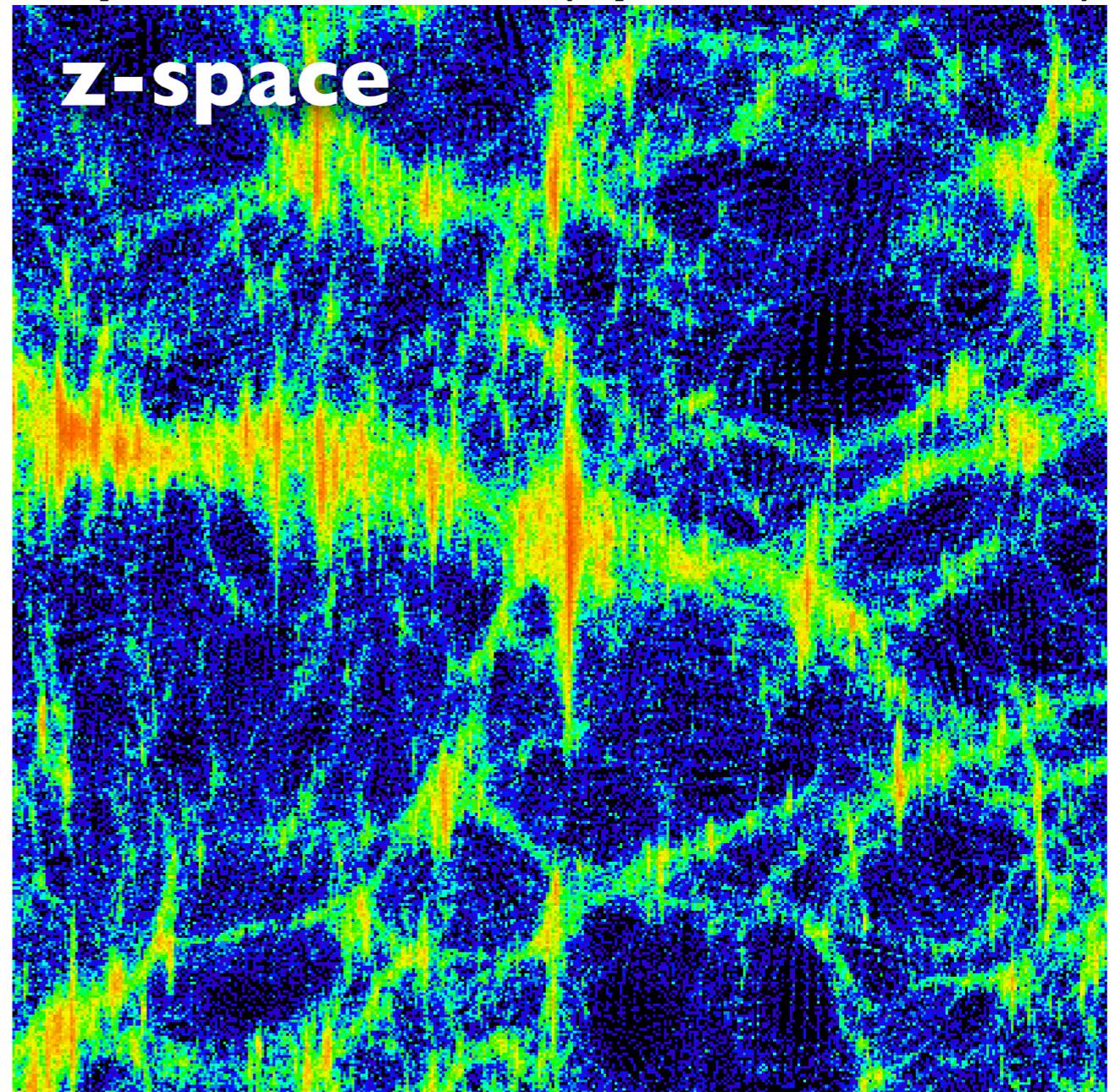
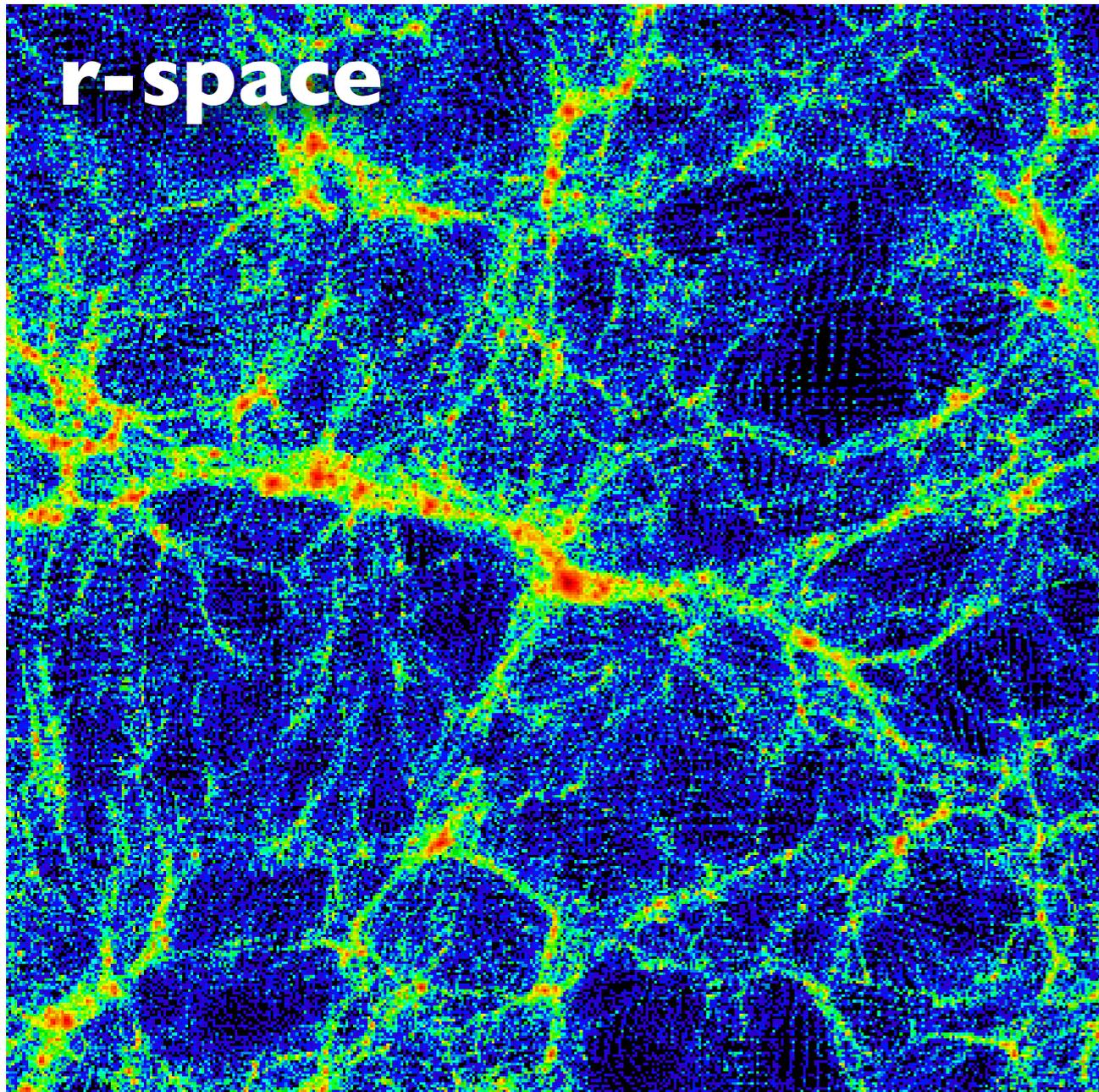


# Redshift-space distortion & Alcock-Paczynski effects

# Redshift-space distortions (RSD)

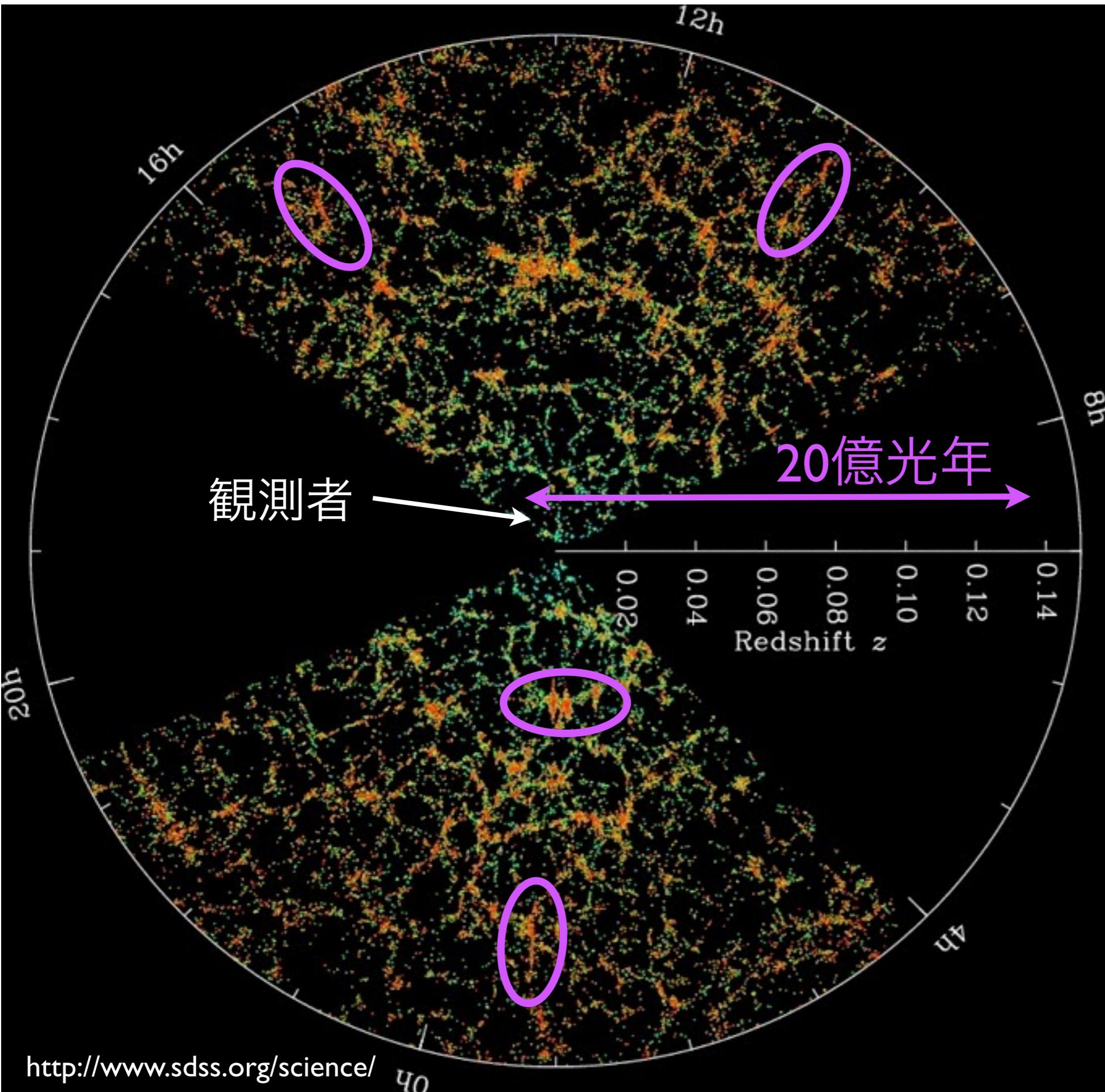
Dark matter in N-body simulations (by T. Nishimichi)



