The Subaru FMOS galaxy redshift survey (FastSound): New constraint on gravity theory from redshift space distortions at z~1.4

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FastSound

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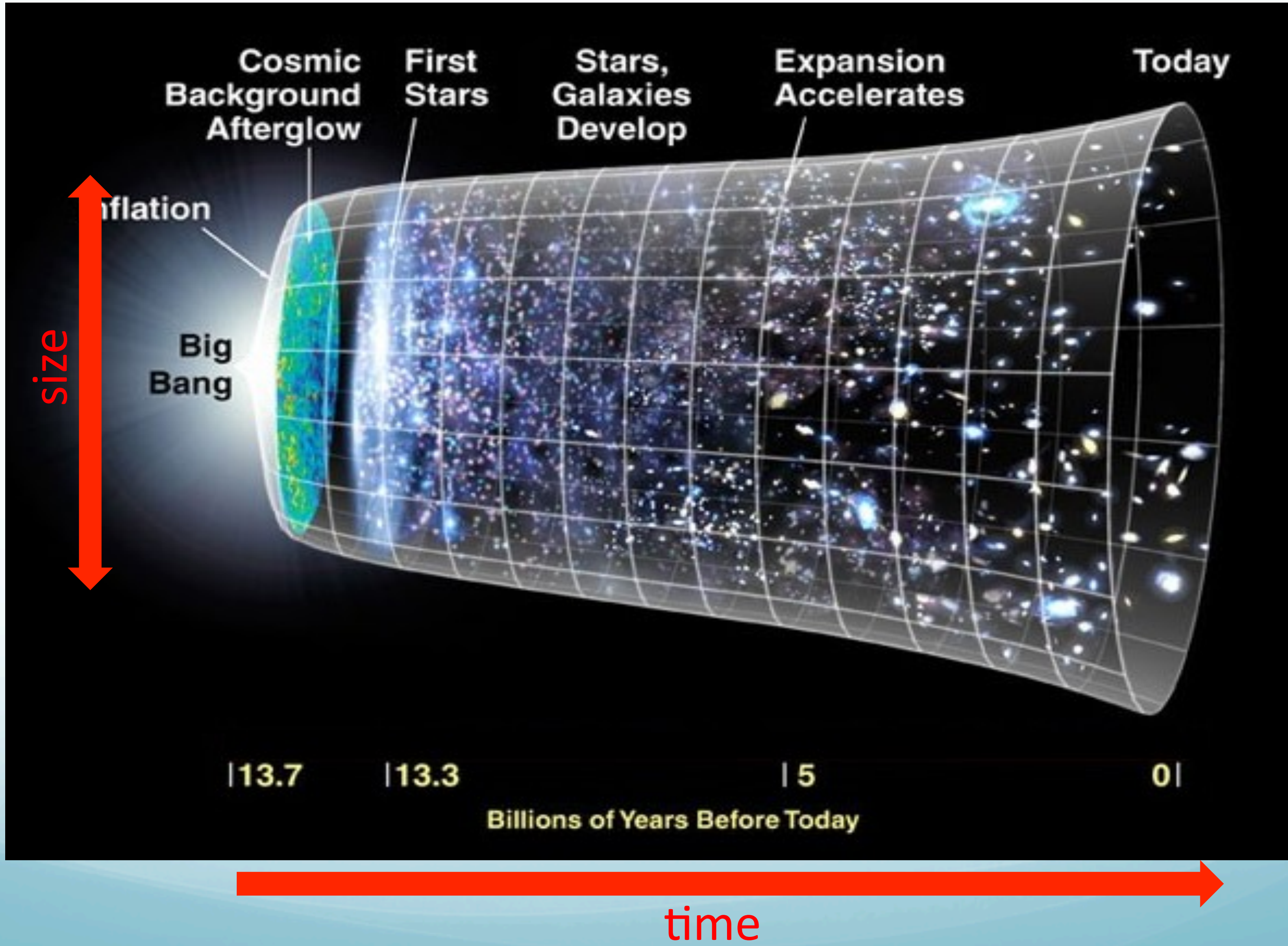
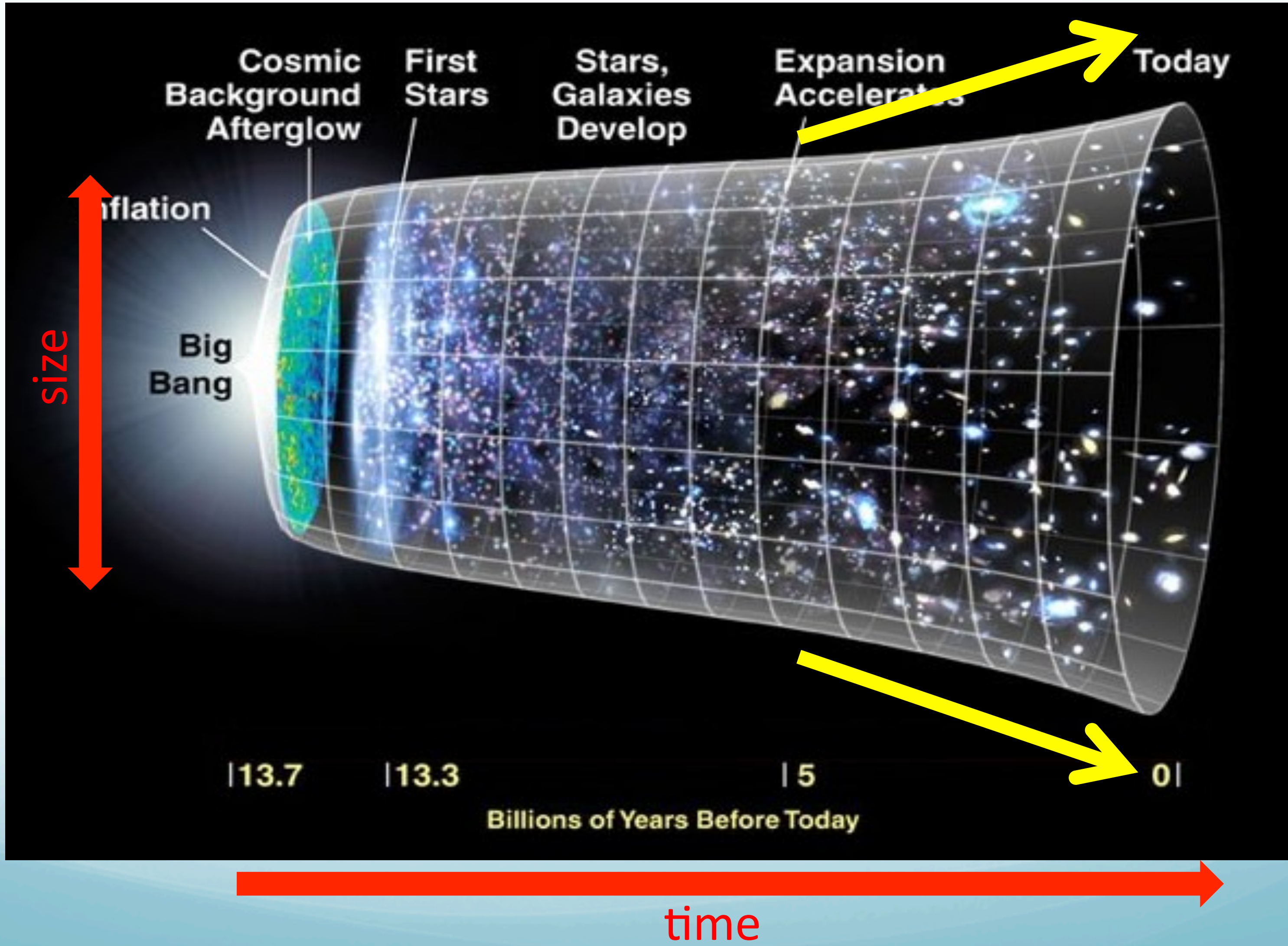
Subaru Users Meeting, Jan 19-21, 2016

Evolution of the expanding Universe



Evolution of the expanding Universe

The expansion is accelerating
= existence of *"Dark Energy"*



What's the origin of the acceleration?

