# Cosmology from galaxy clustering (in the SDSS)

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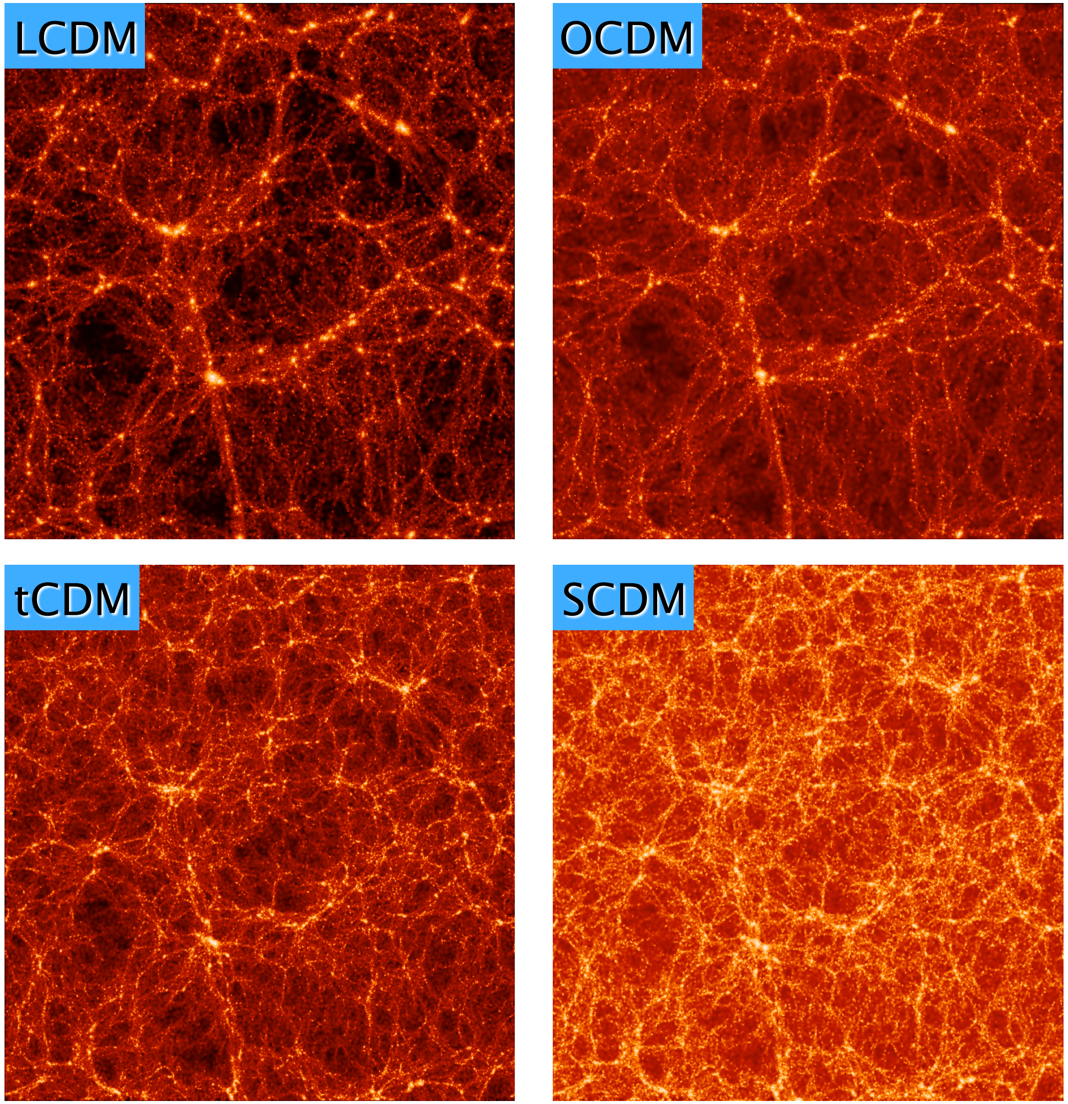
# Introduction to galaxy clustering