$\sim 100 \text{Mpc}/h$  ?

↑ observer's line-of-sight direction

# RSD in SDSS-II main galaxies



色は銀河の年齢

青い : 若い

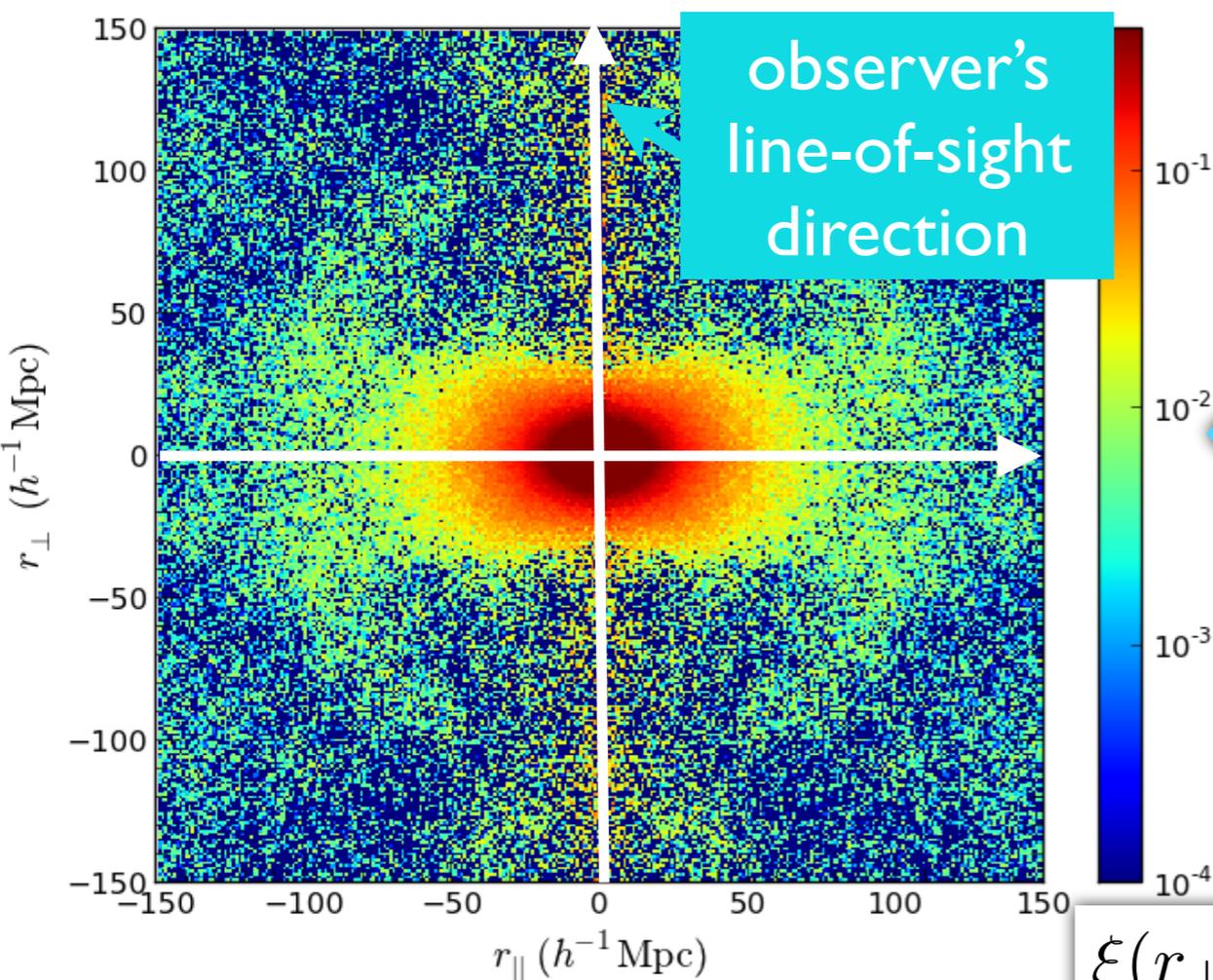
赤い : 古い

# Anisotropic correlation function

Anderson et al.('13)

BOSS DR11, CMASS samples

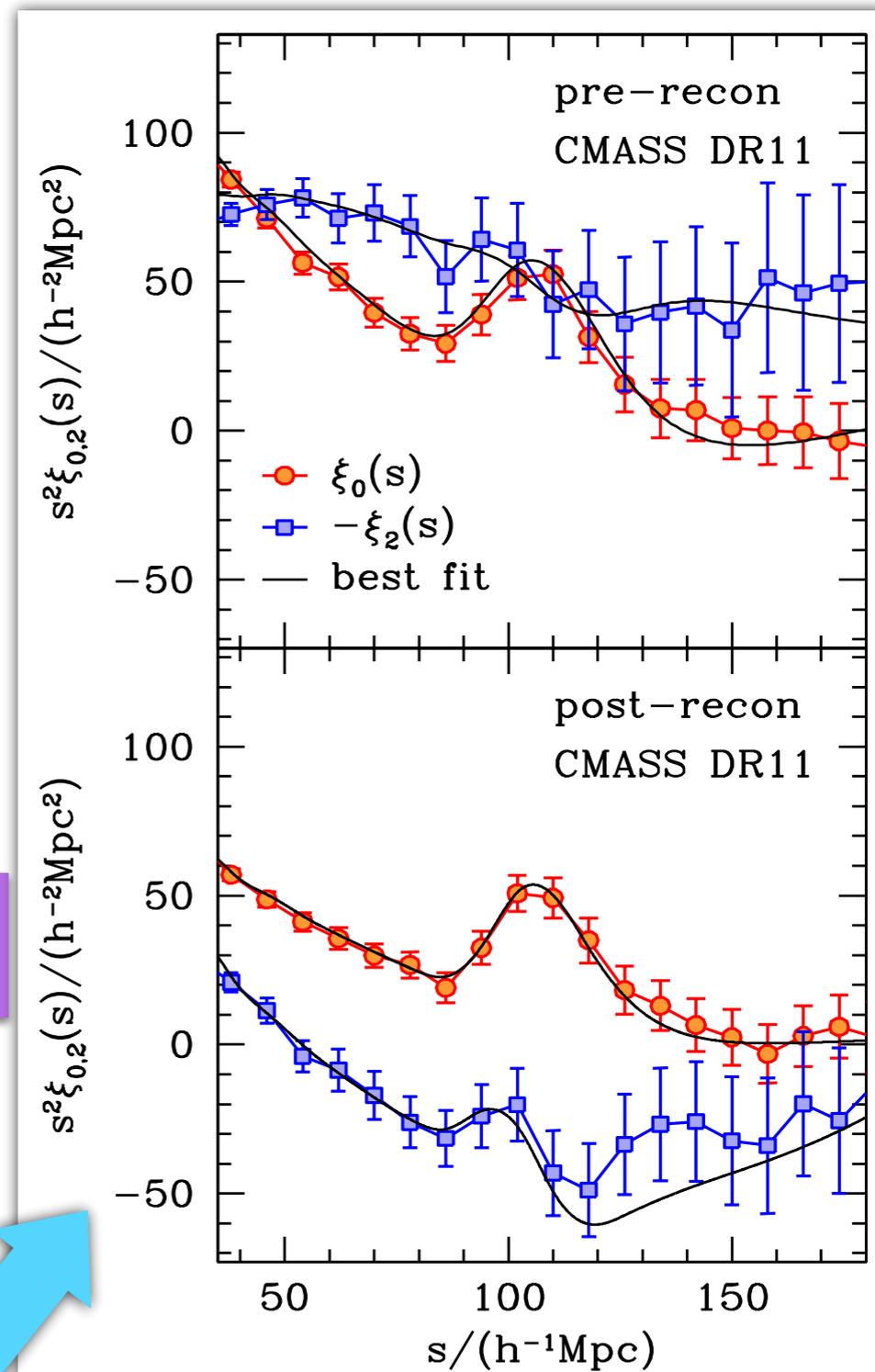
700,000 gals @  $0.43 < z < 0.7$



$$\xi(r_{\perp}, r_{\parallel})$$

Multipole expansion

$$\xi(r_{\perp}, r_{\parallel}) = \sum_{\ell:\text{even}} \xi_{\ell}(s) \mathcal{L}_{\ell}(r_{\parallel}/s) ; s = (r_{\perp}^2 + r_{\parallel}^2)^{1/2}$$

