The Velocity Distribution Function of Galaxy Clusters as a Cosmological Probe

Michelle Ntampaka
McWilliams Center for Cosmology
Carnegie Mellon University

In collaboration with Hy Trac, Jessi Cisewski, & Layne Price


Image credit: nasa.gov

dunkle Materie

Scheinbare Geschwindigkeiten im Comahaufen.

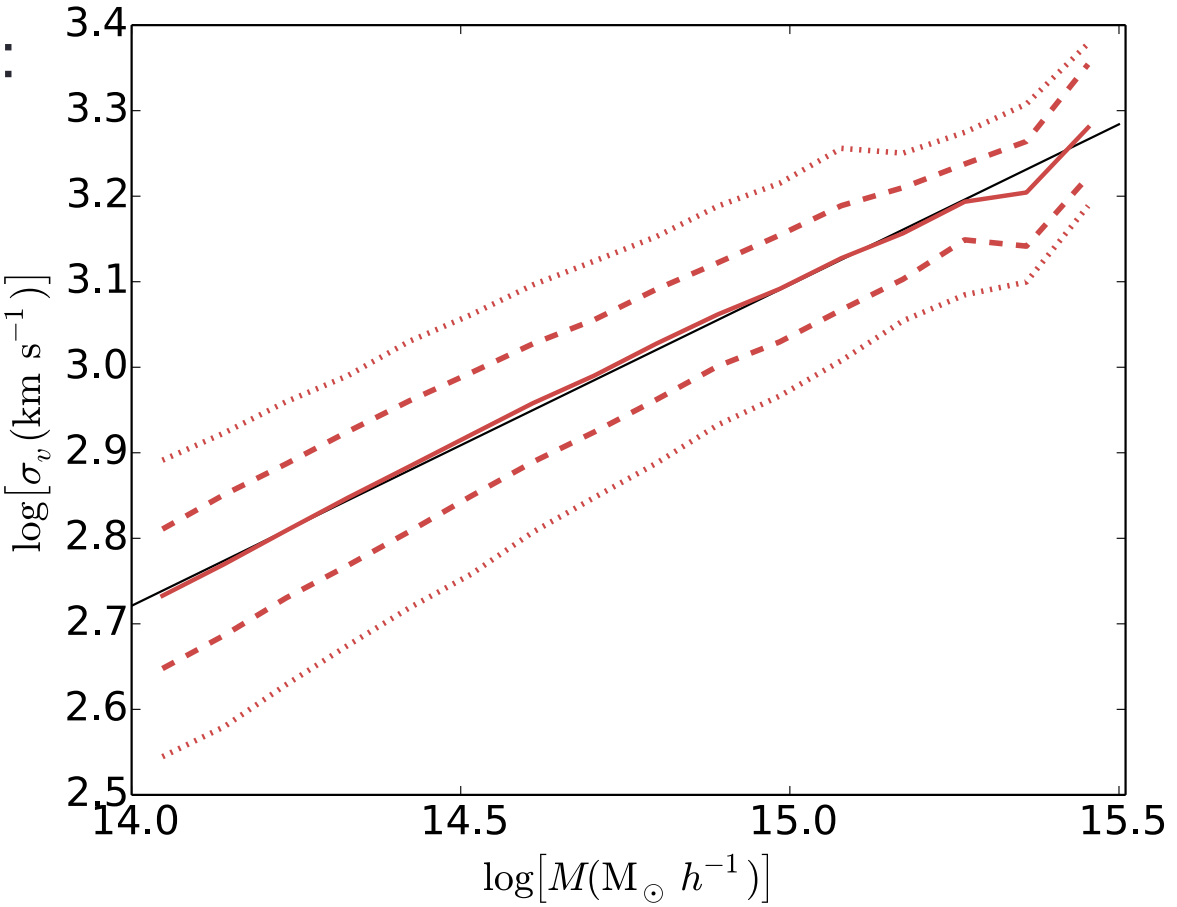
$v =$	8500 km/sek	6900 km/sek
	7900	6700
	7600	6600
	7000	5100 (?)

Sources of Scatter in Dynamical Mass Estimates

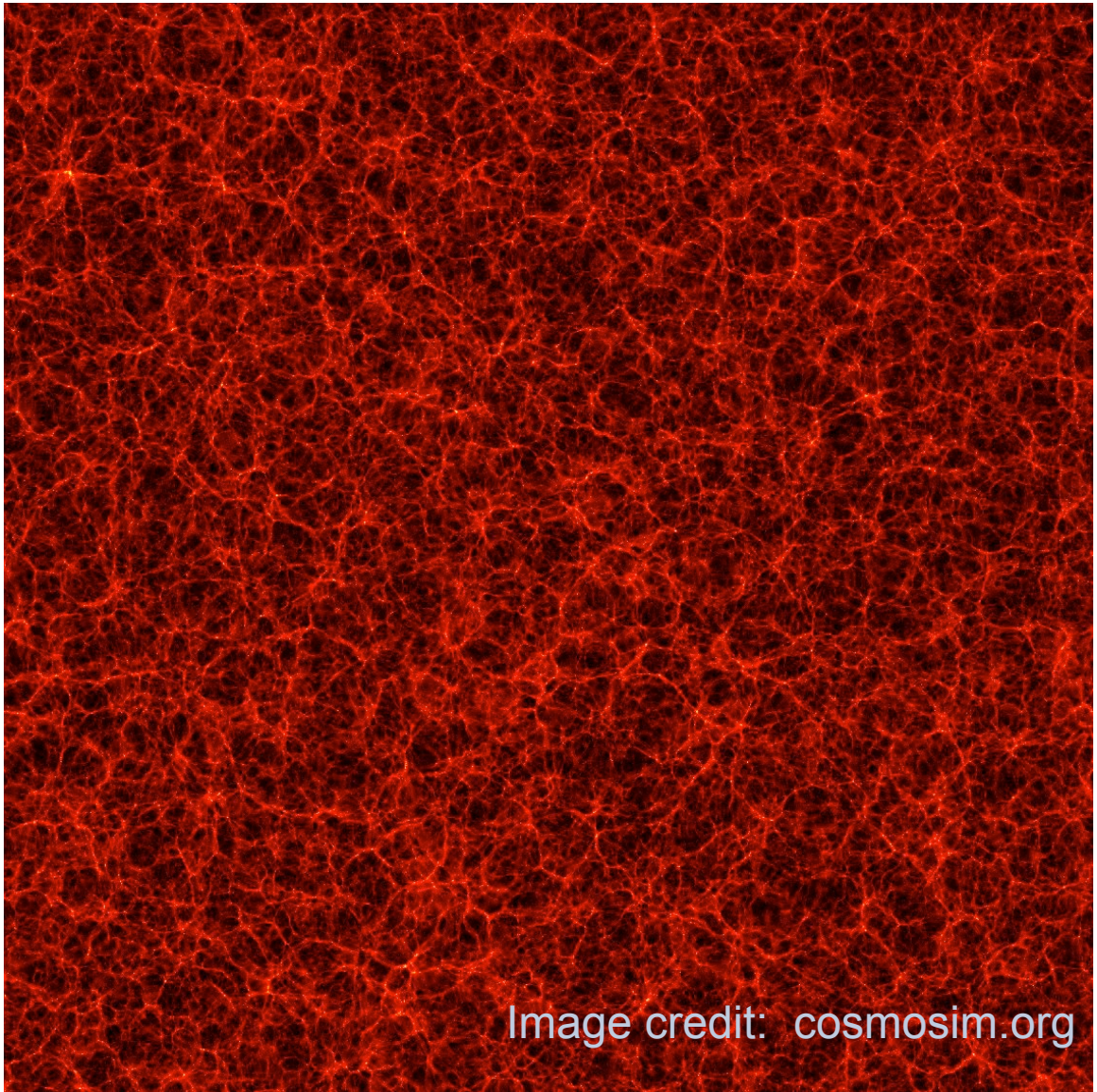
From the virial theorem, $\sigma_v \propto M^{1/3}$

