Reconstructing halo power spectrum from redshift-space galaxy distribution

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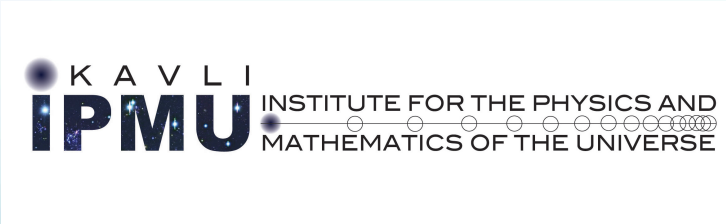
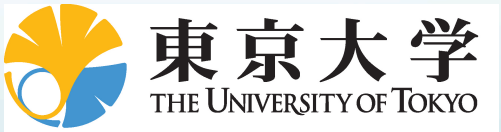
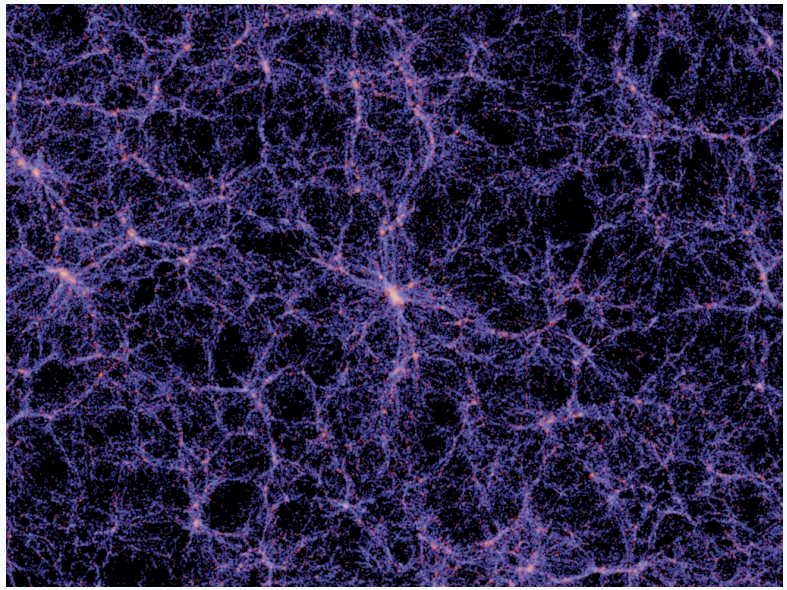




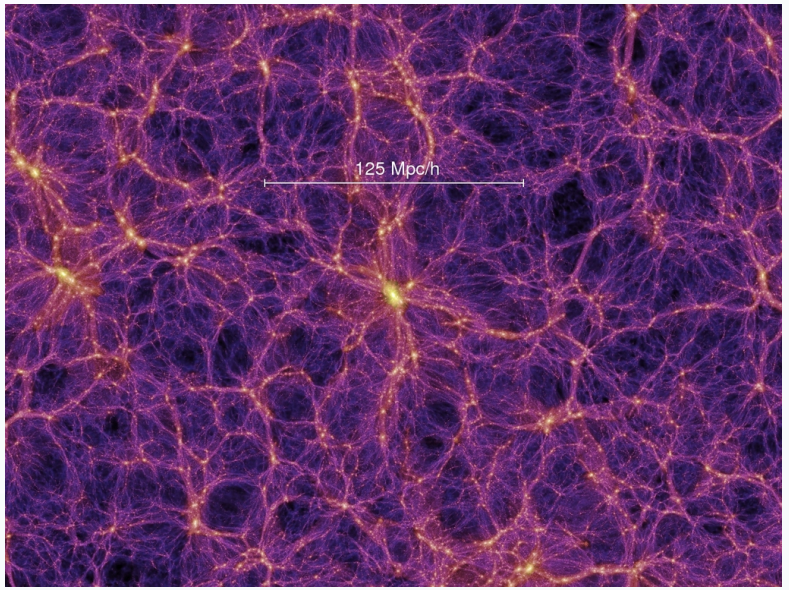
MPA/ESO/MPE/Excellence Cluster Universe Joint Conference

July 20-24, 2015

Observables and theory in redshift surveys



Galaxies



Dark matter

- All the galaxies are considered to be formed in dark matter halos.
- What one can theoretically predict is clustering of dark matter, while what we actually observe are galaxies.

Millennium simulations (Springel+)

