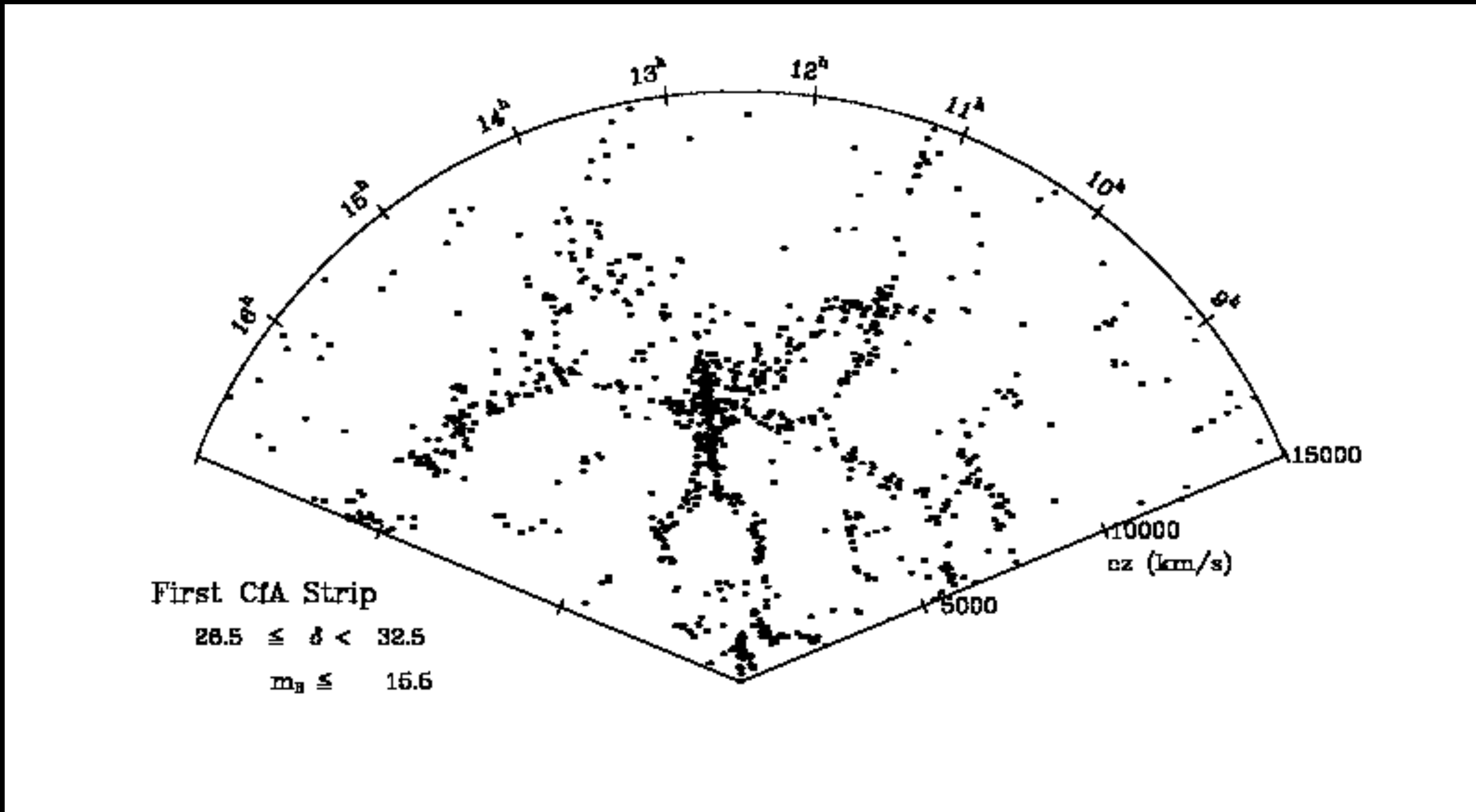
Cosmology W13

Lecture 12: March 4 2013

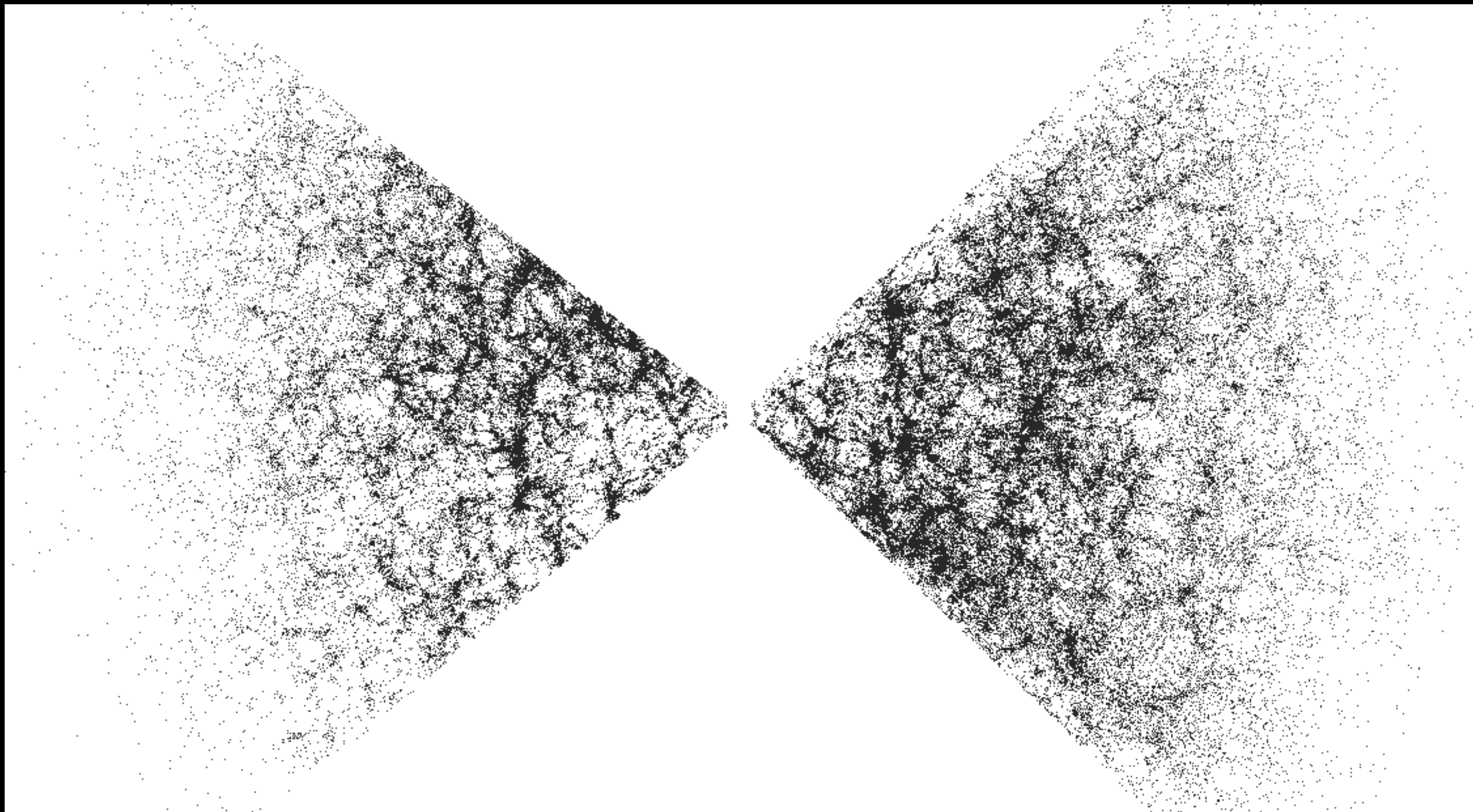
Density fluctuations: from theory to observations