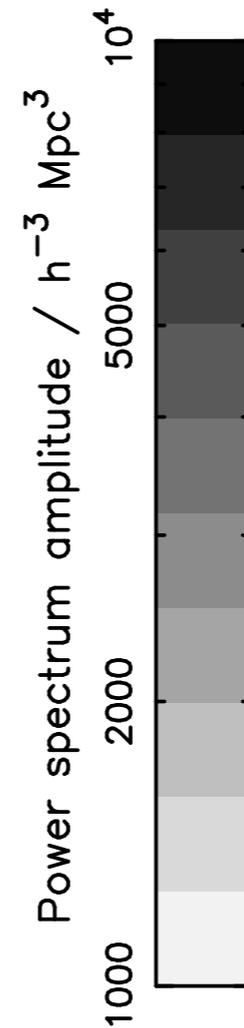
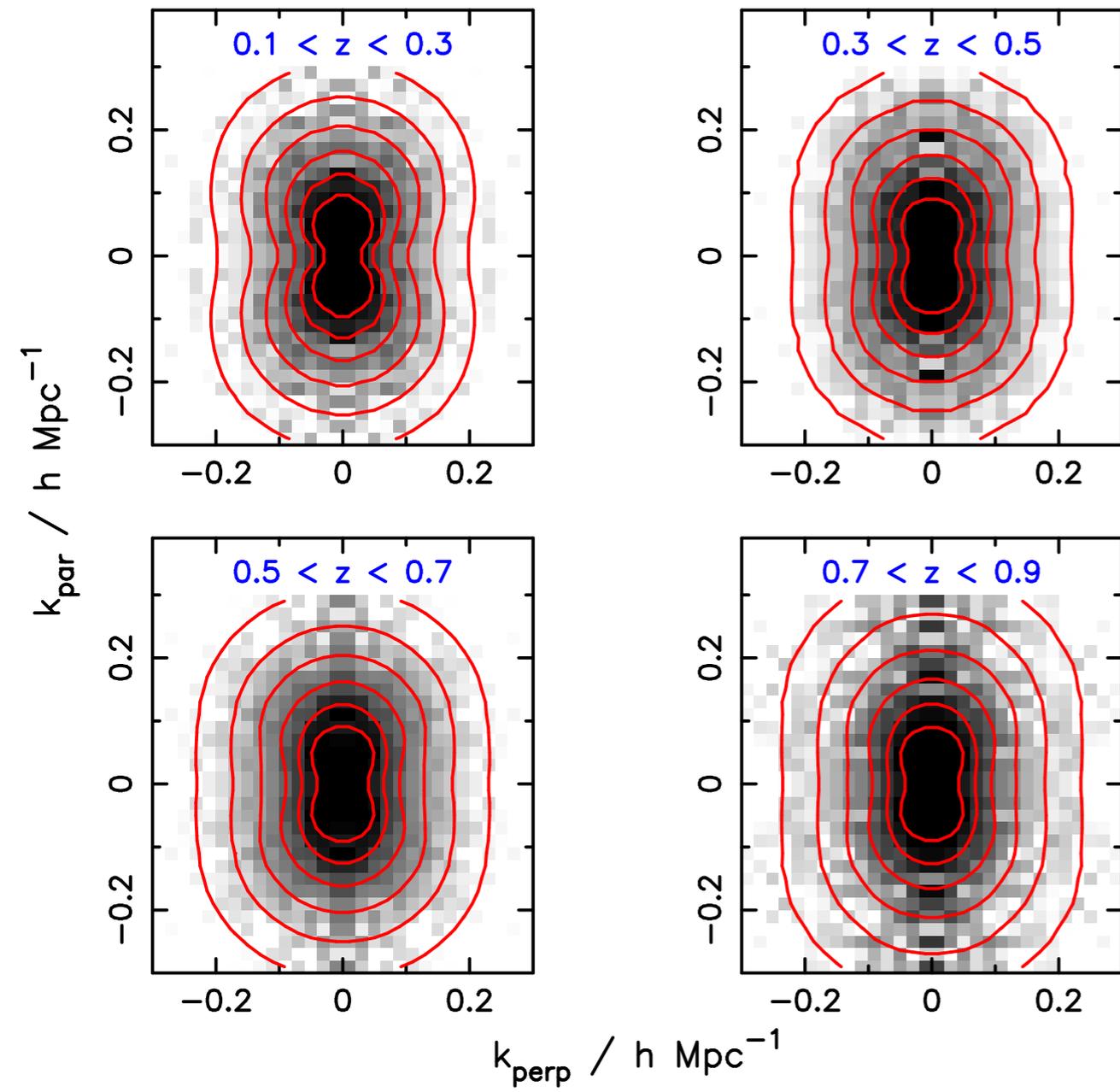


Samushia et al.('13)

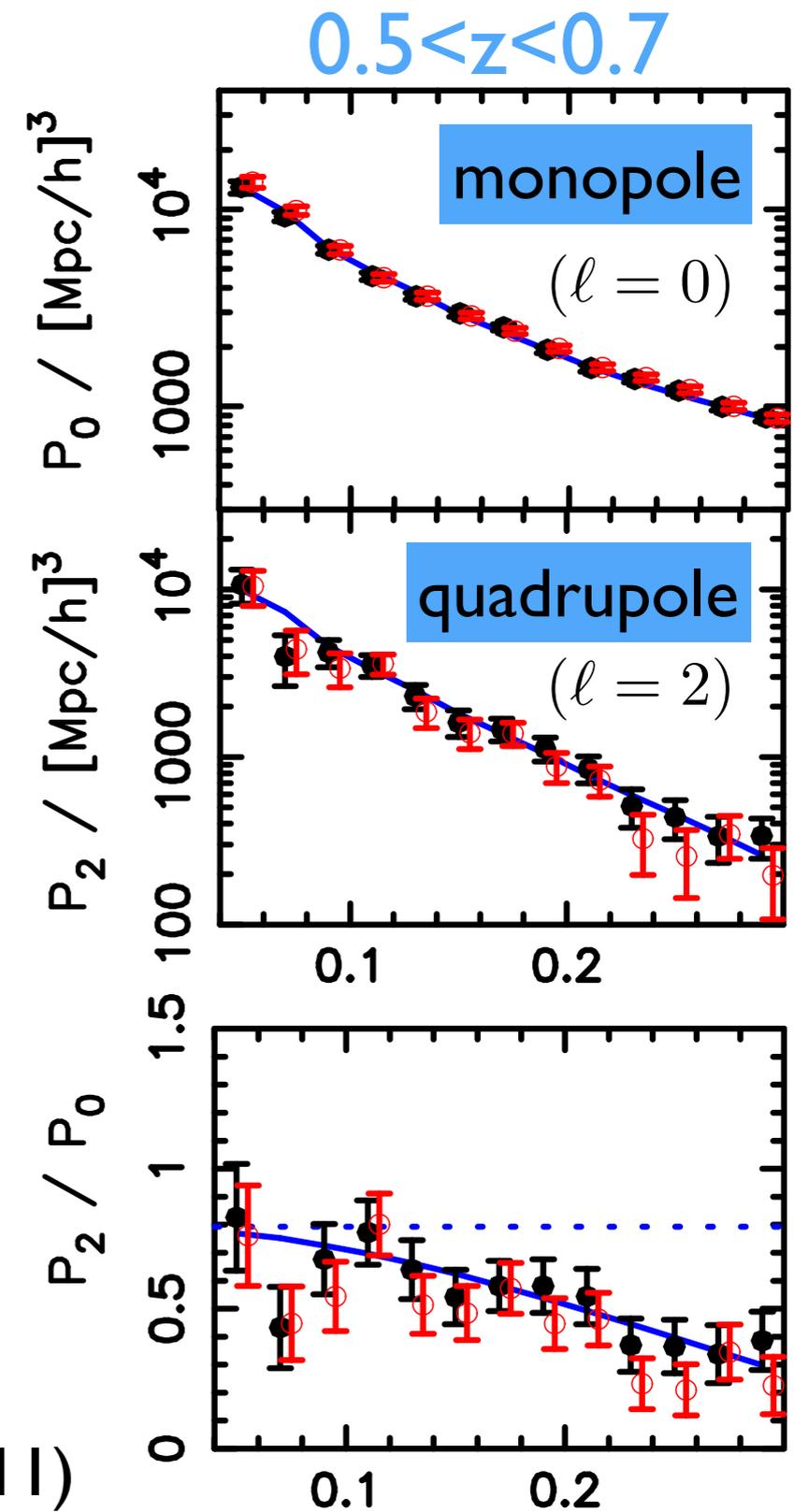
# Anisotropic power spectrum

WiggleZ

150,000 gals @  $0.1 < z < 0.9$



Blake et al. ('11)