Redshift-space clustering of galaxies and their host halos

Multipole power spectrum

$$P_l^S(k) = (2l+1)\int_0^1 P^S(k,\mu)\mathcal{P}_l(\mu)d\mu$$

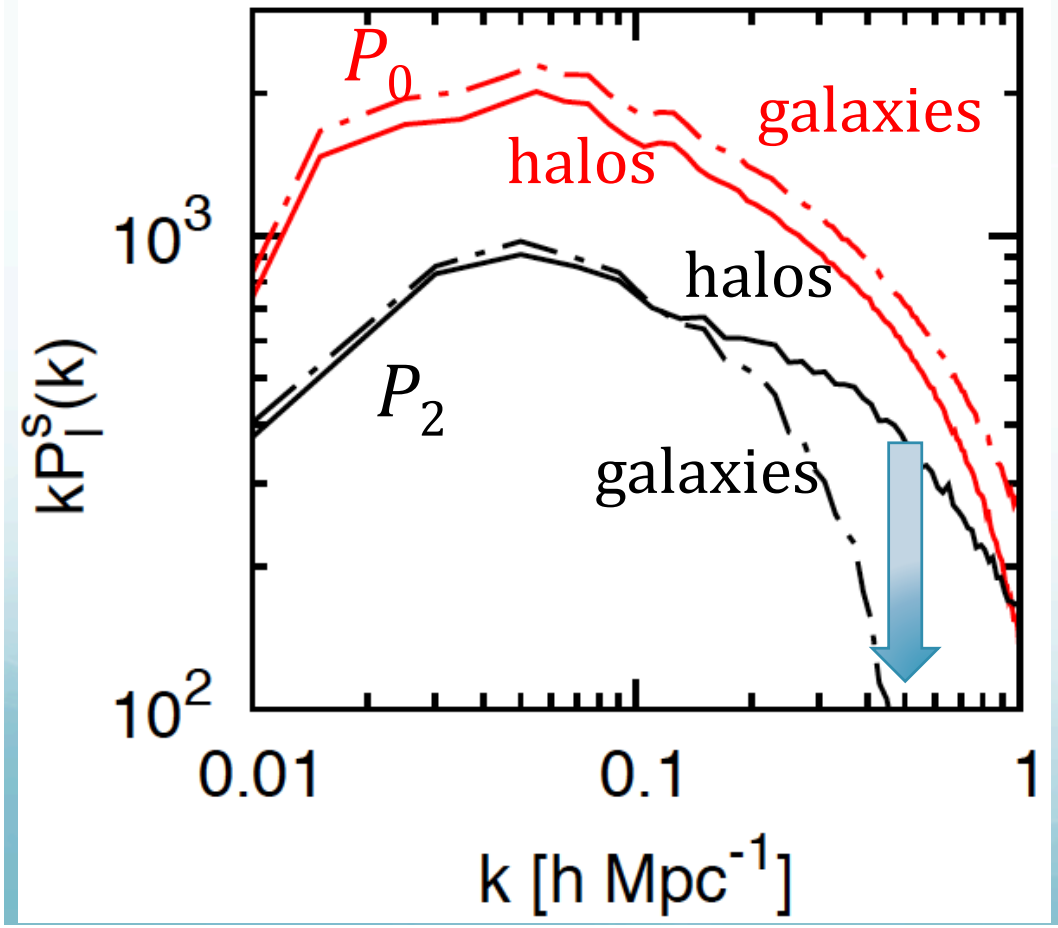
Linear theory limit

P_0: monopole

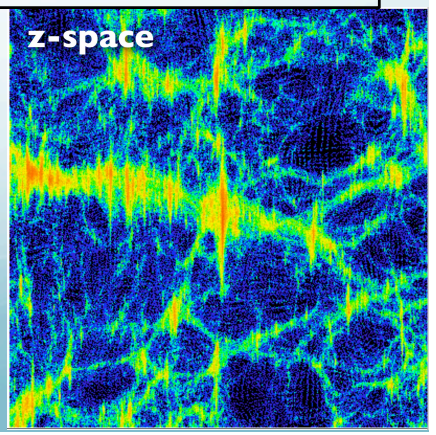
$$P_0^S(k) = \left(b^2 + \frac{2}{3}bf + \frac{1}{5}f^2\right) P_{lin}(k)$$

P_2: quadrupole

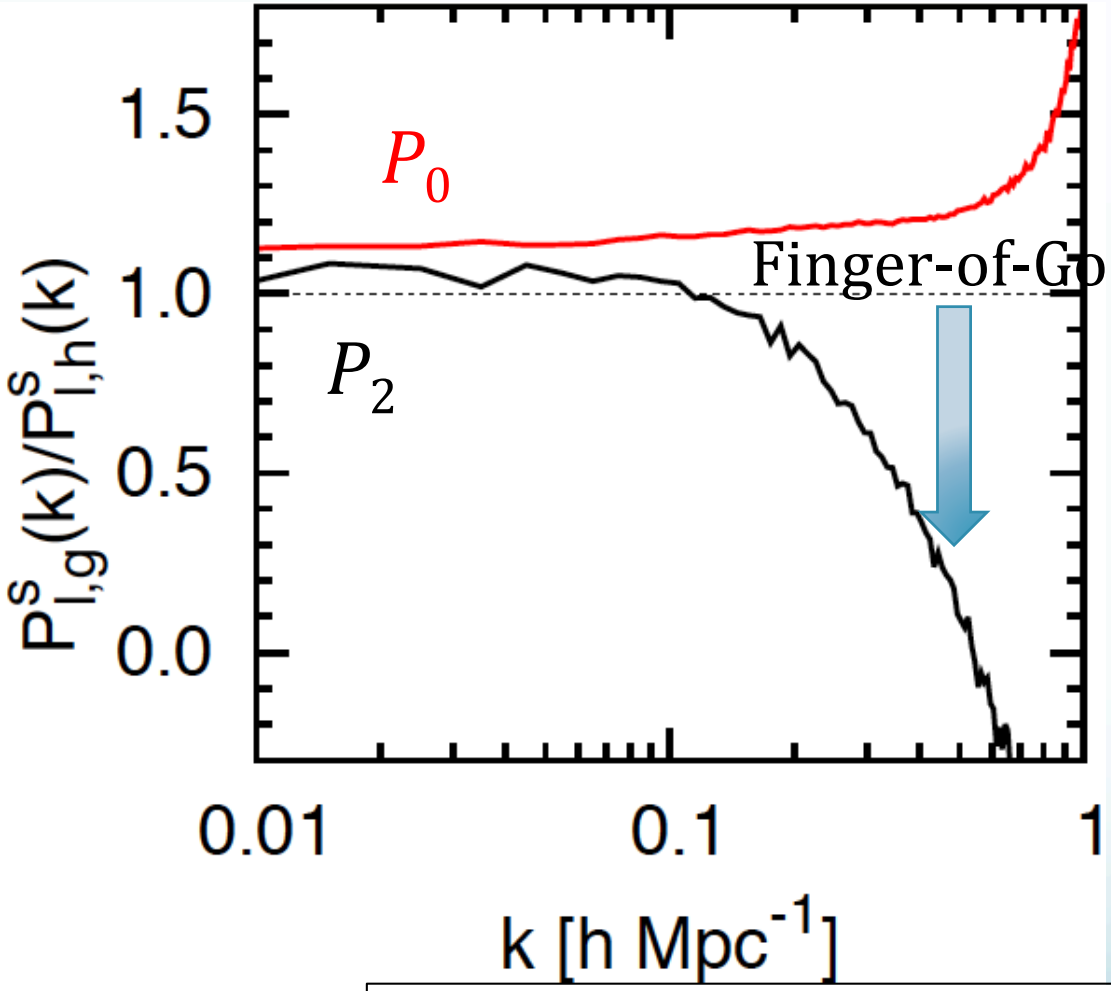
$$P_2^S(k) = \left(\frac{4}{3}bf + \frac{4}{7}f^2\right) P_{lin}(k)$$



Finger-of-God



Ratios of galaxy and halos power spectra: effects of satellites



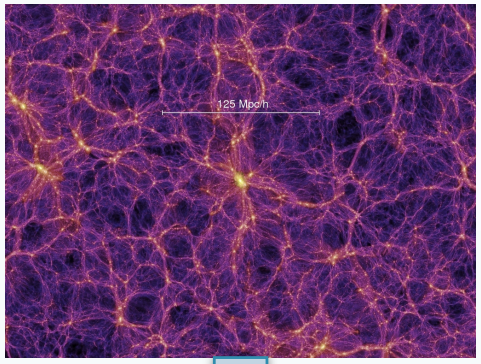
- Galaxy power is more weighted by more massive halos due to satellites

$$P_{gg}(k,\mu) = F_{\rm FoG}(k,\mu;\sigma_v) P_{hh}(k,\mu)$$

Velocity func. of off-centered gals

Halo power spectrum

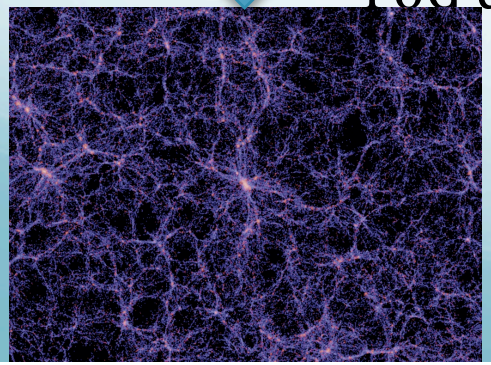
From halos to galaxies



Dark matter (halo)