Sources of scatter:

- Mergers
- Infalling matter
- Halo triaxiality
- Observational effects



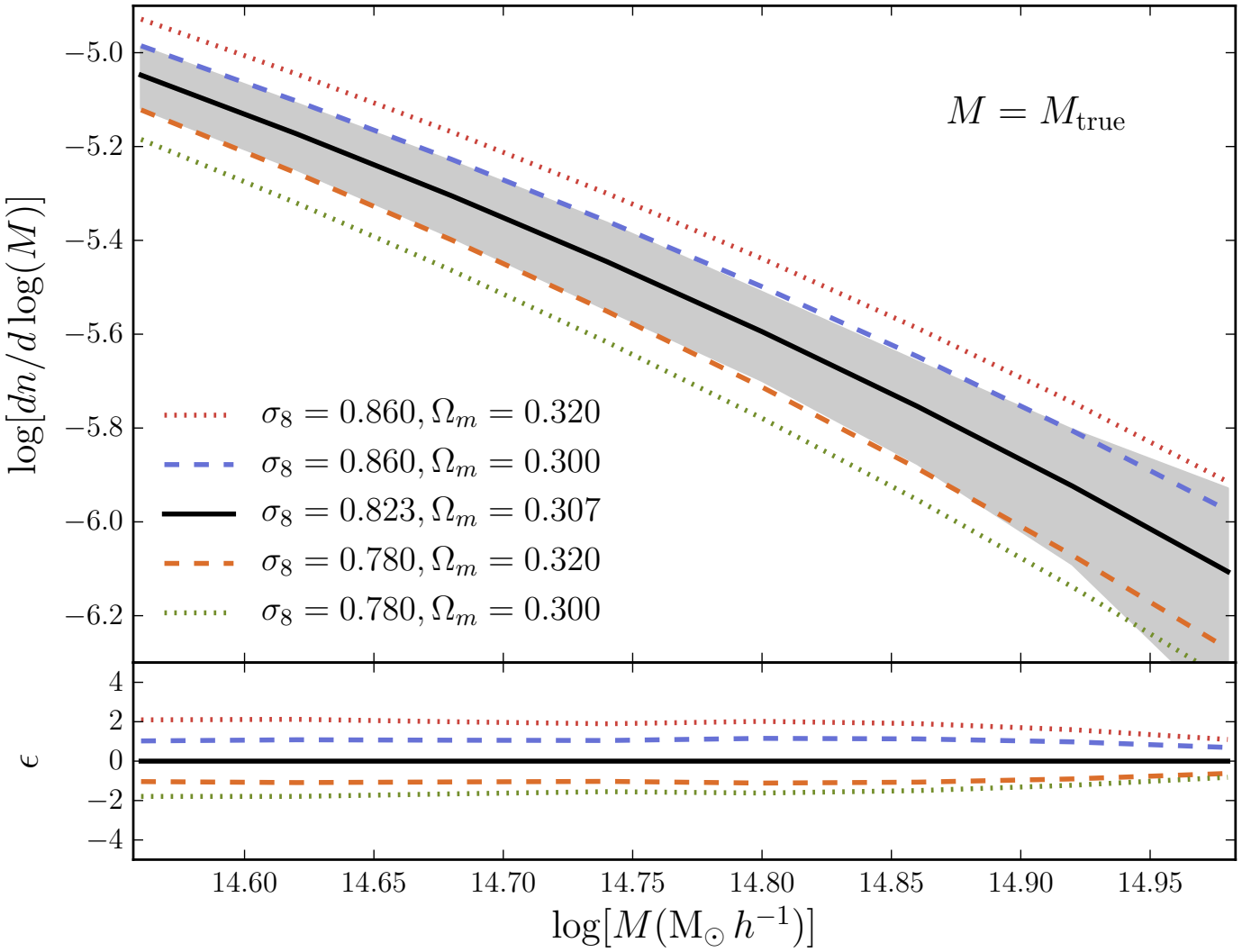
Multidark Simulation



HALO MASS FUNCTION

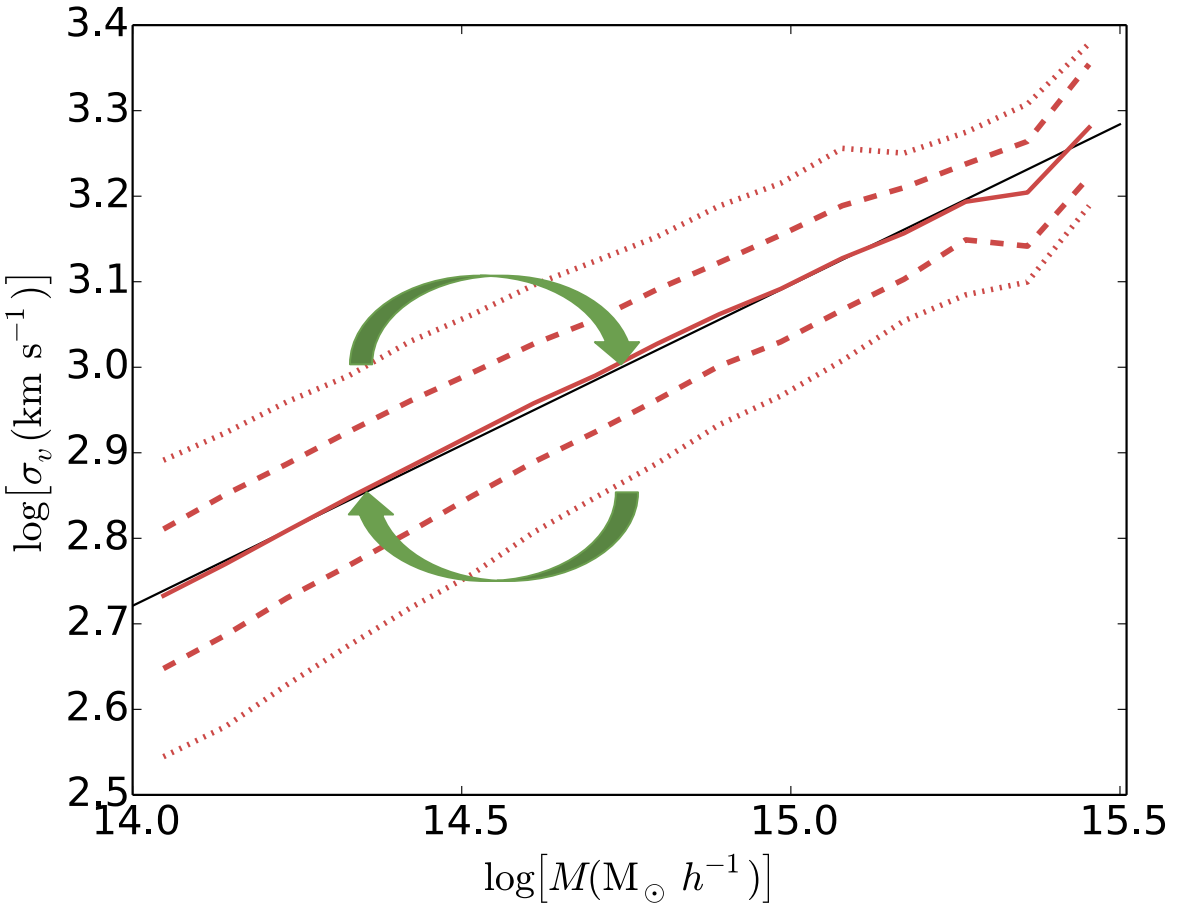
It's impolite to ask a galaxy cluster it's mass

Halo Mass Function

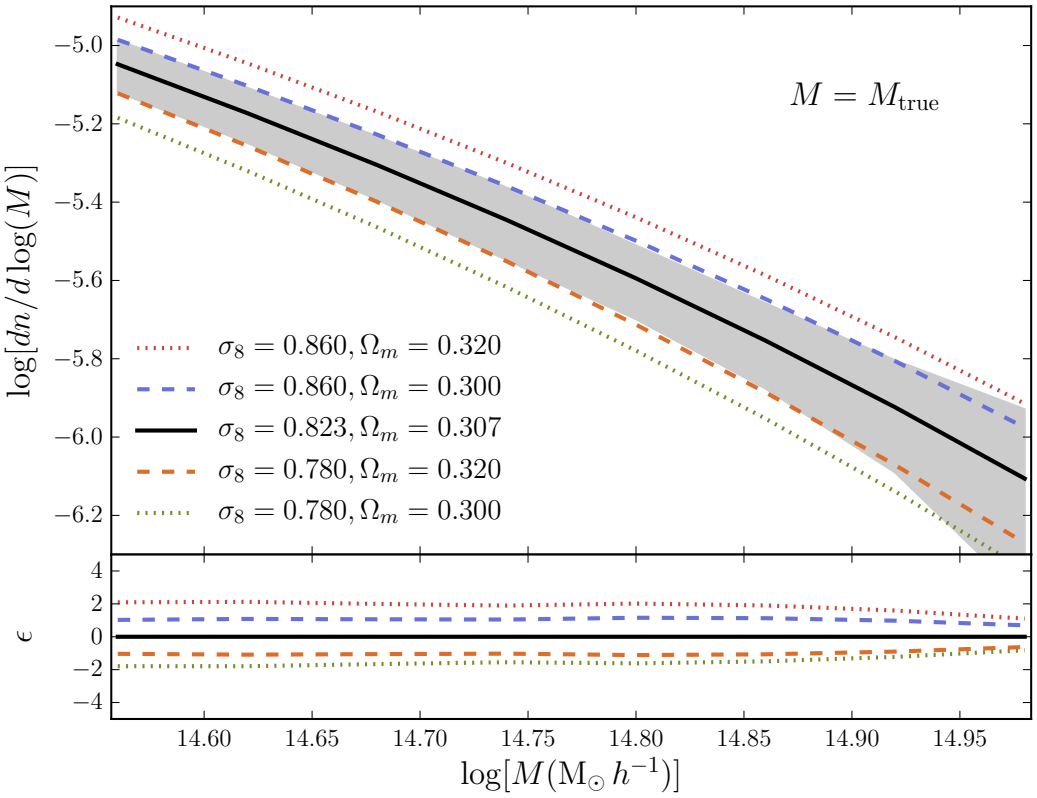


Eddington Bias in Dynamical Masses

Scatter in the M(σ) relationship, coupled with the steeply-declining HMF, alters the observed HMF.