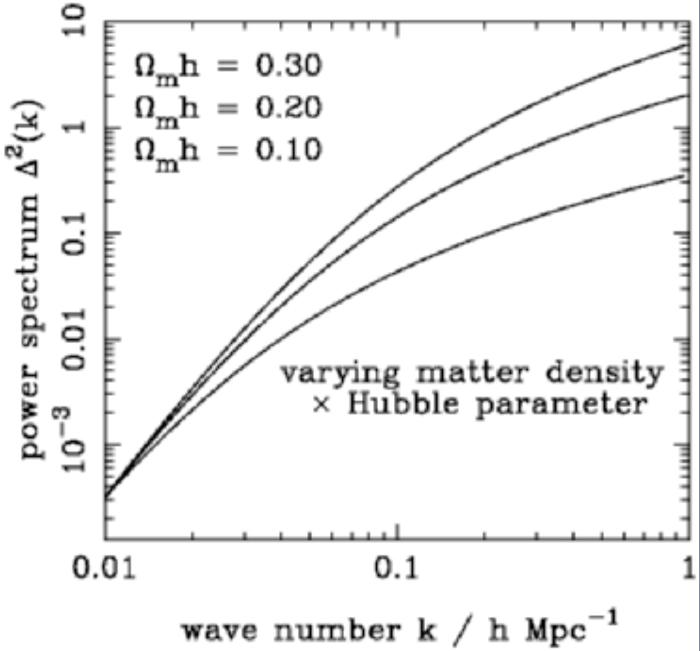
- If galaxy overdensity field is Gaussian
  - 2-pt statistics (counting pairs) are complete
  - can use either $\xi(r)$ (configuration space)
  - or power spectrum $P(k)$ (Fourier space)
- Theory predicts linear mass power spectrum
  - shape depends on $\Omega_m h$
  - BAO depend on $\Omega_b/\Omega_m$
- But we observe galaxies
  - do not form a Poisson sampling of the mass
  - are "biased"
- We calculate galaxy distances from redshifts
  - complicates analysis
  - peculiar velocity misinterpreted as recession velocity

# The power spectrum shape



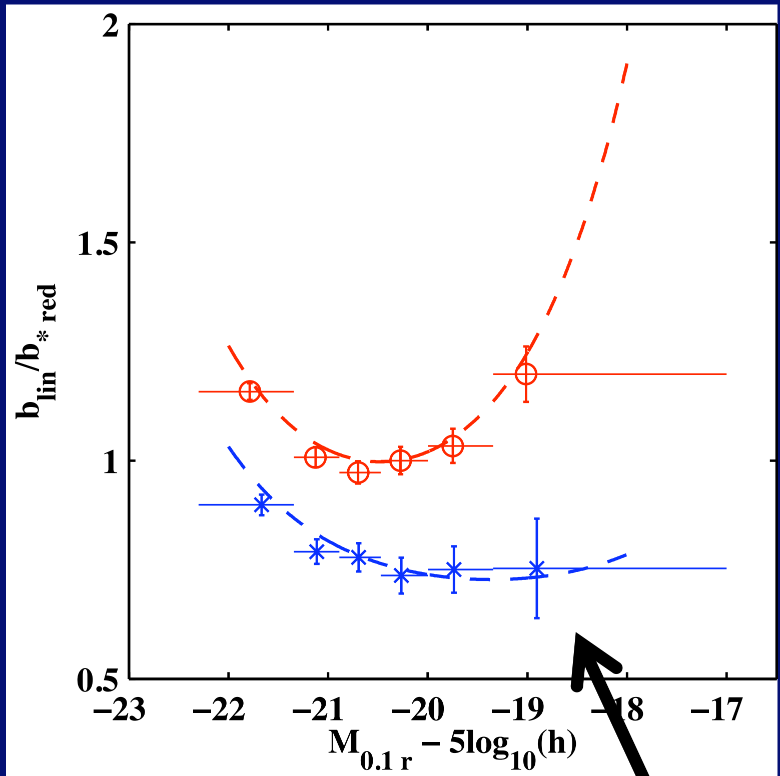

credit: VIRGO consortium

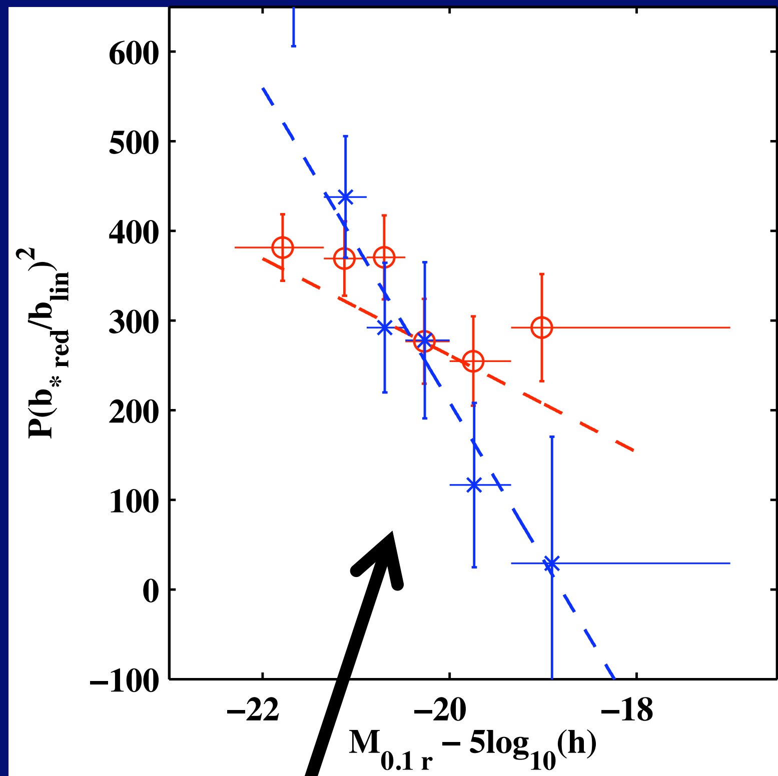
During radiation domination, pressure support means that small perturbations cannot collapse.




