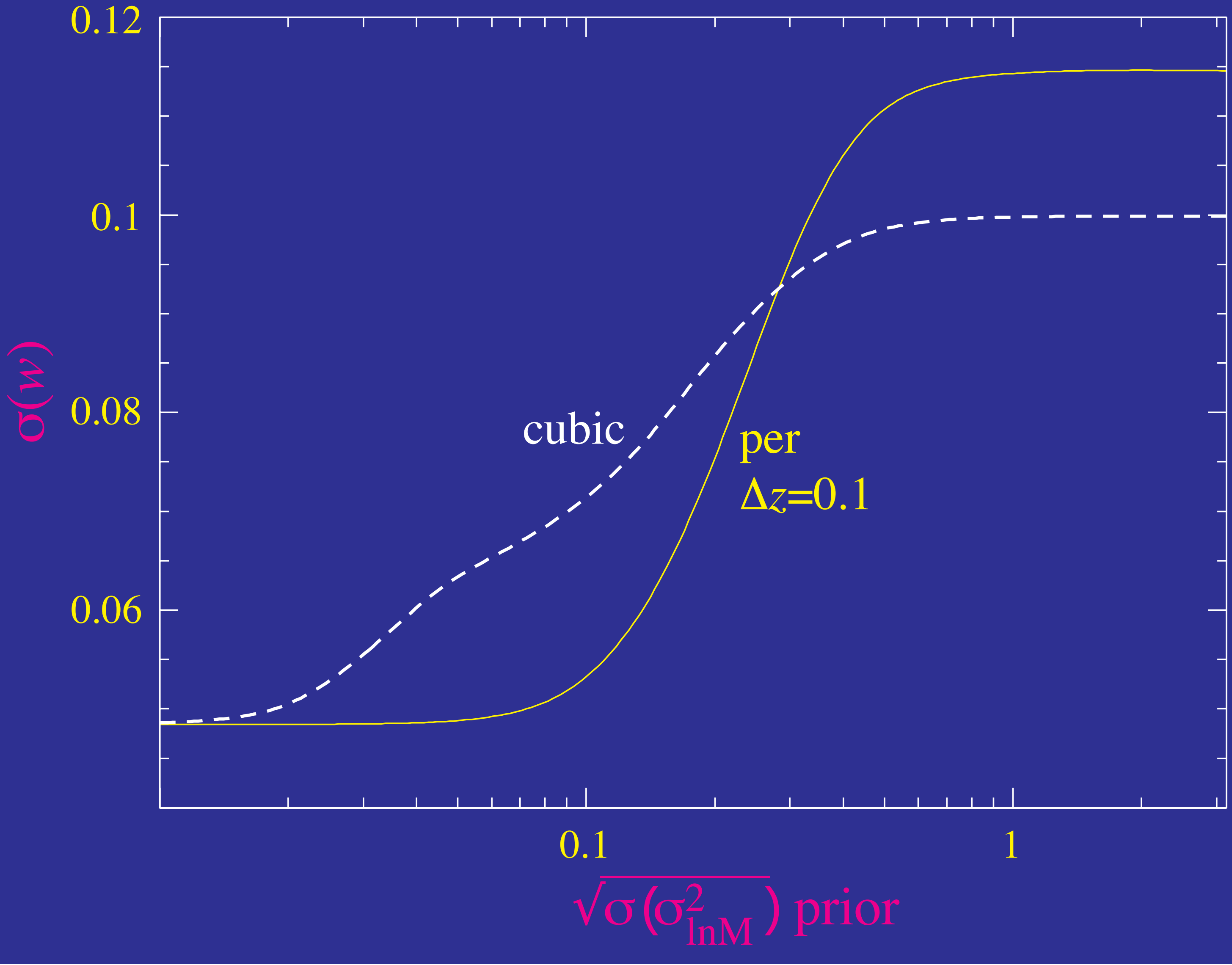
Joint Self Calibration

- 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 $z\sim1$ improves constraints x2 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~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~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!