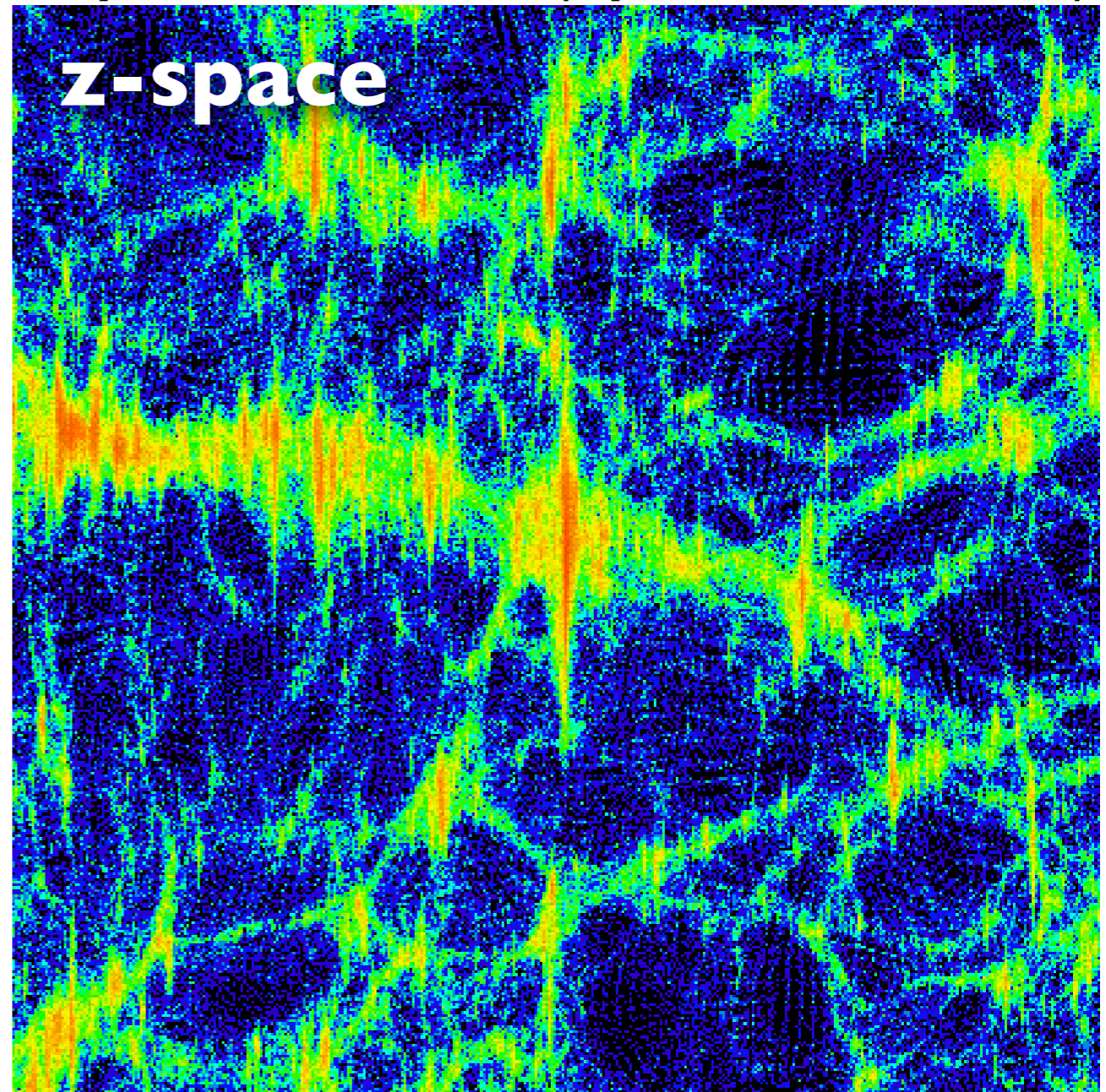
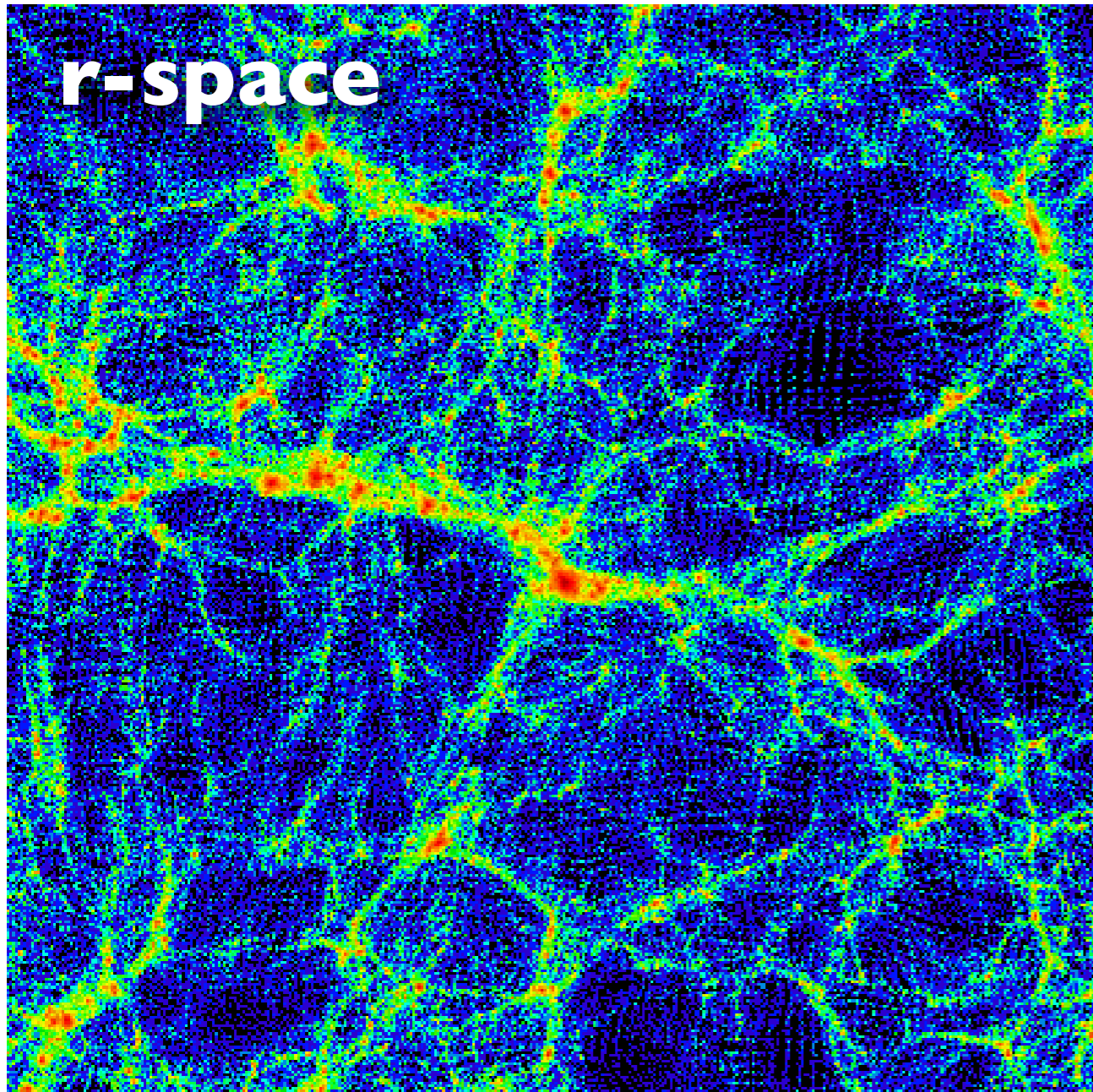


Redshift-space distortion & Alcock-Paczynski effects

Redshift-space distortions (RSD)

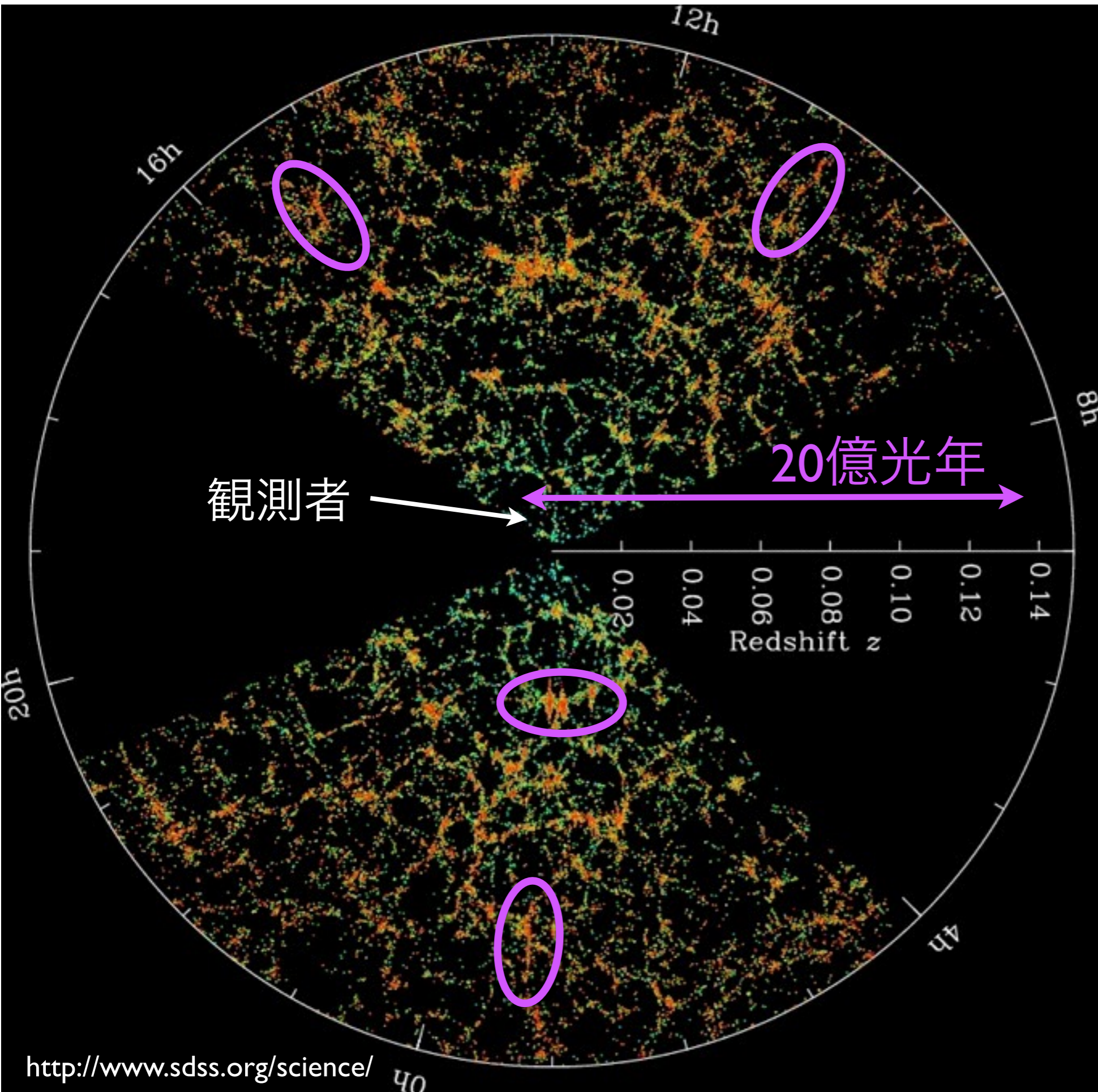
Dark matter in N-body simulations (by T. Nishimichi)