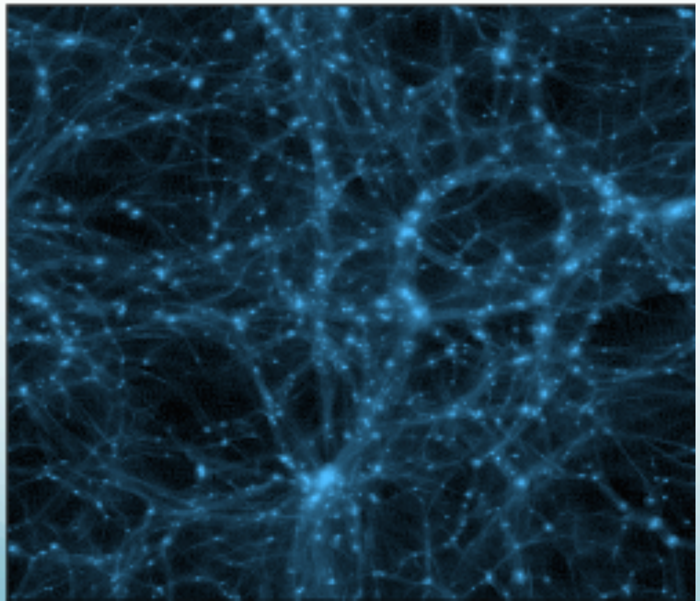
- Dark energy? – probe expansion history (H, D_A,D_L) $G_{\mu\nu} = 8\pi G T_{\mu\nu} + \Delta T_{\mu\nu}$
- Modified gravity? – probe growth of cosmic structure $G_{\mu\nu} + \Delta G_{\mu\nu} = 8\pi G T_{\mu\nu}$

  ($f = d \ln\delta / d \ln a$)

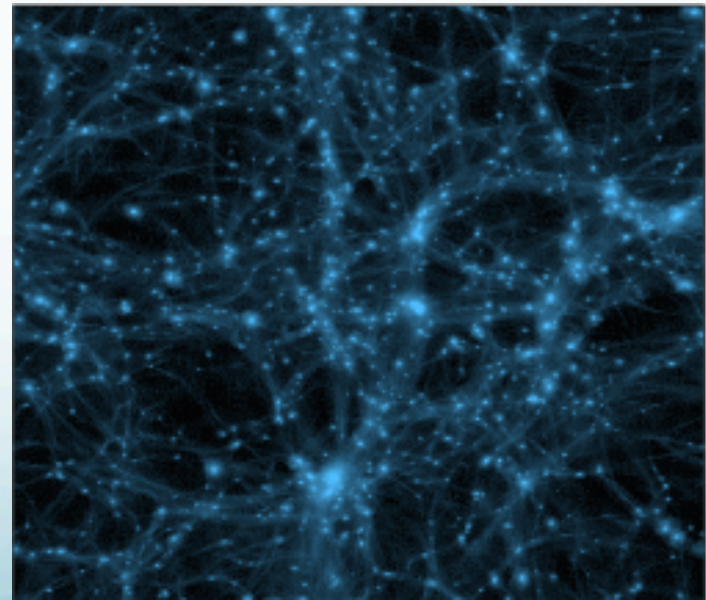
Distribution of galaxies tells properties of gravity

- Cosmic structures grow differently for different gravity models
  - N-body simulations with the same initial condition

General relativity



$f(R)$ gravity



Figures taken from Zhao et al

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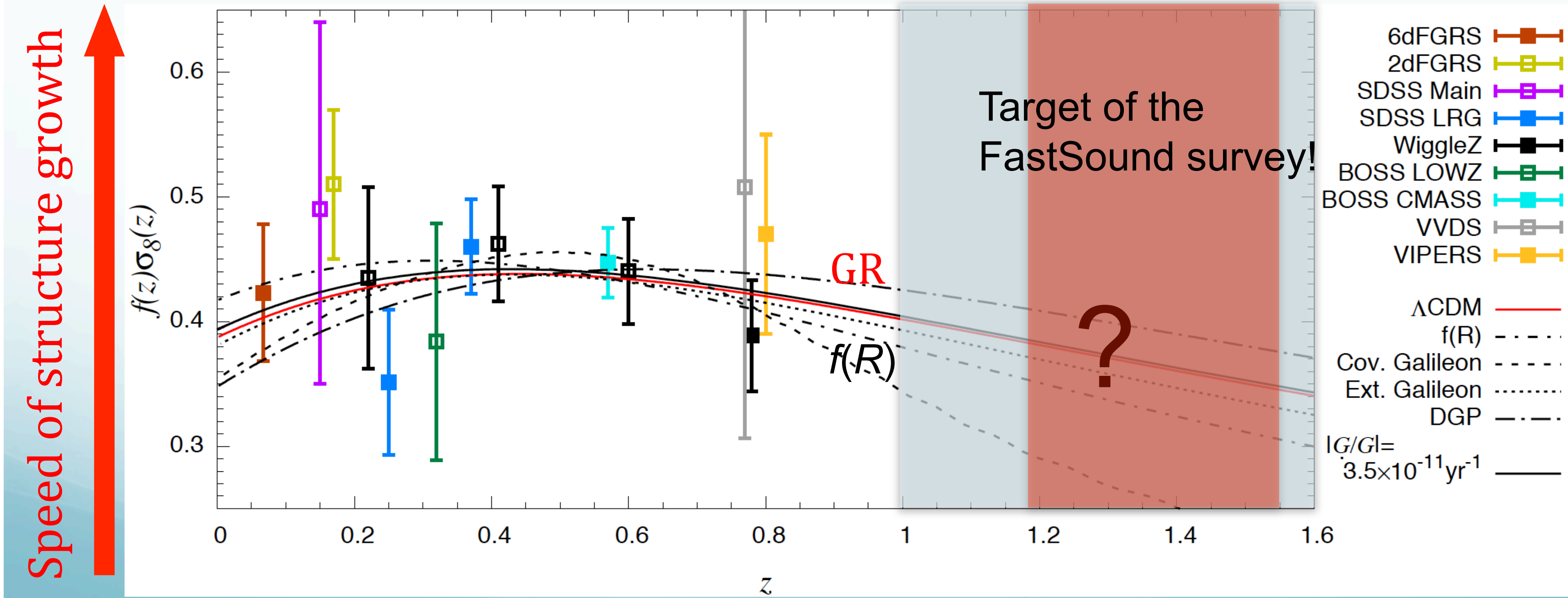
  $(f = d \ln\delta / d \ln a)$