In principle, can measure $\Omega_M h$ from shape of power spectrum, or use as standard ruler

# Problem: galaxy-bias




Function of galaxy color and luminosity

Function of galaxy color and luminosity

$$P_g(k) = b_{\rm lin}^2 P_{\rm lin}(k) + P$$

See poster by James Cresswell at this conference, astro-ph/0808.1101

# BAO from the galaxy distribution

BAO measurements linked to physical BAO scale through:

Radial direction

$$\frac{c}{H(z)}\Delta z$$

Angular direction

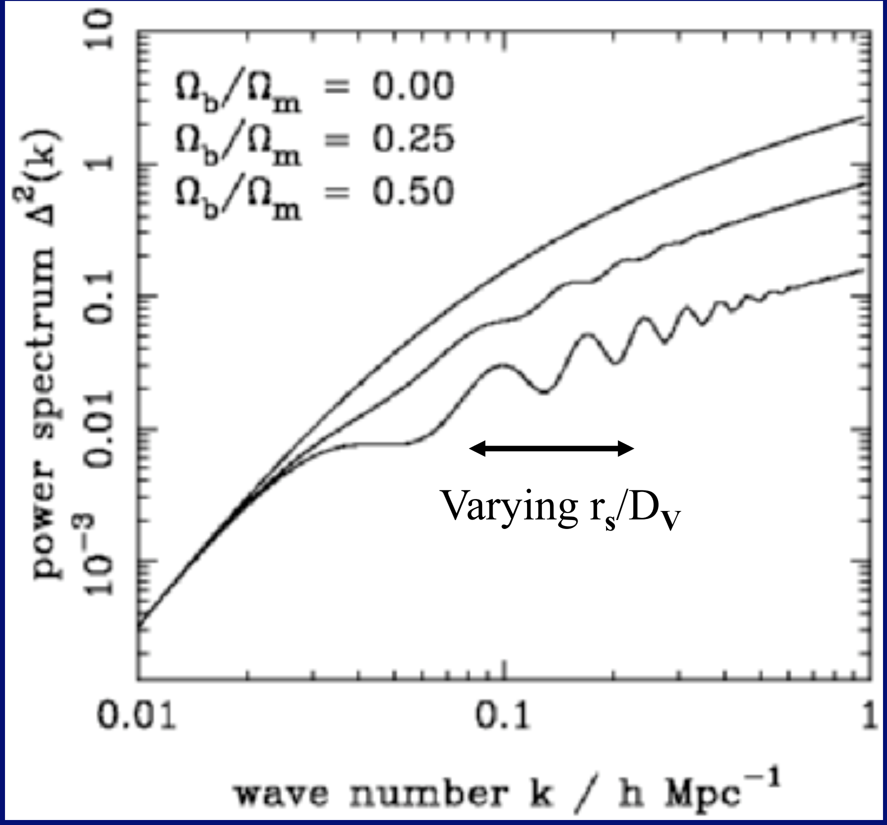
$$(1+z)D_A\Delta\theta$$

To first order, random pairs depend on

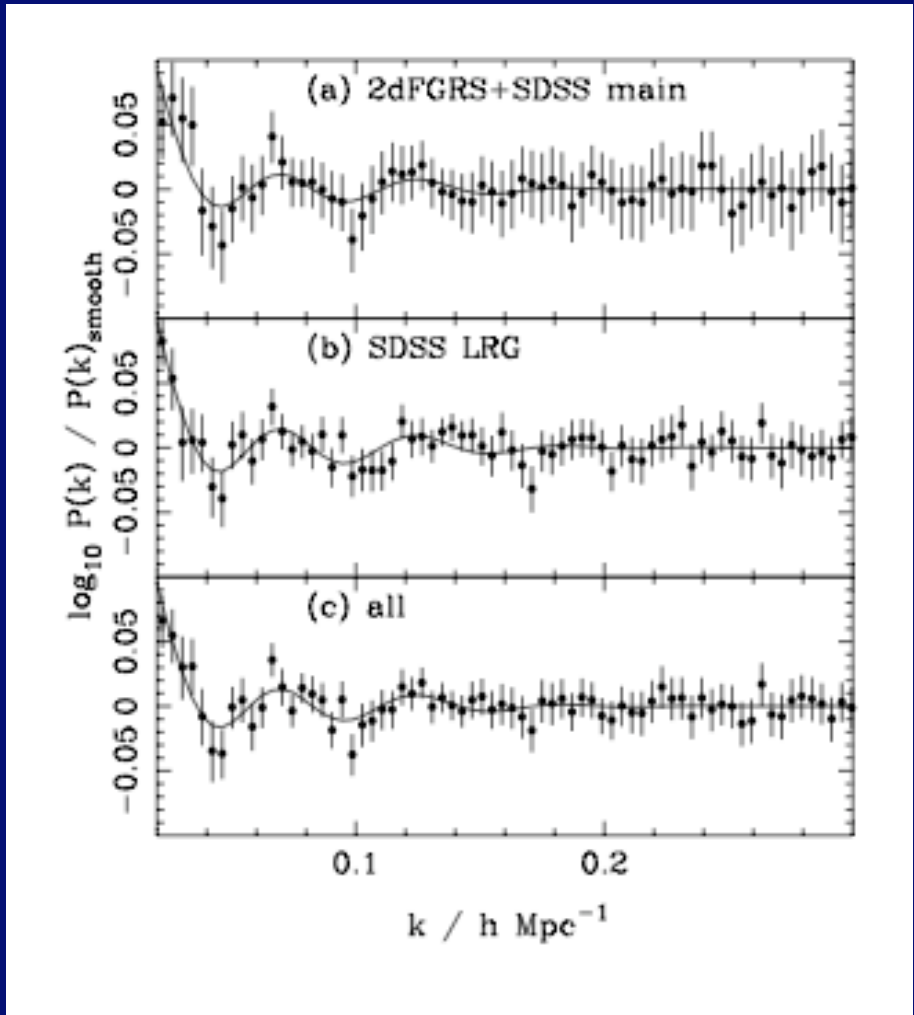
$$D_V=\left[(1+z)^2D_A^2(z)\frac{cz}{H(z)}\right]^{1/3}$$