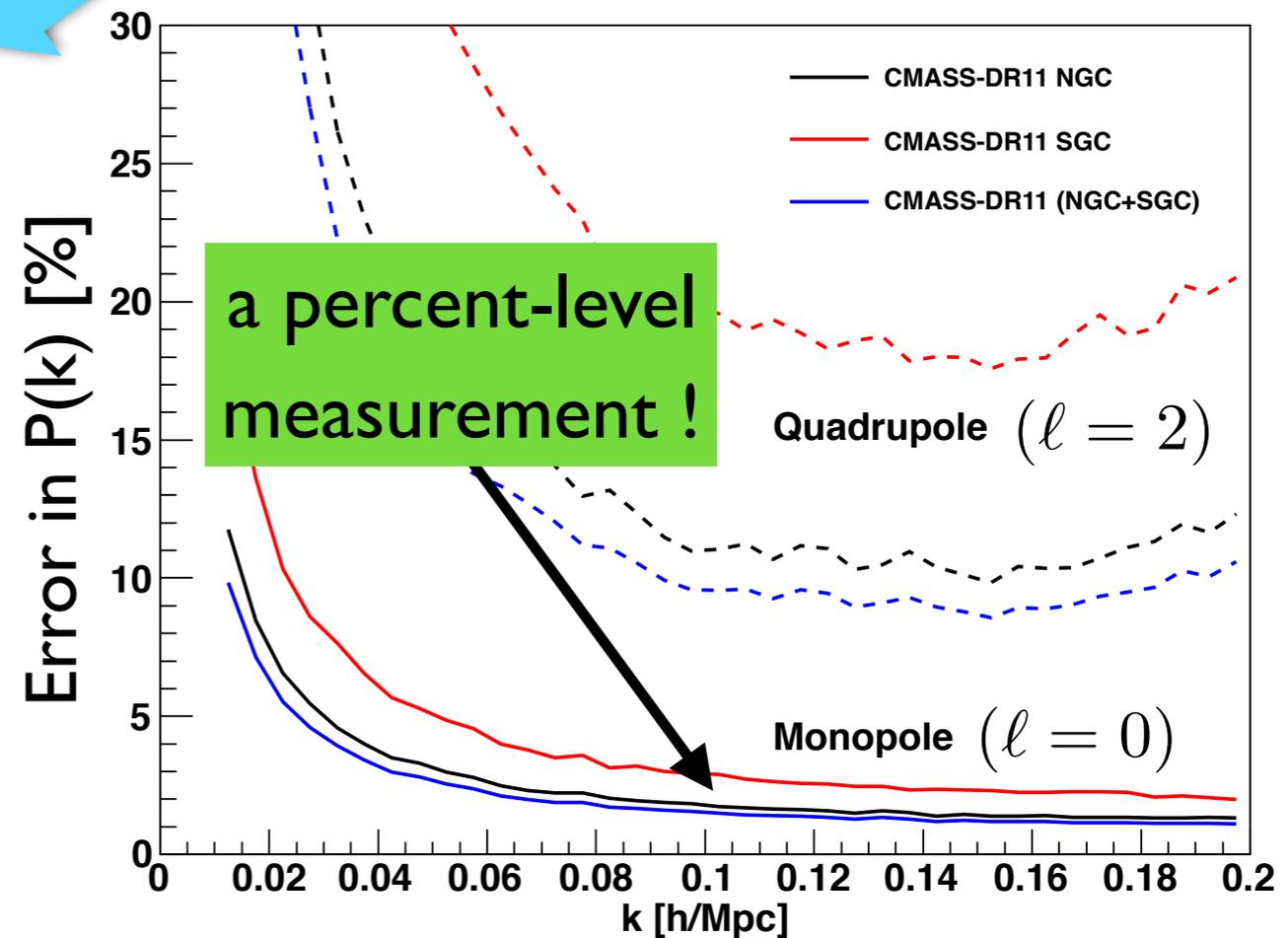
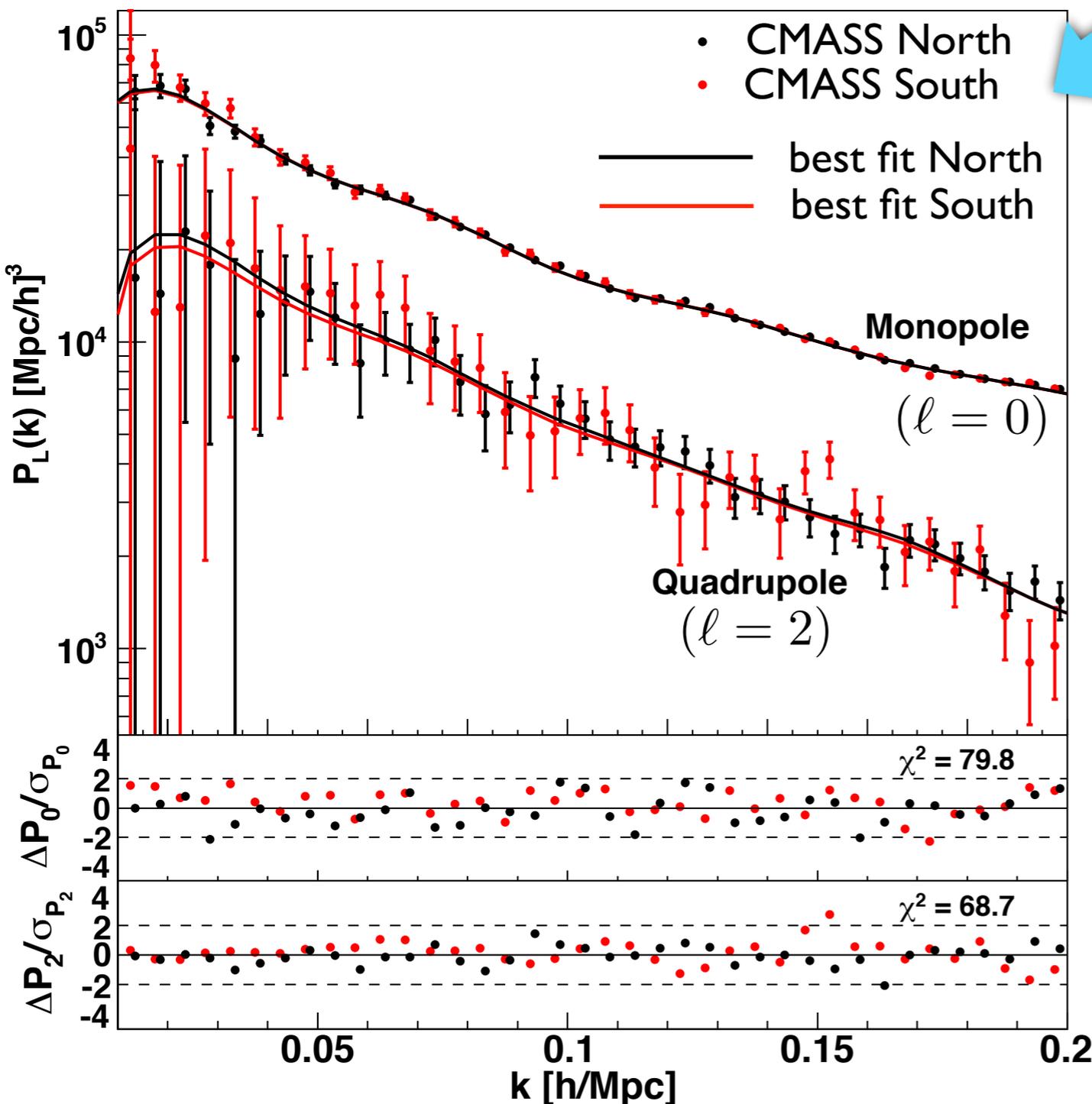


# Anisotropic power spectrum

SDSS-III BOSS DR11/12

Beutler et al. ('13)

Based on Yamamoto ('06) estimator

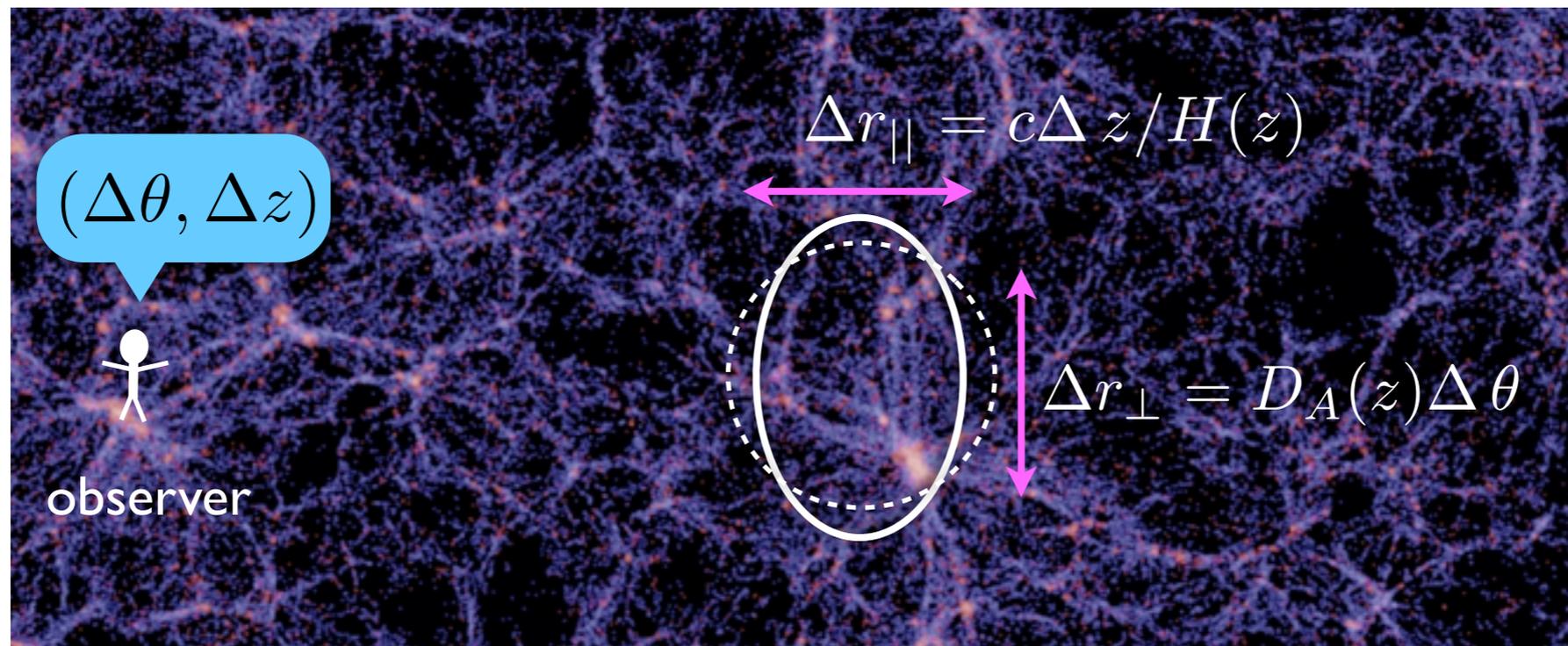


$$P(k_{\parallel}, k_{\perp}) = \sum_{\ell: \text{even}} P_{\ell}(k) \mathcal{P}_{\ell}(k_{\parallel}/k)$$

$$; k = (k_{\parallel}^2 + k_{\perp}^2)^{1/2}$$

# Alcock & Paczynski effect

Cosmological distortions caused by apparent mismatch of underlying cosmological models



