Cosmological information from the small-scale redshift-space correlation functions

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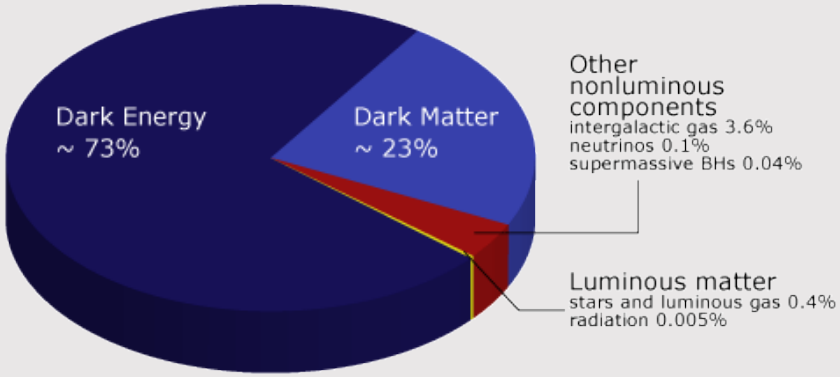
Dark energy

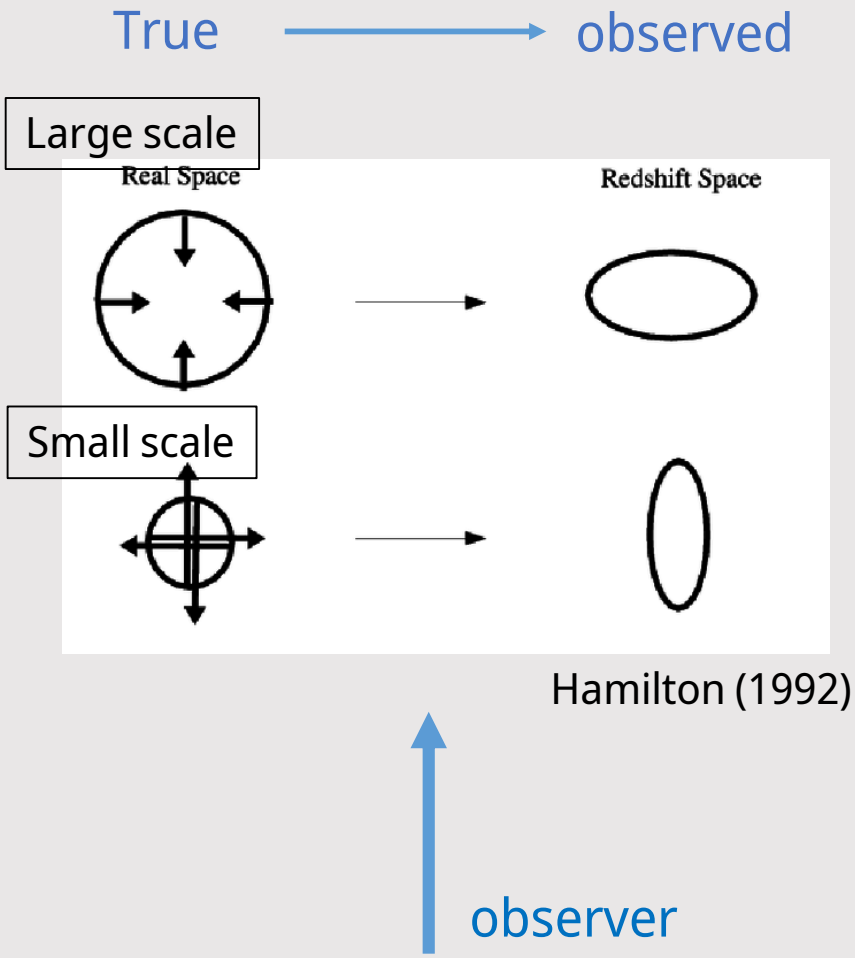
- Accelerating cosmic expansion
  - Gravitational force is attractive
  - Need the repulsive force
    - Dark energy
    - Modified gravity



- Two types of dark energy test
  - Geometry test
    - Measurement of the cosmic expansion
  - Dynamical test
    - Measurement of dynamical motion of objects