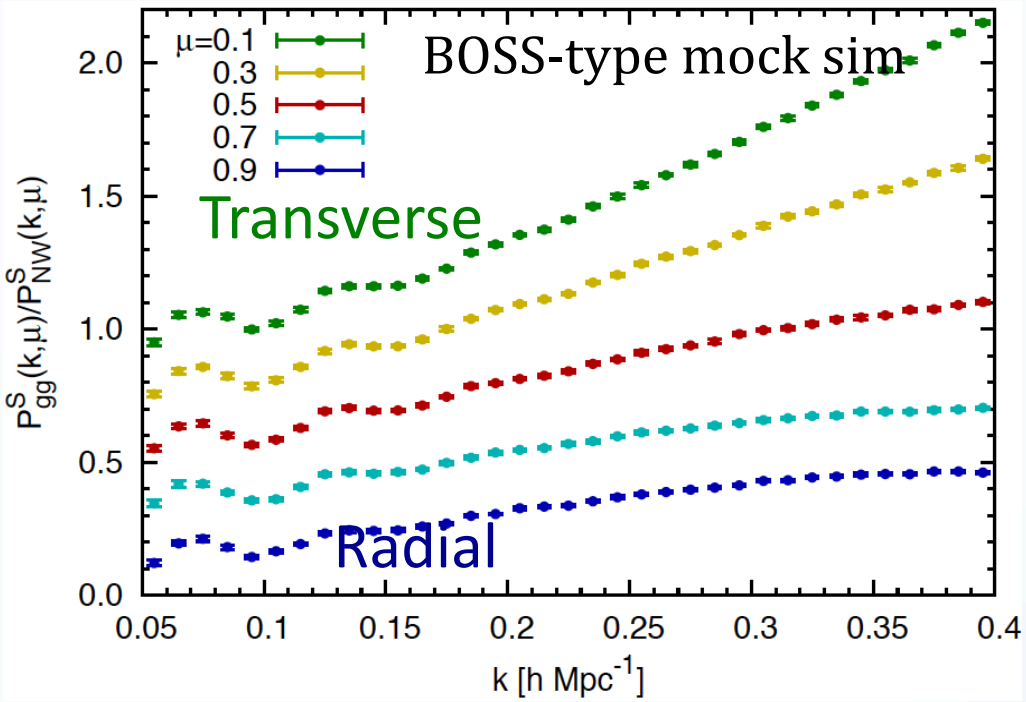
+satellites

- Halo model
- PT for matter RSD
- Halo biasing
- FoG damping



Galaxies

Okumura, Hand, Seljak, Vlah, Desjacques (arxiv:1506.05814)



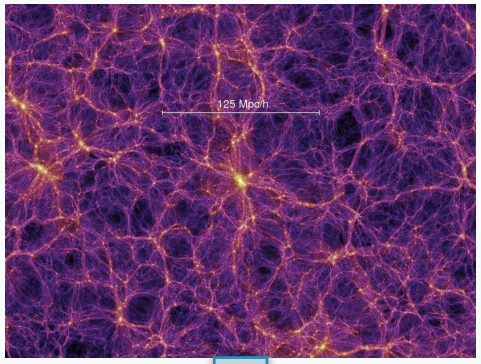
$$P^S_{gg}(\mathbf{k}) = P^{S1h}_{gg}(\mathbf{k}) + P^{S2h}_{gg}(\mathbf{k}), \quad (5)$$

where the 2-halo and 1-halo terms are given by

$$P^{S2h}_{gg}(\mathbf{k}) = (1-f_s)^2 P^S_{cc}(\mathbf{k}) + 2f_s(1-f_s) \times \left(\frac{N_{c_A}}{N_c} P^S_{c_A s}(\mathbf{k}) + \frac{N_{c_B}}{N_c} P^{S2h}_{c_B s}(\mathbf{k}) \right) + f_s^2 \left(\frac{N^2_{s_A}}{N^2_s} P^S_{s_A s_A}(\mathbf{k}) + \frac{2N_{s_A} N_{s_B}}{N^2_s} P^S_{s_A s_B}(\mathbf{k}) + \frac{N^2_{s_B}}{N^2_s} P^{S2h}_{s_B s_B}(\mathbf{k}) \right), \quad (6)$$

$$P^{S1h}_{gg}(\mathbf{k}) = 2f_s(1-f_s) \frac{N_{c_B}}{N_c} P^{S1h}_{c_B s}(\mathbf{k}) + f_s^2 \frac{N^2_{s_B}}{N^2_s} P^{S1h}_{s_B s_B}(\mathbf{k}). \quad (7)$$

From halos to galaxies



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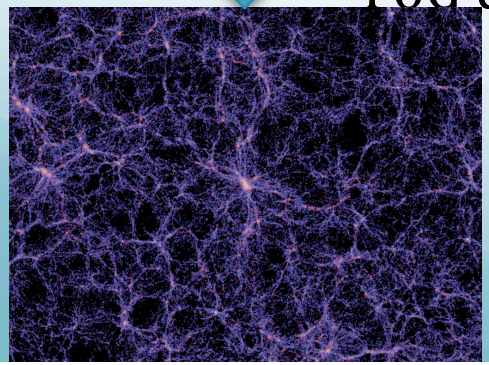