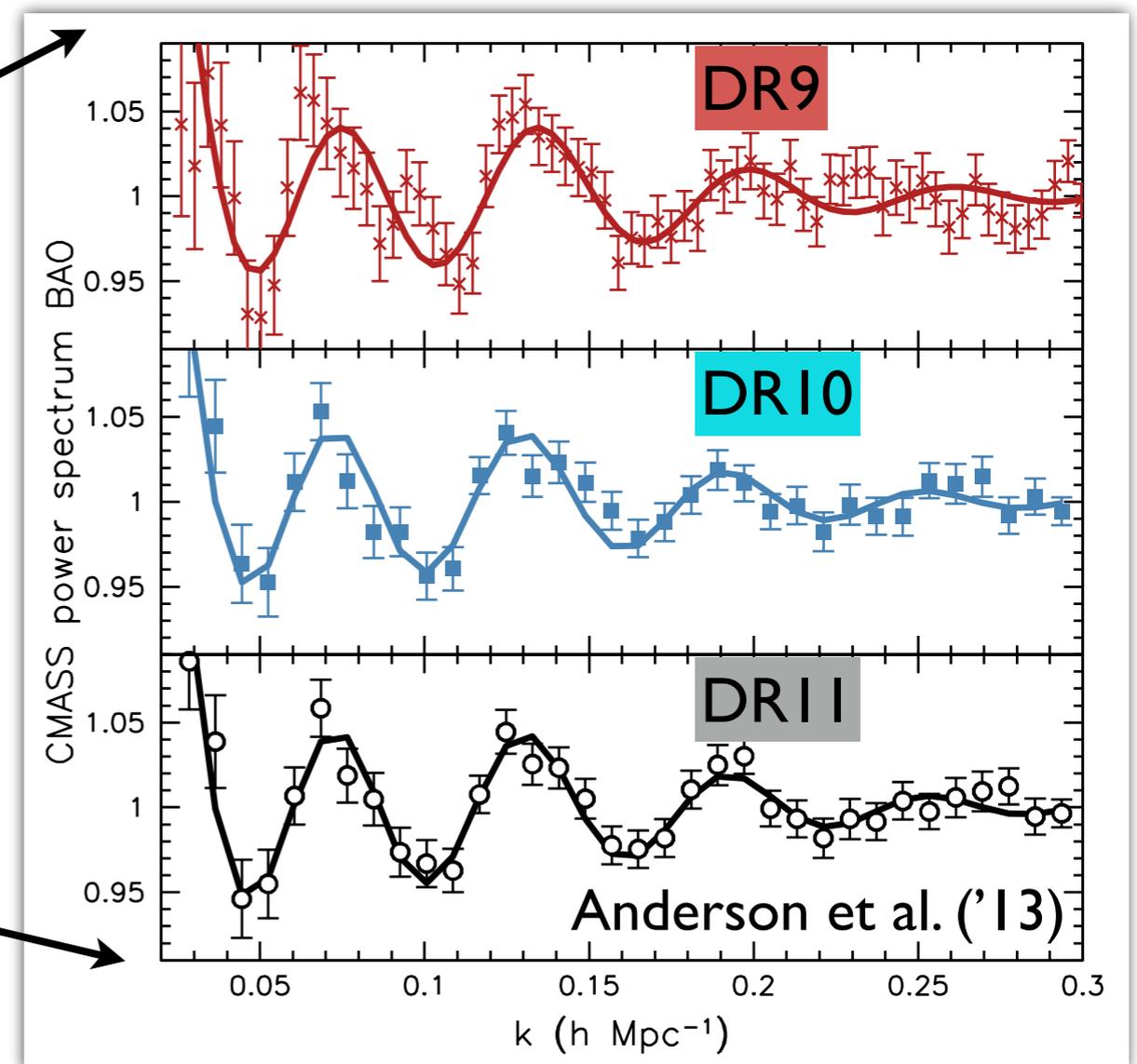
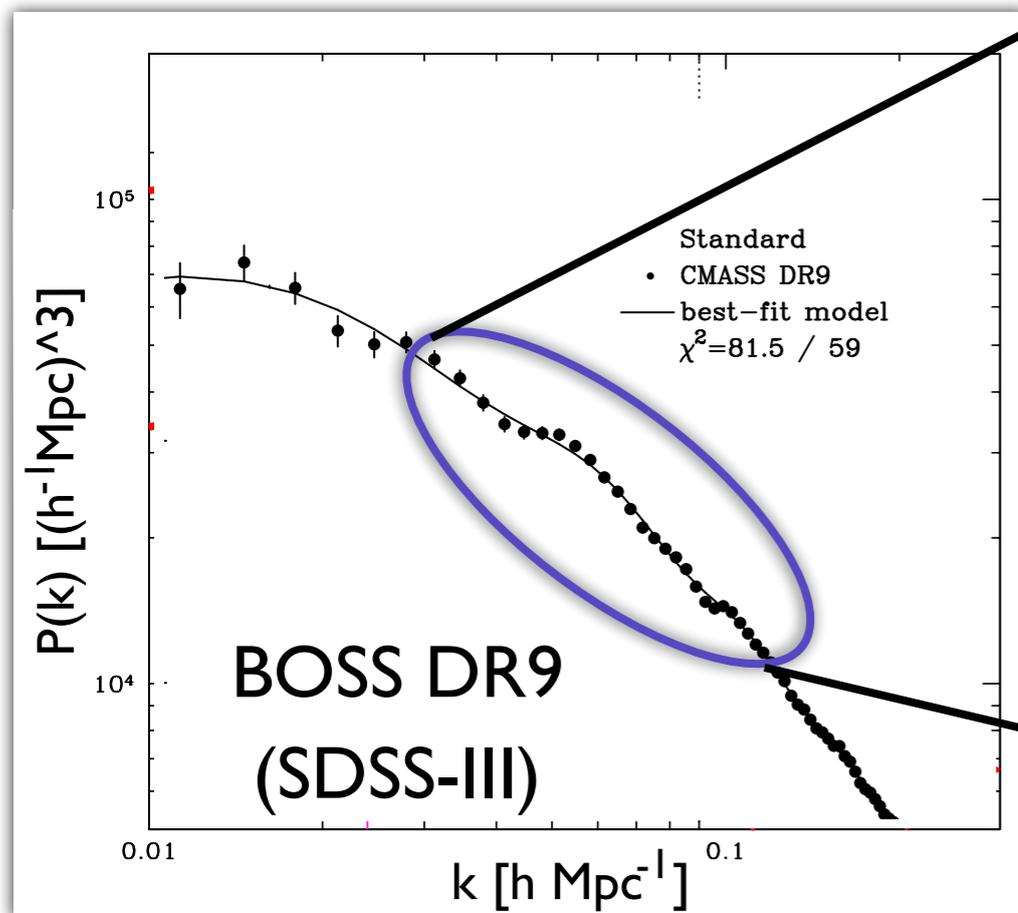
→ can generate higher multipole moments of clustering anisotropies