Observed BAO position therefore constrains some multiple of

$$\frac{r_s}{D_V}$$



# BAO from the 2dFGRS + SDSS



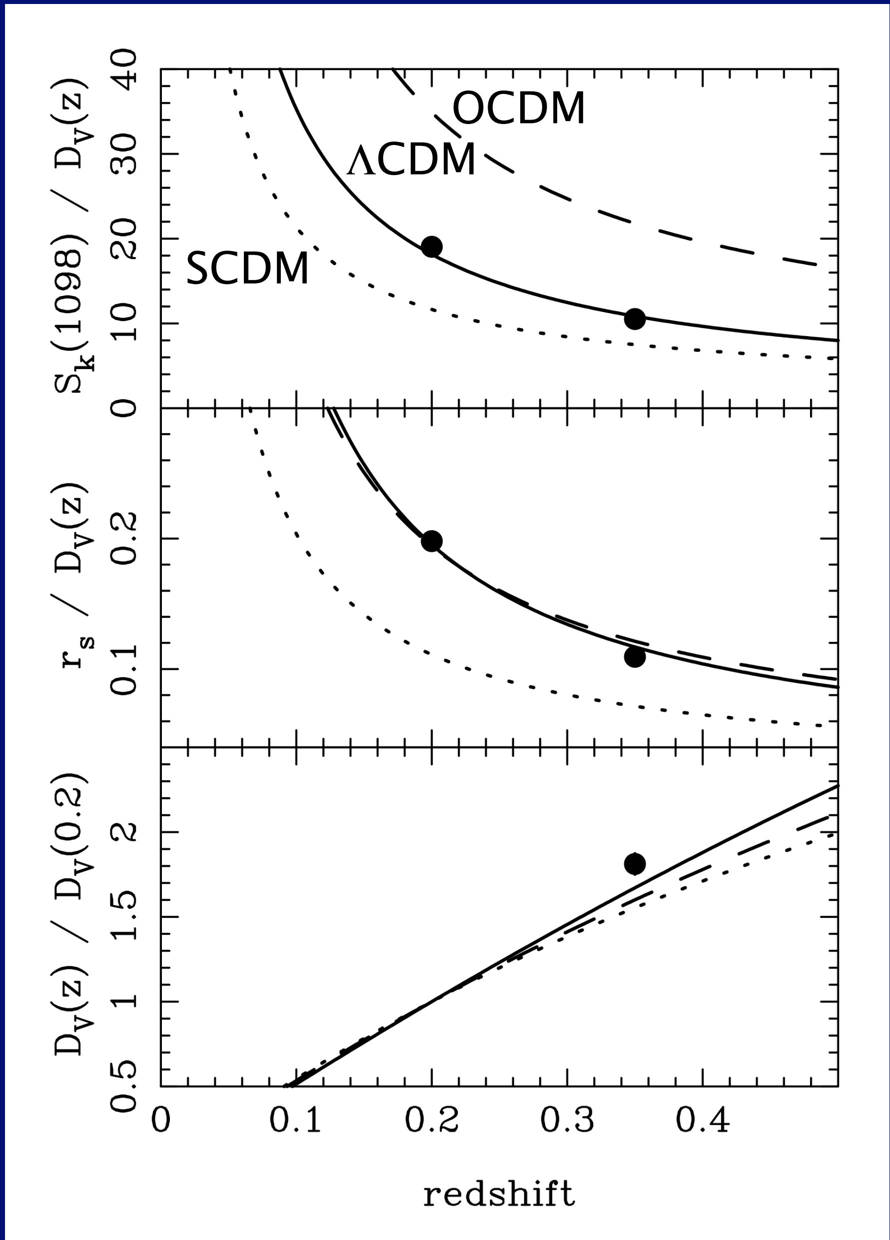

BAO detected at z~0.2

BAO detected at z~0.35

BAO from combined sample