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

↑ observer's line-of-sight
direction

RSD in SDSS-II main galaxies



色は銀河の年齢

青い : 若い

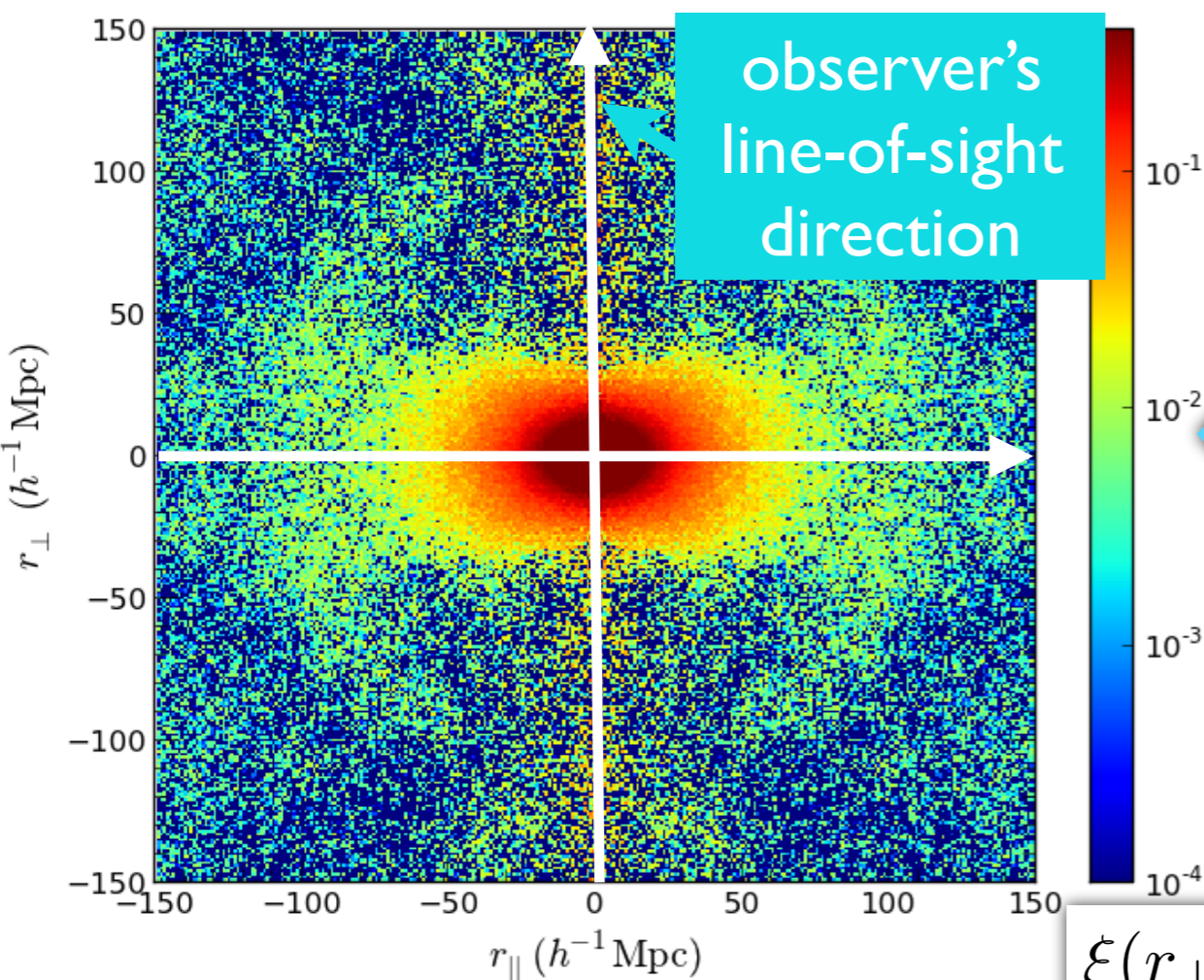
赤い : 古い

Anisotropic correlation function

Anderson et al.('13)