Using BAO as standard ruler,

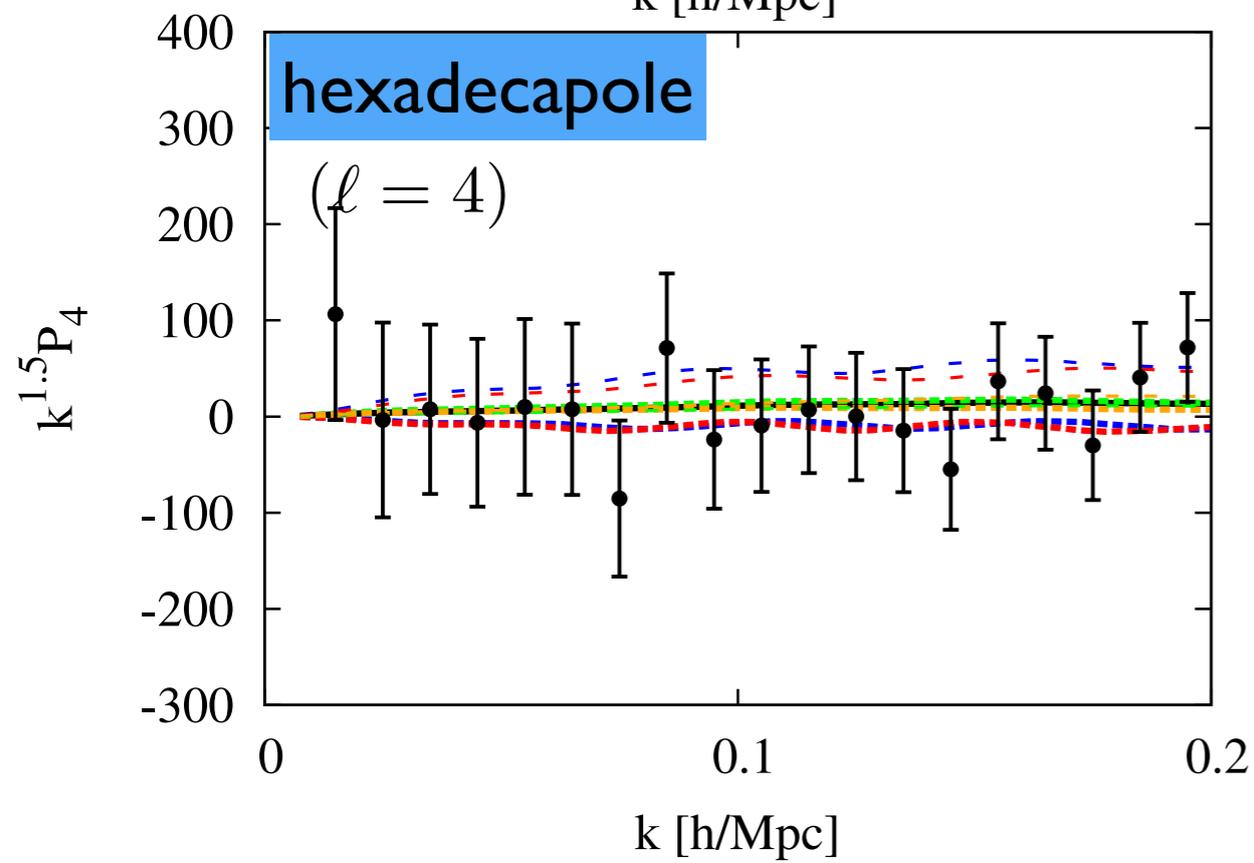
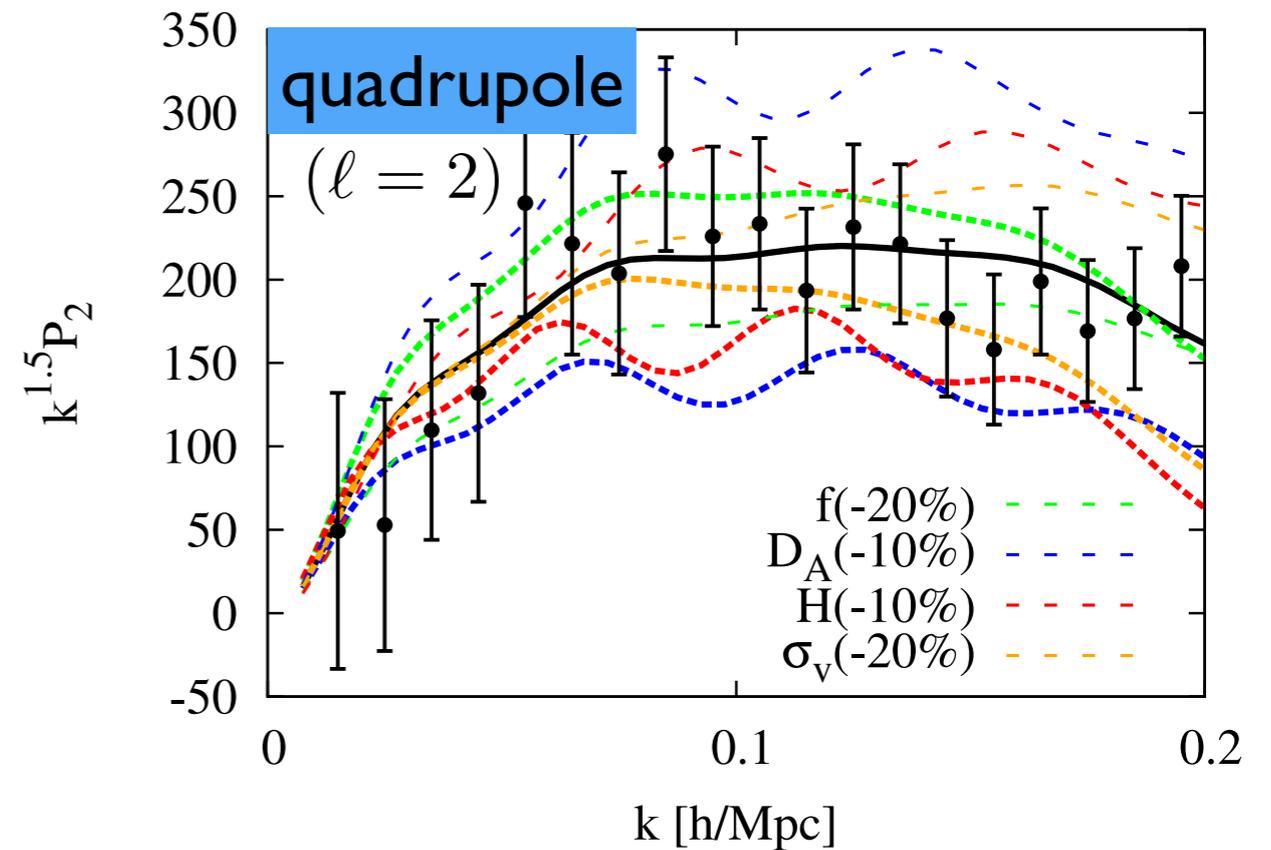
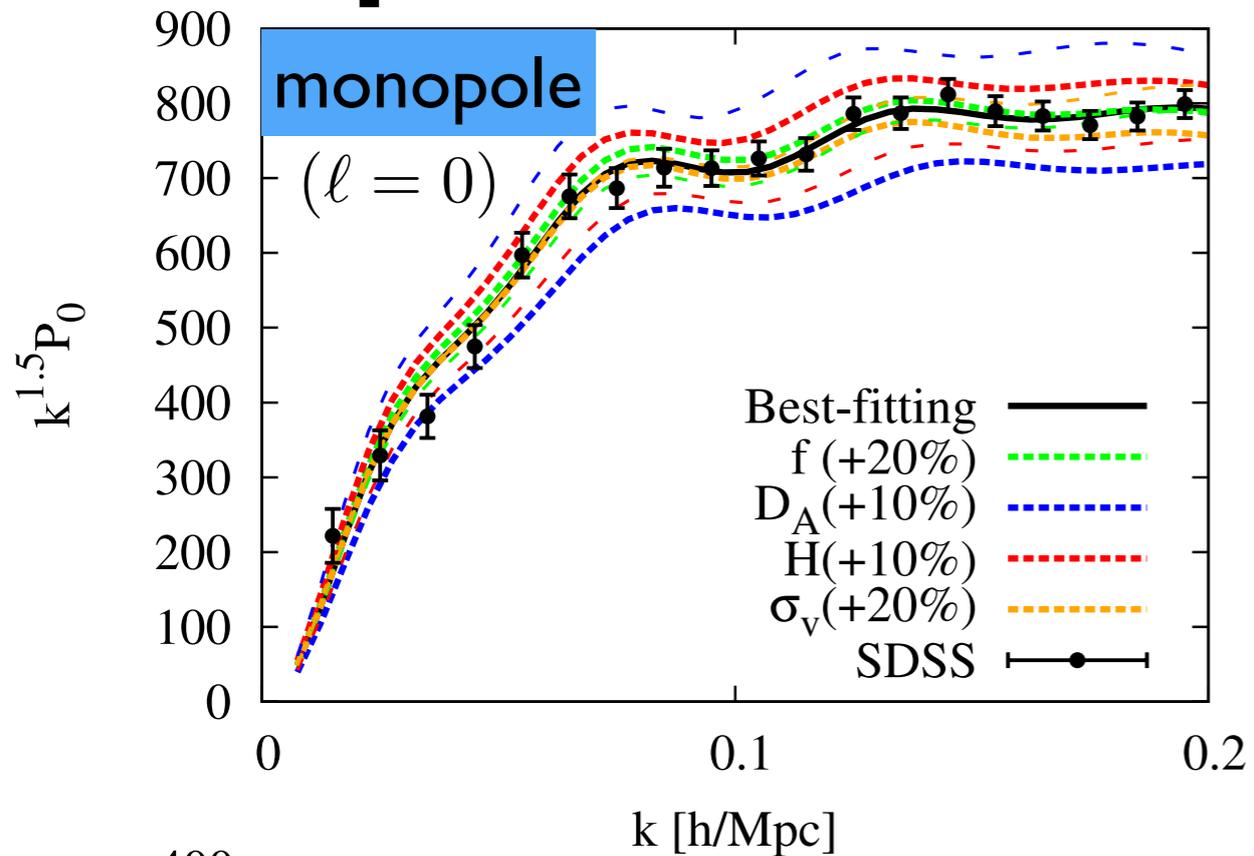
**H(z)** & **D<sub>A</sub>(z)** can be measured simultaneously

# Baryon acoustic oscillations

- Characteristic scale of primeval baryon-photon fluid ( $\sim 150\text{Mpc}$ ) imprinted on  $P(k)$  or  $\xi(r)$
- Can be used as standard ruler to estimate distance to galaxies