Percival et al., 2007, MNRAS, astro-ph/0705.3323

# BAO distance scale measurements




including $r_s/d_A(\text{cmb})=0.0104$,

$D_V(0.2)/d_A(\text{cmb}) = 0.0525\pm0.0016$

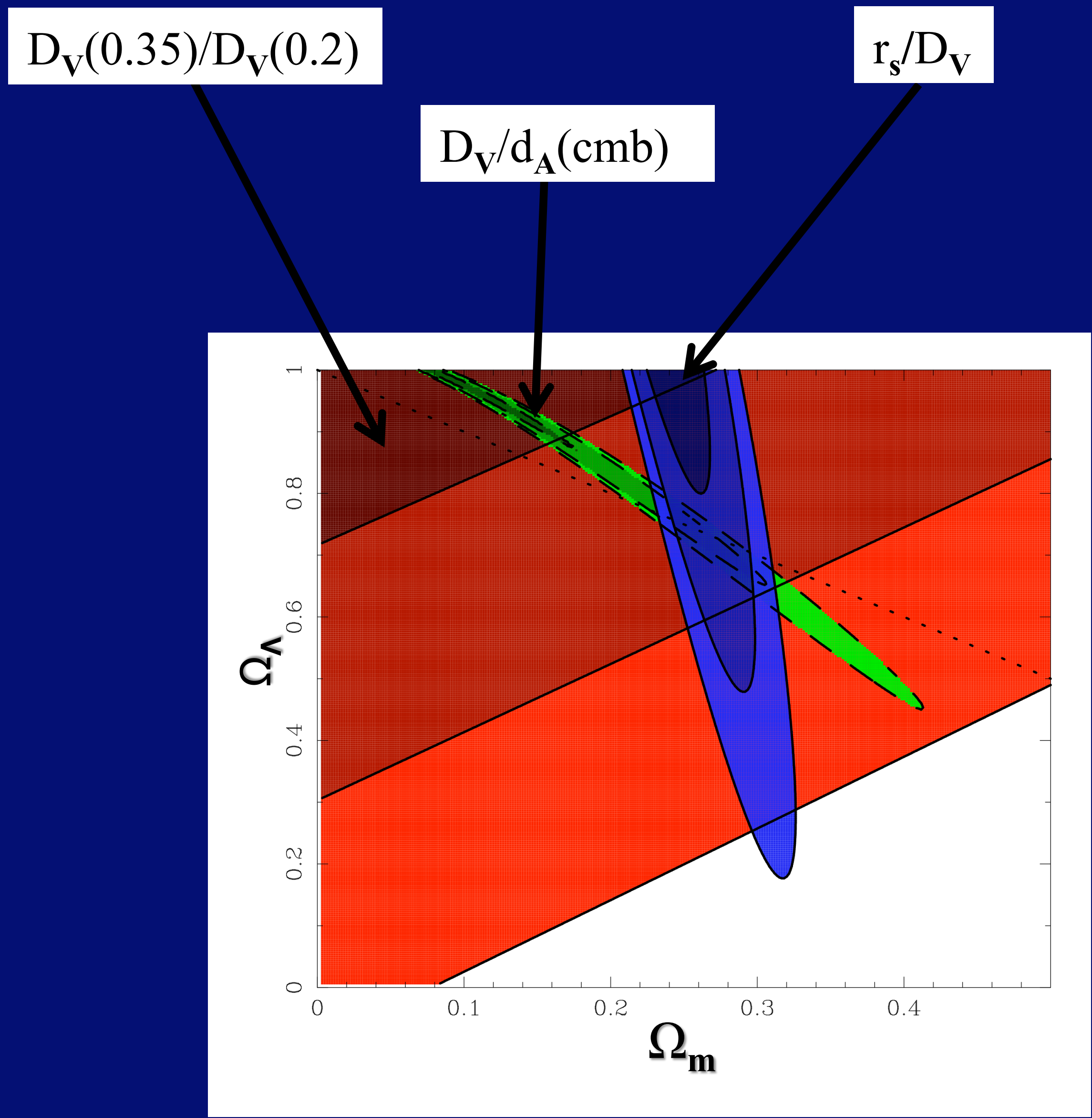
$D_V(0.35)/d_A(\text{cmb}) = 0.0951\pm0.0029$