- Galaxy clustering
- Power spectrum of fluctuations
- Bias
- Transfer function
- Baryonic acoustic oscillations

Galaxies are clustered



Galaxies are clustered



Galaxy clustering: correlation function

- Probability of finding two galaxies next two each other is larger than random

$$dN(r) = N_0[1+\xi(r)]dV$$

$$\xi = \left(\frac{r}{r_0}\right)^{-\gamma}$$

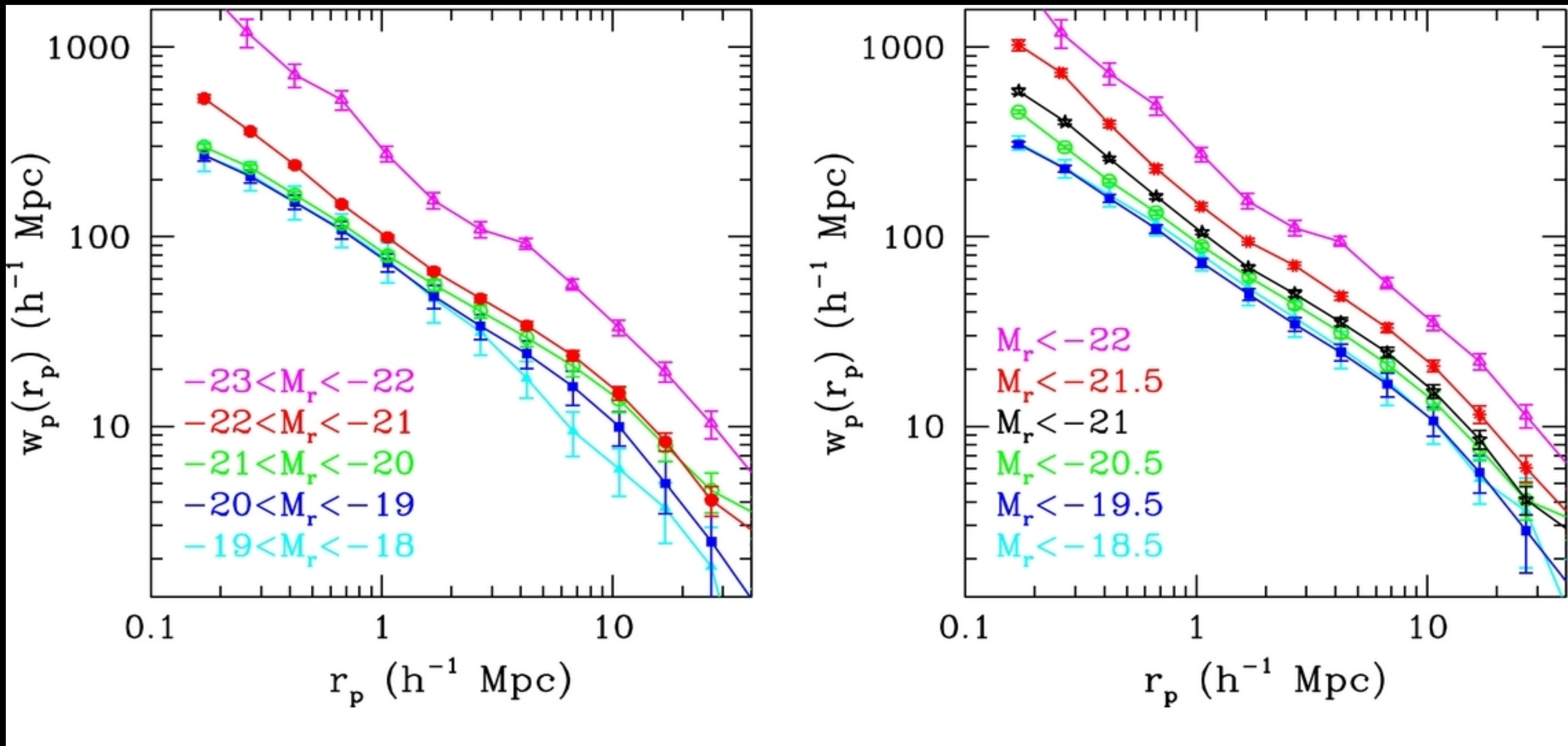
$$\gamma \sim 1.8 \quad r_0 \sim 8Mpc$$

$$w(\theta) \propto \theta^{-\gamma+1}$$

Correlation function: observations

- Probability of finding two galaxies next two each other is larger than random

Zehavi et al. 2011



Correlation function is connected to density perturbations!

$$\Delta_k = \frac{1}{V}\int \Delta(\mathbf{r}) e^{i\mathbf{k}\cdot\mathbf{r}} d^3x$$

$$\frac{1}{V}\int \Delta^2(\mathbf{r}) d^3x = \frac{V}{(2\pi)^3}\int |\Delta_k|^2 d^3k = \langle \Delta^2 \rangle$$

$$P(k) \equiv |\Delta_k|^2$$

$$p(\Delta) = N(0, \langle \Delta^2 \rangle)$$

$$\xi = \frac{V}{2\pi^2}\int P(k) \frac{\sin kr}{kr} k^2 dk$$

Two big problems

- What is the connection between the power spectrum now and the primordial one?

$$\Delta_k(z=0) = T(k)f(z)\Delta_k(z)$$

- How do we connect galaxy (cluster) power spectrum to underlying mass power spectrum? Bias

$$\xi_{\rm gal} = b^2\xi_{\rm DM}; P_{\rm gal} = b^2 P_{\rm DM}; \Delta_{\rm gal} = b\Delta_{\rm DM}$$

Initial power spectrum

- For a power law form (observed one is approximately power law)

$$P(k) = |\Delta_k|^2 = Ak^n$$

$$\xi \propto r^{-n-3}$$

$$\Delta(M) = \langle \Delta^2 \rangle^{\frac{1}{2}} \propto M^{-(n+3)/6}$$

Harrison-Zeldovich Spetrum

- Index n=1
- Early-fluctuations outside horizon grow as a^2
- Horizon grows as t~a^2