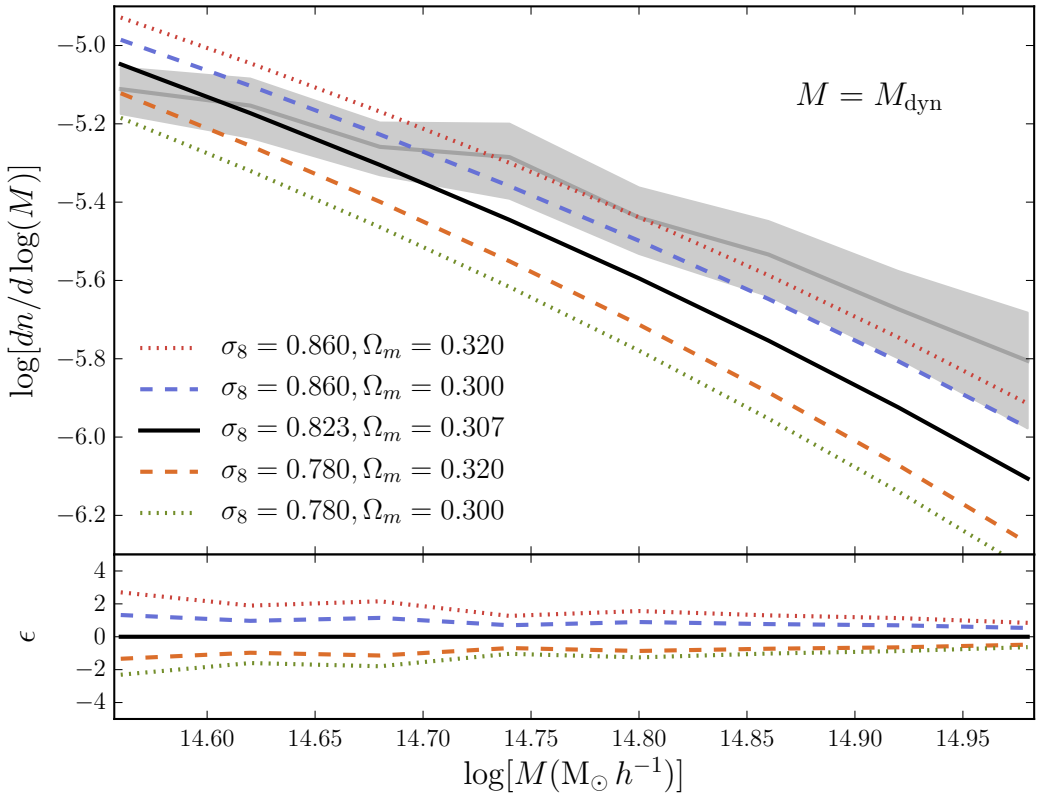


Halo Mass Function



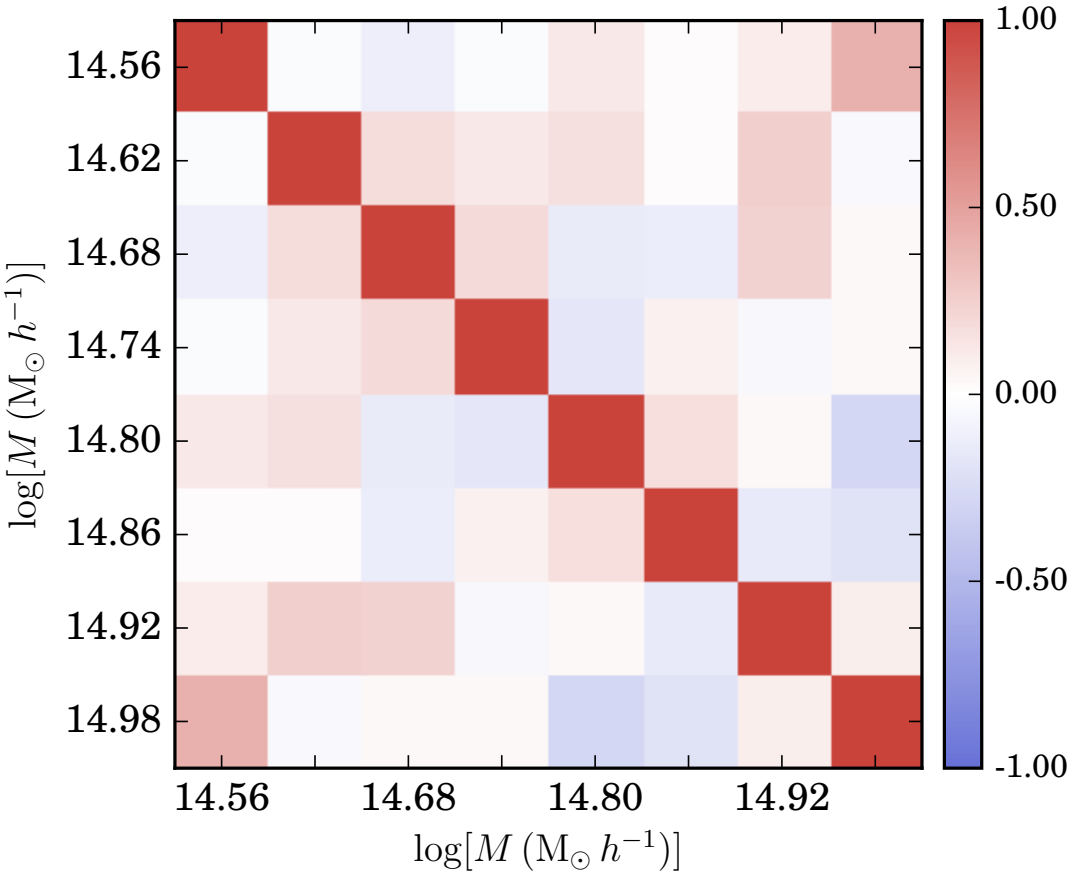
Halo Mass Function with Measurement Error

- True mass function can be recovered if the scatter is well-understood.