$r_s/D_V(0.2) = 0.1980 \pm 0.0060$

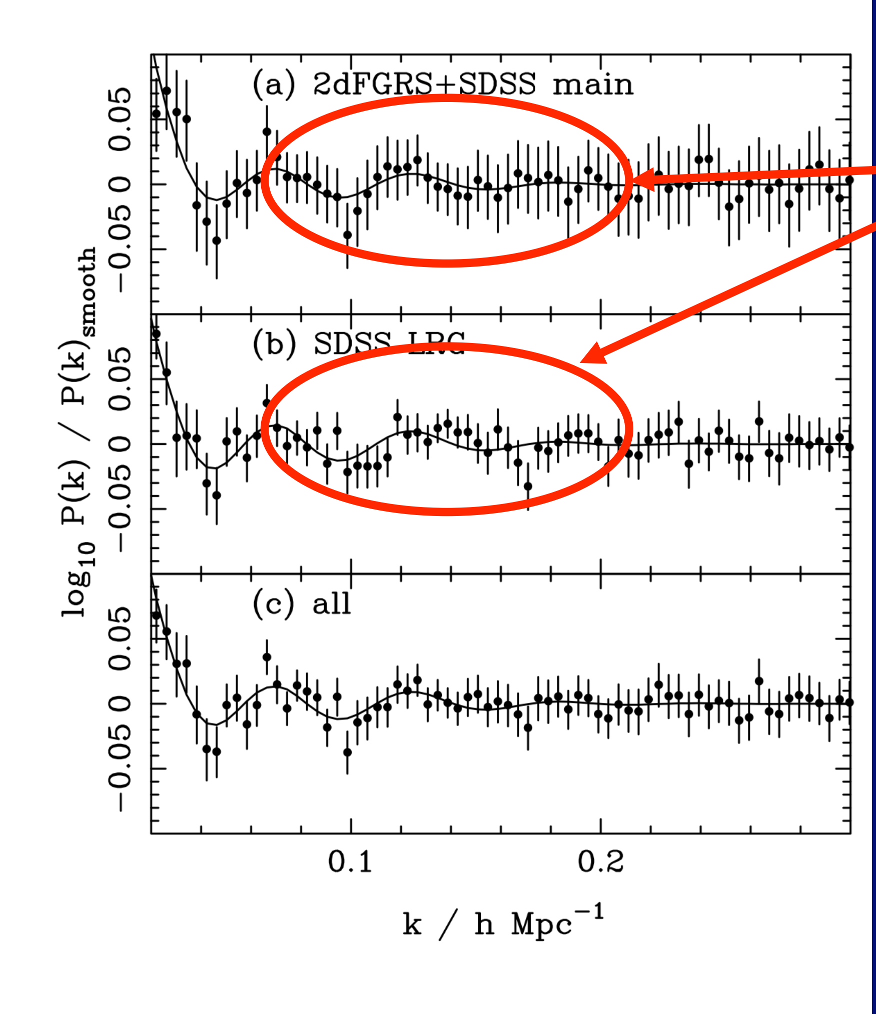
$r_s/D_V(0.35) = 0.1094 \pm 0.0033$

$D_V(0.35)/D_V(0.2) = 1.812 \pm 0.060$

# Cosmological constraints on ΛCDM models



# Discrepancy with ΛCDM?



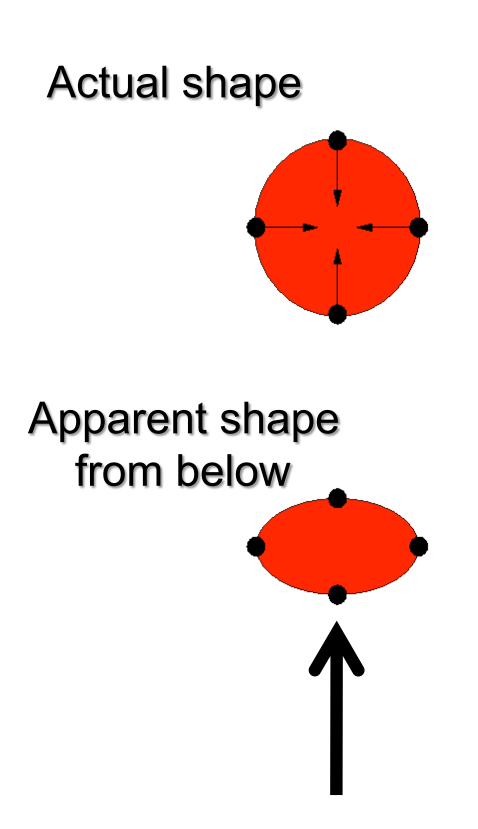

LRG BAO on too small scales: further away than expected, so more acceleration between z=0.2 and 0.35

Distance ratio found is
$D_V(0.35)/D_V(0.2) = 1.812 \pm 0.060$