- Current constraints on the growth rate from galaxy surveys

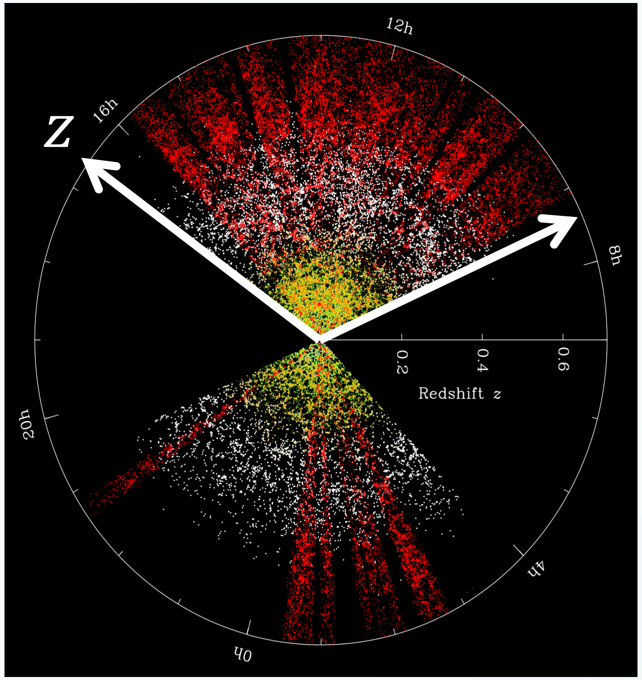


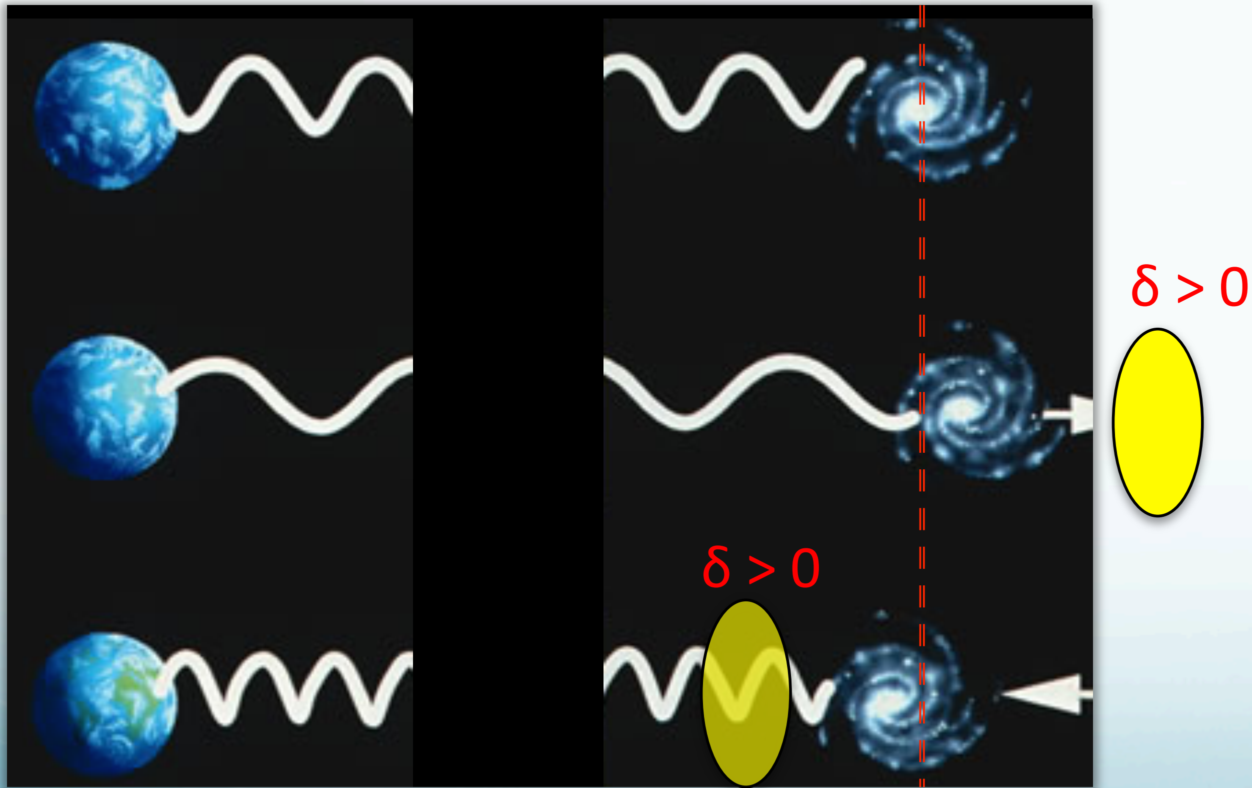
- Lines: predictions from different gravity models (LSS-normalized)

Redshift space distortions (RSD)

- Radial coordinates of galaxies are measured through redshift *z* (Doppler shift)

Redshift z = peculiar velocity + expansion
distance





- Only radial positions are affected by RSD, not angular positions.

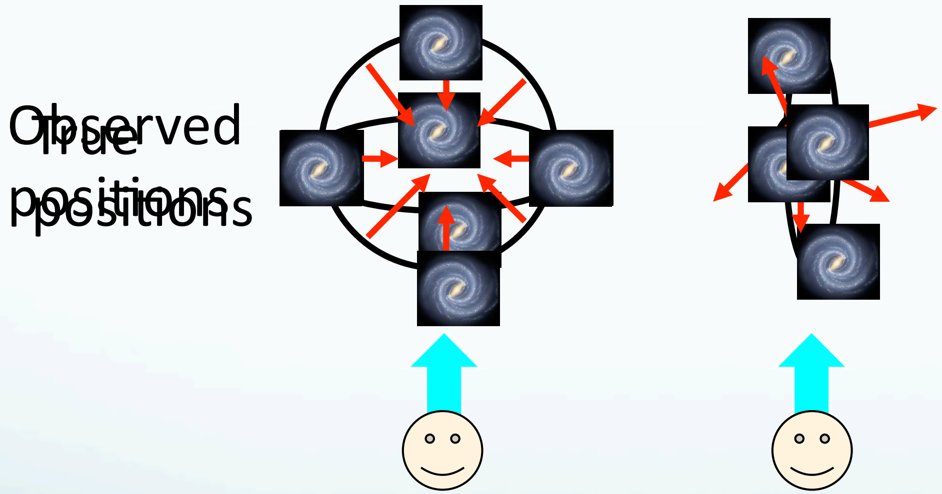
Redshift space distortions (RSD)

- Radial coordinates of galaxies are measured through redshift z (Doppler shift)