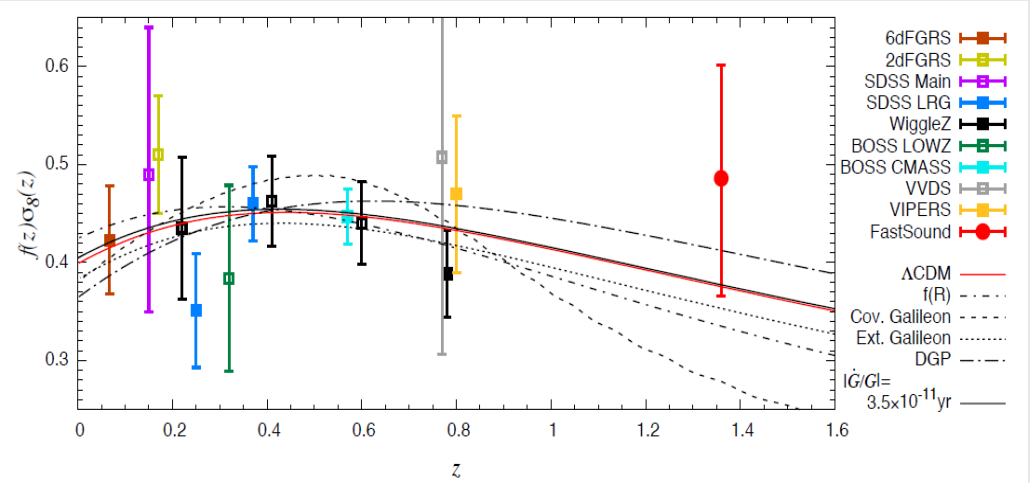
Redshift Space Distortion (RSD)

- Peculiar velocities of galaxies slightly shift observed redshifts
- Kaiser effect
  - at large scales (>10Mpc)
  - Induced by the coherent motion of galaxies
- Finger-of-God effect
  - at small scales (<~5Mpc)
  - Caused by random motions of galaxies inside virialized systems



Hamilton (1992)

Purpose of this work



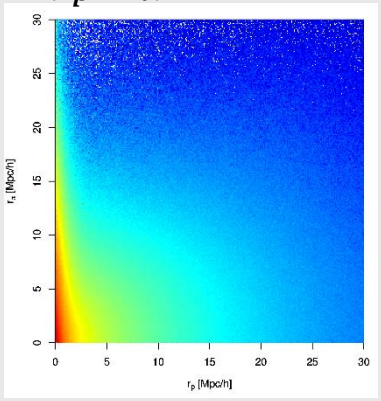
Okumura et al. (2016)

- The large-scale RSD
  - measures the growth rate f
  - major target of planned/ongoing surveys
- The small-scale RSD
  - also expected to have cosmological information
  - not widely used currently

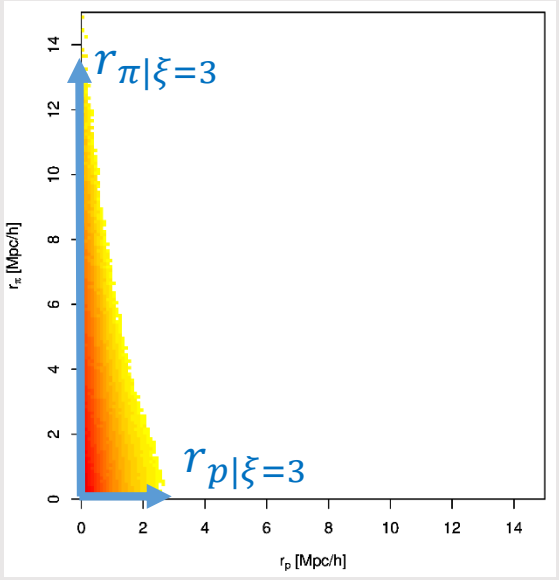
➔ Can the two-point correlation function of small scales add additional constraints on cosmological parameters?