BOSS DR11, CMASS samples

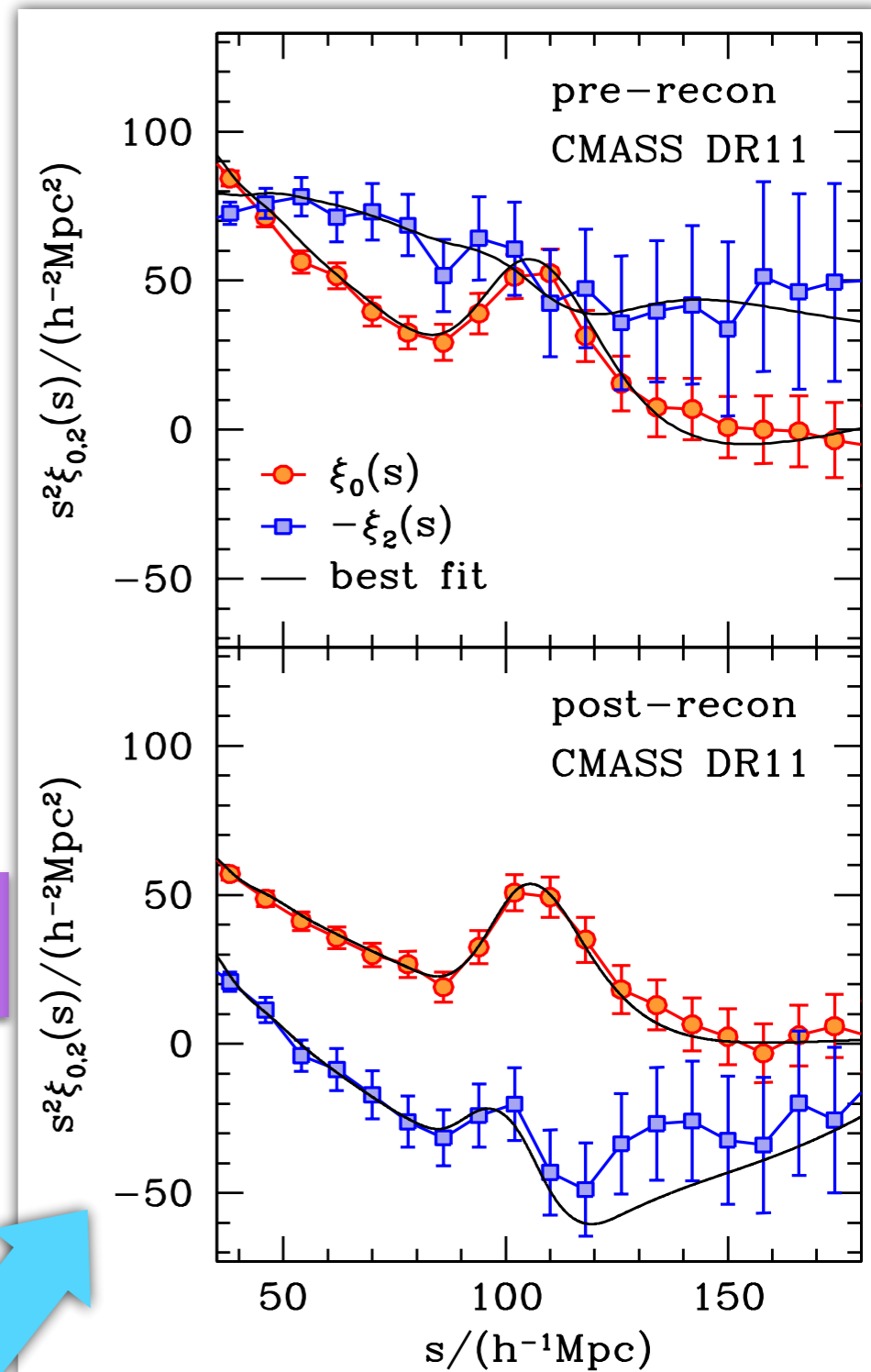
700,000 gals @ $0.43 < z < 0.7$



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

Multipole expansion

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

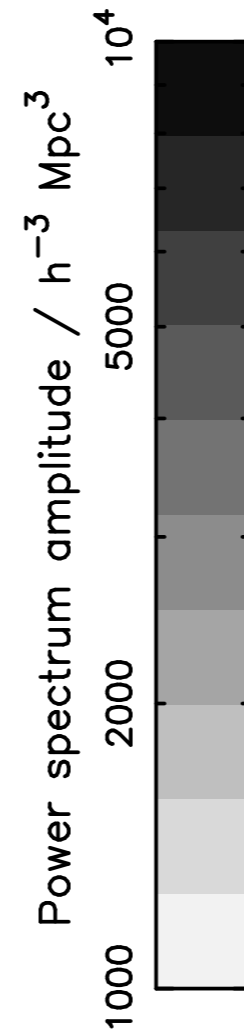
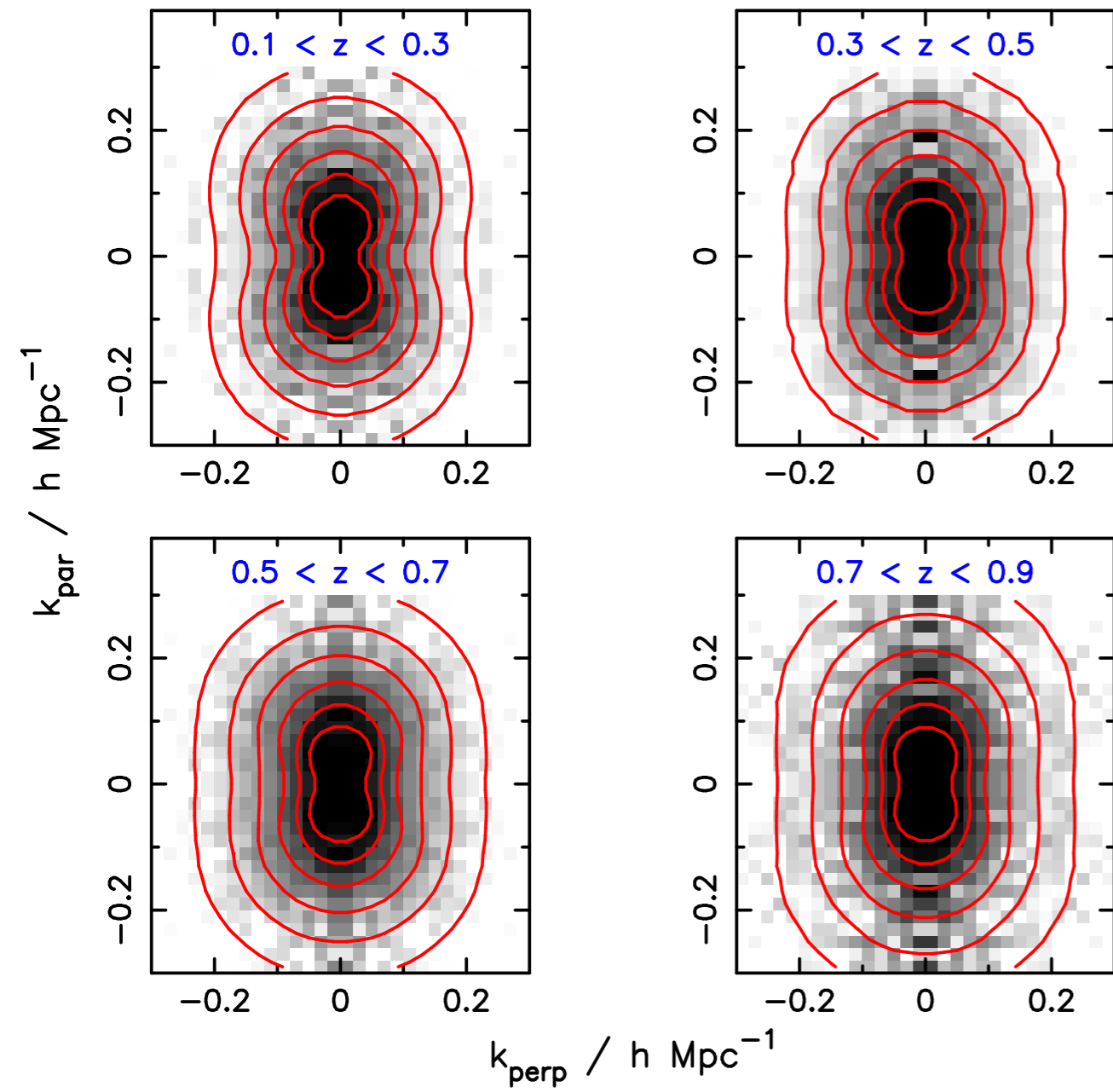


Samushia et al.('13)

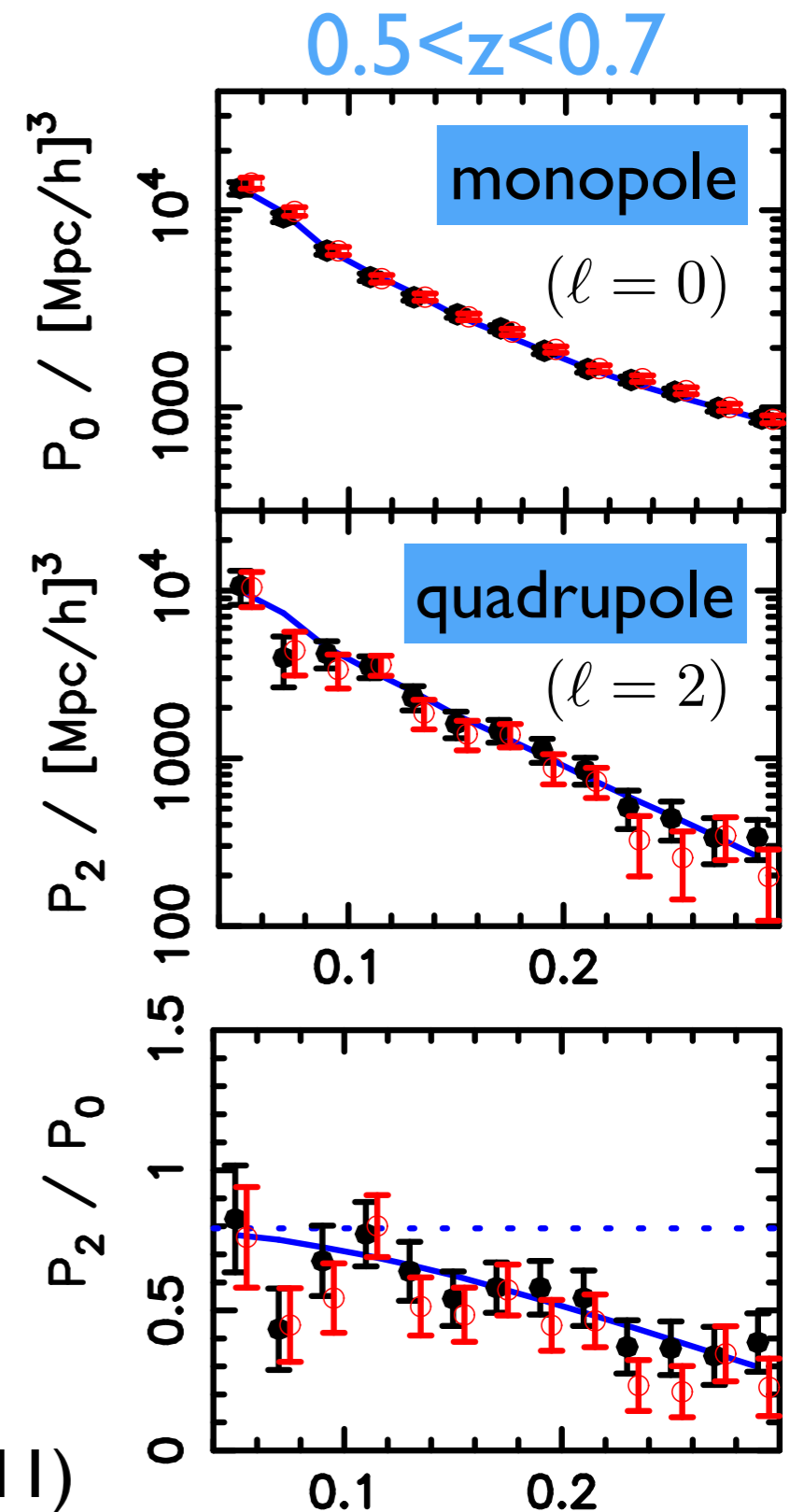
Anisotropic power spectrum

WiggleZ

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



Blake et al. ('11)