Redshift z = peculiar velocity + expansion

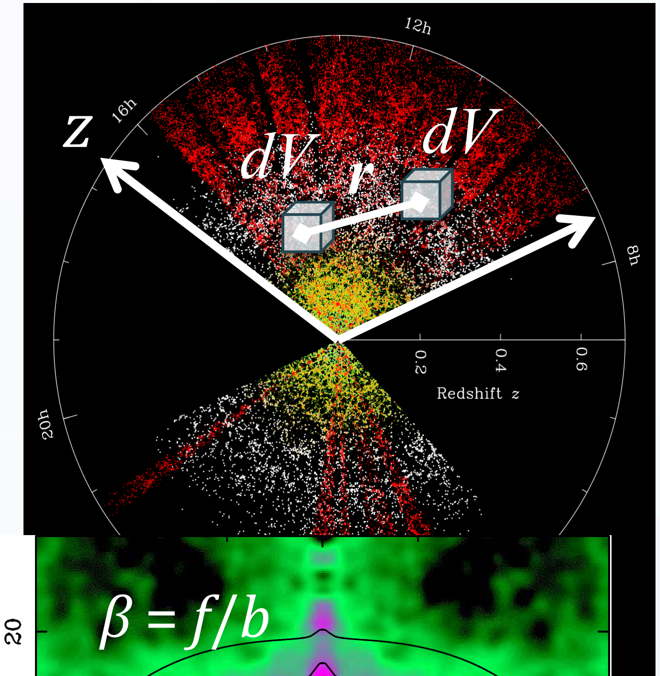
distance

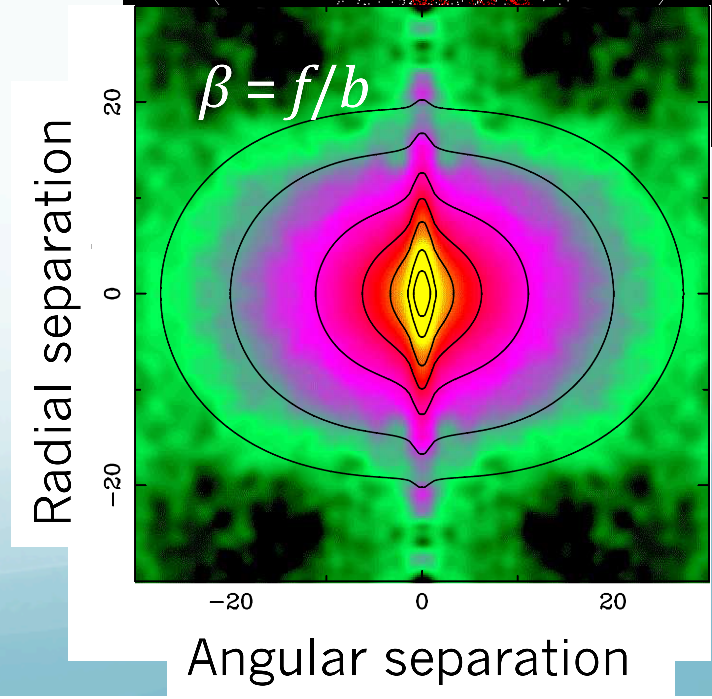
linear RSD non-linear RSD



Clustering is : enhanced suppressed

on : large scales small scales

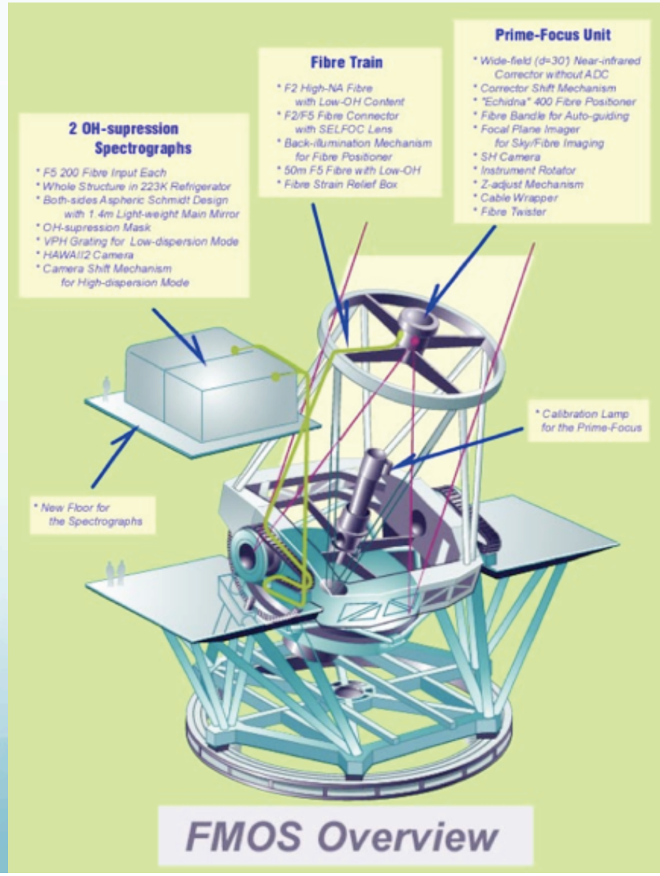




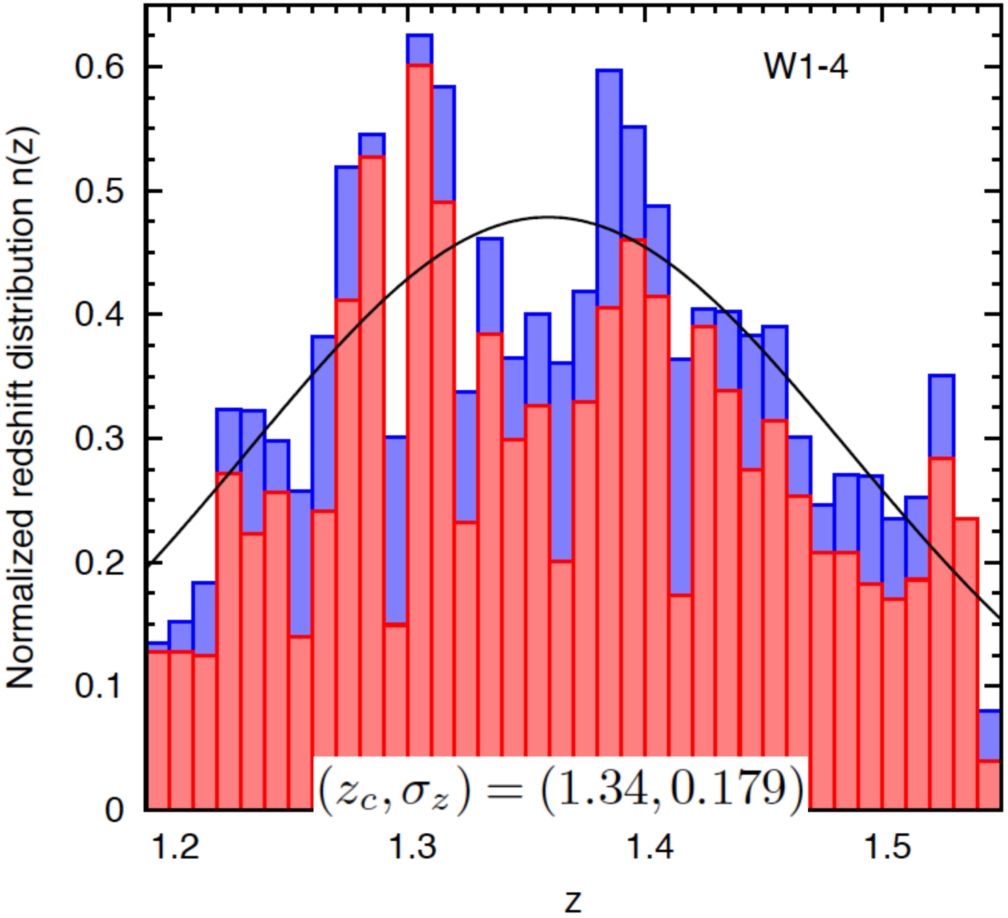
Peacock+(2001) Nature

FastSound survey in one slide

- Cosmology-purpose redshift survey by FMOS of Subaru Telescope
- 20 deg^2, ~4000 galaxy redshifts in 4 CFHTLS Wide fields
  - Targeting Hα emitting galaxies at z~1.2-1.5
  - Target selection: photo-z & Hα flux est. by five optical (ugriz) bands
  - 30 min. exposures for each field-of-view (0.2deg^2)
  - ~10% detection efficiency for 400 FMOS fibers
  - ~40 nights for 2 years from Mar. 2012 – Jul. 2014

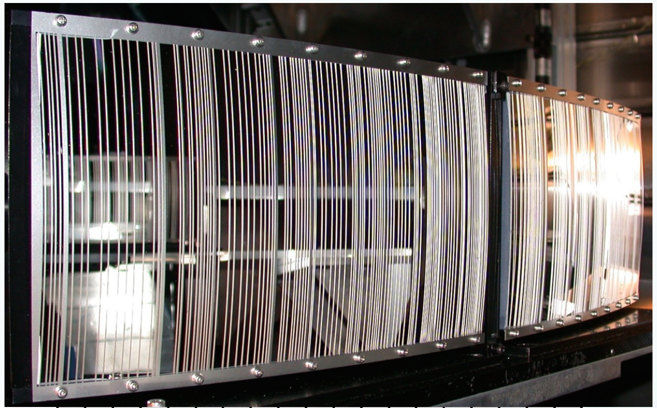


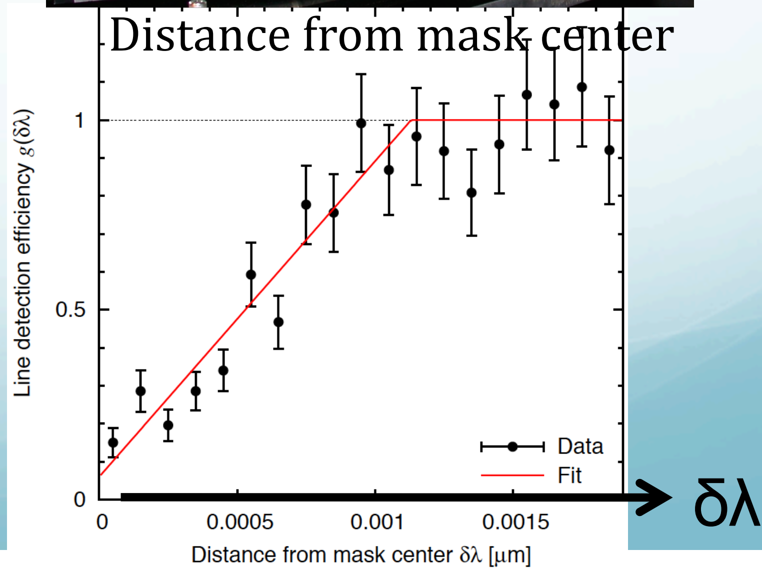
Radial distribution of FastSound galaxy sample



$$y = Az^2 \exp\left(-\frac{(z - z_c)^2}{\sigma_z^2}\right)$$

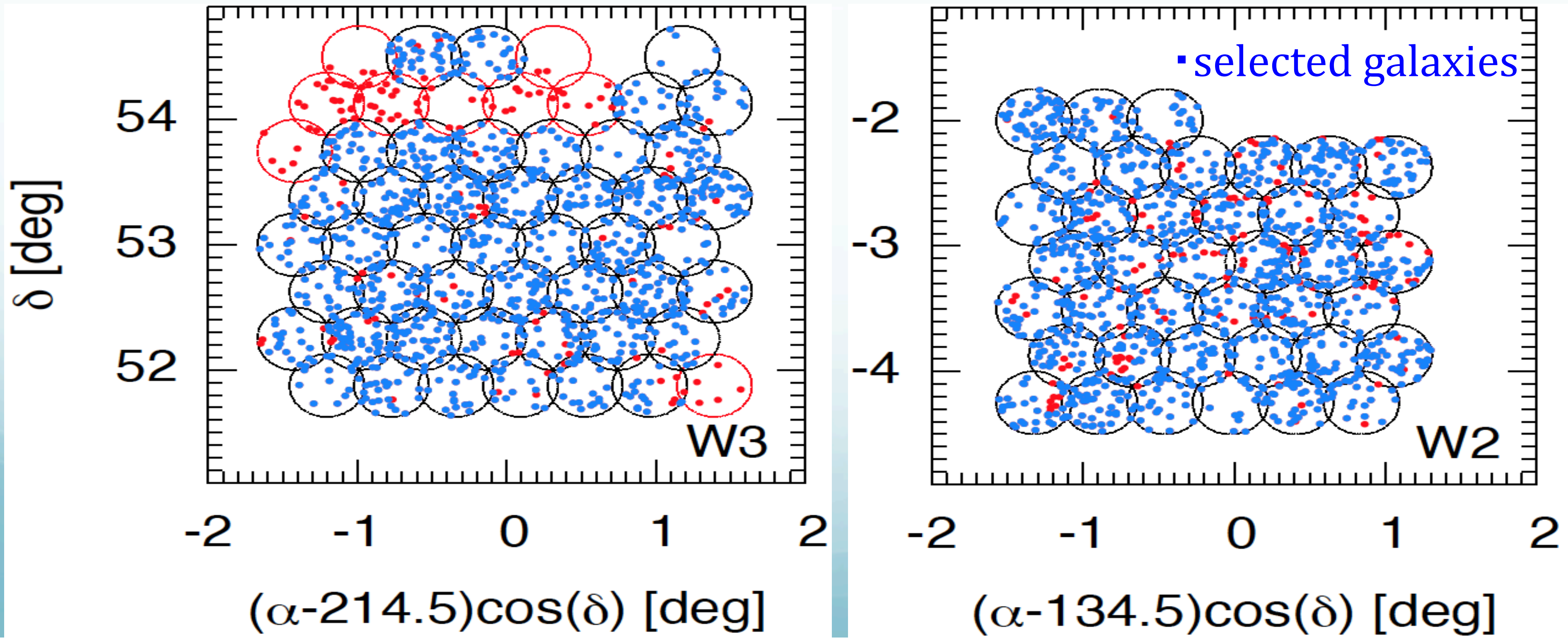
- Decrease of detection efficiency for emission line due to OH masks