$$\Delta(M) \propto a^2 M^{-(n+3)/6}$$

$$M_H \propto \rho t^3 \propto a^3$$

$$\Delta(M_H) \quad \text{is independent of mass}$$

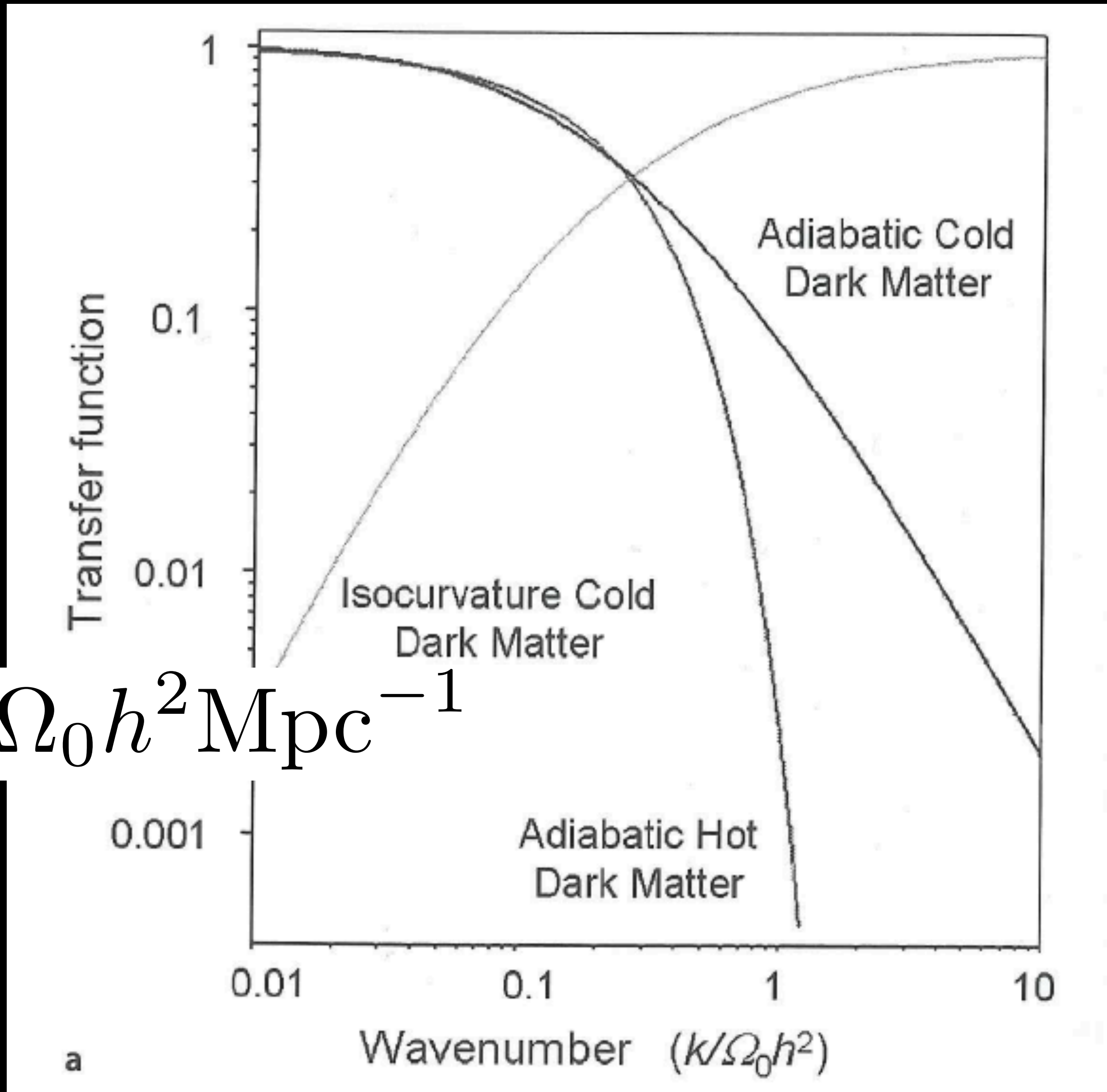
Transfer function

Longair

- During the radiation dominated era dark matter subhorizon scale perturbations grew slowly ("held back by stable radiation").
- So we expect transfer function to drop for scales smaller than horizon at time of equality ($k>k_{eq}$)

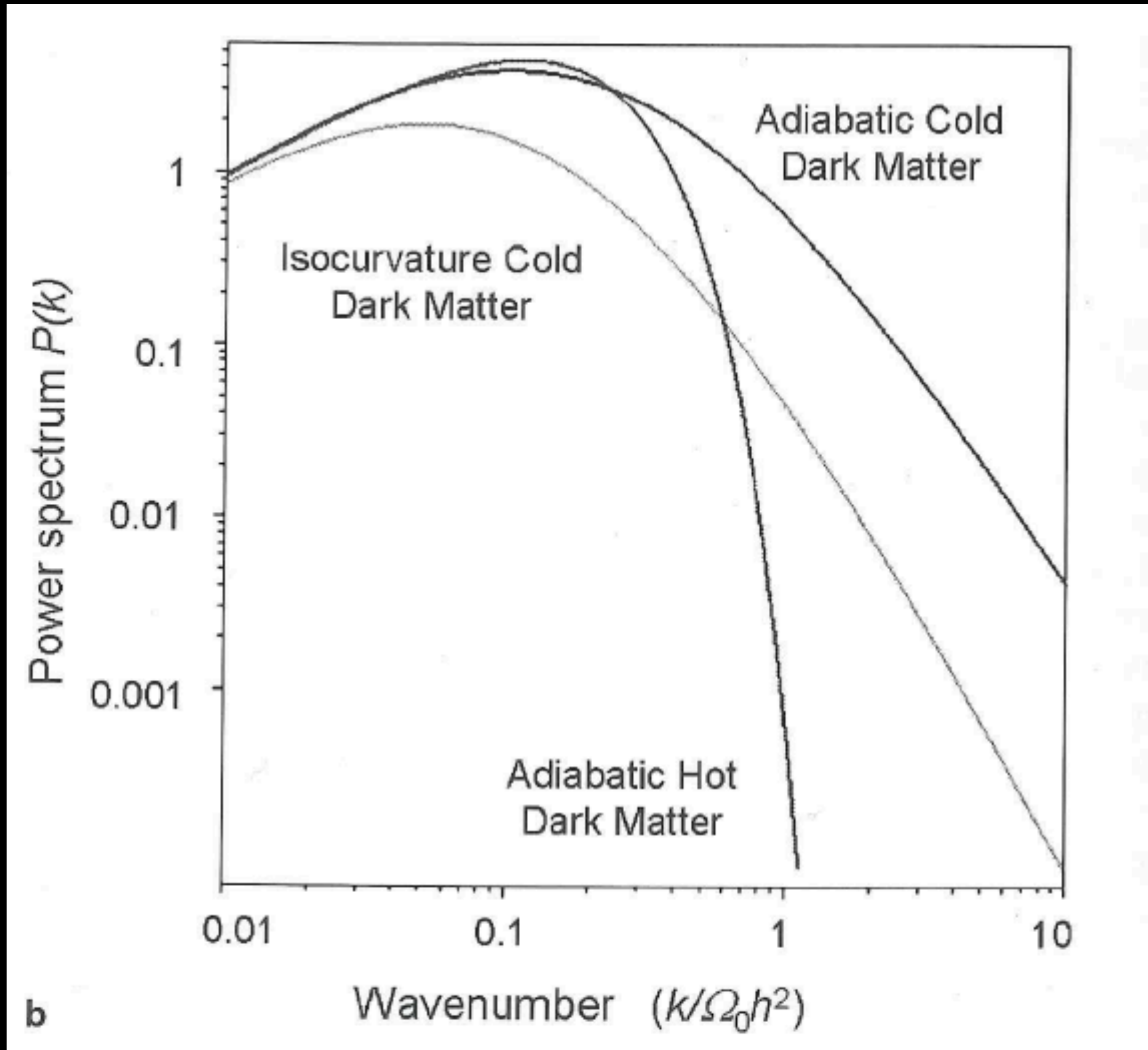
$$k_{\rm eq} \approx 7.3 \times 10^{-2} \Omega_0 h^2 \mathrm{Mpc}^{-1}$$