CDM expects
$D_V(0.35)/D_V(0.2) = 1.67$

Discrepancy is 2.4σ

# Linear redshift-space distortions

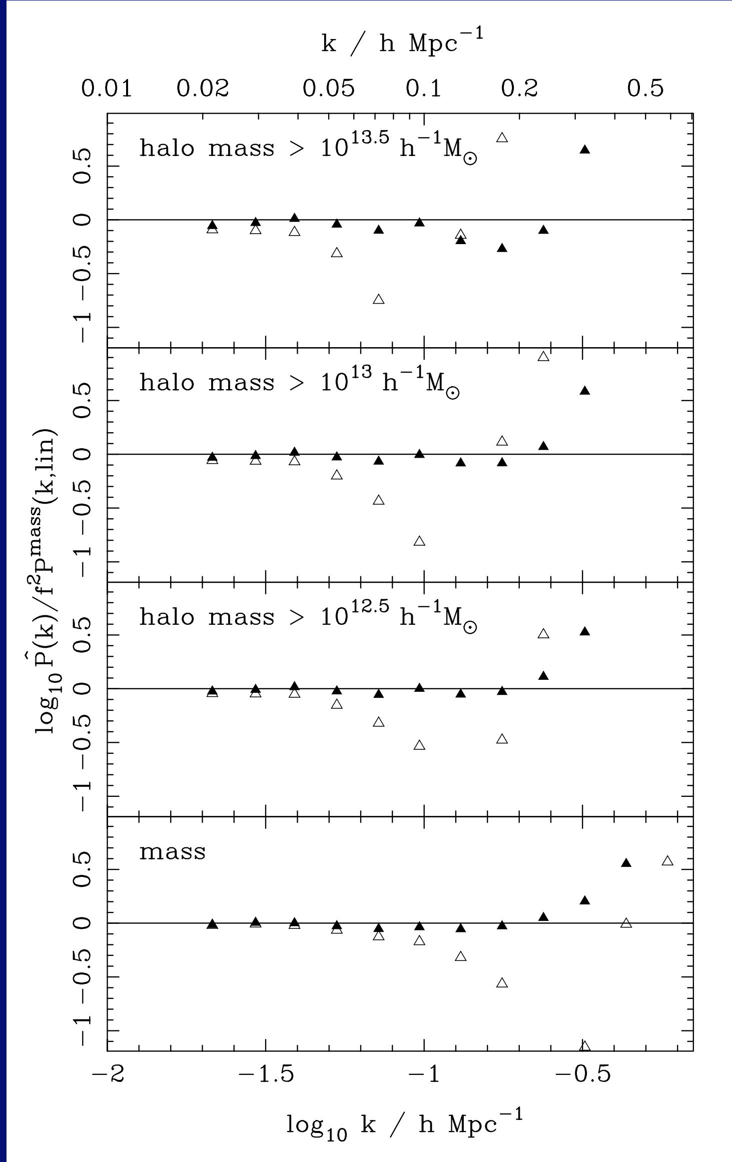



Galaxies act as test particles in matter velocity field

Any two galaxies would have the same velocity at the same location

Can construct an estimator for the **mass** power spectrum multiplied by $f^2$

$$\hat{P}(k)=\frac{7}{48}\left[5(7P_0+P_2)-\sqrt{35}(35P_0^2+10P_0P_2-7P_2^2)^{1/2}\right]$$