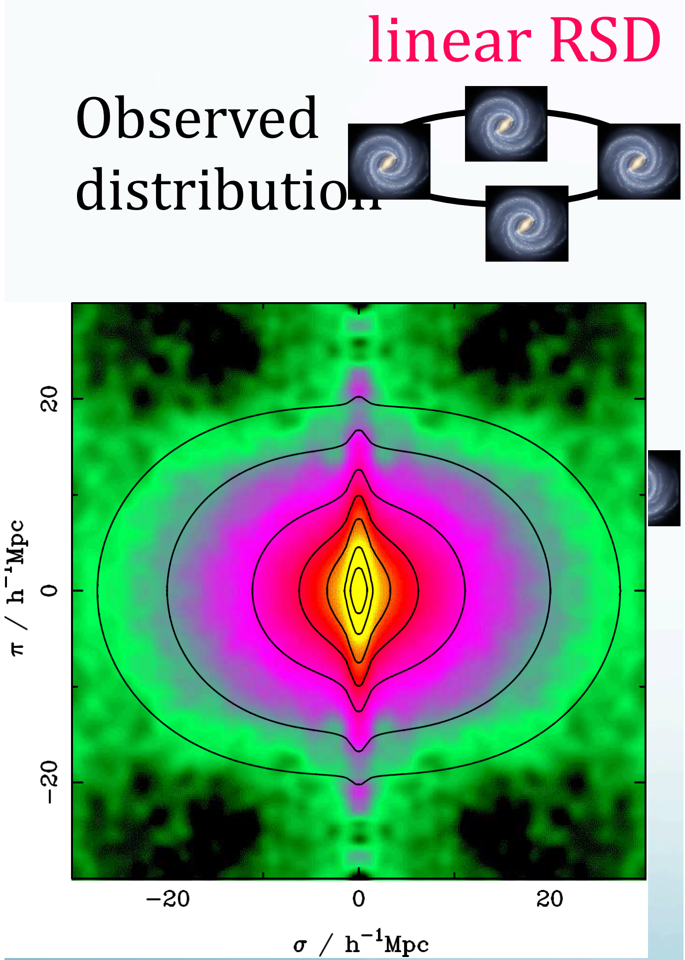


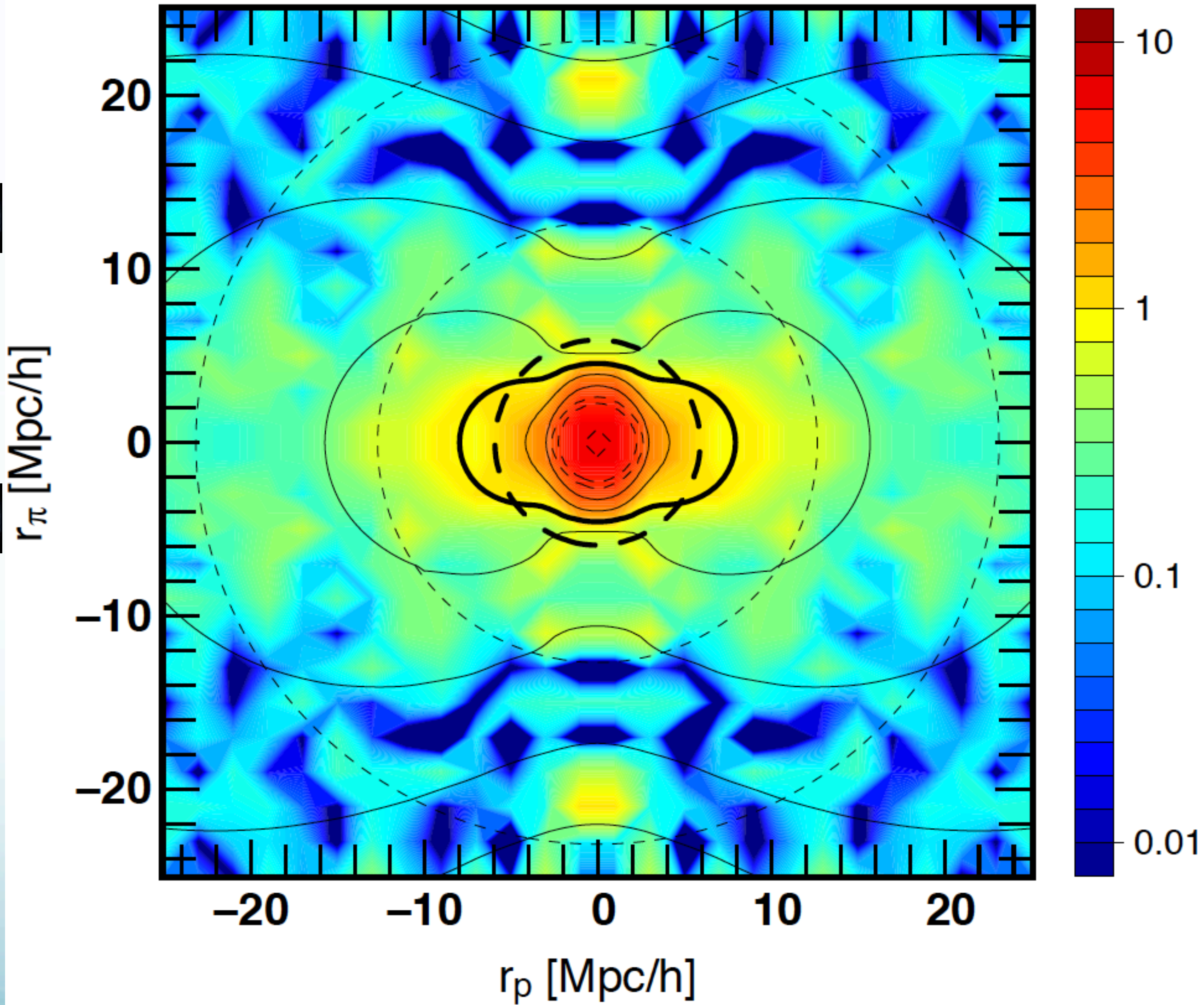
Angular distribution of FastSound galaxy sample

# of data with line S/N>4.5	W1	W2	W3	W4	W1-4
Total number	211	1295	1286	383	3175
Selected number	197	1165	1145	276	2783



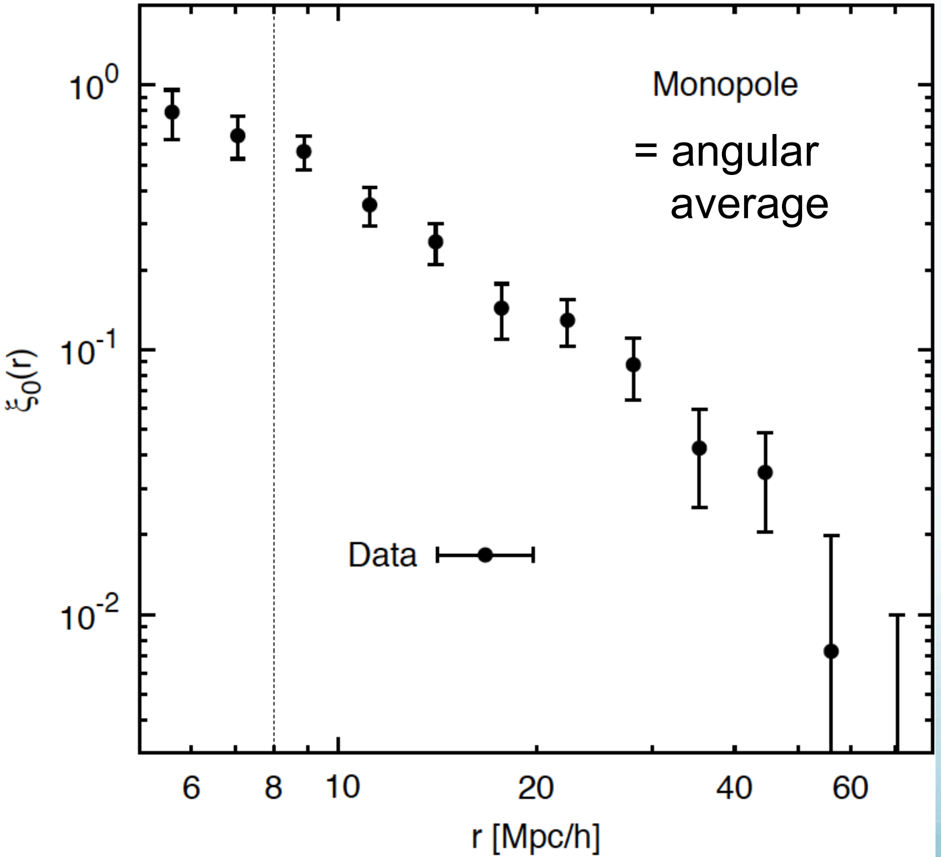
Anisotropic correlation function measured at $z \sim 1.4$