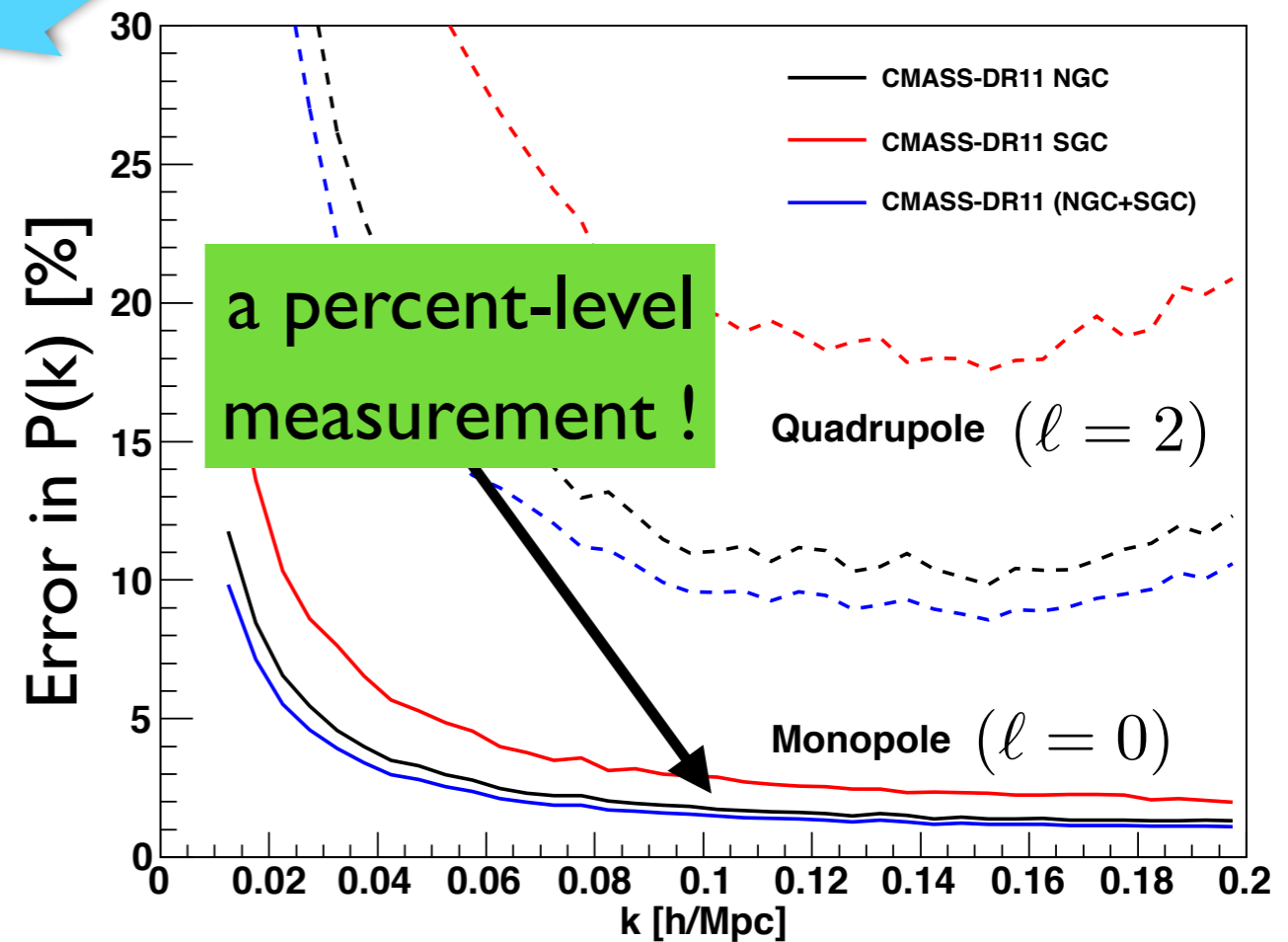
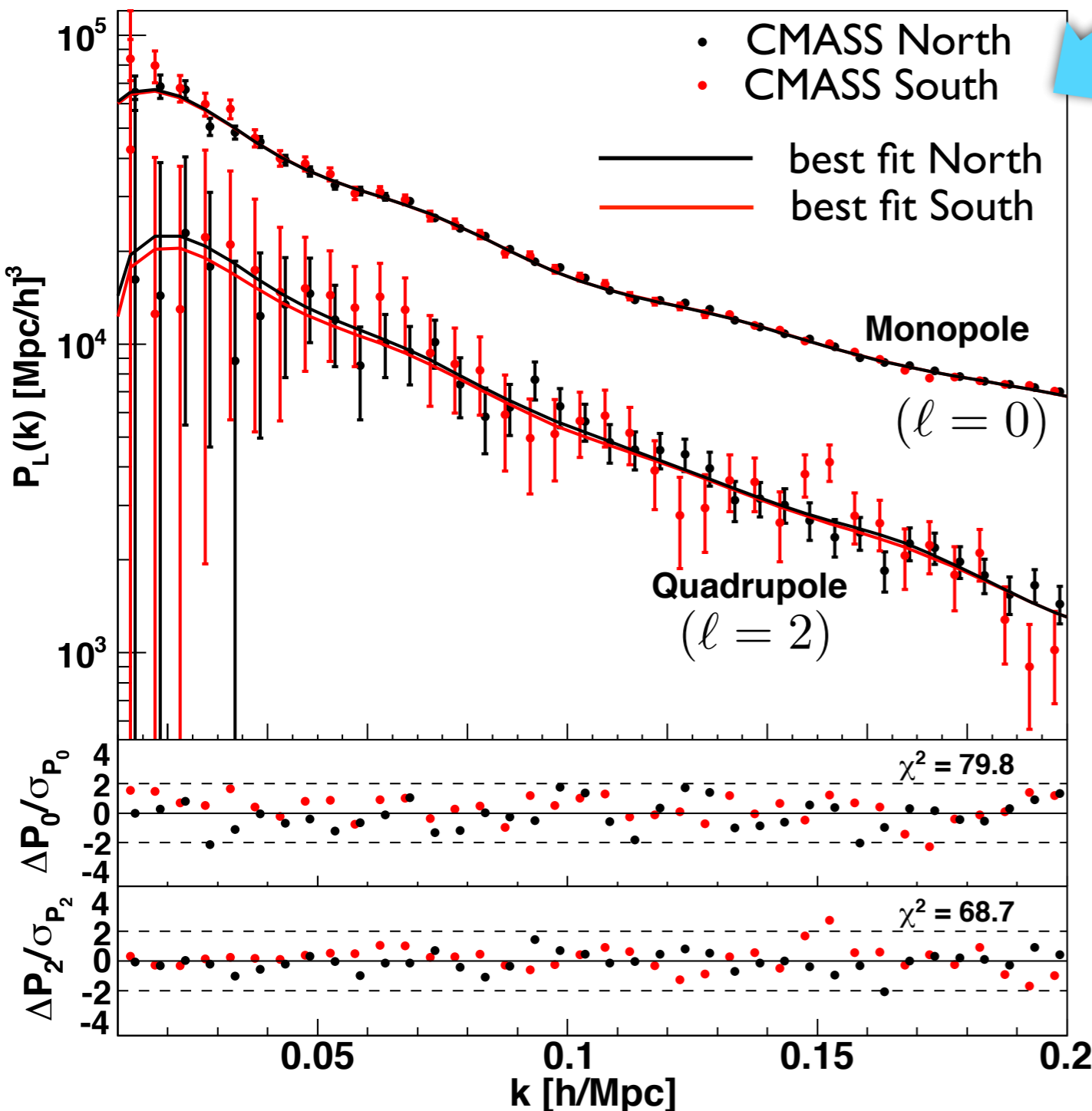


Anisotropic power spectrum

SDSS-III BOSS DR11/12

Beutler et al. ('13)

Based on Yamamoto ('06) estimator

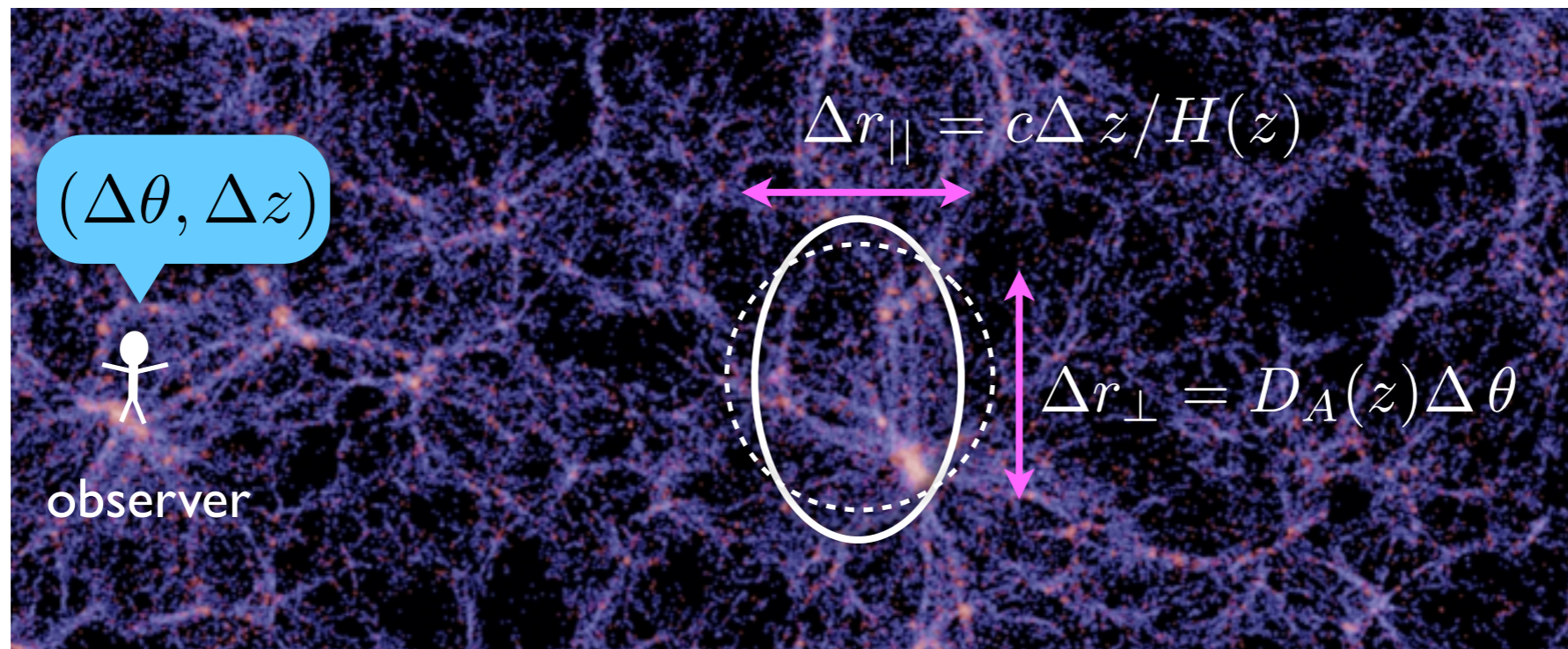


$$P(k_{\parallel}, k_{\perp}) = \sum_{\ell: \text{even}} P_{\ell}(k) \mathcal{P}_{\ell}(k_{\parallel}/k)$$