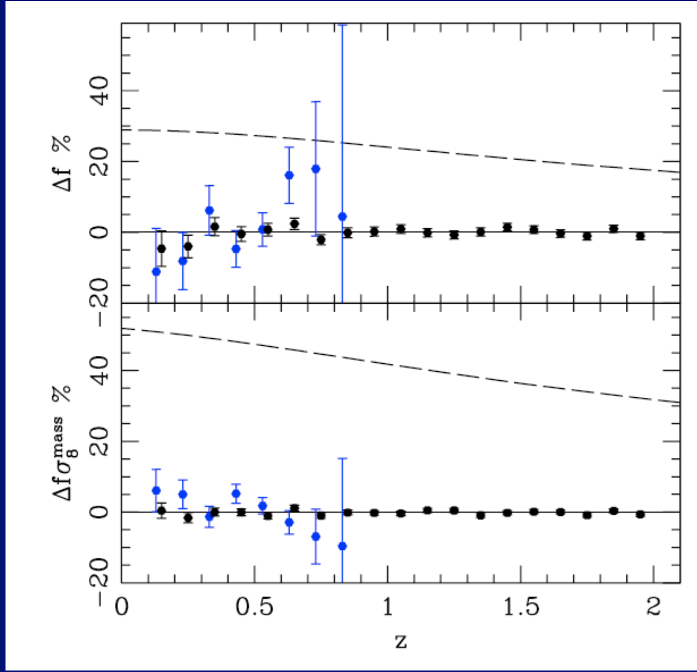


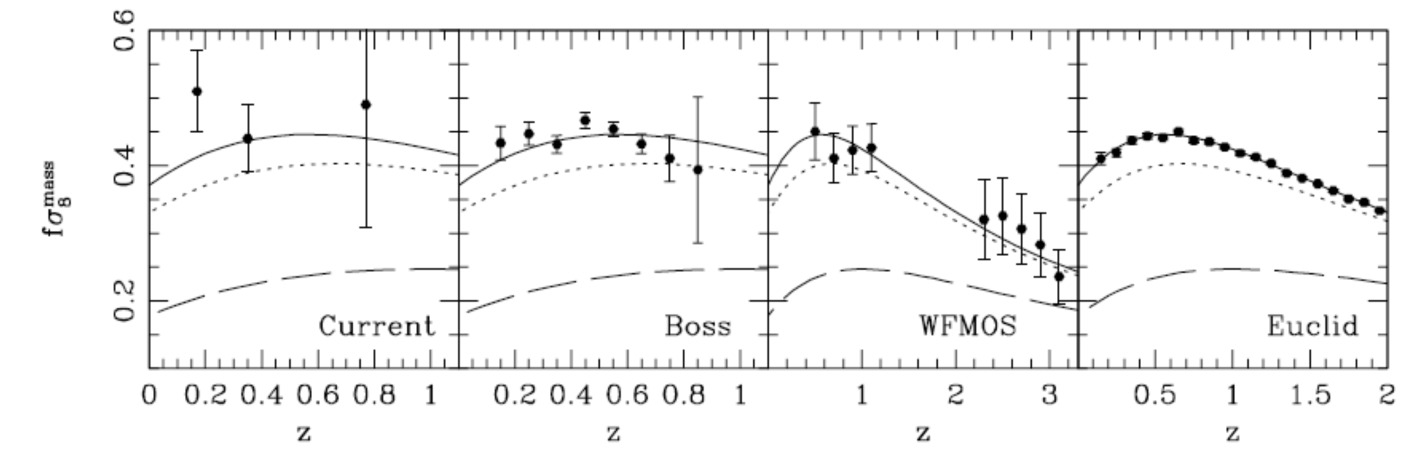

Percival, White, 2008, astro-ph/0808.0003

# Testing General Relativity

Redshift-space distortions constrain $f\sigma_8$, which is as good a test of GR as f

$$f \equiv \frac{d\log D}{d\log a} \qquad f\sigma_8 \propto \frac{dD}{d\log a}$$




Song, Percival, 2008, astro-ph/0807.0810

# Conclusions

- Galaxy clustering allows us to test cosmological models in many ways
- Smooth shape of the power spectrum?
  - degenerate with galaxy bias
  - can tell us about galaxy formation
  - SDSS data shows that galaxy bias is a strong function of luminosity and color (see Cresswell poster)
- Baryon acoustic oscillations
  - avoids (almost all of) galaxy bias
  - shown to work as a function of redshift using SDSS
- Redshift-space distortions
  - avoids density bias completely
  - get "for free" for spectroscopic BAO surveys (eg. BOSS)
  - structure formation test so complementary to geometrical tests
  - similar to weak lensing but tests temporal metric fluctuations