Quantifying FoG

$\xi(r_p, r_\pi)$



region of $\xi(r_p, r_\pi) > 3$

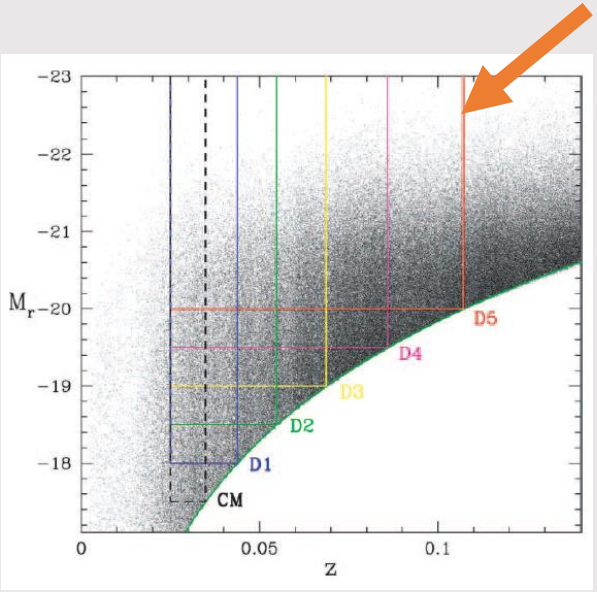


- $R_{|\xi=3} = \frac{r_{\pi|\xi=3}}{r_{p|\xi=3}}$
- Cosmic variance of the density field is expected to cancel out, giving a clean "length" of FoG
- $R_{|\xi=2}$, $R_{|\xi=4}$, … can be defined likewise, corresponding to different scales

Data

- Multiverse simulation
  - 2048^3 particles in 1024 h^{-1}Mpc cubic box
  - $(\Omega_m, w) = (0.21, -1), (0.26, -1), (0.31, -1), (0.26, -0.5), (0.26, -1.5)$
  - Galaxy assignment by the most bound particles (MBPs) approach (Hong et al. 2016)
  - α parameter is adjusted to 1.5 to reproduce $w(r_p)$ of SDSS galaxies

- KIAS value added catalog (KIAS-VAGC)
  - SDSS DR7 main galaxies supplemented by other spectroscopic surveys
  - The nearest-neighbor redshift is assigned for fiber-collided galaxies
  - D5 volume-limited sample
    - $0.025 < z < 0.10713, M_r < -20.0$
    - 134,318 galaxies, ~7000deg^2

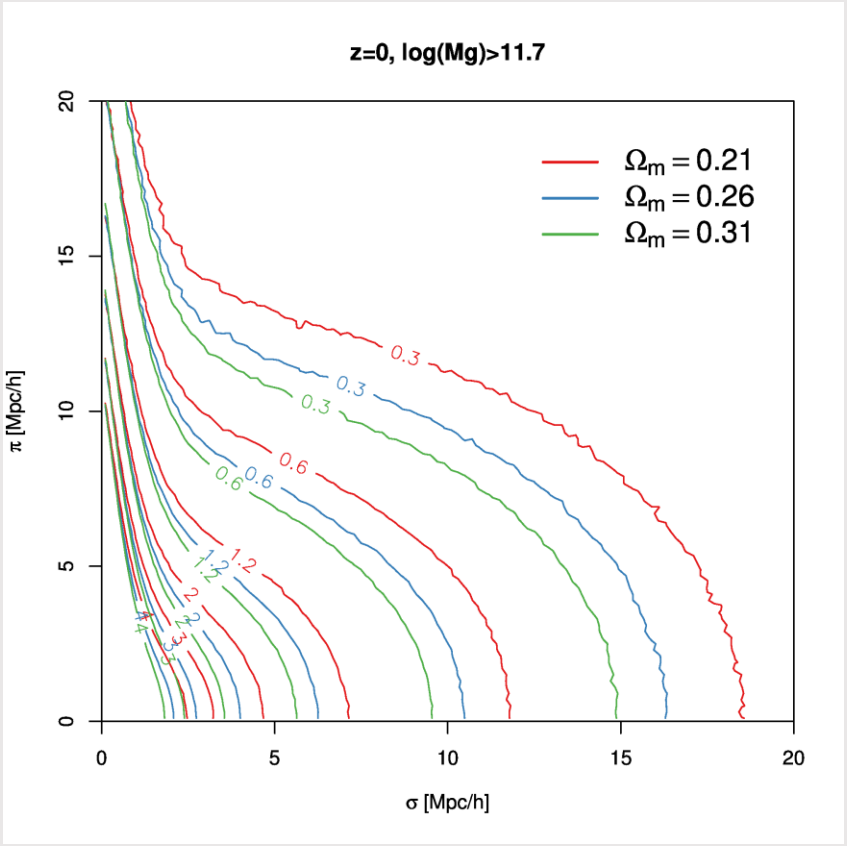


Choi et al. (2009)