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

Alcock & Paczynski effect

Cosmological distortions caused by apparent mismatch of underlying cosmological models



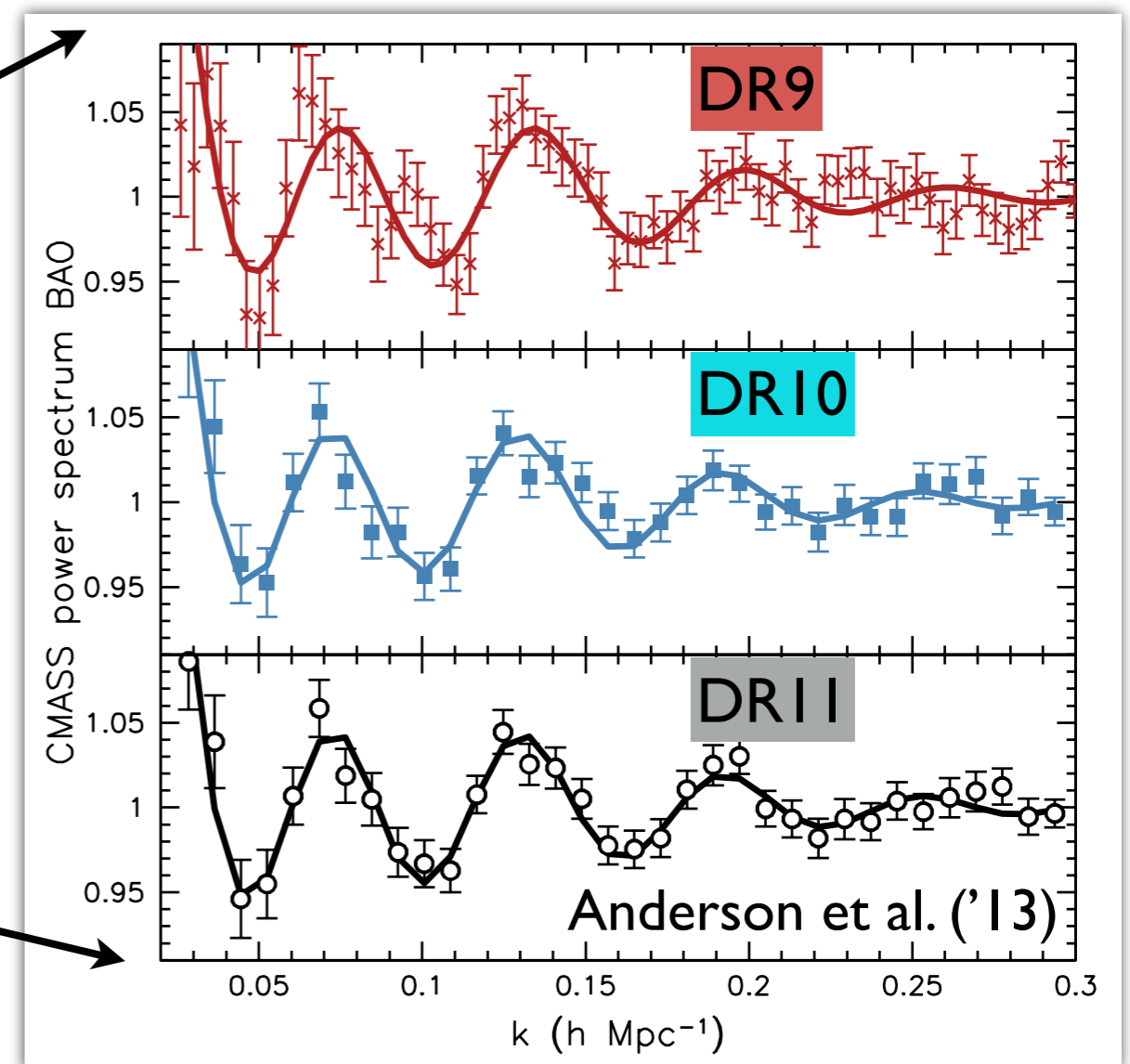
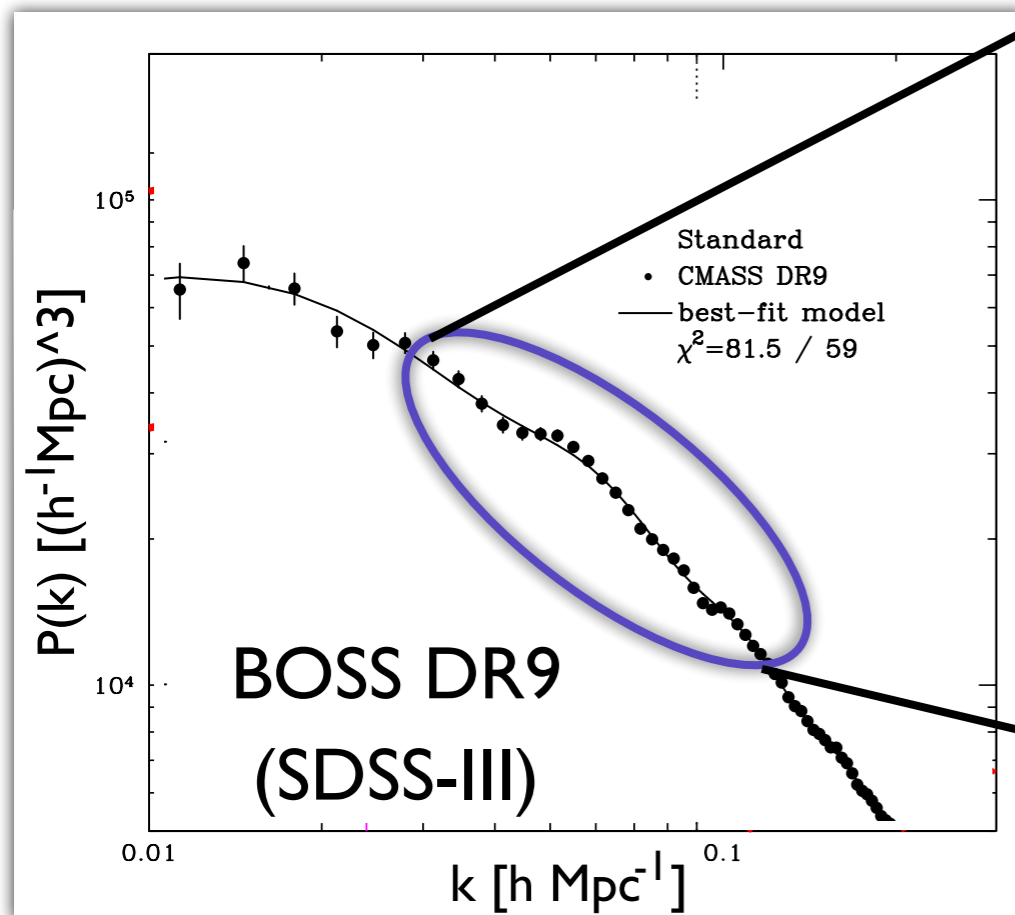
→ can generate higher multipole moments of clustering anisotropies