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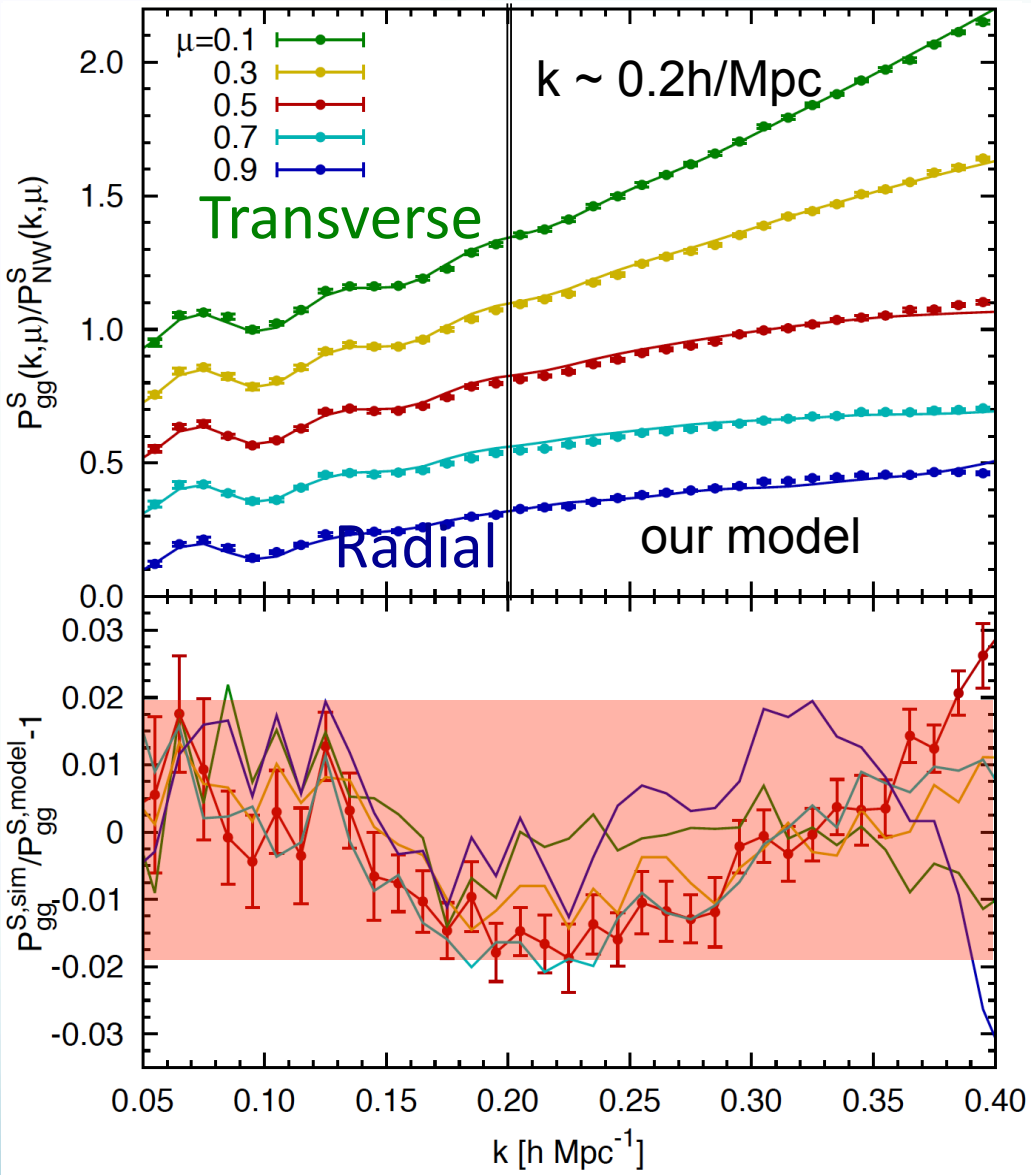
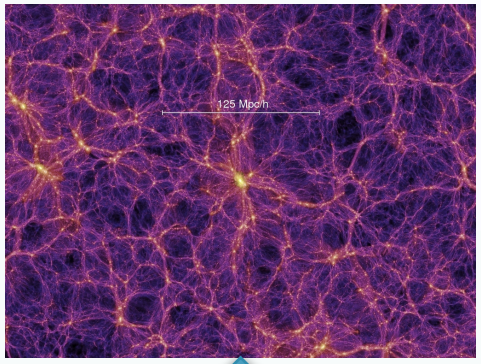


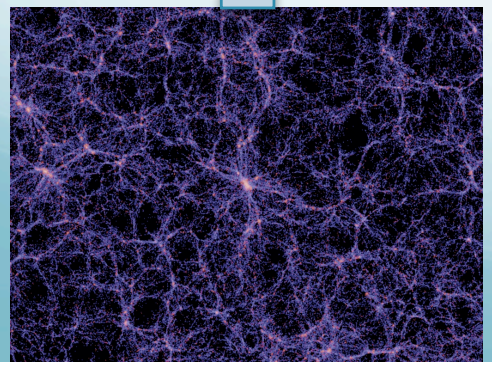
Okumura, Hand, Seljak, Vlah, Desjacques (arxiv:1506.05814)

Purpose of this study:
From galaxies to halos



Dark matter (halo)

Exclude satellites



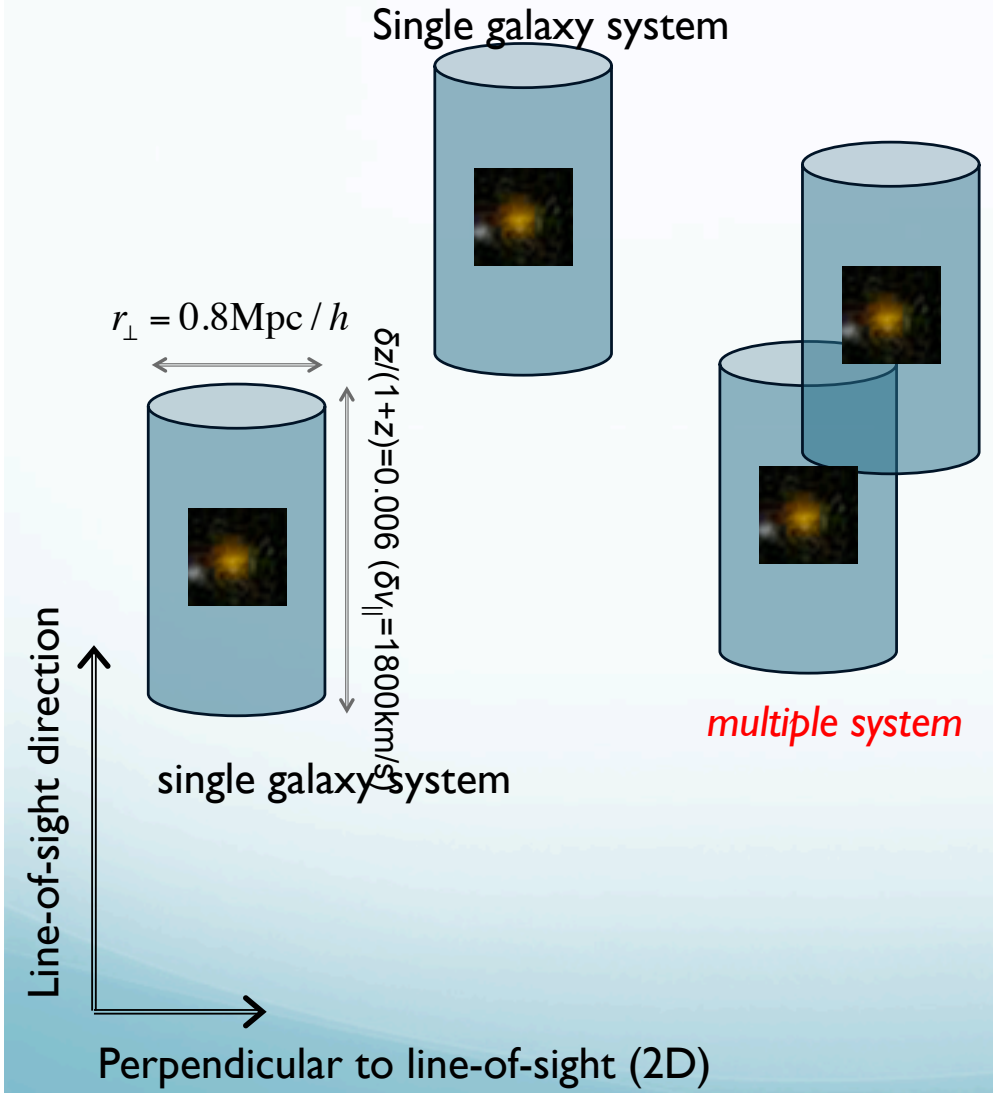
Galaxies

- From 3D galaxy distribution in redshift surveys, reconstruct halo power spectrum (exclude the effect of satellites).
- It will allow to constrain cosmology using theoretical models of halo clustering.
- Earlier studies:
  - Tegmark et al (2006)
    FoG compression
  - Reid & Spregel (2009)
    Counts-in-Cylinders (CiC)

Okumura, Takada, More & Masaki, in prep.