χ^2 analysis for constraining σ_8 & Ω_m

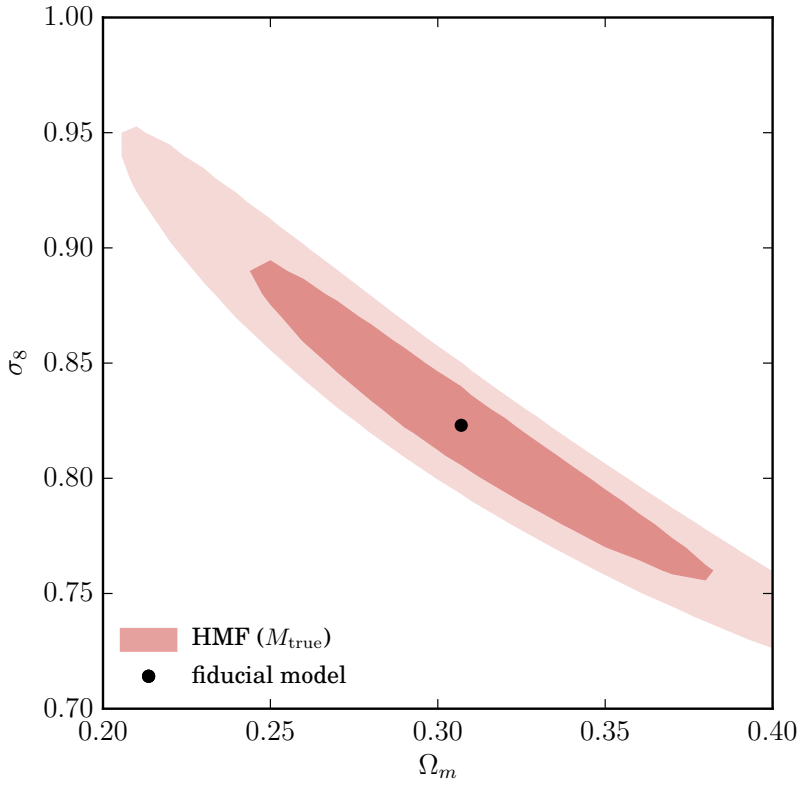
$$\chi^2(y|\sigma_8, \Omega_m) = (\bar{y} - y^\star)^T \, \hat{\Psi}^{-1} \, (\bar{y} - y^\star)$$



- Compare the mock observed HMF to that predicted by an analytic HMF.

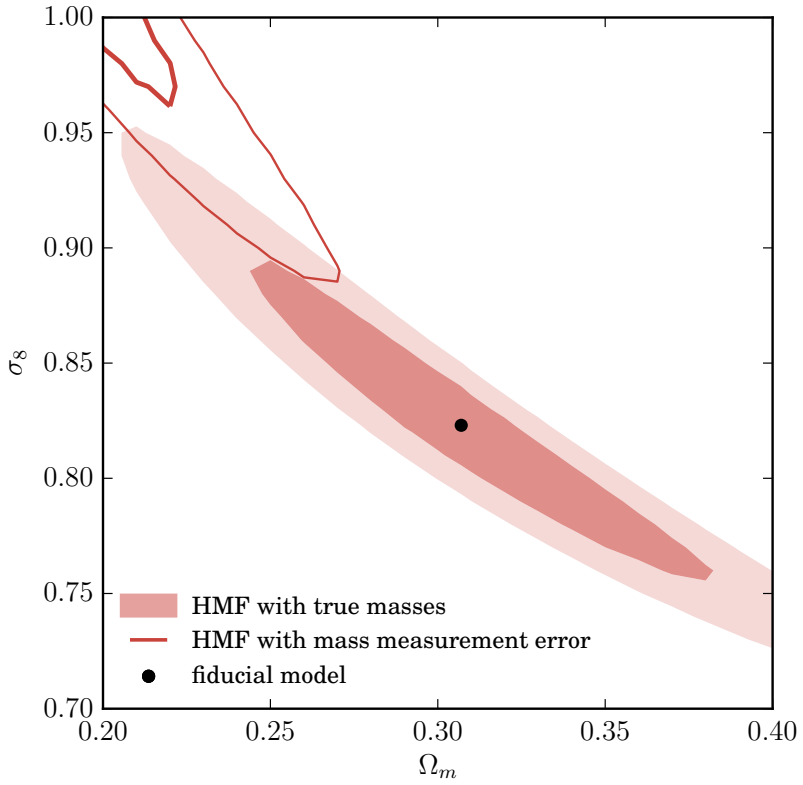
Constraining Cosmological Models

- When cluster masses are perfectly known, the parameter constraints contain the fiducial model.