Using BAO as standard ruler,

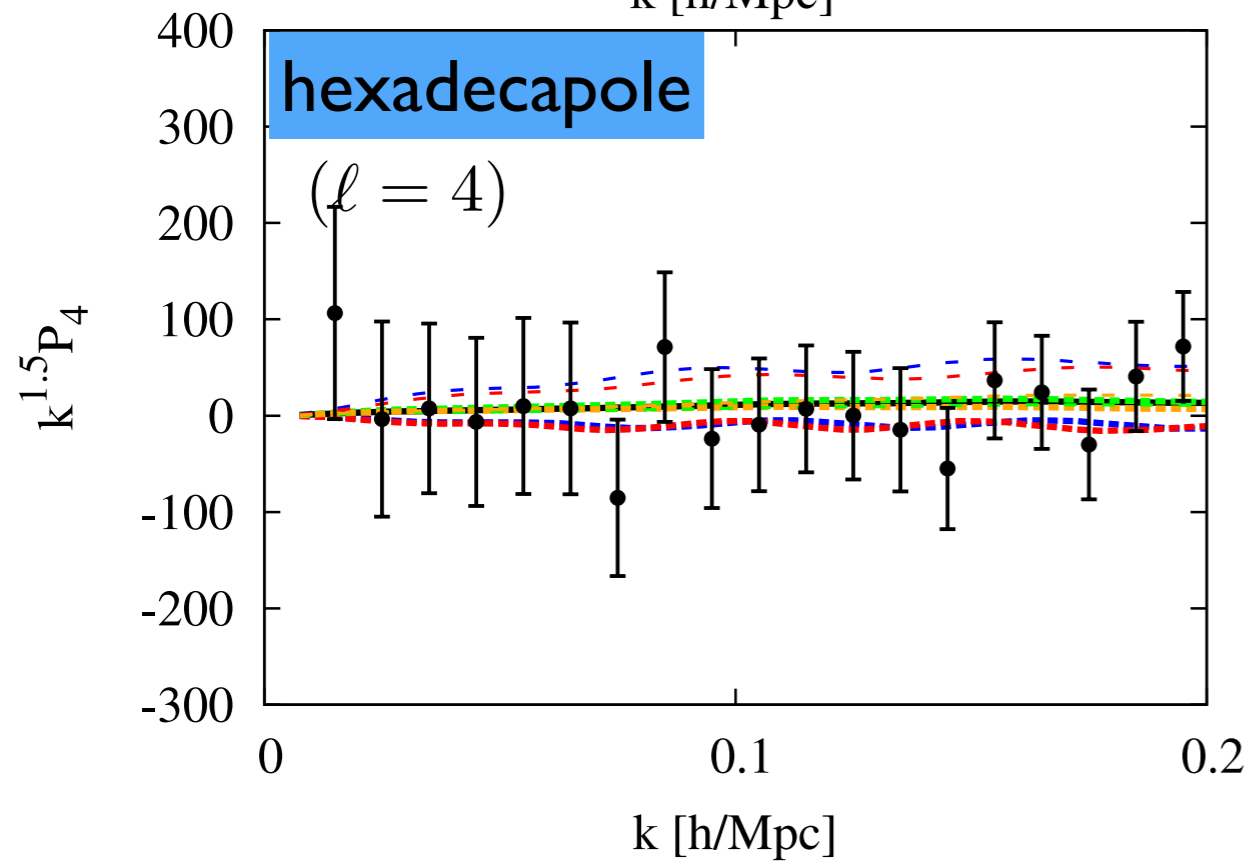
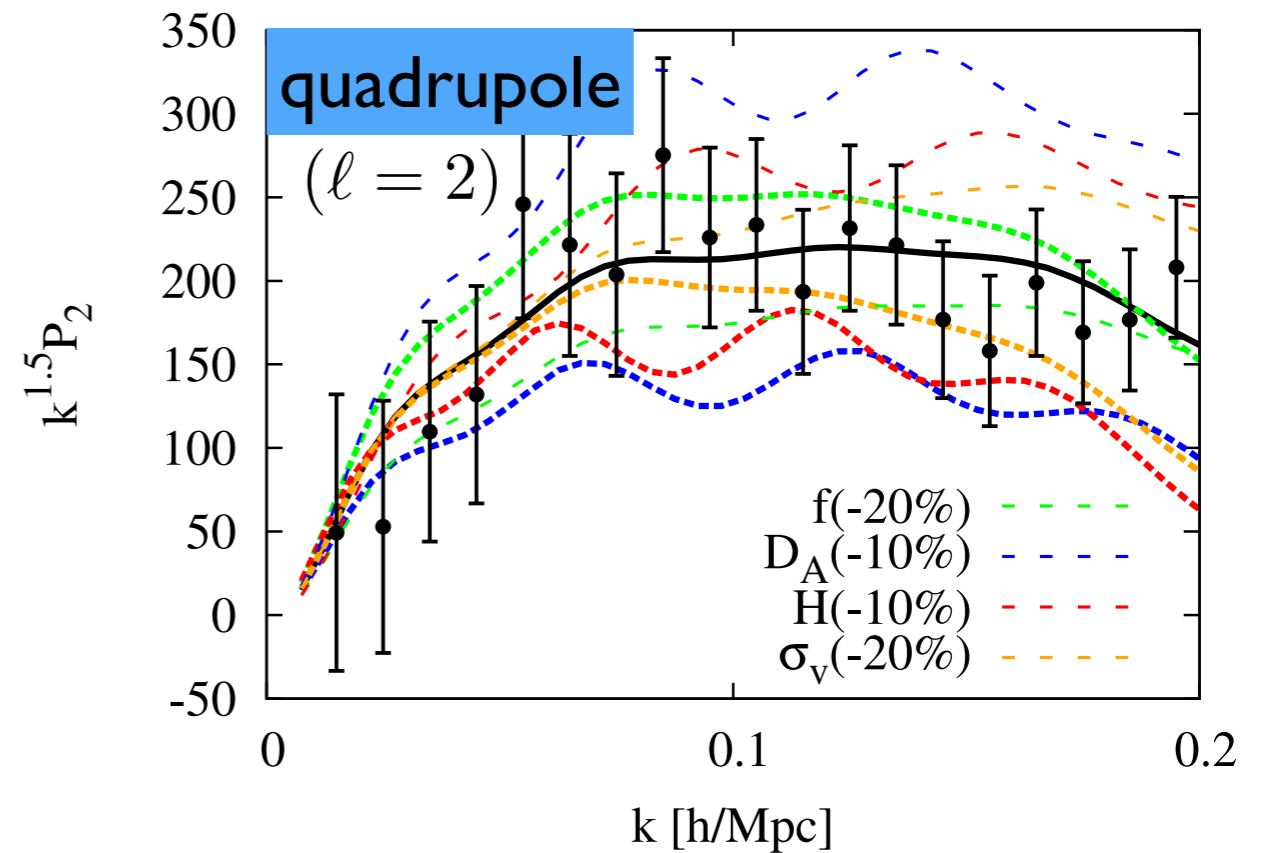
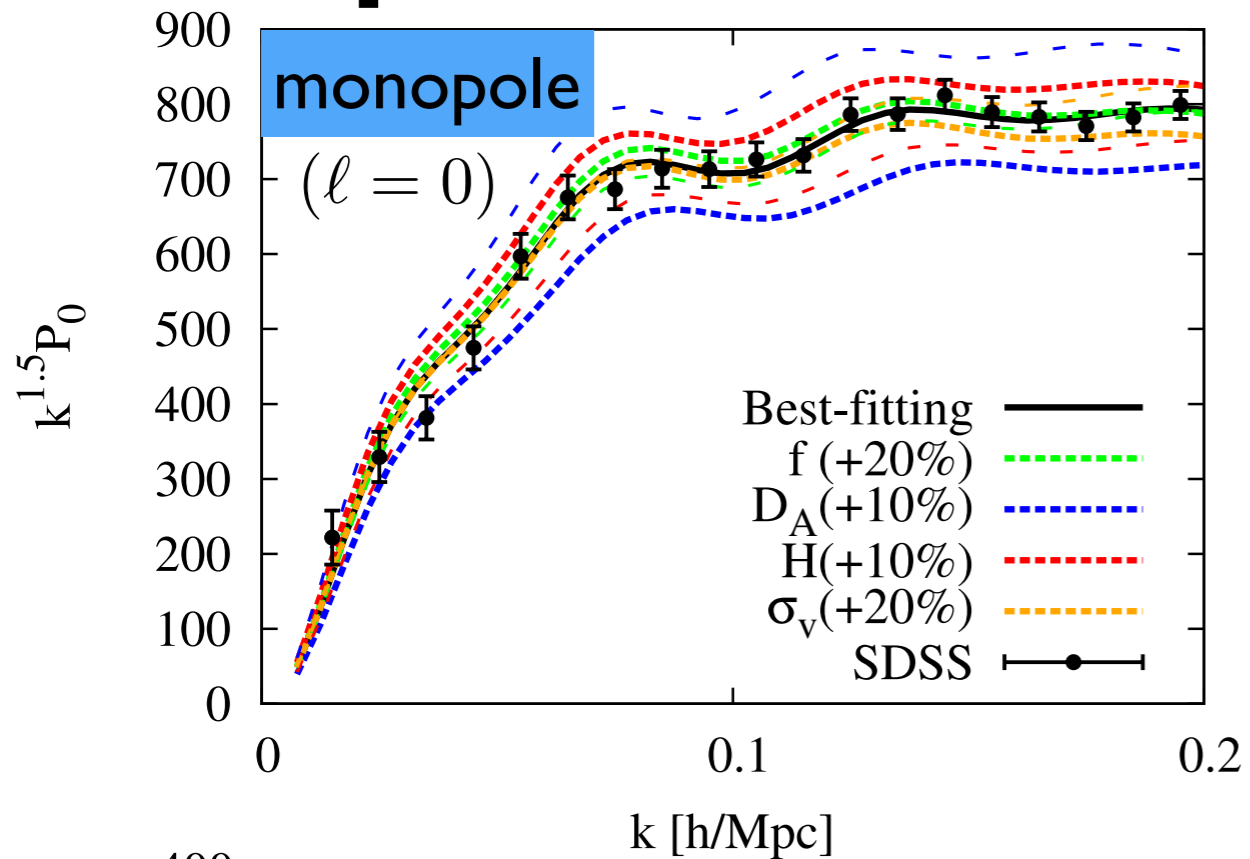
H(z) & **DA(z)** can be measured simultaneously