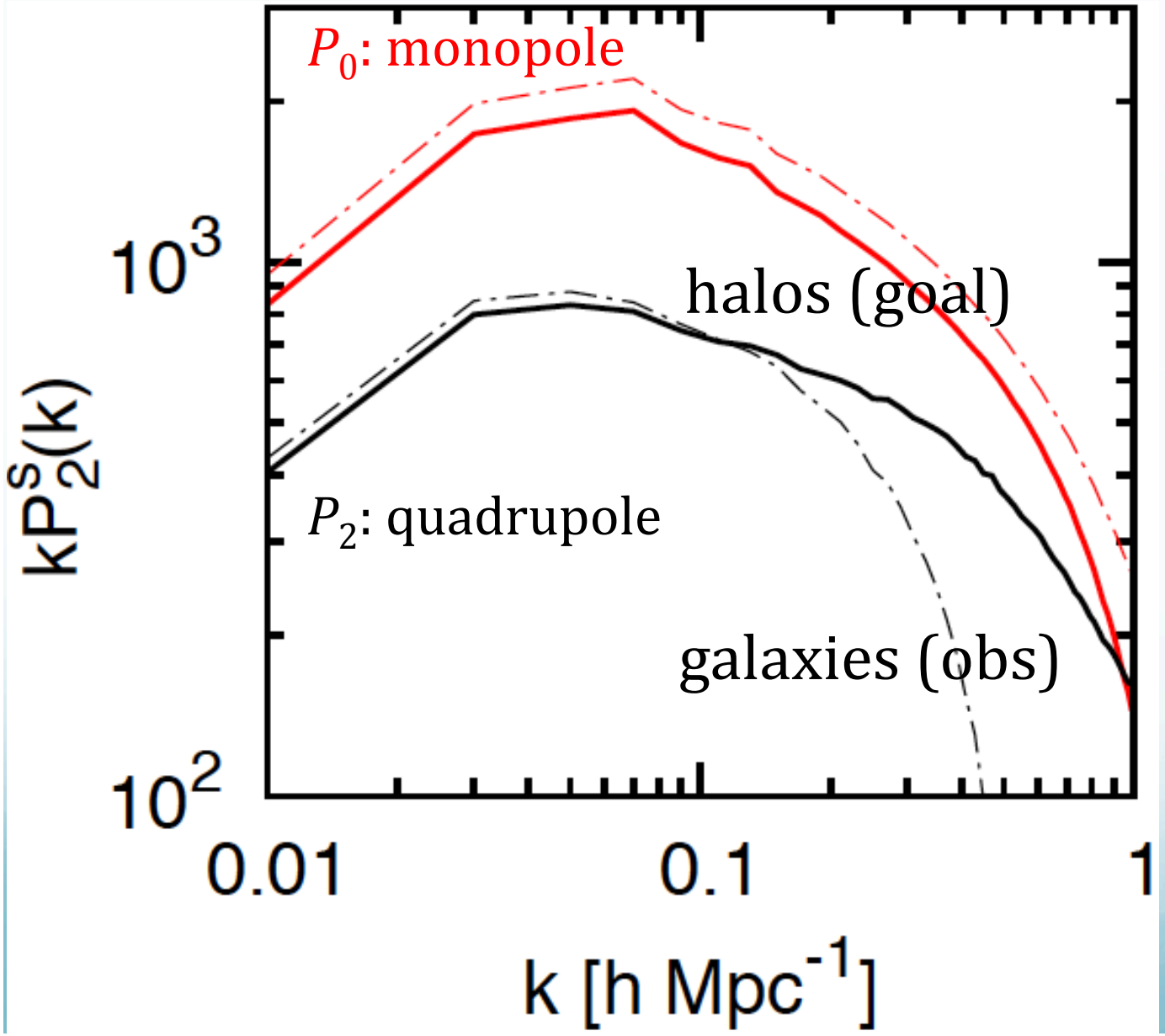
From galaxies to halos: Counts-in-Cylinders technique

Reid & Spergel 2009



- Apply a cylinder-shape region around each galaxy (taking into account RSD)
- Overlapped cylinders are considered to be in the same halo.
- RS09 found multiple SDSS LRG systems are about 5-6% of all LRGs
- *Question: can we apply this technique for high-density samples with higher satellite fraction, such as BOSS CMASS?*