- In hot dark matter free streaming kills power on small scales faster

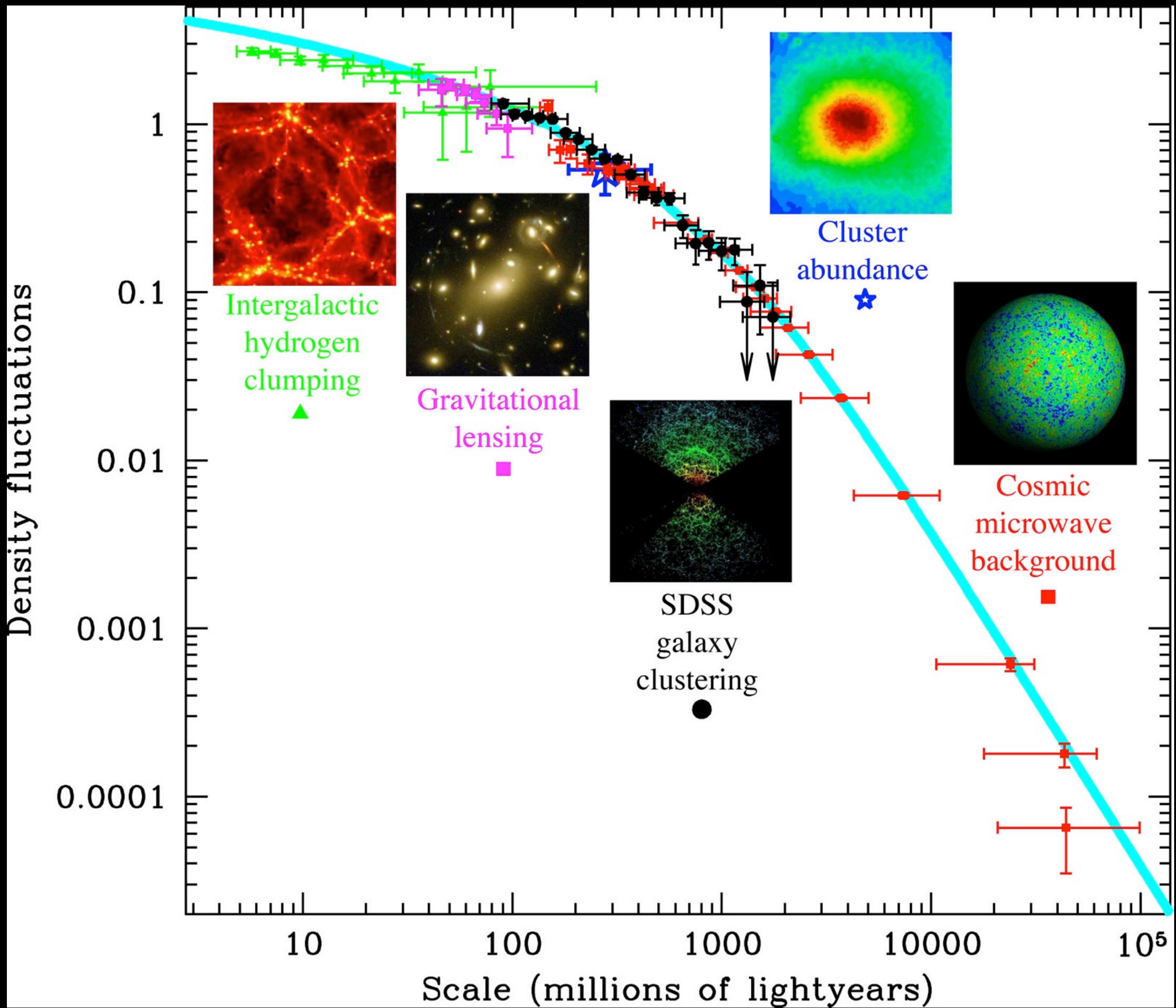


Power spectrum

Longair

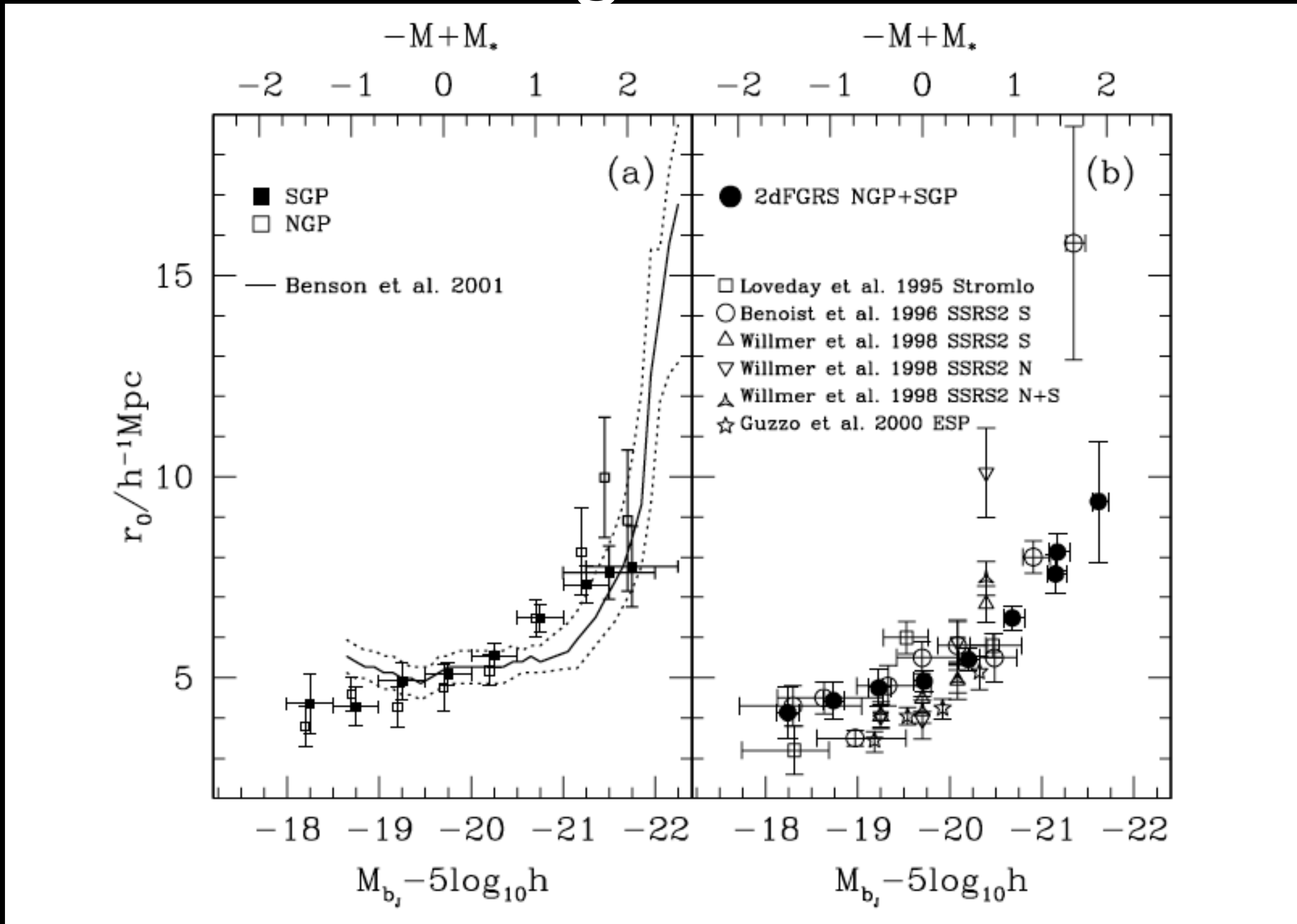


How are fluctuations measured?