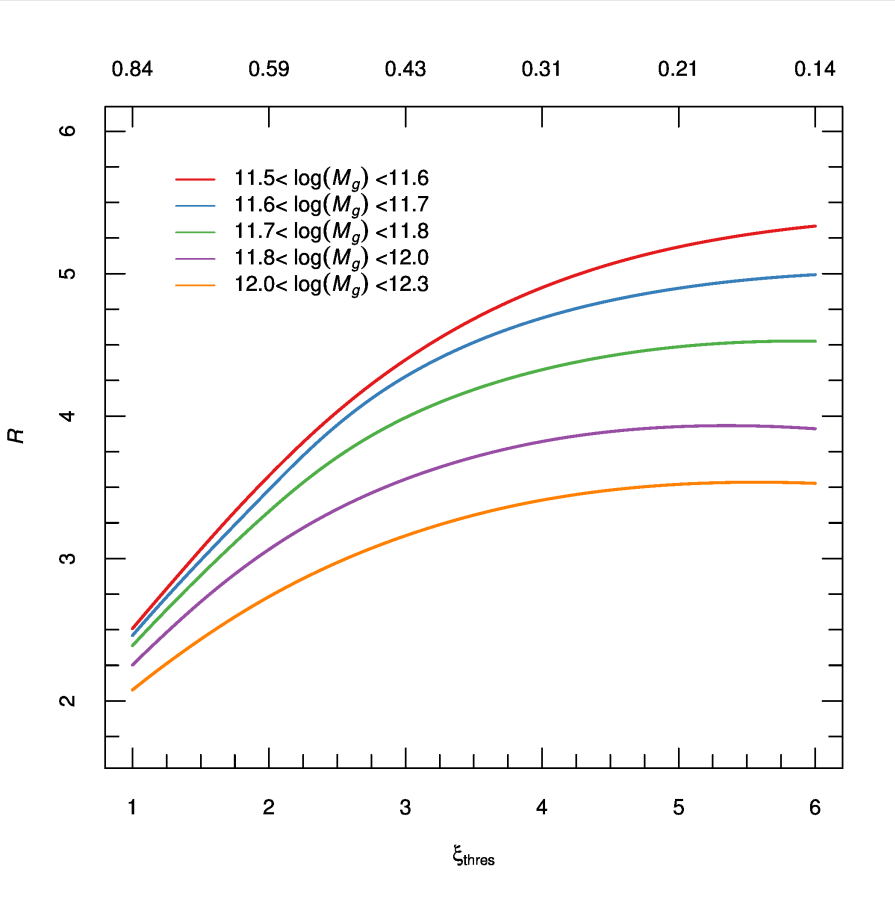
Two-point correlation function

- Two-point correlation function

$$\xi(r_\sigma, r_\pi) = \frac{DD - 2DR + RR}{RR}$$

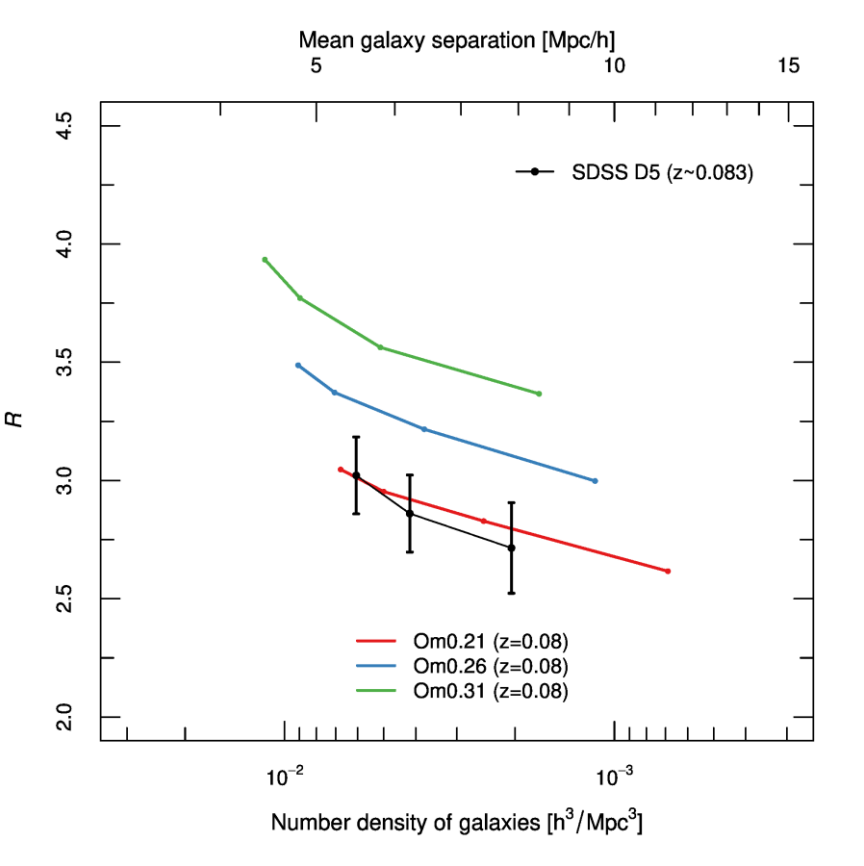


Simulation: Mass and threshold dependence