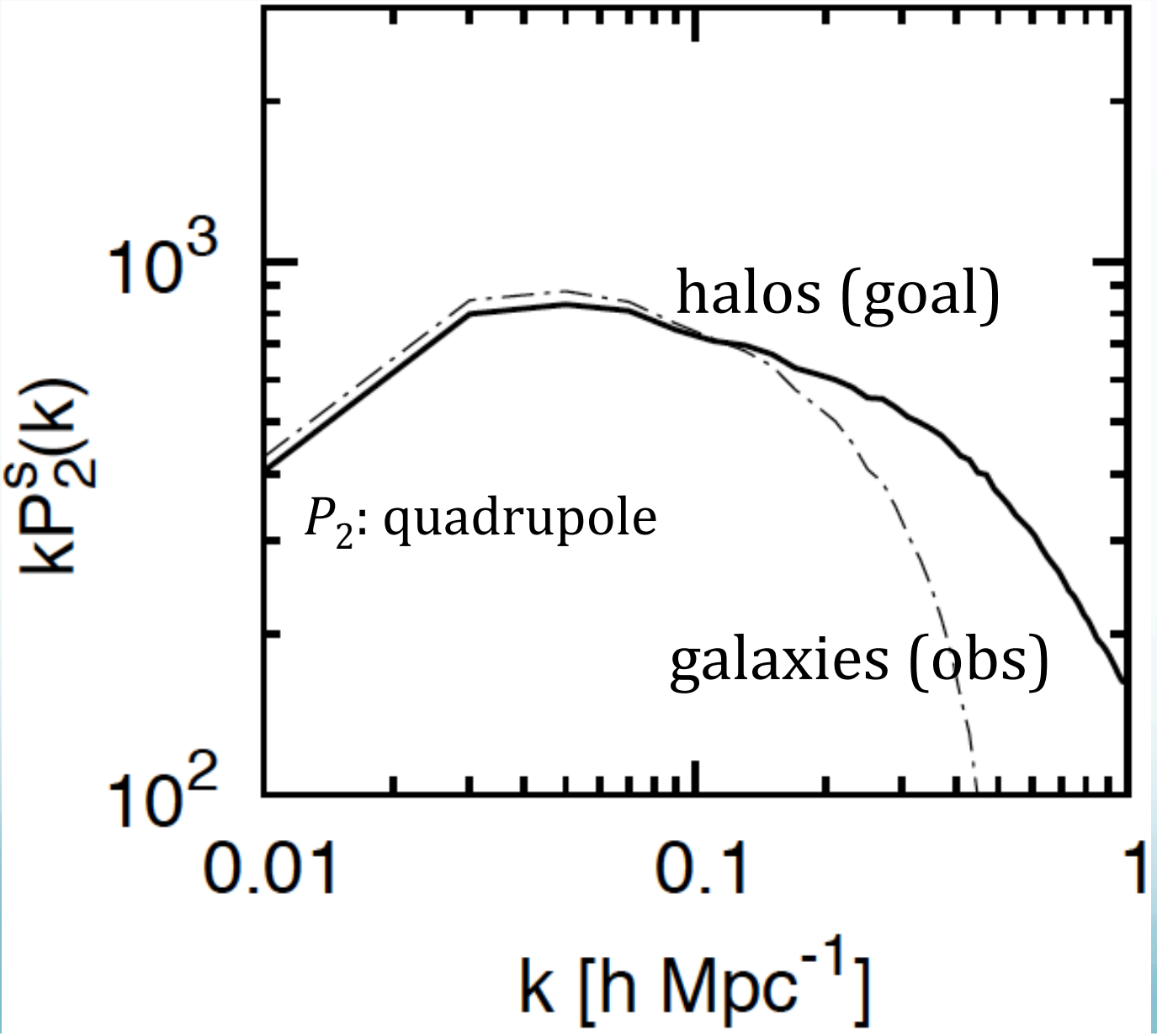
Applying CiC to mock galaxies at z=0.5



- Galaxy dist.
- Identify halos using CiC and compute its power spectrum
- Halo clustering?
- $n_g \sim 3.5\times10^{-4}$ $_{(h/Mpc)^3}$

  $\sim n_{BOSS}$

Applying CiC to mock galaxies at z=0.5



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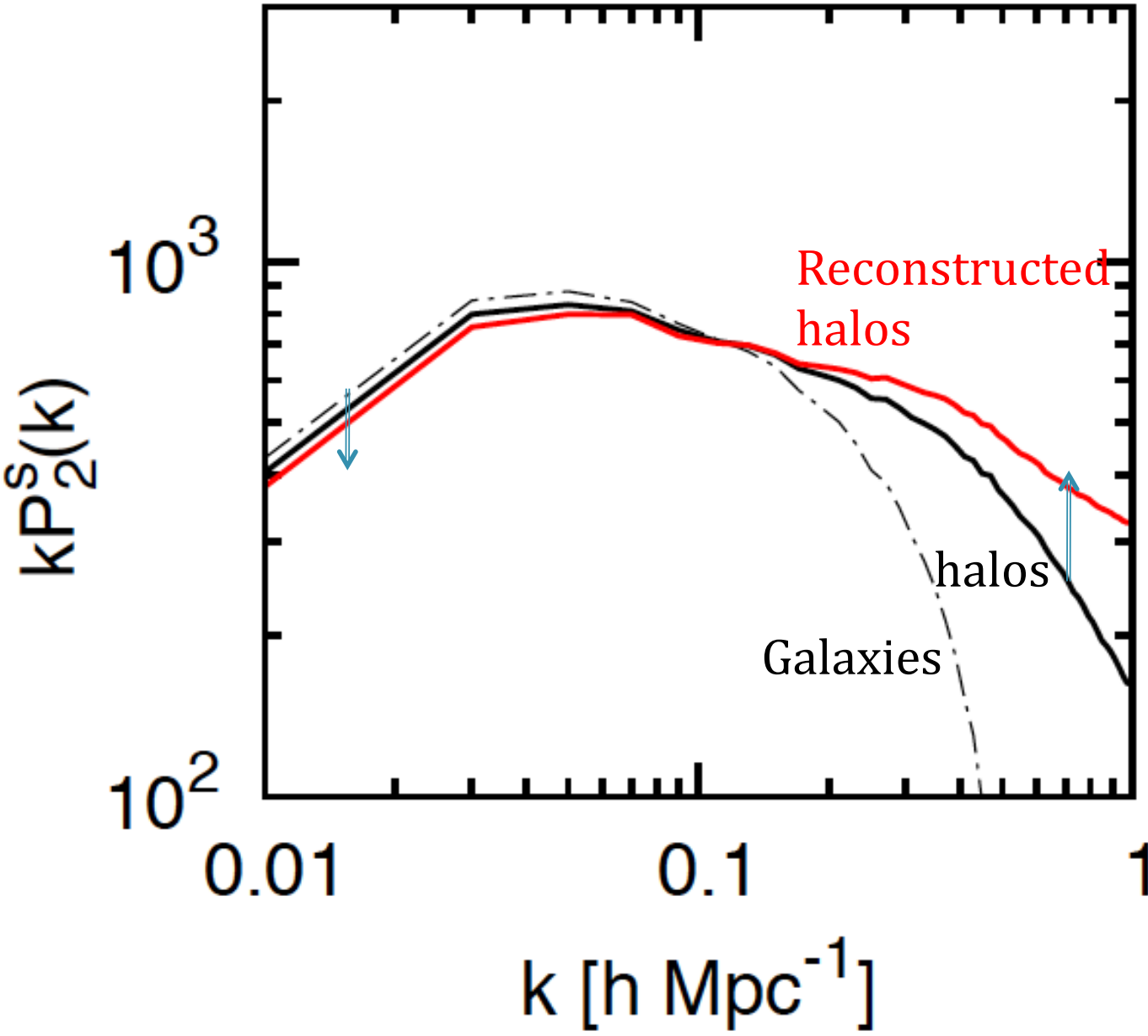


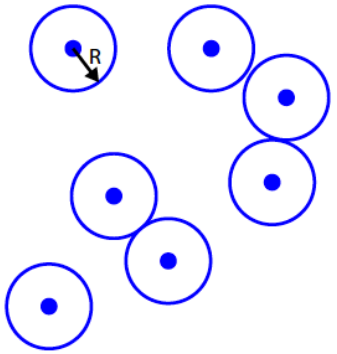
- The cylinder itself has an anisotropic shape, thus produces the artificial quadrupole.

Correcting for the cylinder anisotropies

- Formula for the effect of halo exclusion with clustering

$$P_h^S(\mathbf{k}) = \frac{1}{\bar{n}} + P_c^S(\mathbf{k}) - W(\mathbf{k}) - \left[W * P_c^S\right](\mathbf{k})$$

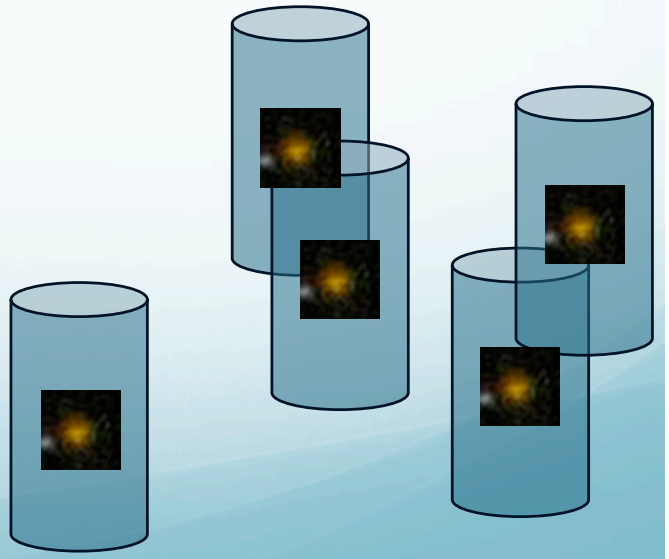
Baldauf et al (2013)



They are all observables!