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

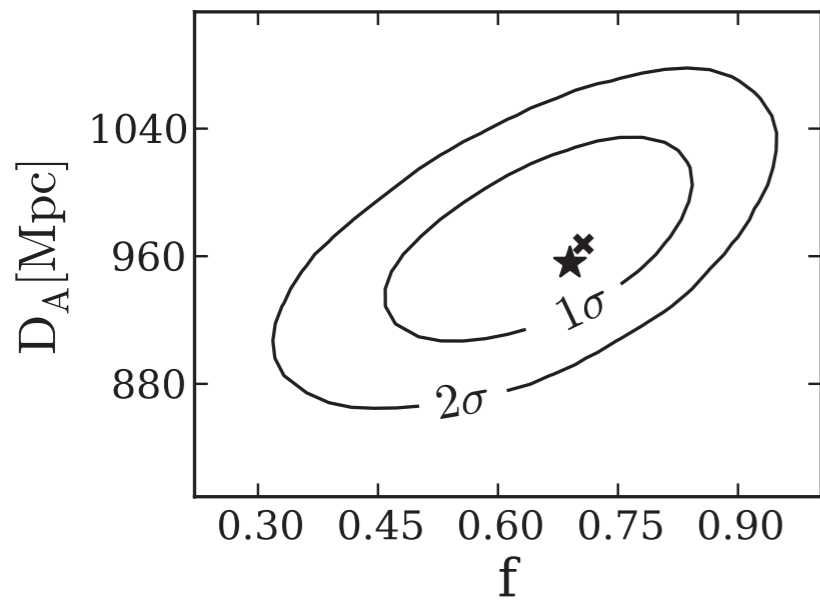


Sensitivity of clustering anisotropies to D_A , H & f

Obs. data: SDSS-II DR7 LRG

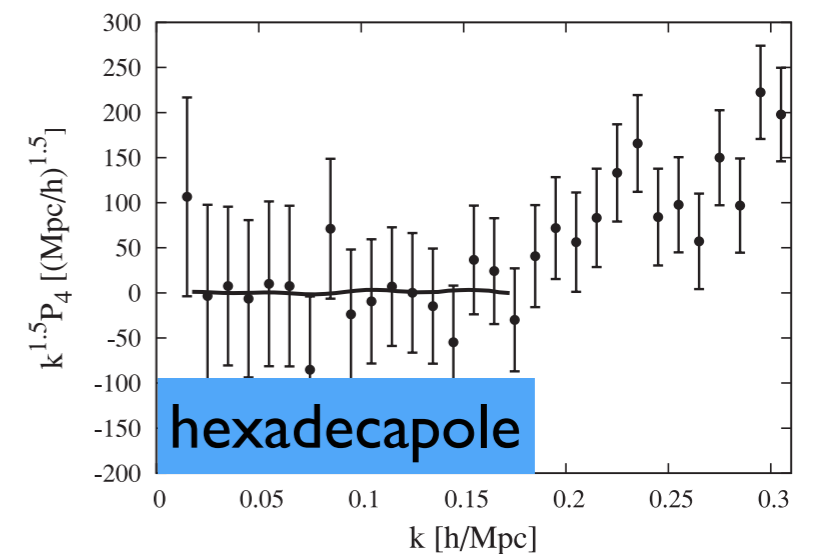
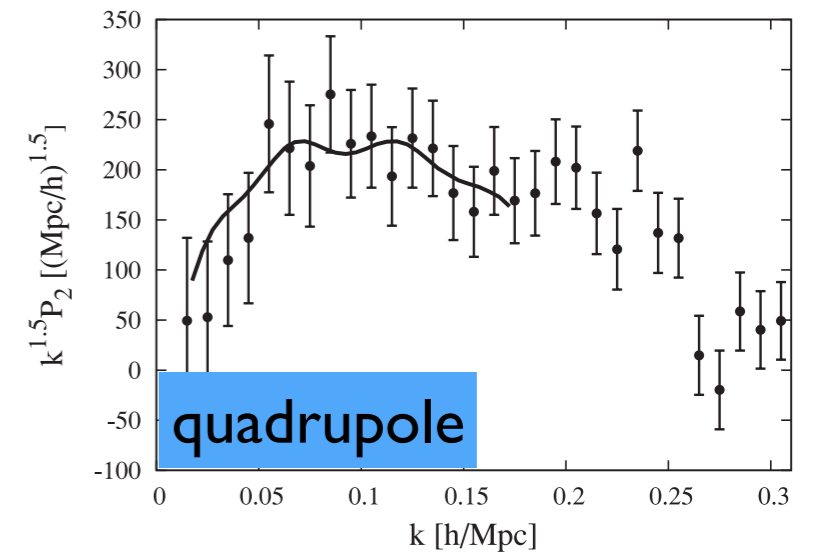
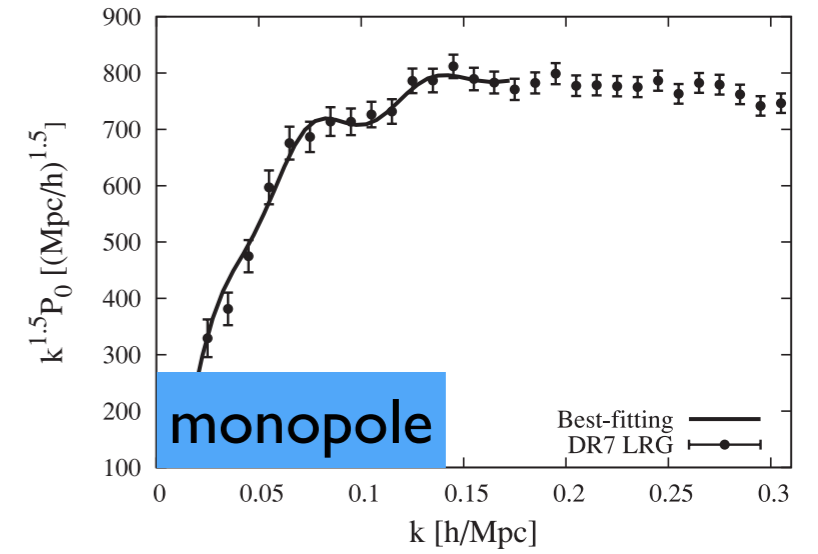
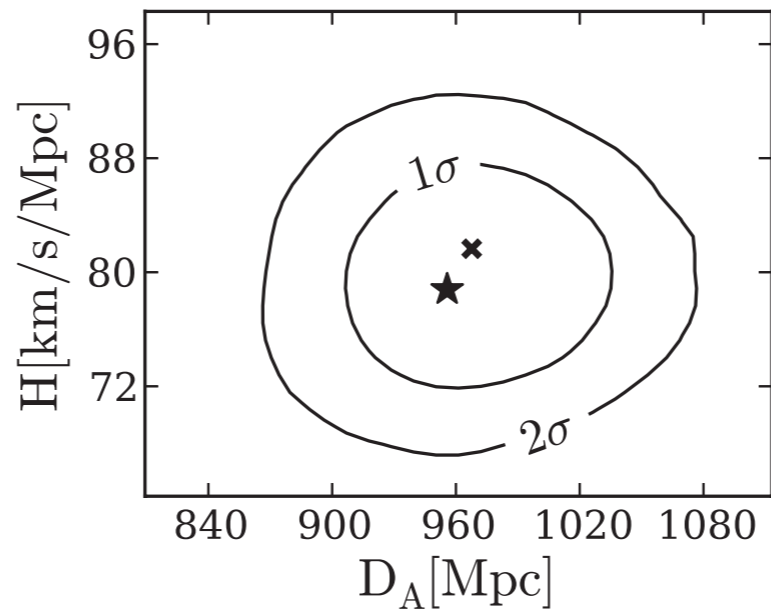
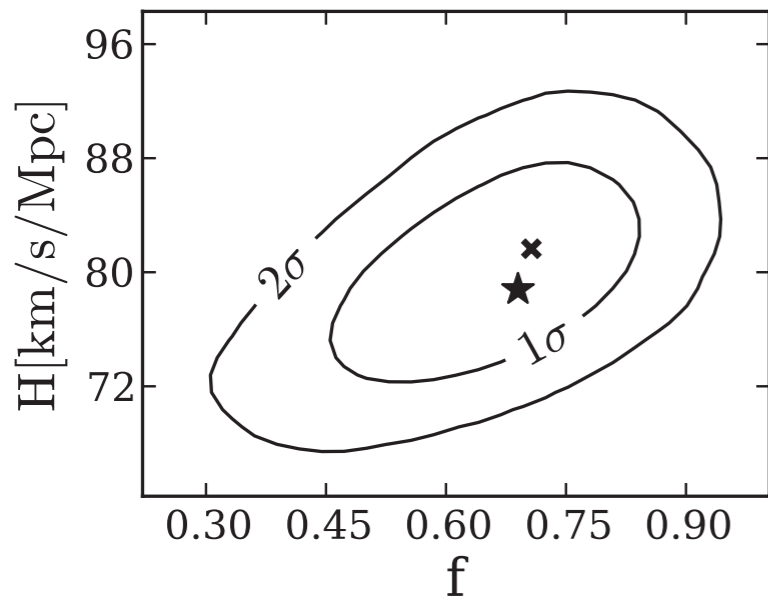
Oka et al.('13) modified