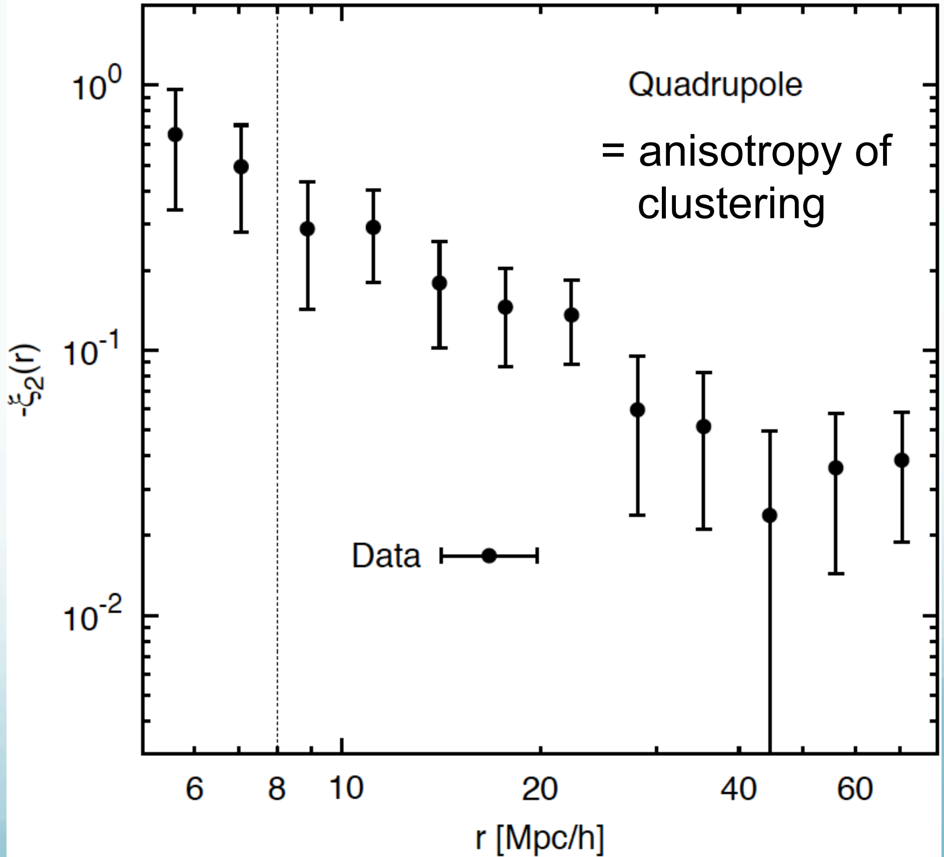




Monopole and quadrupole moments

$$\xi_l^s(r) = \frac{2l+1}{2}\int_{-1}^{1}\xi^s(r_p, r_\pi)\mathcal{P}_l(\mu)d\mu$$





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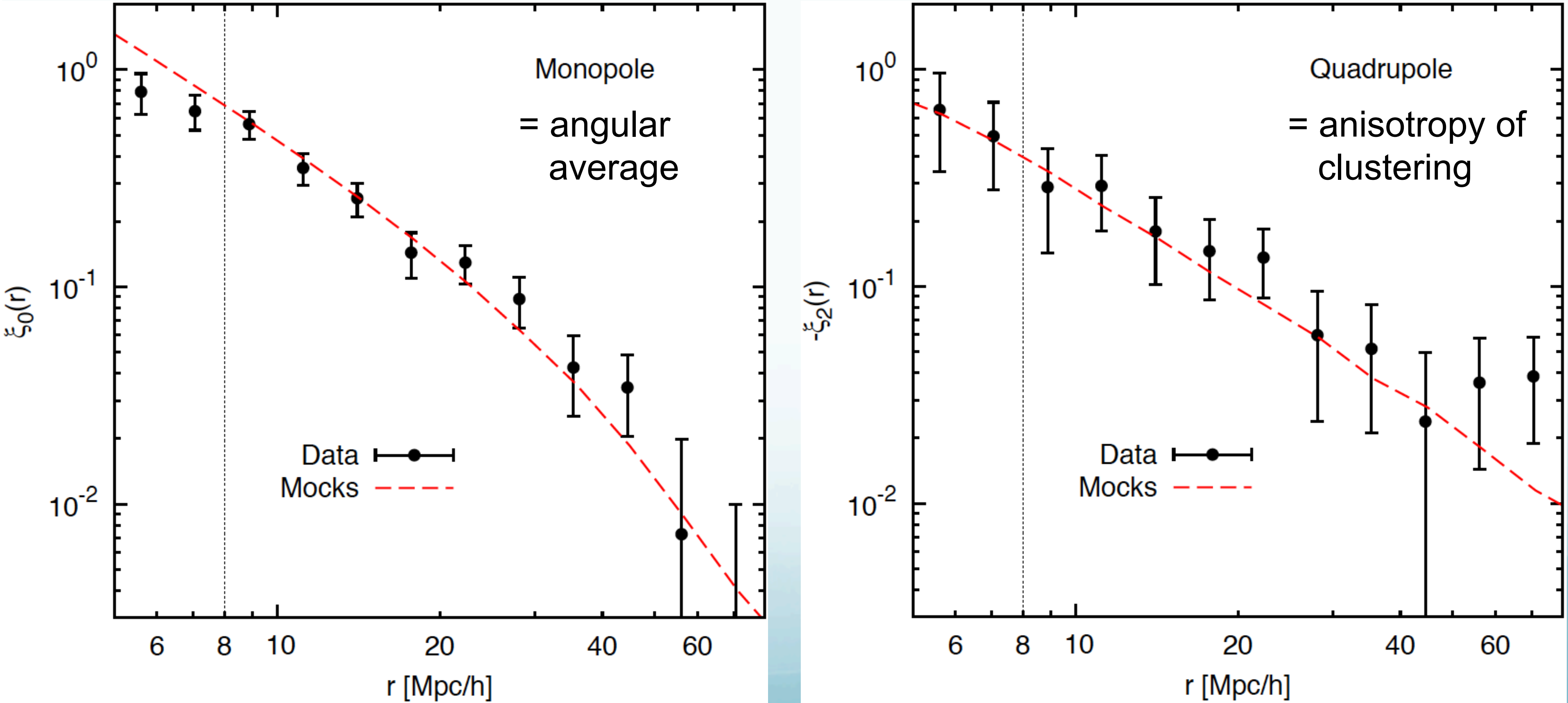


Redshift blunder corrections

- Two sources
  - Fake (noise) lines ~ 4.1% (for sample with S/N>4.5)
  - OIII doublets ~ 3.2%
- $1-f_{blund}=(1-f_{fake})(1-f_{\mathrm{OIII}})=0.929$
- Simple model

$$\xi^{true}(r)=\xi^{true}(r)(1-f_{blund})^{-2}$$

  - We assume these blunders do not have clustering or are not correlated with the true galaxy distribution
  - This is not true, but the former is suppressed by f_{blund}^2 and the latter by f_{blund}