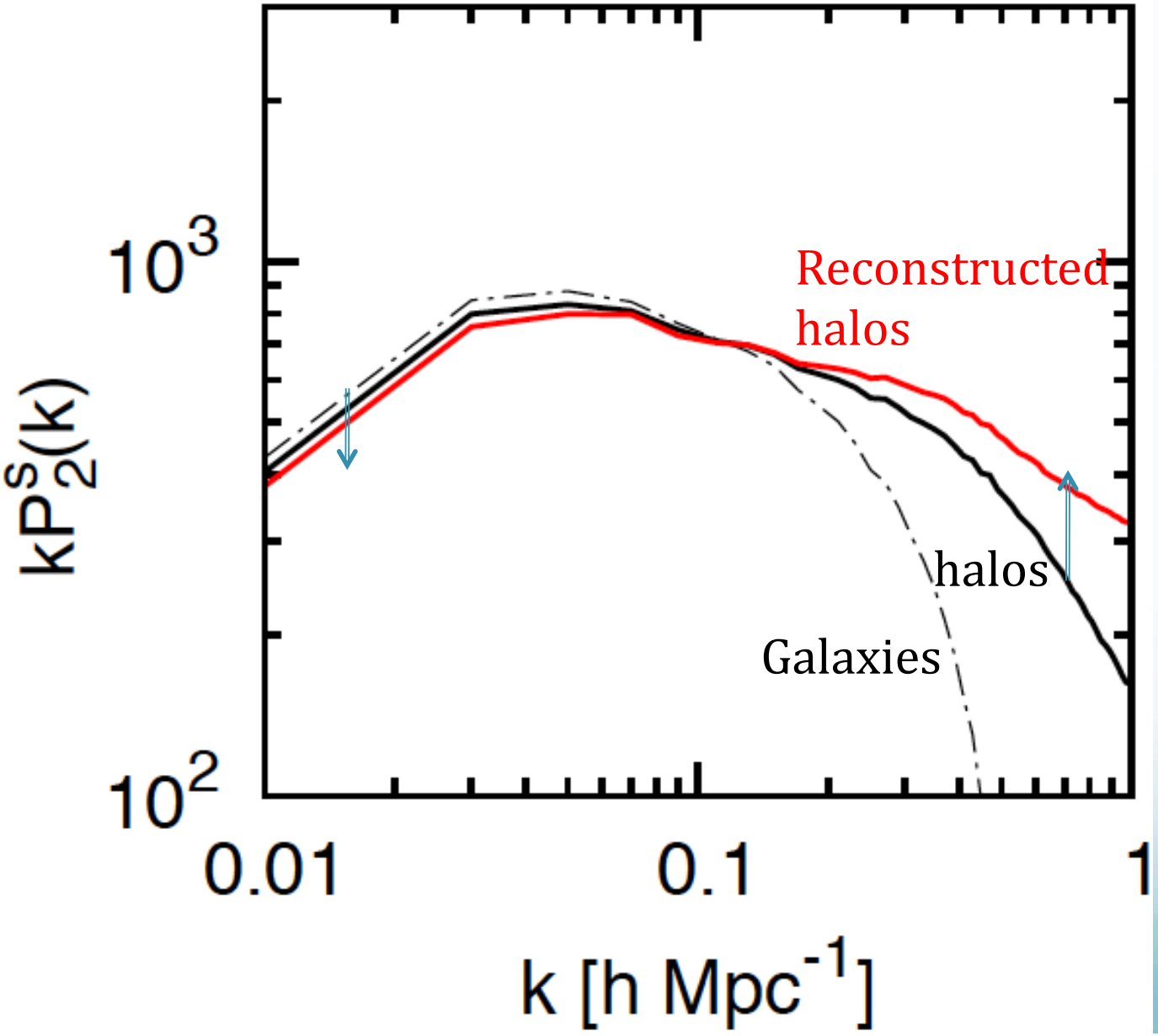
- In our situation $W(\mathbf{k})$ is the Fourier transform of cylinders. (Two galaxies cannot be in the same Cylinder.)

$$|W(\mathbf{k})| = 2\frac{J_1(k_\perp r)}{k_\perp r}\frac{\sin(k_\parallel l)}{k_\parallel l}V_W$$



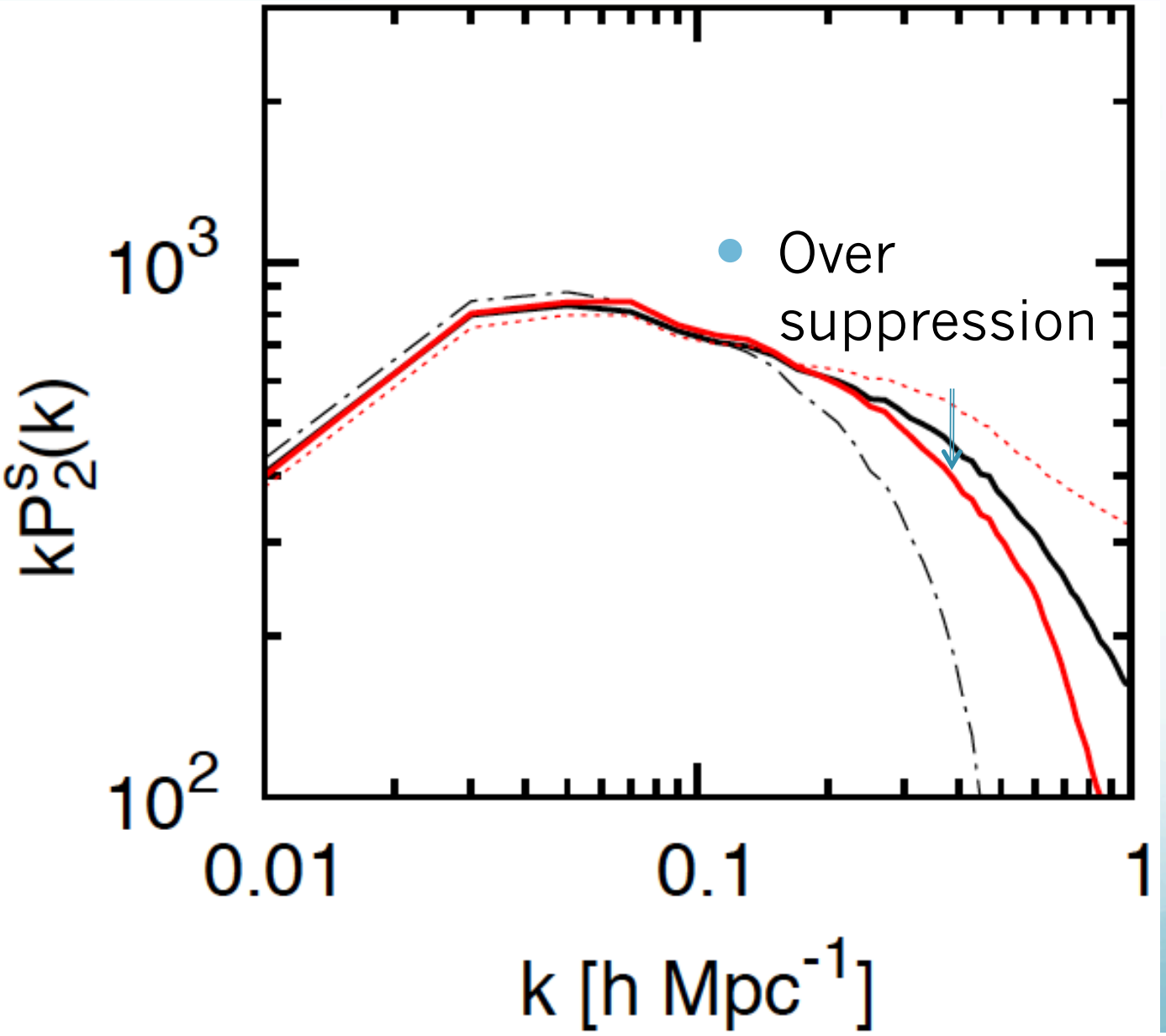
- On large scales, the clustering amplitude is corrected for using the real−space quadrupole (coming only from cylinder anisotropy).