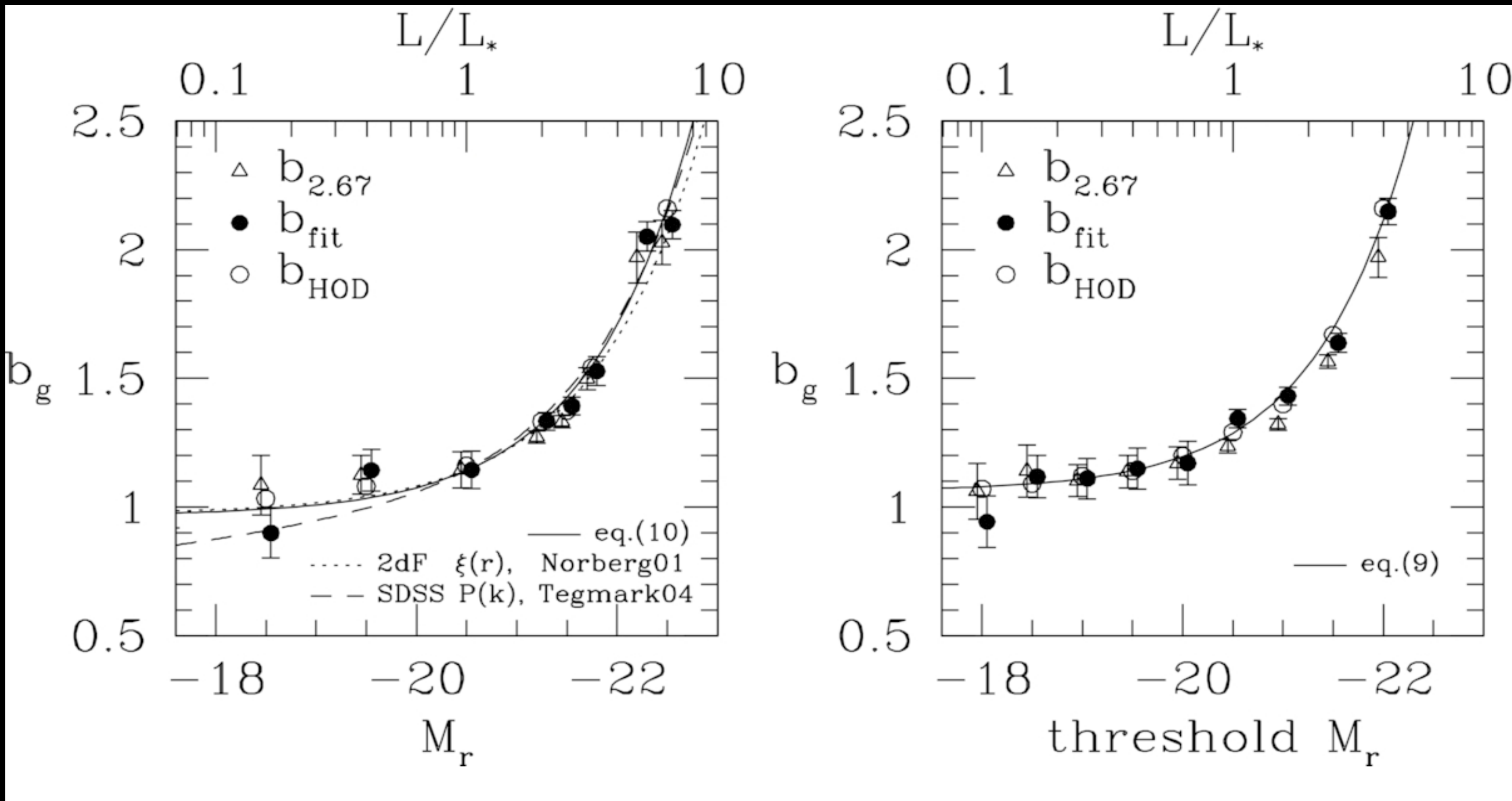
Tegmark

Measuring Relative Bias



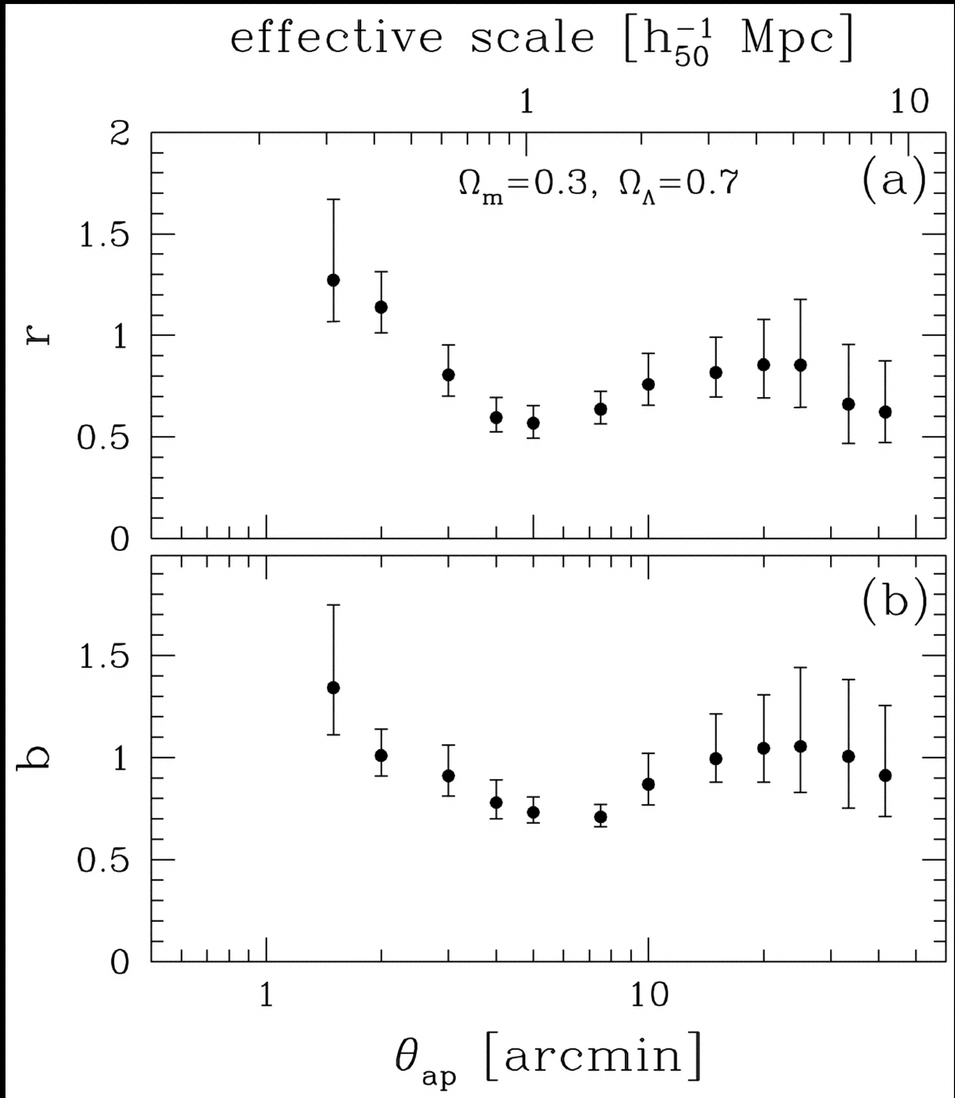
Norberg et al. 2001

SDSS



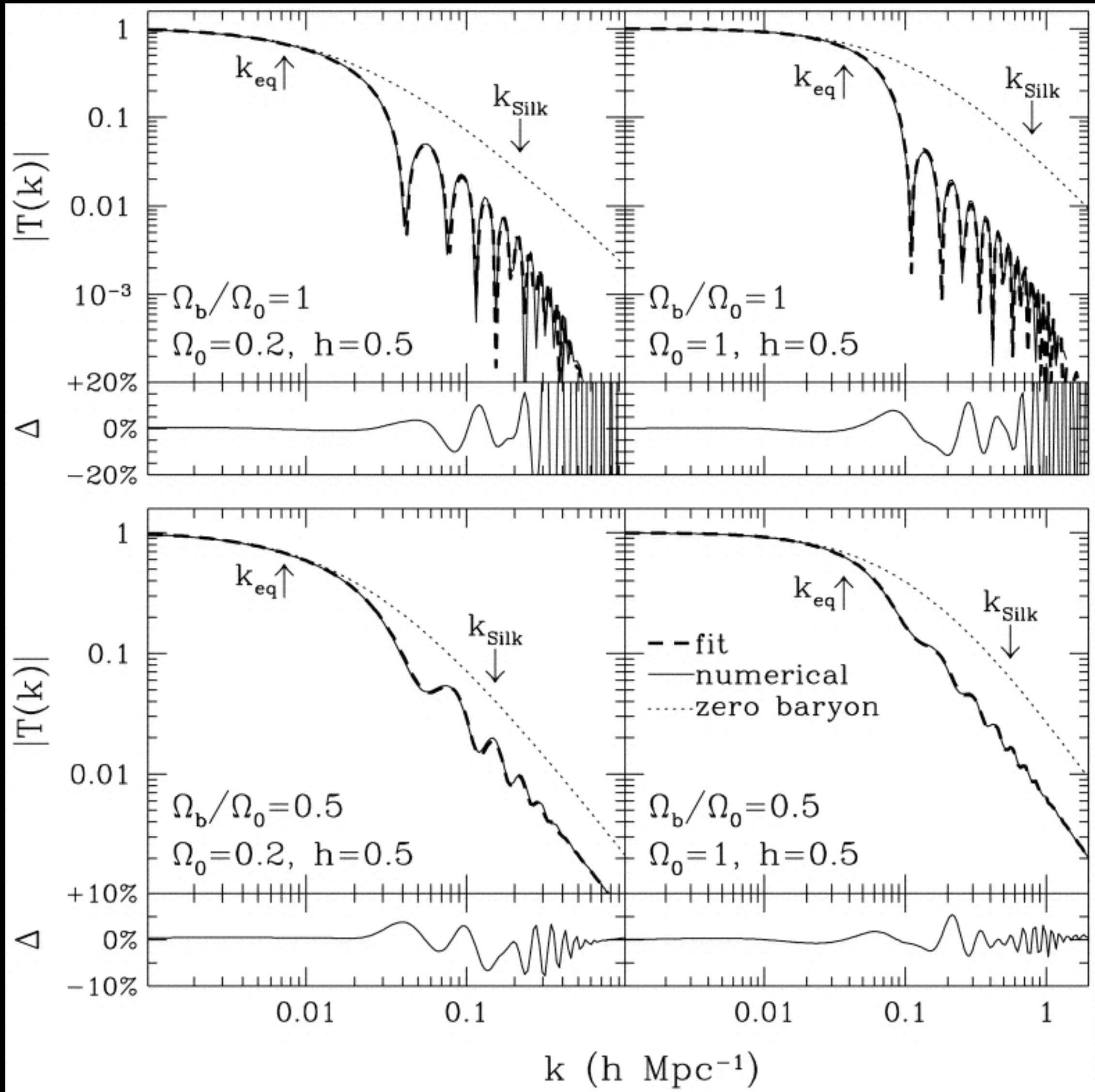
Zehavi et al. 2011

Measuring Absolute Bias