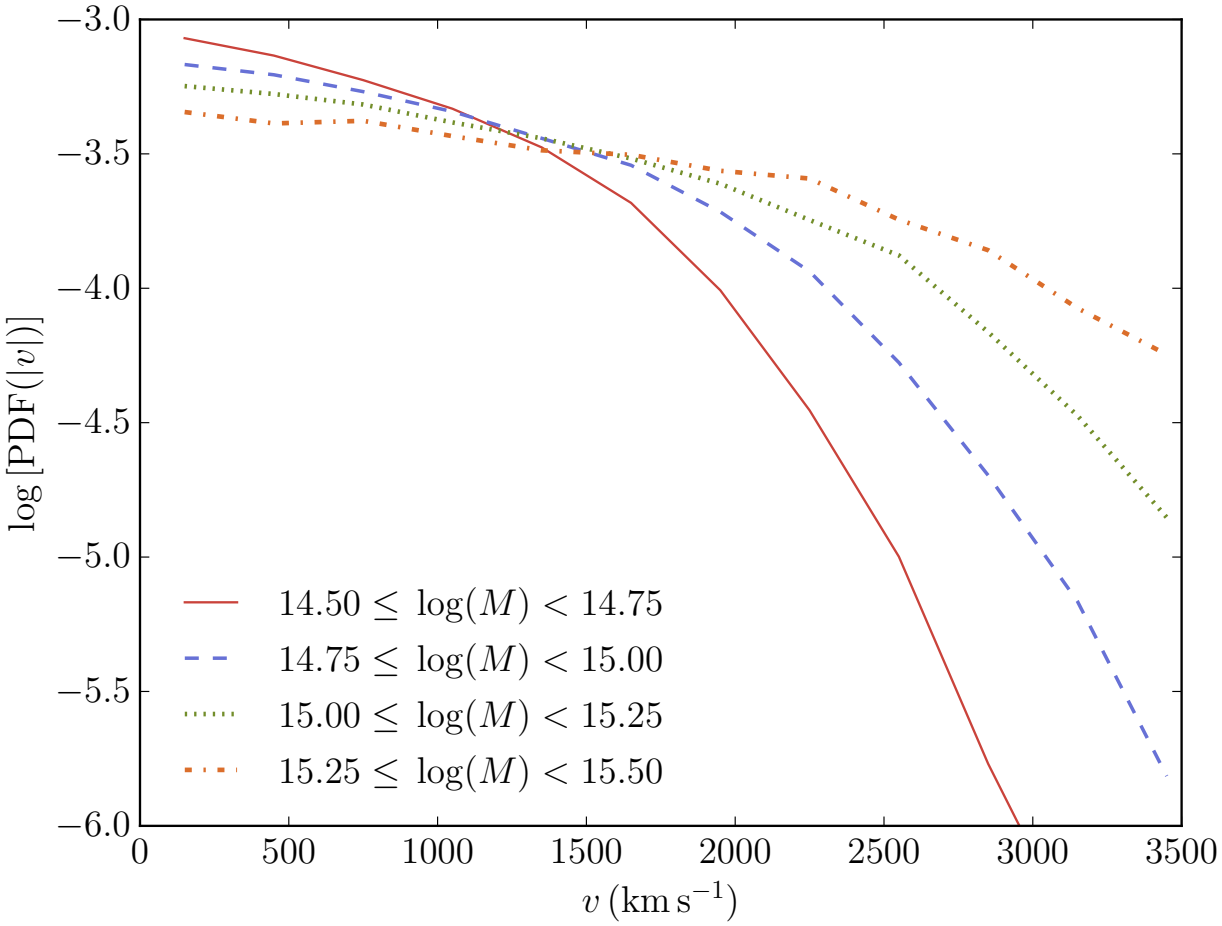
Constraining Cosmological Models

- Measurement error biases to low Ω_m and high σ_8.
- Fiducial model lies outside of the 99% likelihood contour.