Joint constraints on growth rate and bias

$$\chi^2 = \chi^2(f\sigma_8, b\sigma_8, \sigma_v)$$

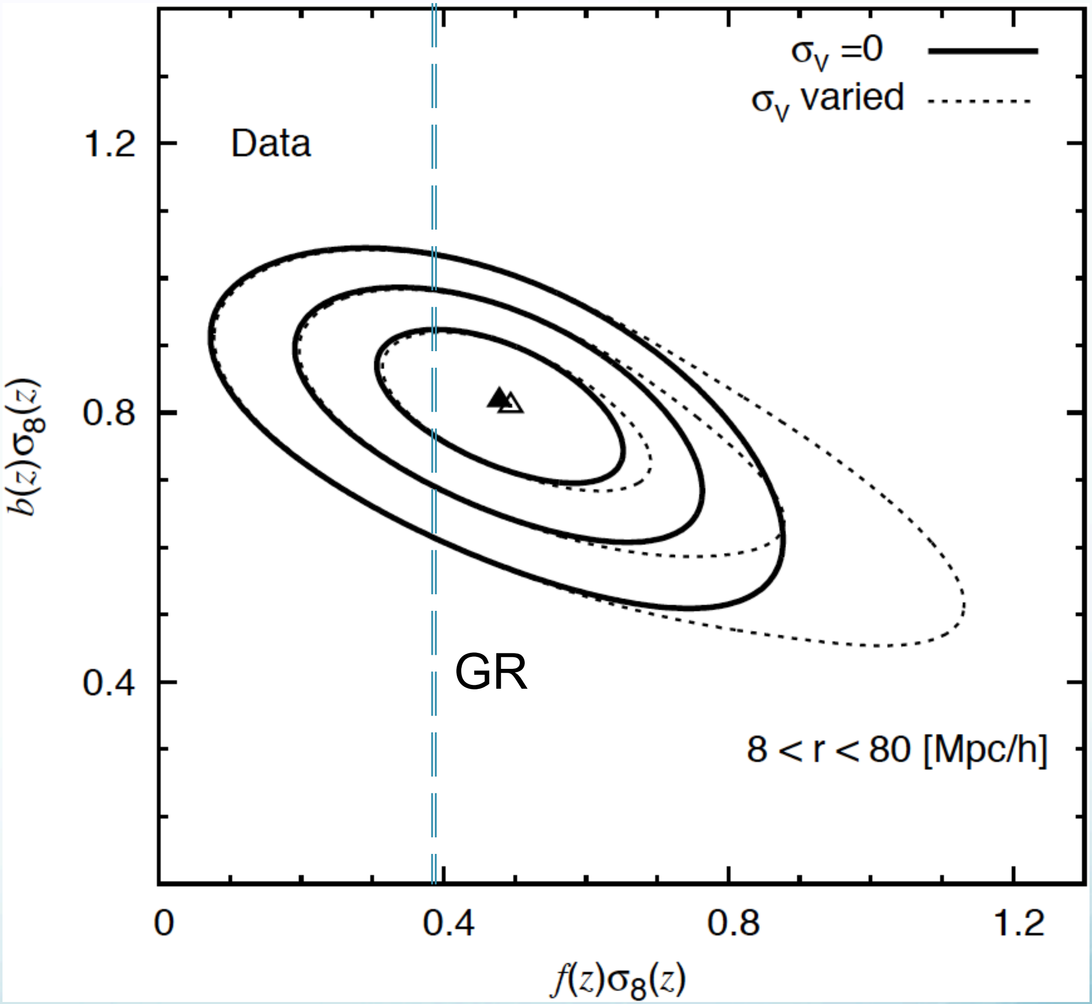
- $\sigma_v = 0$ or varied
- Best fitting parameters

$$f\sigma_8 = 0.482^{+0.116}_{-0.116}$$

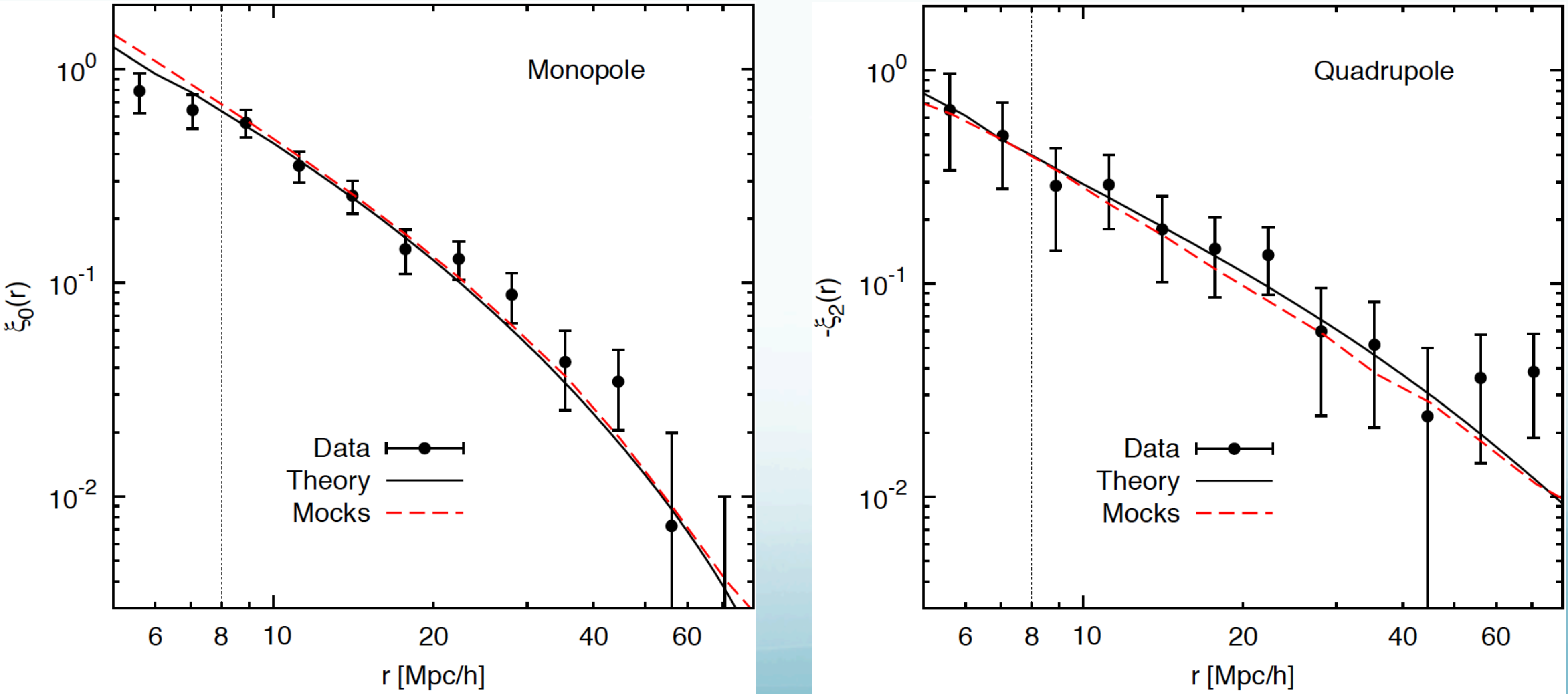
  - cf. GR: $f\sigma_8 \sim 0.392$

$$b\sigma_8 = 0.814^{+0.076}_{-0.080}$$

  - → LCDM: $b \sim 1.9$
  - Consistent with HOD independent analysis by Hikage+ and Geach+.