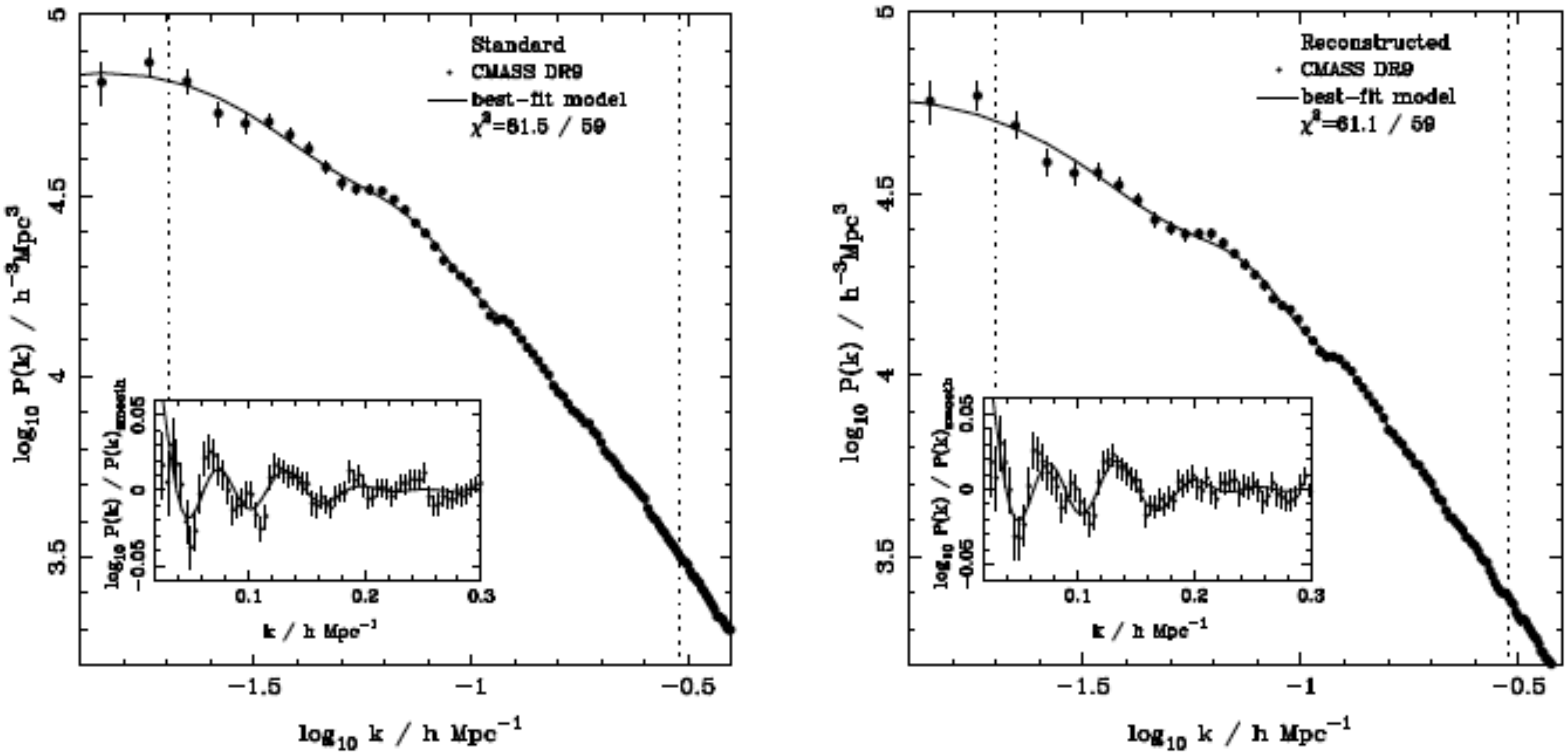
Hoekstra et al. 2002

Baryonic Acoustic Oscillations



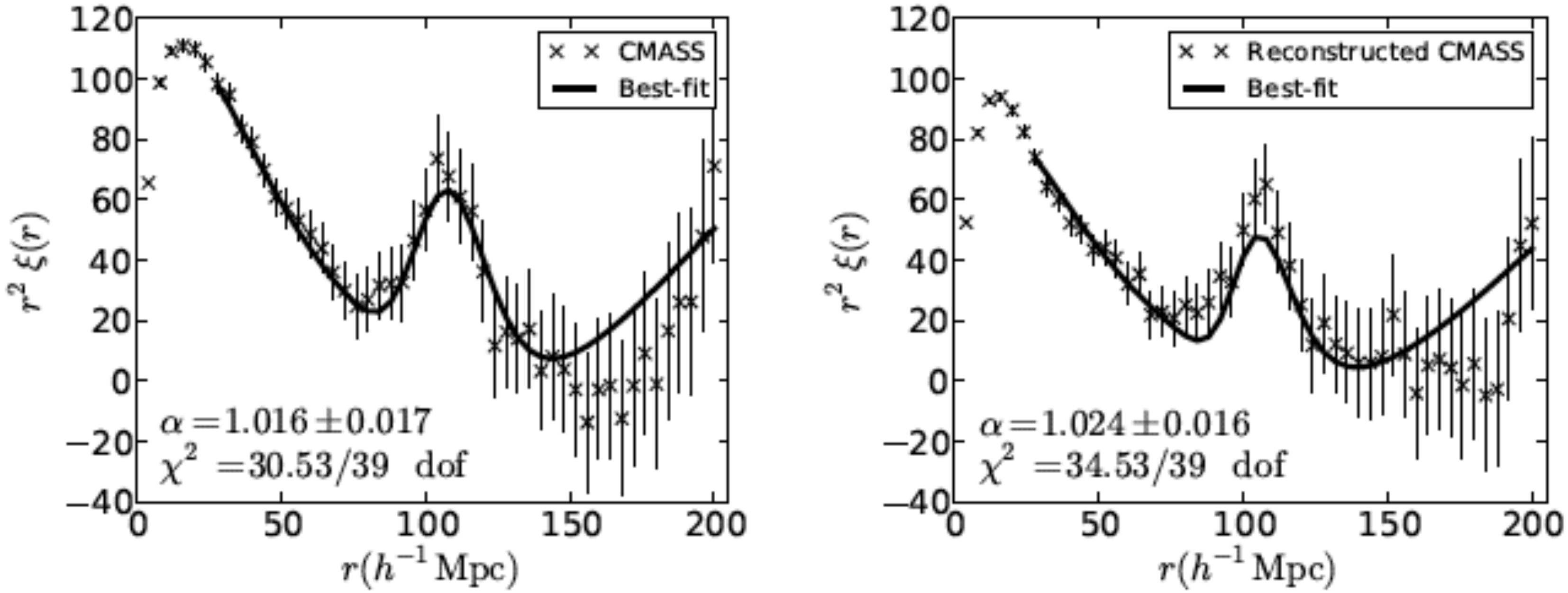
Einsenstein & Hu 1998

Baryonic acoustic oscillations from BOSS



Anderson et al 2012