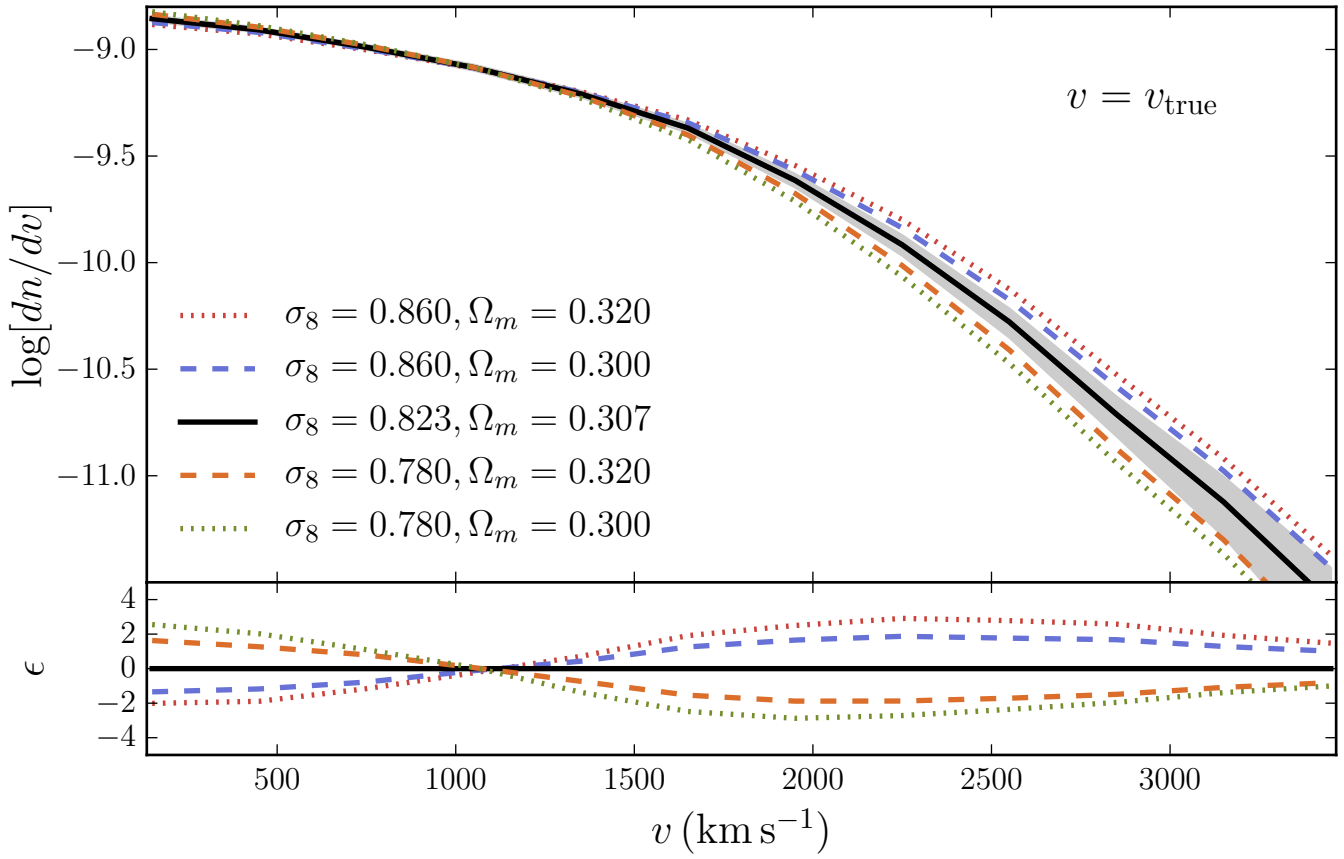


THE VELOCITY DISTRIBUTION FUNCTION

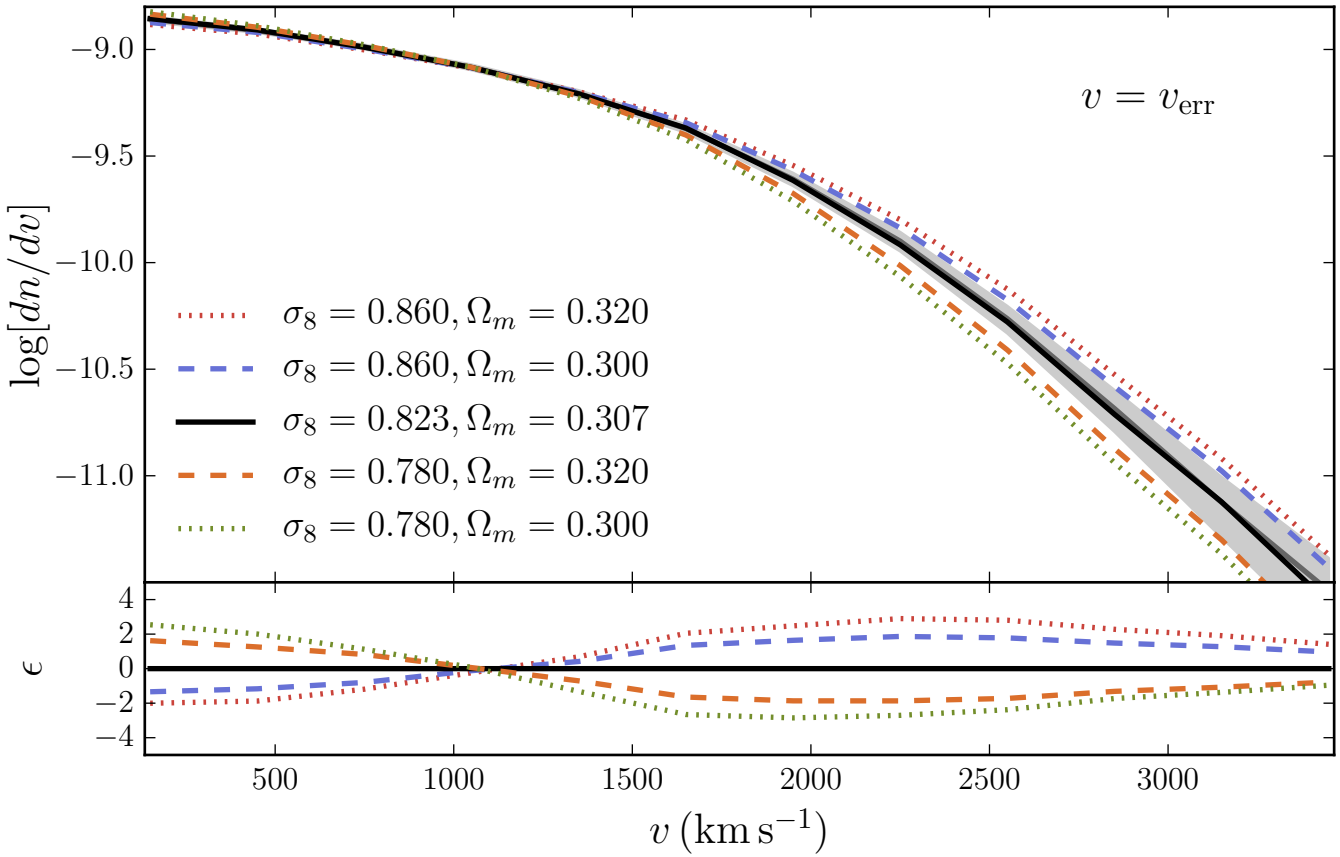
Velocity PDF



Velocity Distribution Function

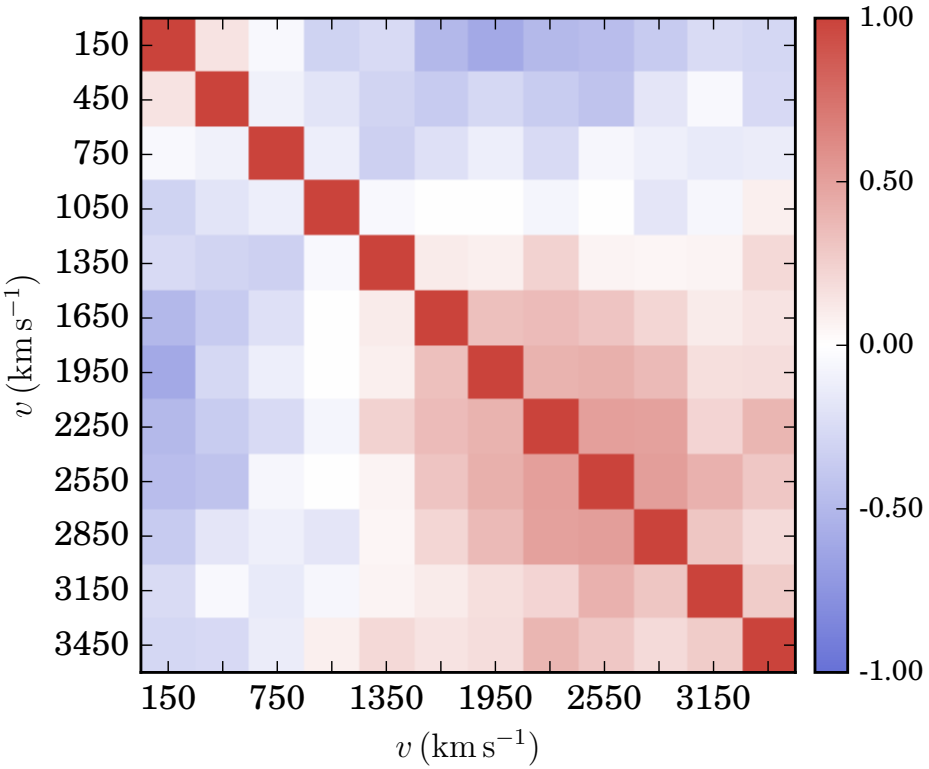


Velocity Distribution Function with velocity error



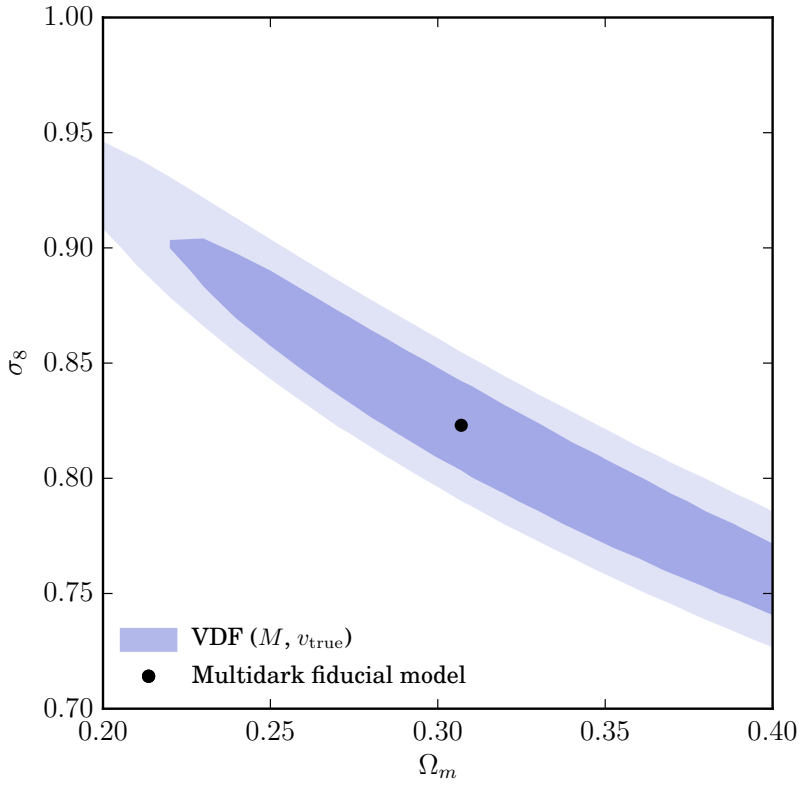
χ^2 analysis for constraining σ_8 & Ω_m

$$\chi^2(y|\sigma_8, \Omega_m) = (\bar{y} - y^\star)^T \, \hat{\Psi}^{-1} \, (\bar{y} - y^\star)$$



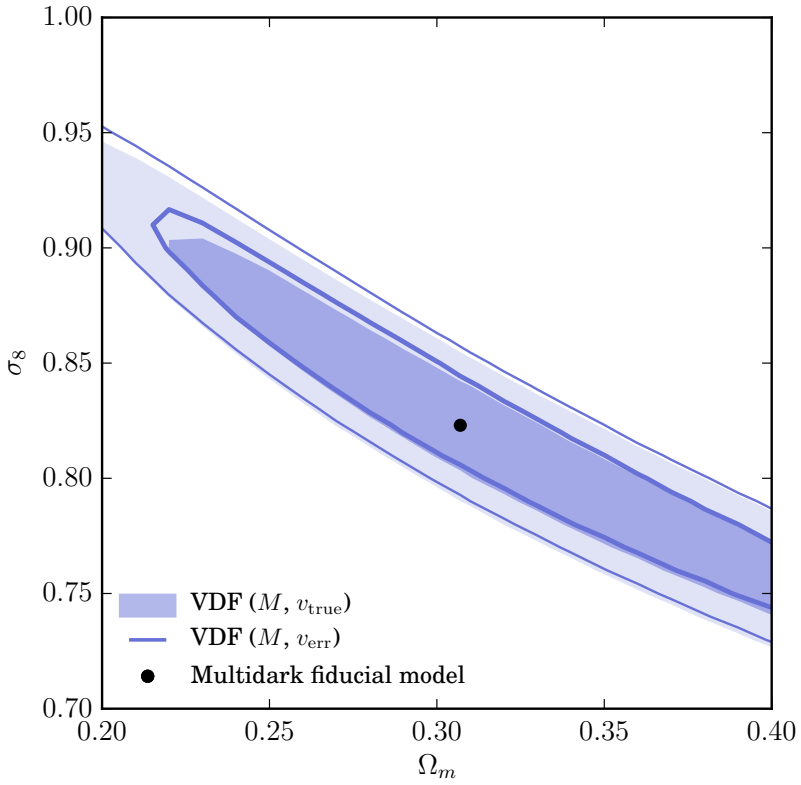
Constraining Cosmological Models with the VDF