# Impact of RSD & A-P effects

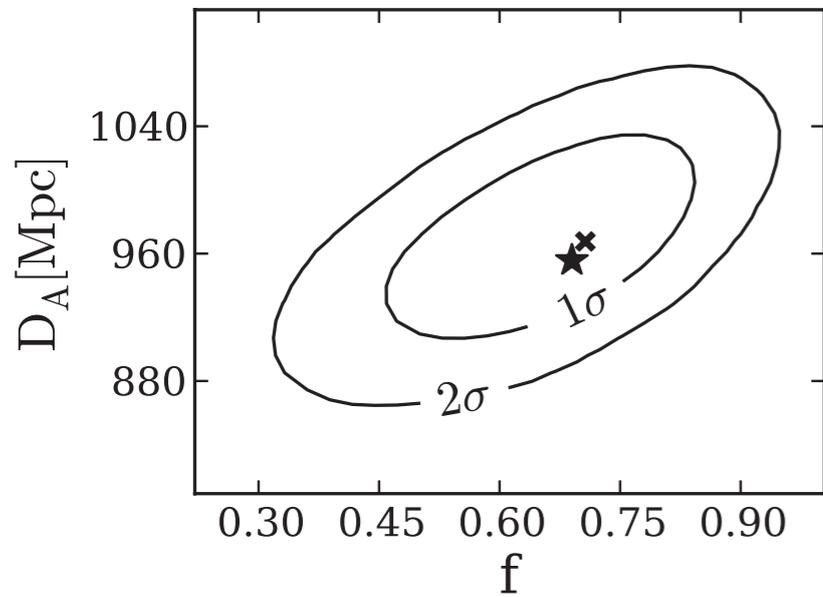


Sensitivity of clustering anisotropies to  $D_A$ ,  $H$  &  $f$

Obs. data: SDSS-II DR7 LRG

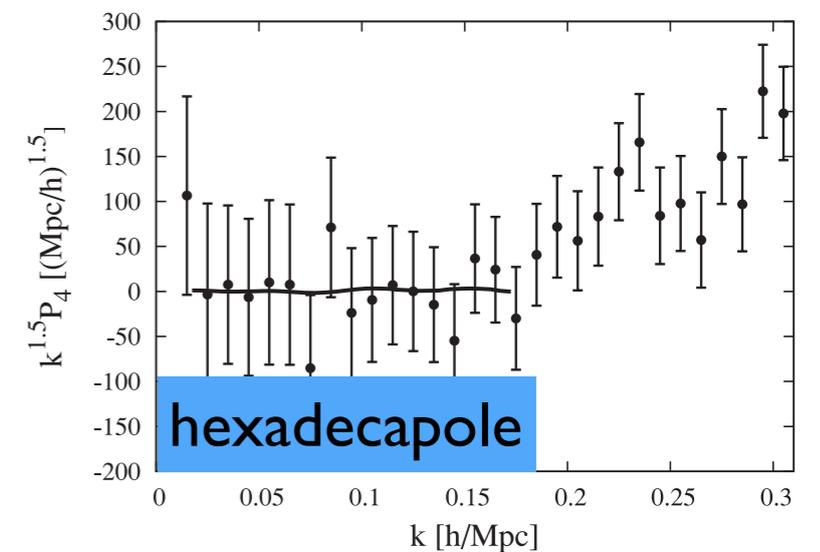
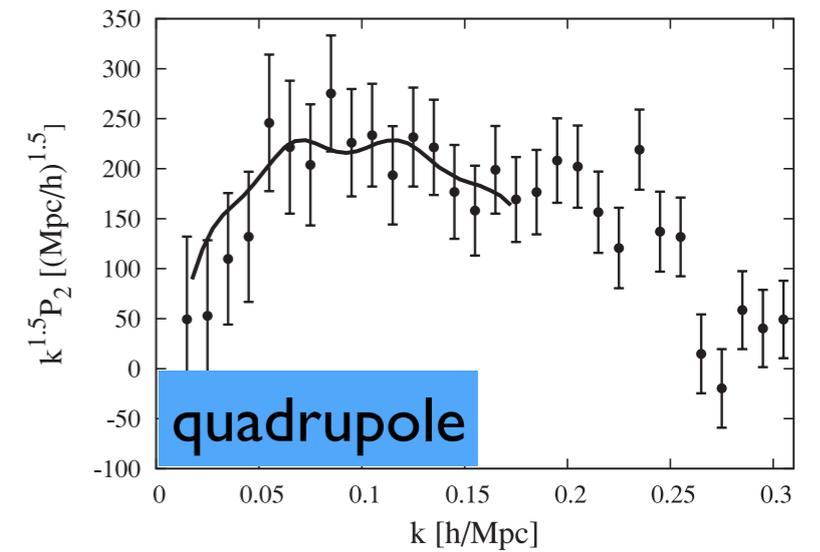
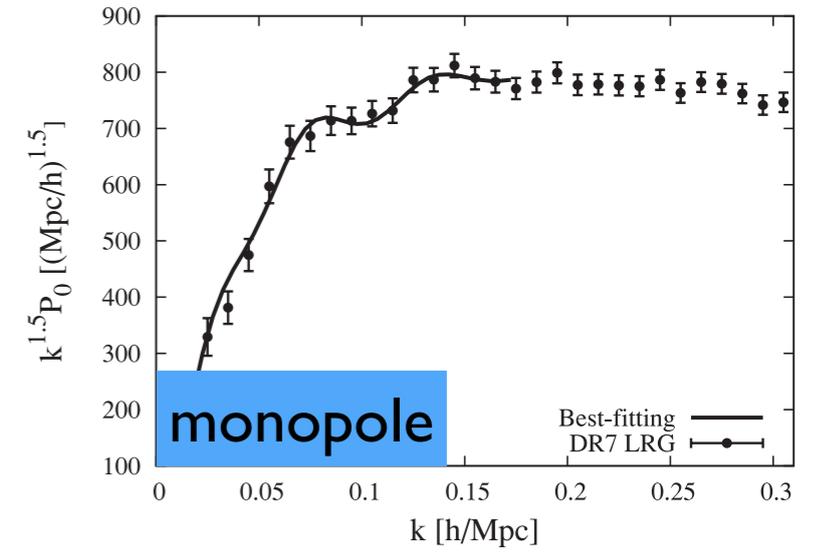
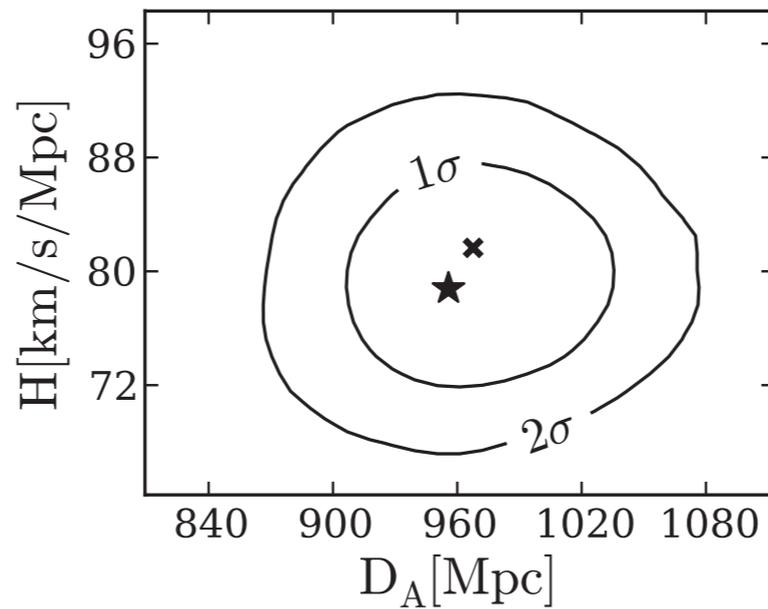
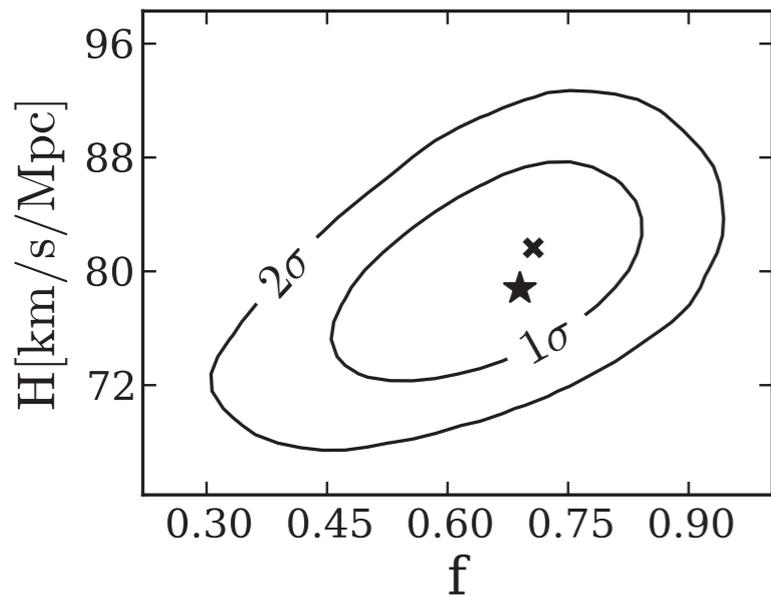
Oka et al.('13) modified