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

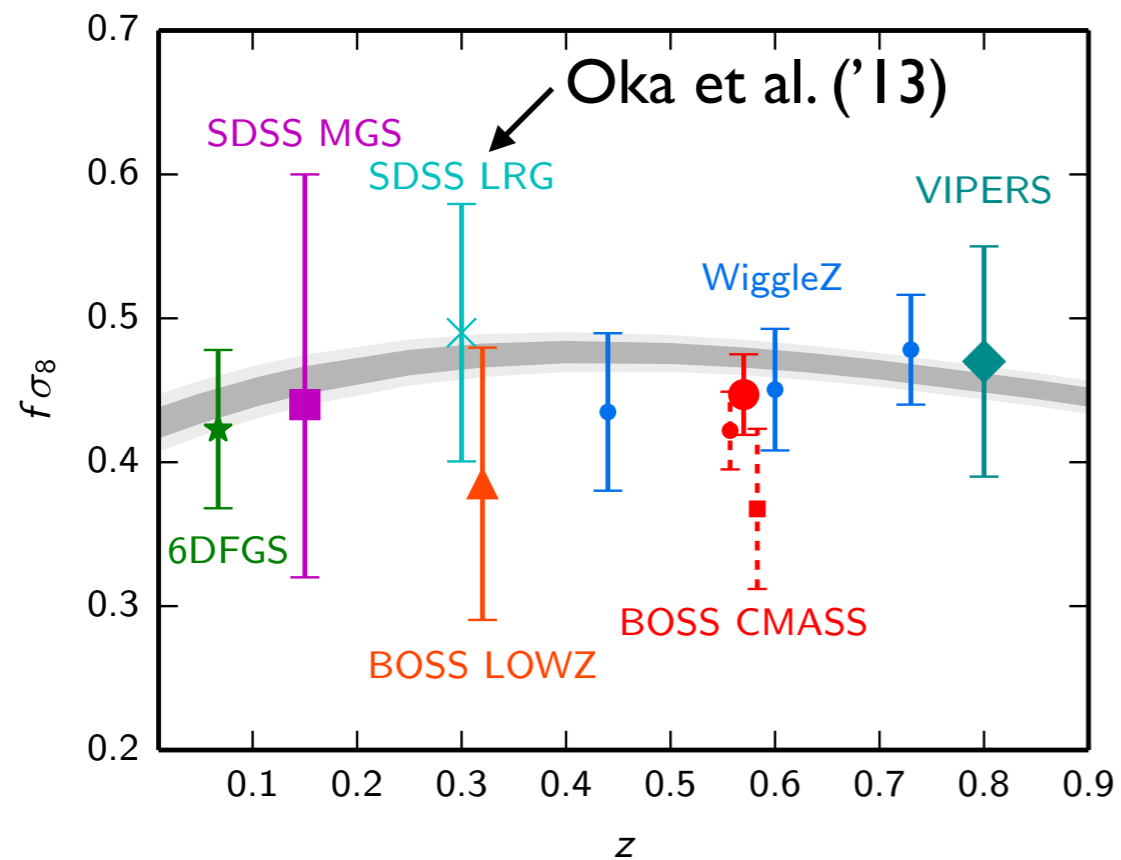
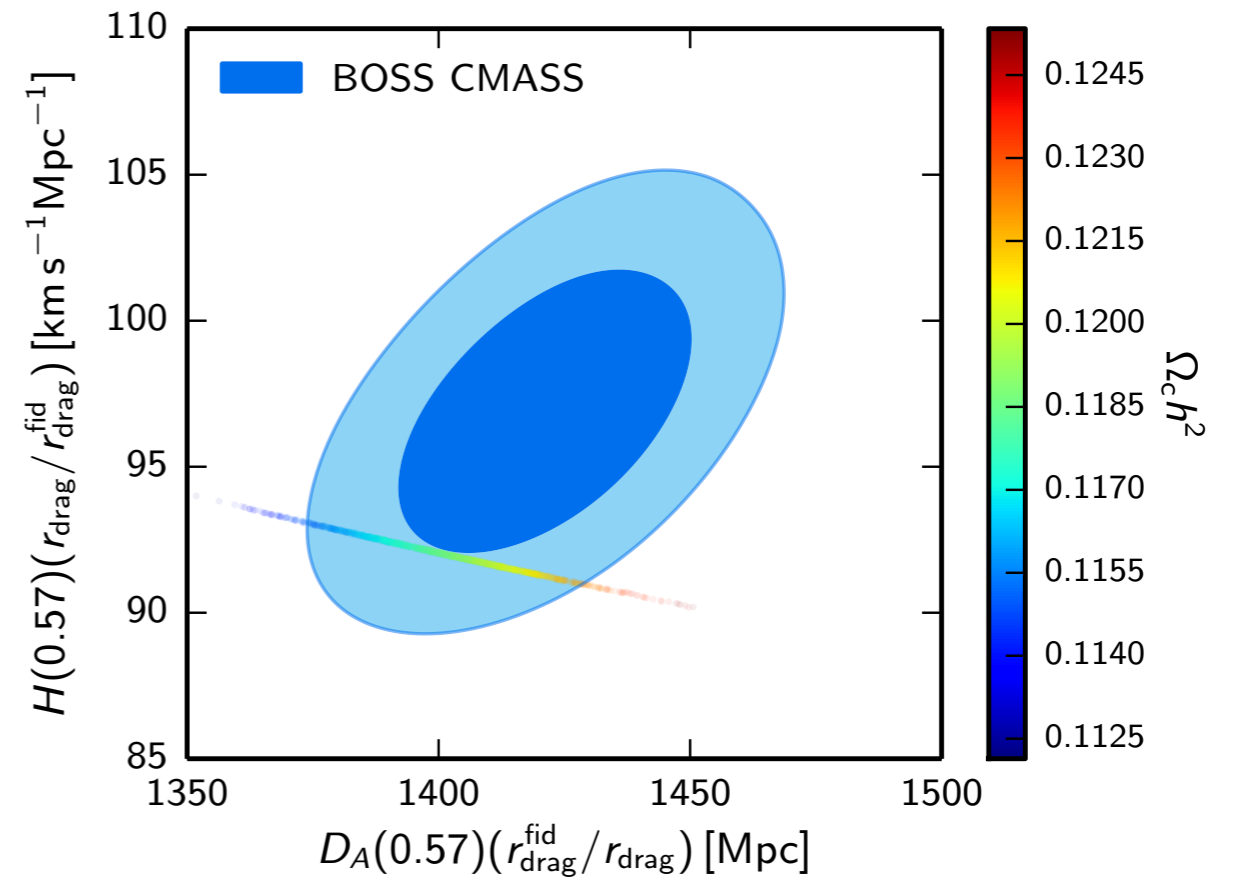
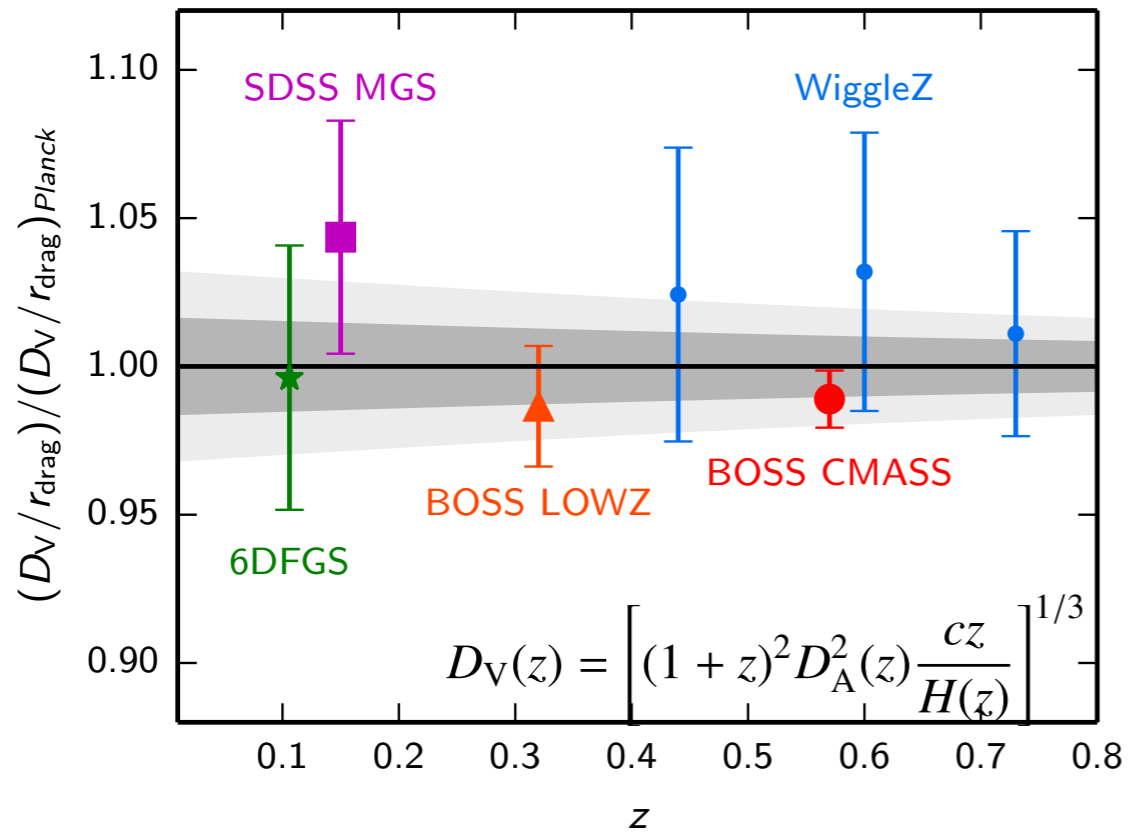


DR7 LRG ($z = 0.3$)

- × Our results
- ★ Planck Λ CDM prediction



Compilation of other observations



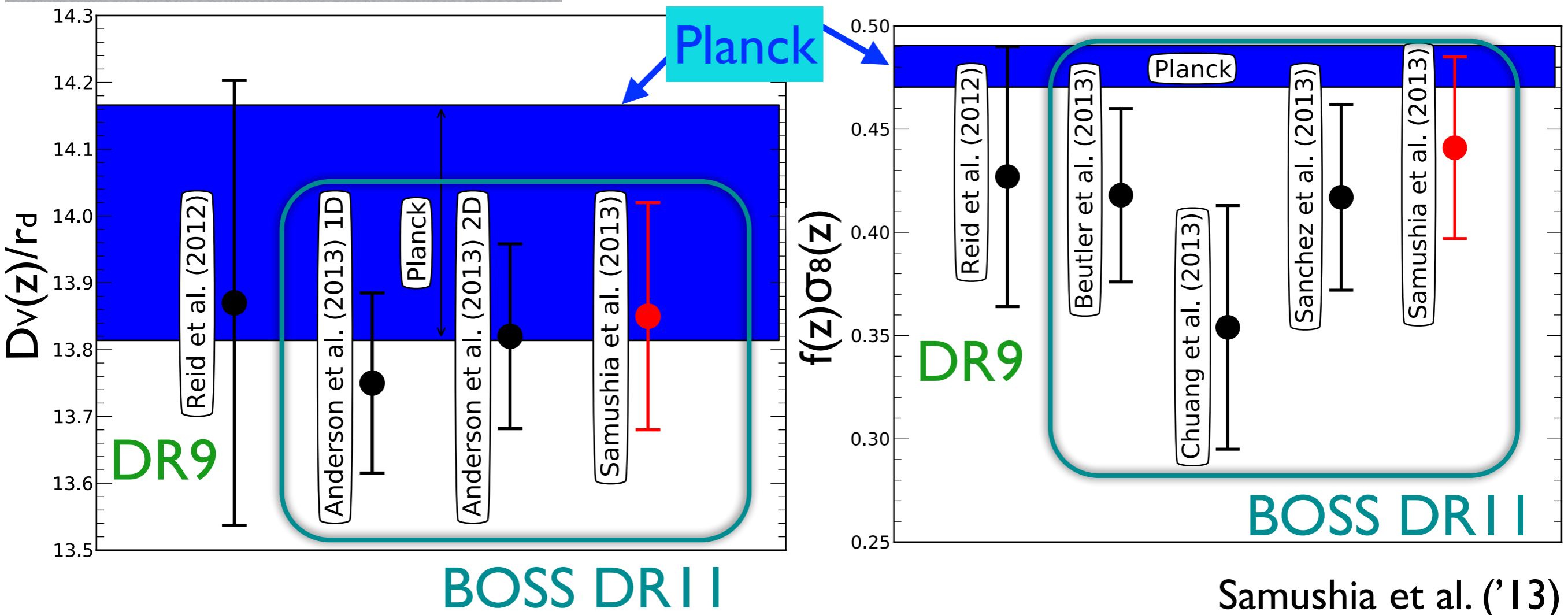
Planck 2015 results. XIII

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)