- Constraints can be approximated as a band in the Ω_m-σ_8 plane.



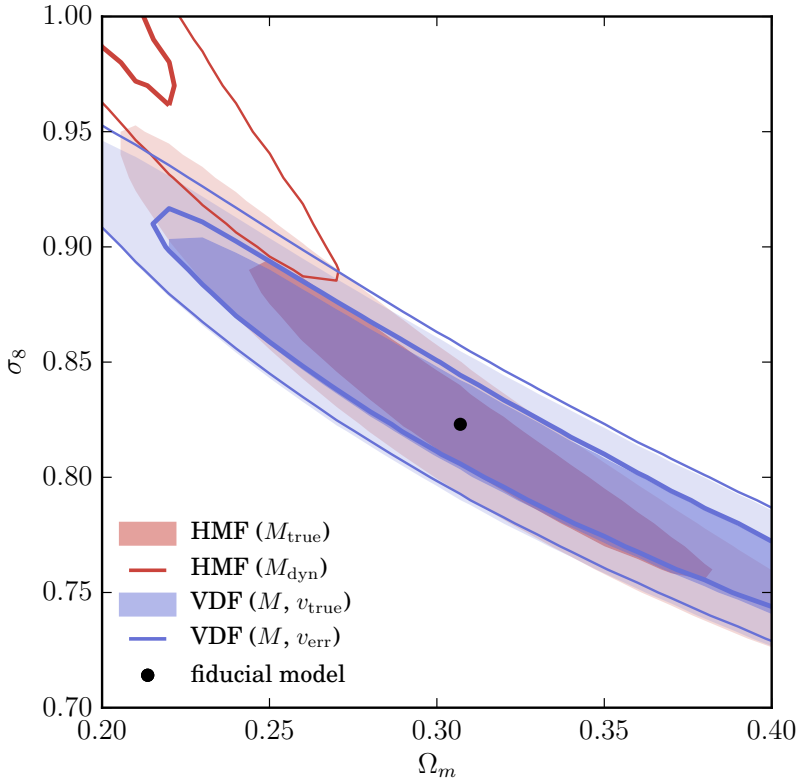
Constraining Cosmological Models with the VDF

- Measurement error introduces a nearly-negligible bias.



Constraining Cosmological Models with the VDF

- HMF and VDF give similar constraints *when true cluster properties are known*.
- VDF is less sensitive to measurement error than the HMF.



- Can be robustly predicted from *N*-body simulations that capture dynamics of substructure in clusters.
- Applying the VDF requires a large spectroscopic data set of cluster members.
- Applying the VDF to smaller observations (N<200) retains the insensitivity to measurement error, though with broader constraints.

The Velocity Distribution Function of Galaxy Clusters

- A new way to quantify the abundance of galaxy clusters using dynamic measurements (arxiv: 1602.01837).
- Less sensitive to systematics than a more traditional halo mass function approach where scatter in mass estimate introduces bias.