# Constraints on $f$ , $D_A$ & $H$ at $z=0.3$

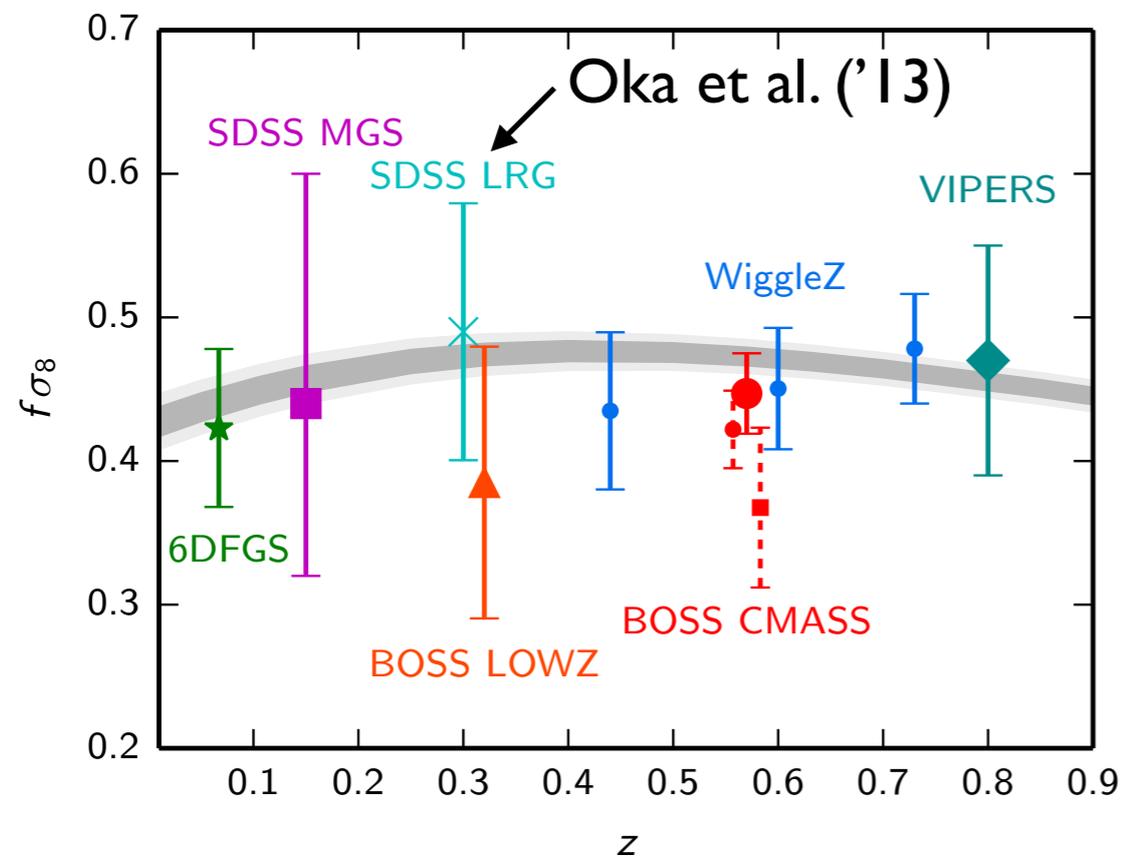
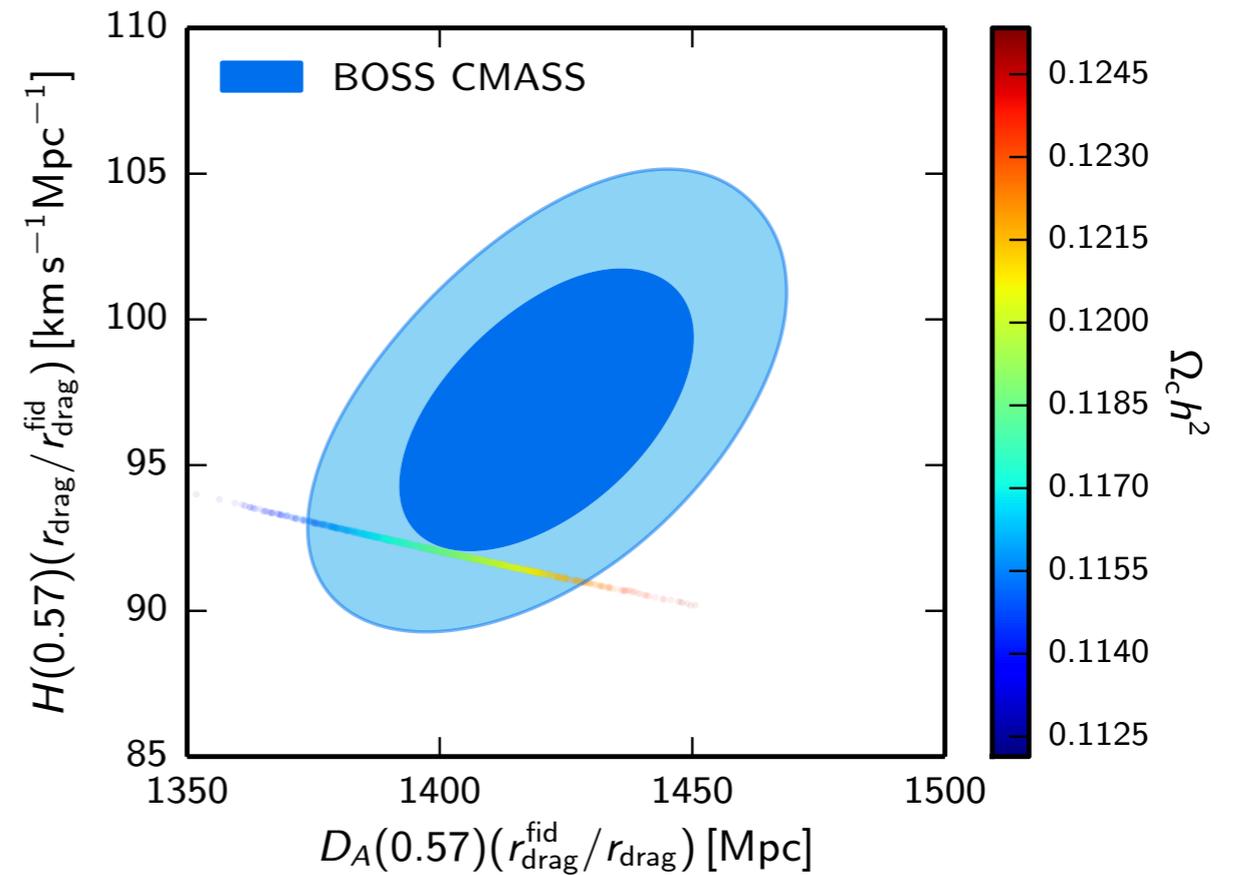
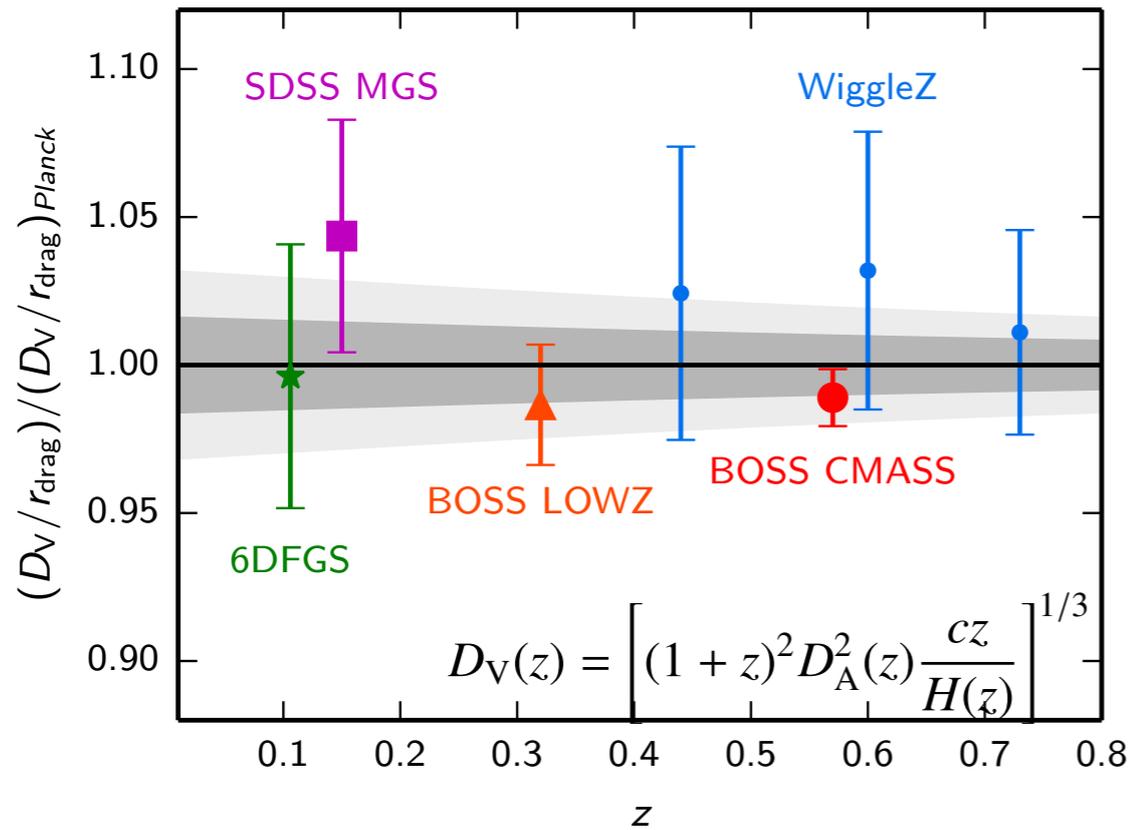


DR7 LRG ( $z = 0.3$ )

- ✕ Our results
- ★ Planck  $\Lambda$ CDM prediction



# Compilation of other observations



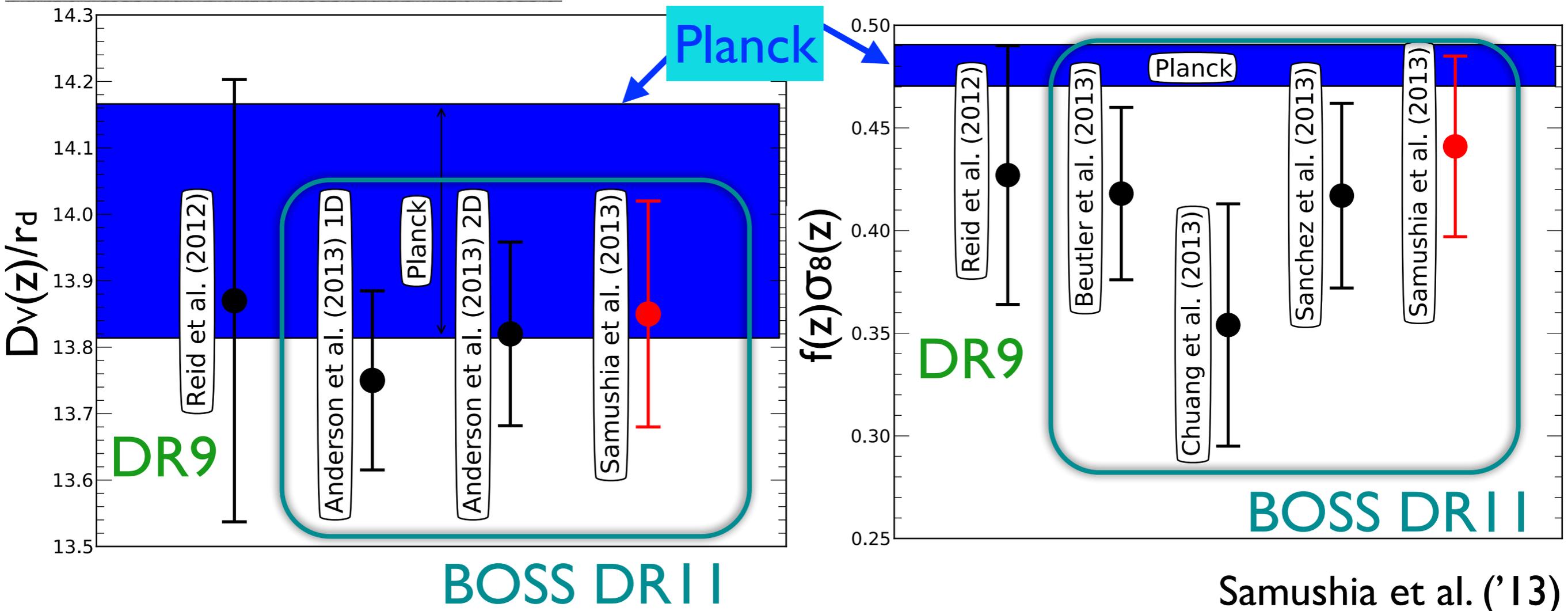
Planck 2015 results. XIII

# Remarks on systematics

- **Measurement:** seeing, spec-z failure, fiber collision, ...
- **Theory:** Nonlinear systematics arising from **RSD**, **gravity** & **galaxy bias**

➔ Imperfect model or aggressive use of template may lead to a biased constraints

CMASS sample ( $z=0.57$ )



Samushia et al. ('13)