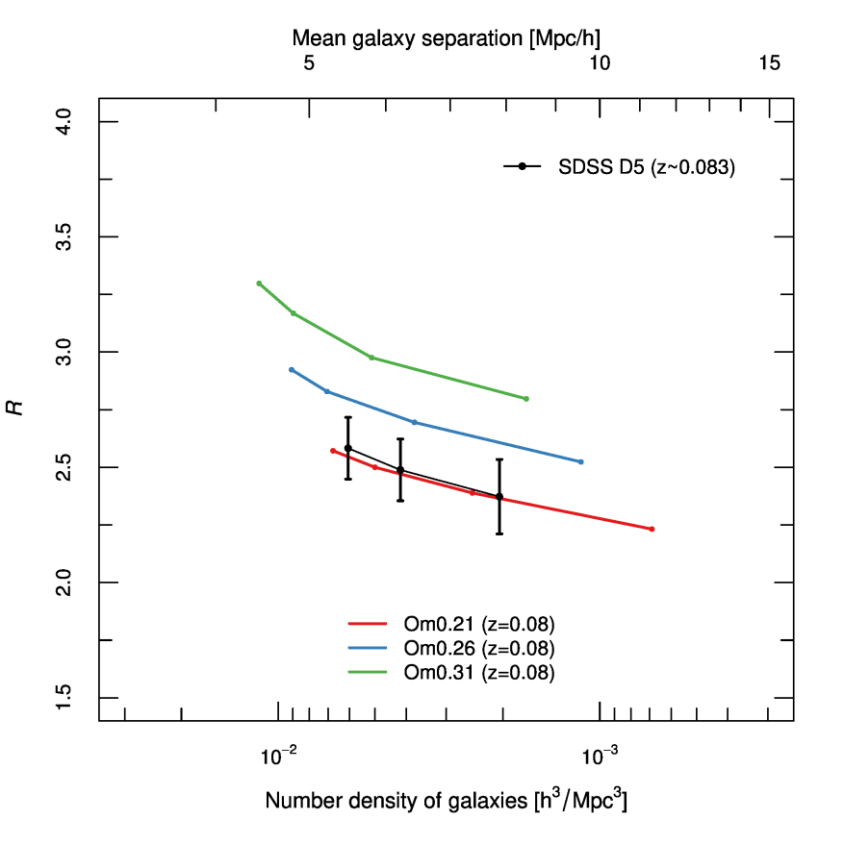
- $(\Omega_m, w, z) = (0.26, -1, 0)$
- Massive galaxies tend to reside in the center of haloes
  → smaller FoG effect
- Lower threshold
  → larger scales
  → less affected by FoG