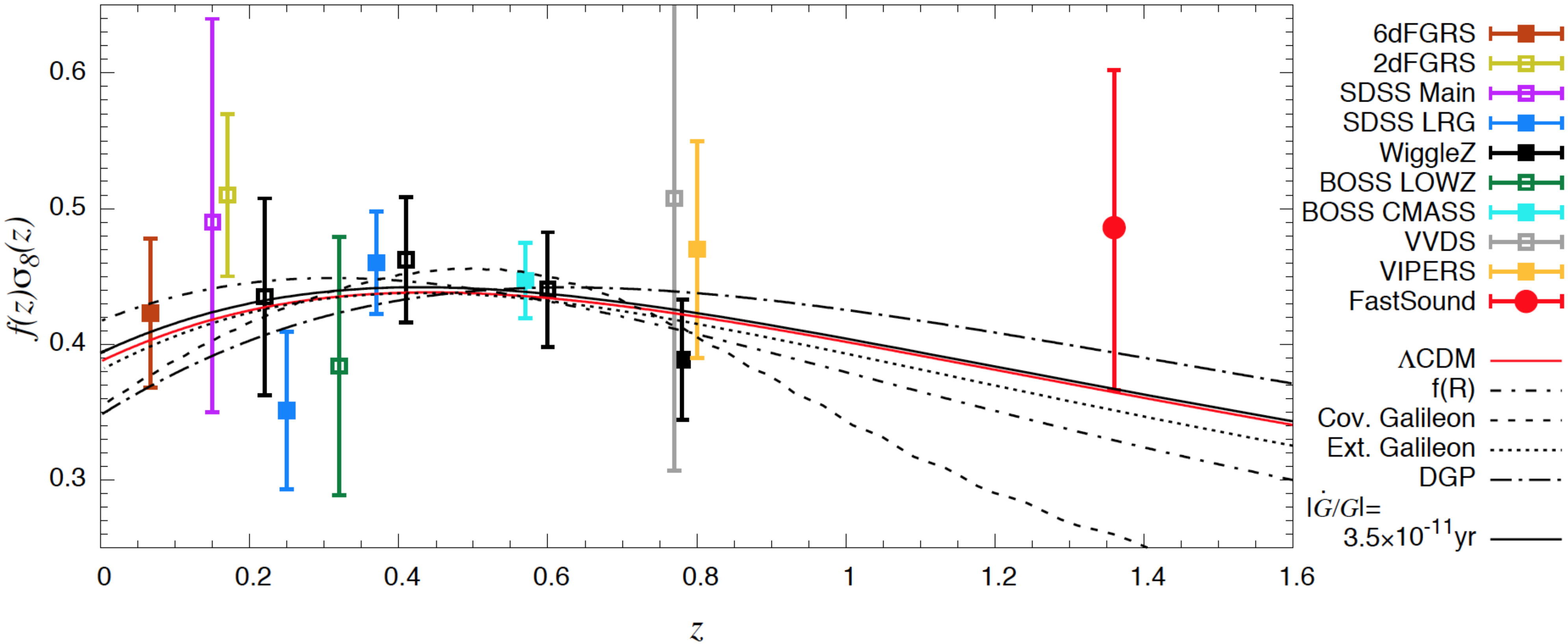


Correlation functions with the best-fitting parameters



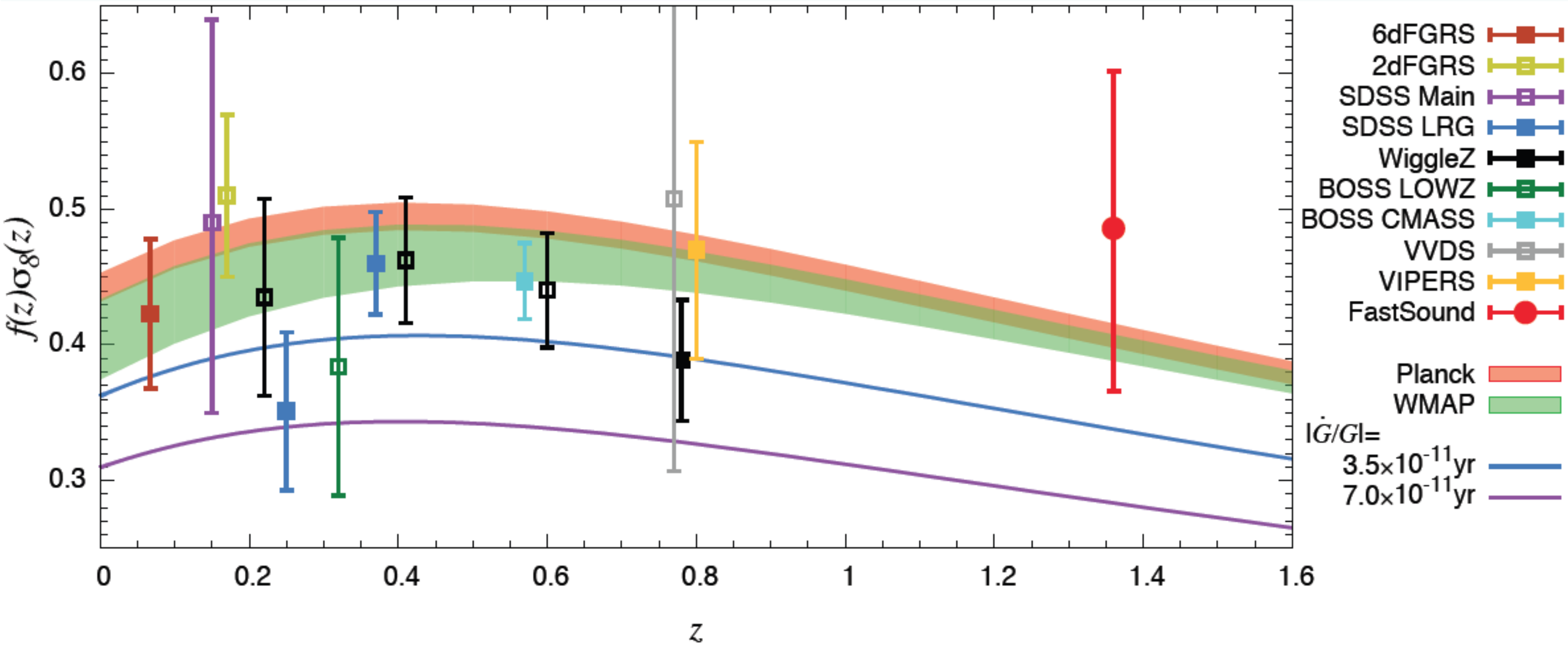
Gravity theory models as a function of z

- Different models predict how the growth of structure changes.
- For each model we fit the amplitude of $f\sigma_8$ using RSD data.



Consistency with CMB anisotropy experiments

- All the gravity models approach $f \sim 1$ at $z > 1$.



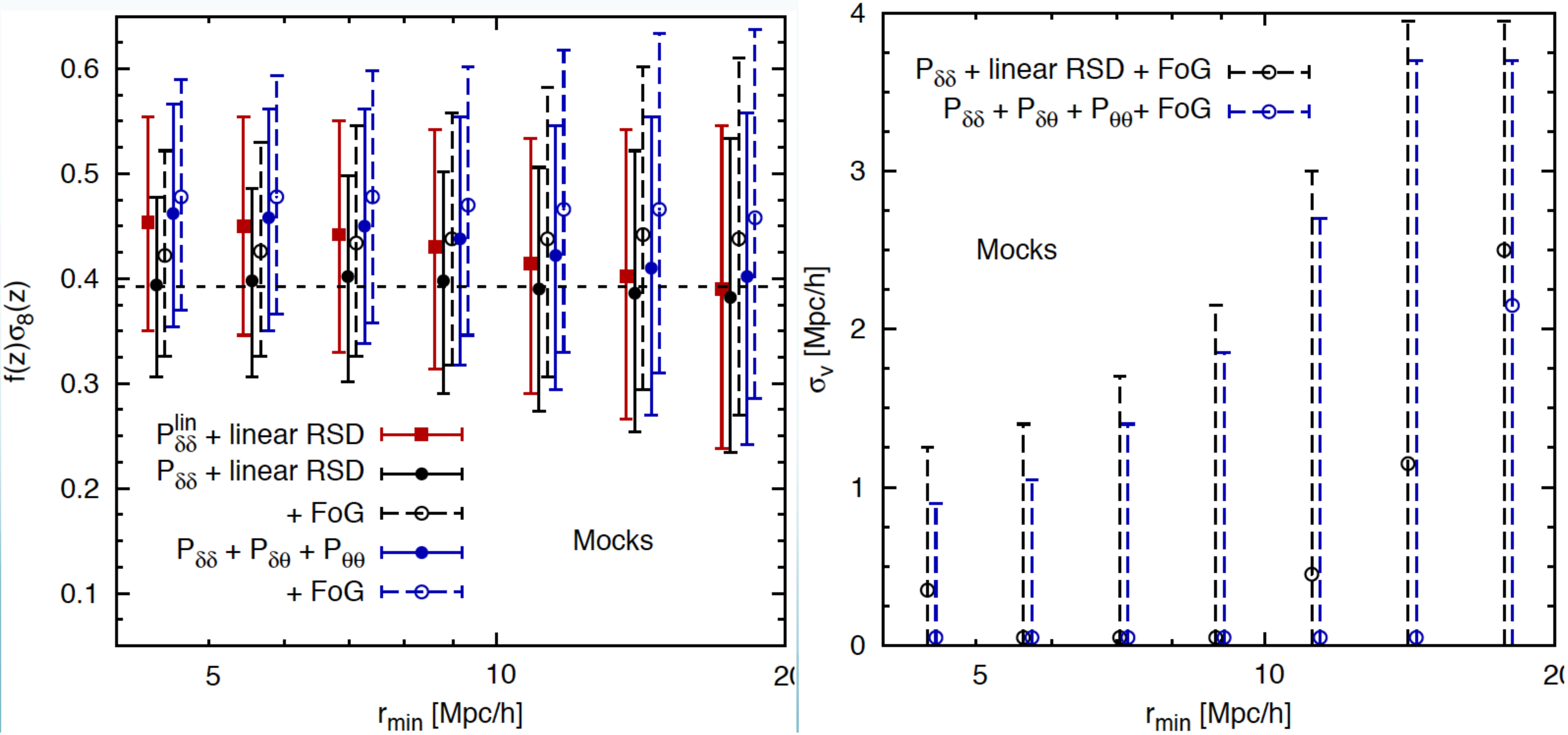
Summary

- We measure redshift-space clustering of emission line galaxies from the Subaru FMOS FastSound survey,
- Detect clear anisotropy due to redshift-space distortions,
- Constrain the growth rat $f\sigma_8 = 0.482^{+0.116}_{-0.116}$
- And perform a consistency test of general relativity at z~1.4.
- Future large surveys at high redshift, such as the Subaru PFS, could distinguish different modified gravity models by combining with low-z RSD measurements, independently of CMB experiments.

Test against mocks

- Apply 5 theoretical RSD models to see which can reproduce the input cosmological model of simulation at which scale.
- Fitting parameters: $\theta = (f\sigma_8, b\sigma_8, \sigma_v)$

$$P_g^s(k,\mu) = (b + f\mu^2)^2 P_m^r(k) \times \exp(-k^2\mu^2\sigma_v^2)$$



Accounting for fiber allocation corrections

$$[1 + w^{\rm fib}(\theta)]/[1 + w^{\rm tar}(\theta)] = \exp\left[-(\theta/\theta_0)^{-a}\right]$$