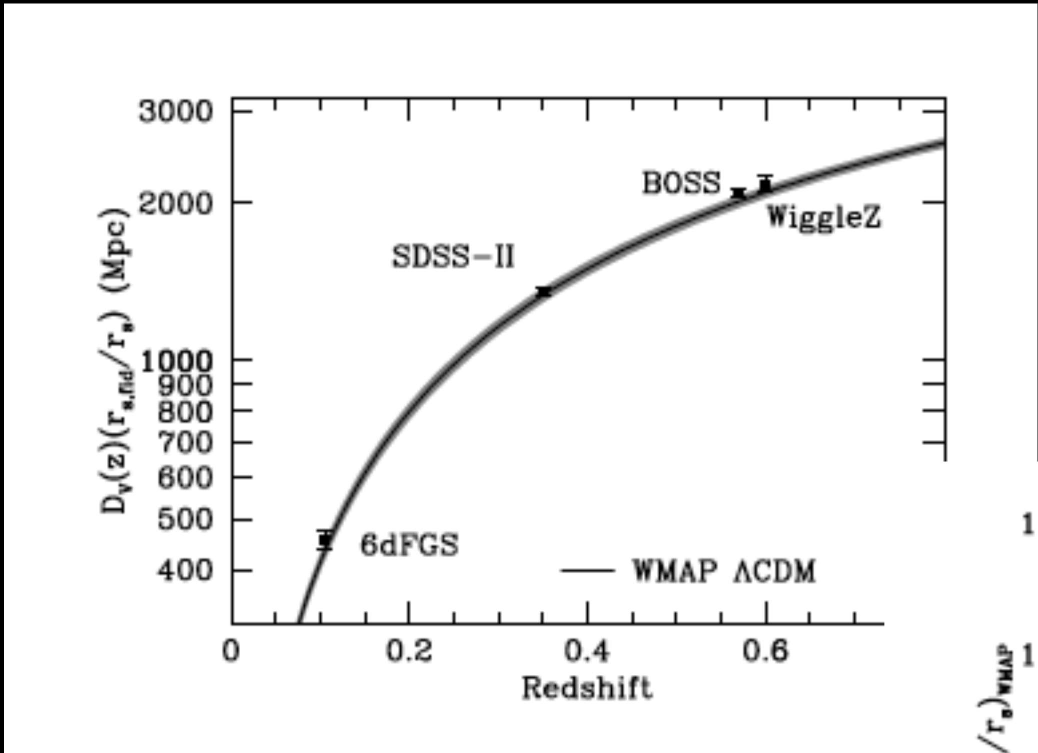
Baryonic acoustic oscillations from BOSS

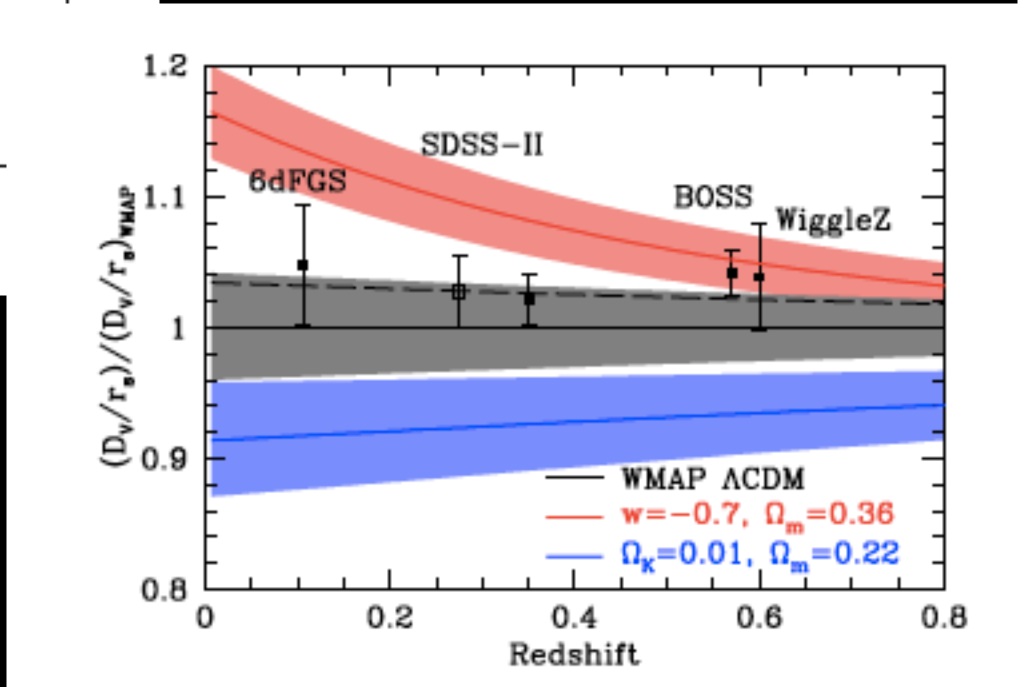


Position of peak is given by the sound horizon at epoch of decoupling of matter and radiation