Comparison with observational data

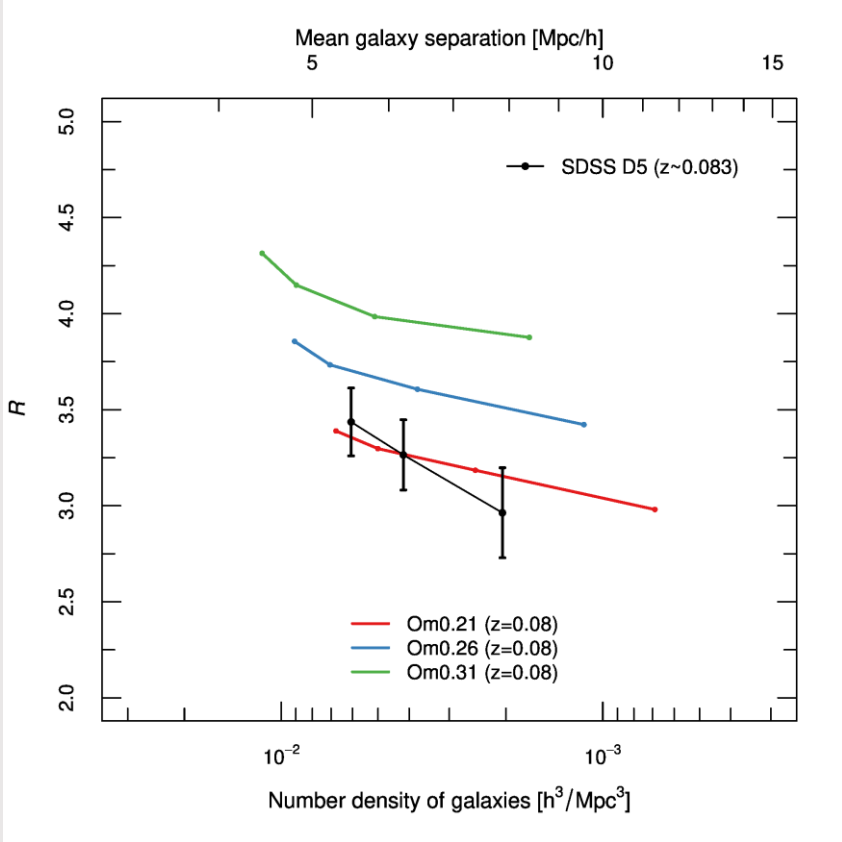


- $\xi_{\mathrm{thres}} = 3.0$
- absolute r-mag thresholds (SDSS) :
  -20.02, -20.3, and -20.72
- x-axis is the number density of the sample
  (instead of mass/magnitudes)
- Hhigher Ω_m gives larger R

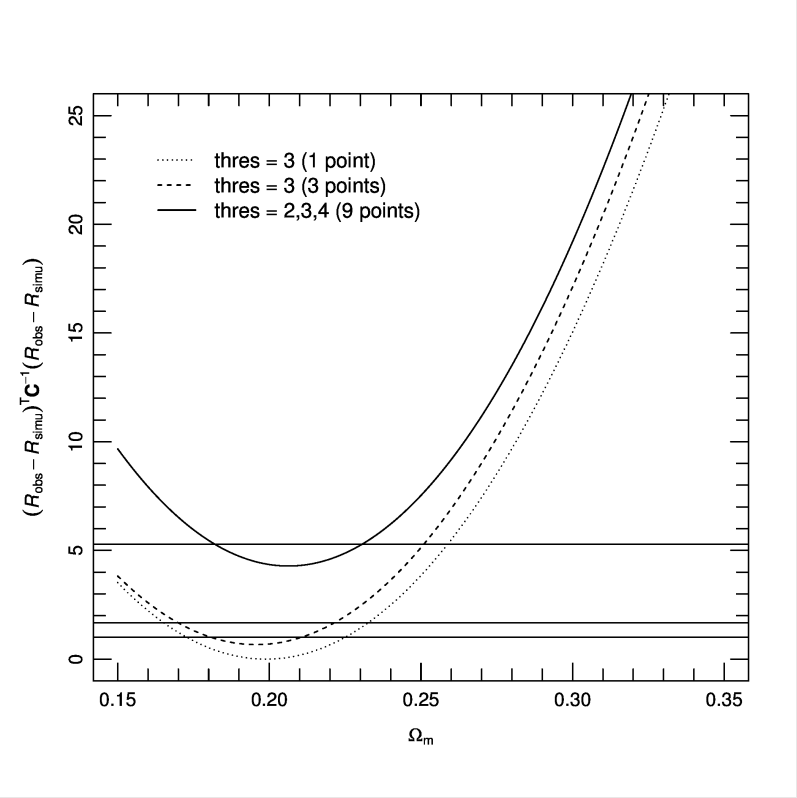
$\xi_{\mathrm{thres}} = 2.0$



$\xi_{\mathrm{thres}} = 4.0$



Constraint on Ω_m



- Log-likelihood ${}^{T}(\boldsymbol{R}_{\mathrm{SDSS}} - \boldsymbol{R}_{\mathrm{simu}})\mathbf{C}^{-1}(\boldsymbol{R}_{\mathrm{SDSS}} - \boldsymbol{R}_{\mathrm{simu}})$ for
  - 1 data point (dotted)
  - 3 data points (dashed)
  - 9 data points (solid)
- Covariance $\mathbf{C}$ estimated from the HR4 mock catalog
- SDSS D5 (~10^5 galaxies) gives $\Delta\Omega_m \sim 0.02$
  - the preferred value is below 0.26 (WMAP) and 0.31 (Planck)
  - due to the velocity bias $\alpha < 1$? (e.g., Guo et al. 2015)

Summary

- We used KIAS-VAGC spectroscopic data to measure $R_{|\xi}$ and compared with Multiverse simulation to see the power of cosmological constraints from the small-scale RSD

- ~10^5 galaxies give $\Delta\Omega_m$~0.02

- The lower value of Ω_m could be due to the existence of the velocity bias