Anderson et al 2012

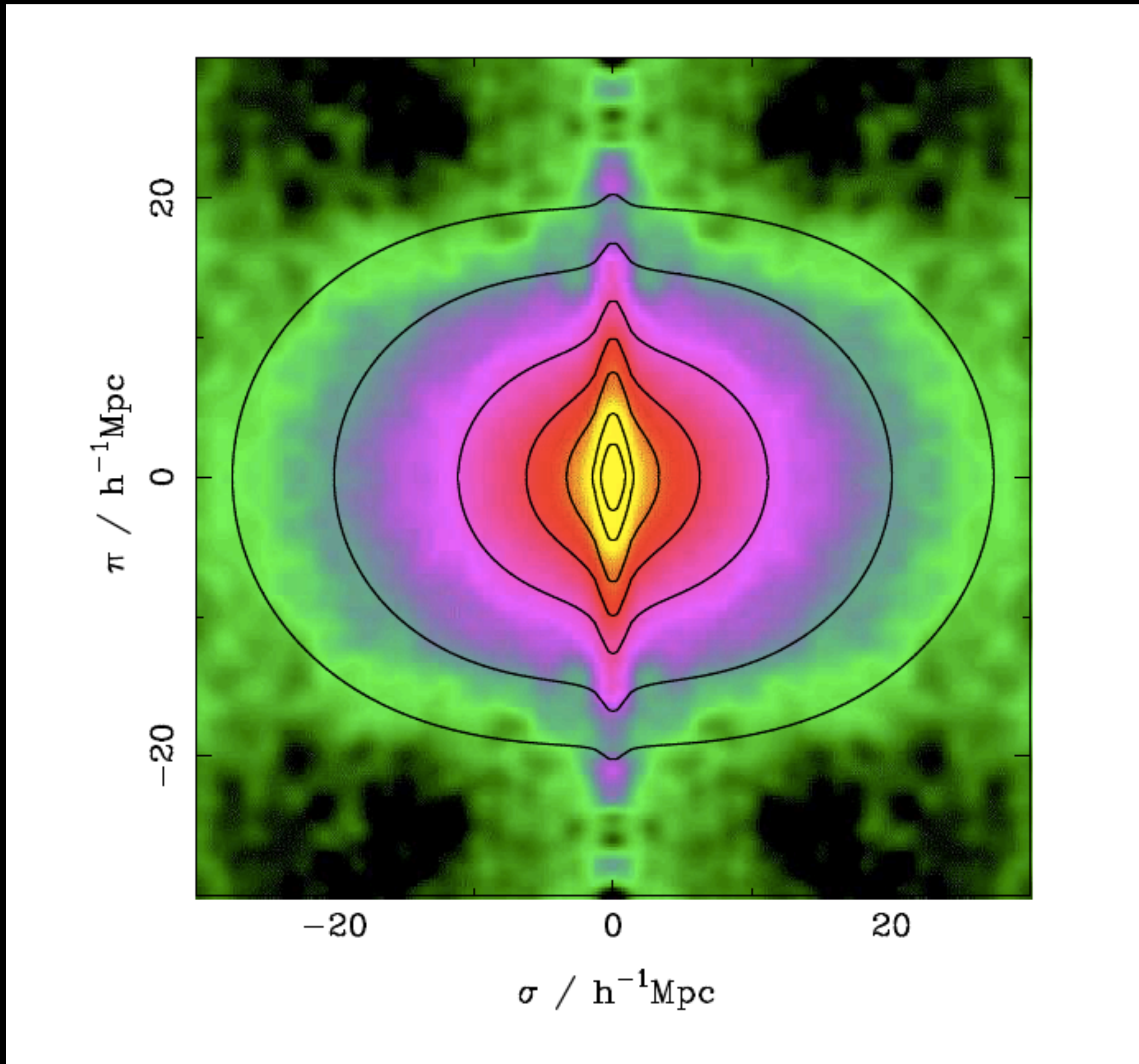
BAO as a standard ruler





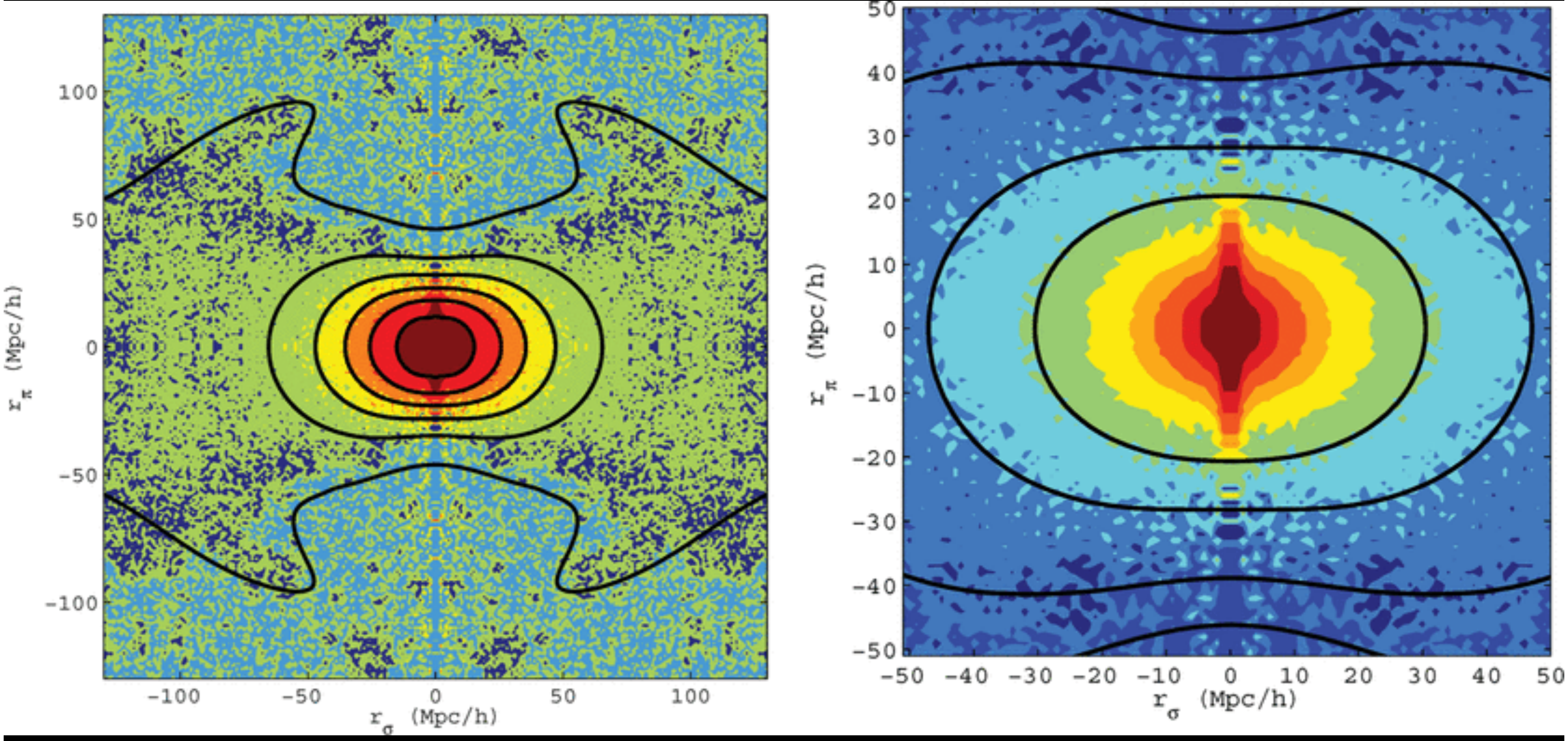
Anderson et al 2012

Redshift space distortions



Peacock+ 2001

Redshift space distortions



Reid et al 2012

The end