Applying CiC to mock galaxies at z=0.5



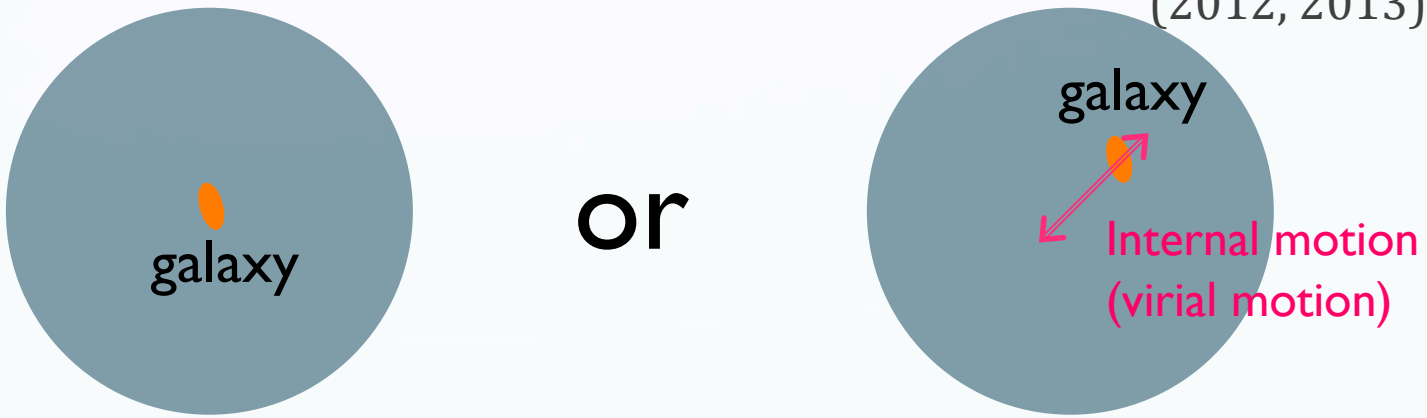
- The cylinder itself has an anisotropic shape, thus produces the artificial quadrupole.

Applying CiC to mock galaxies at z=0.5



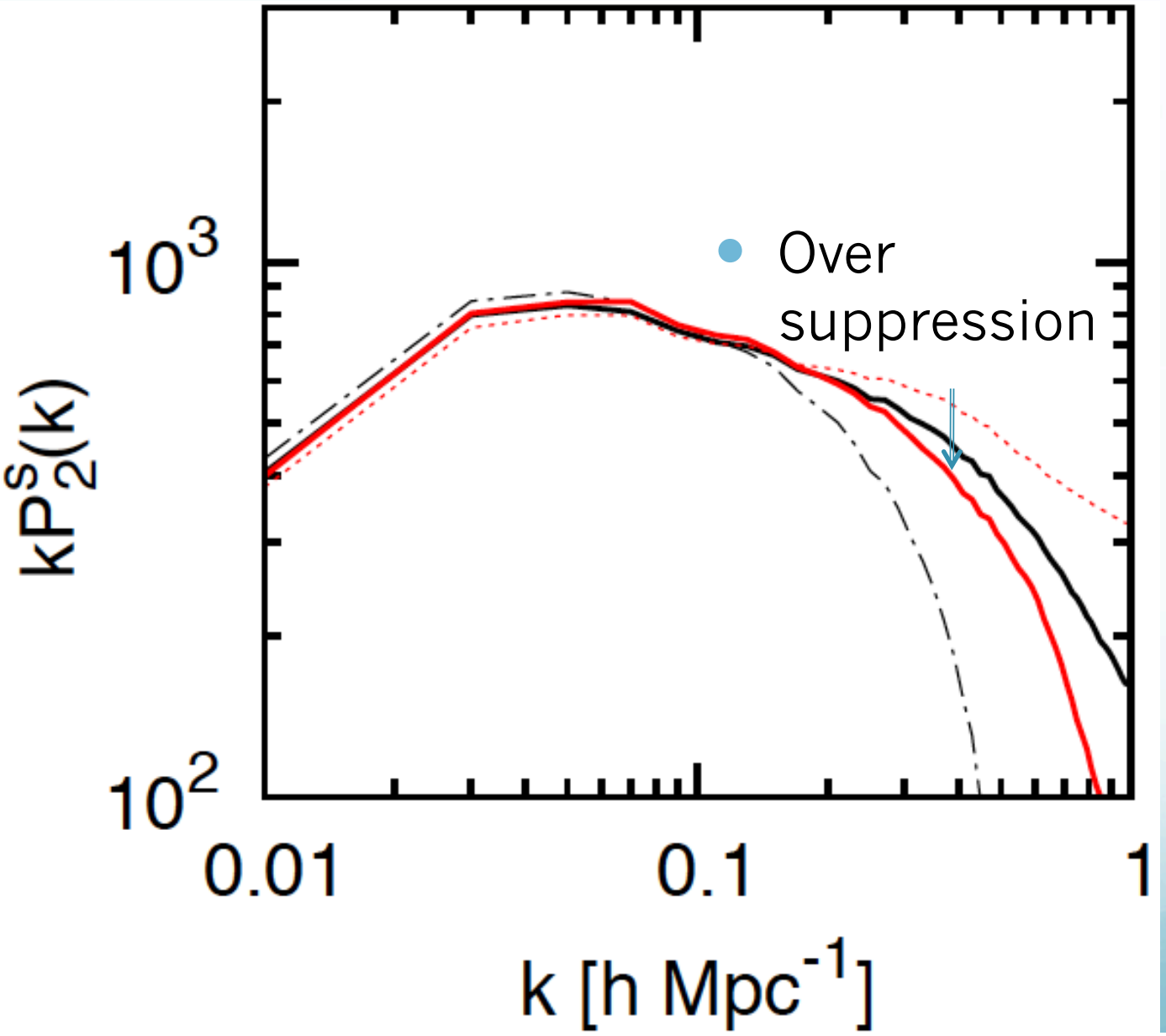
Off-centering effect even for single galaxy systems

Hikage, Takada et al (2012, 2013)

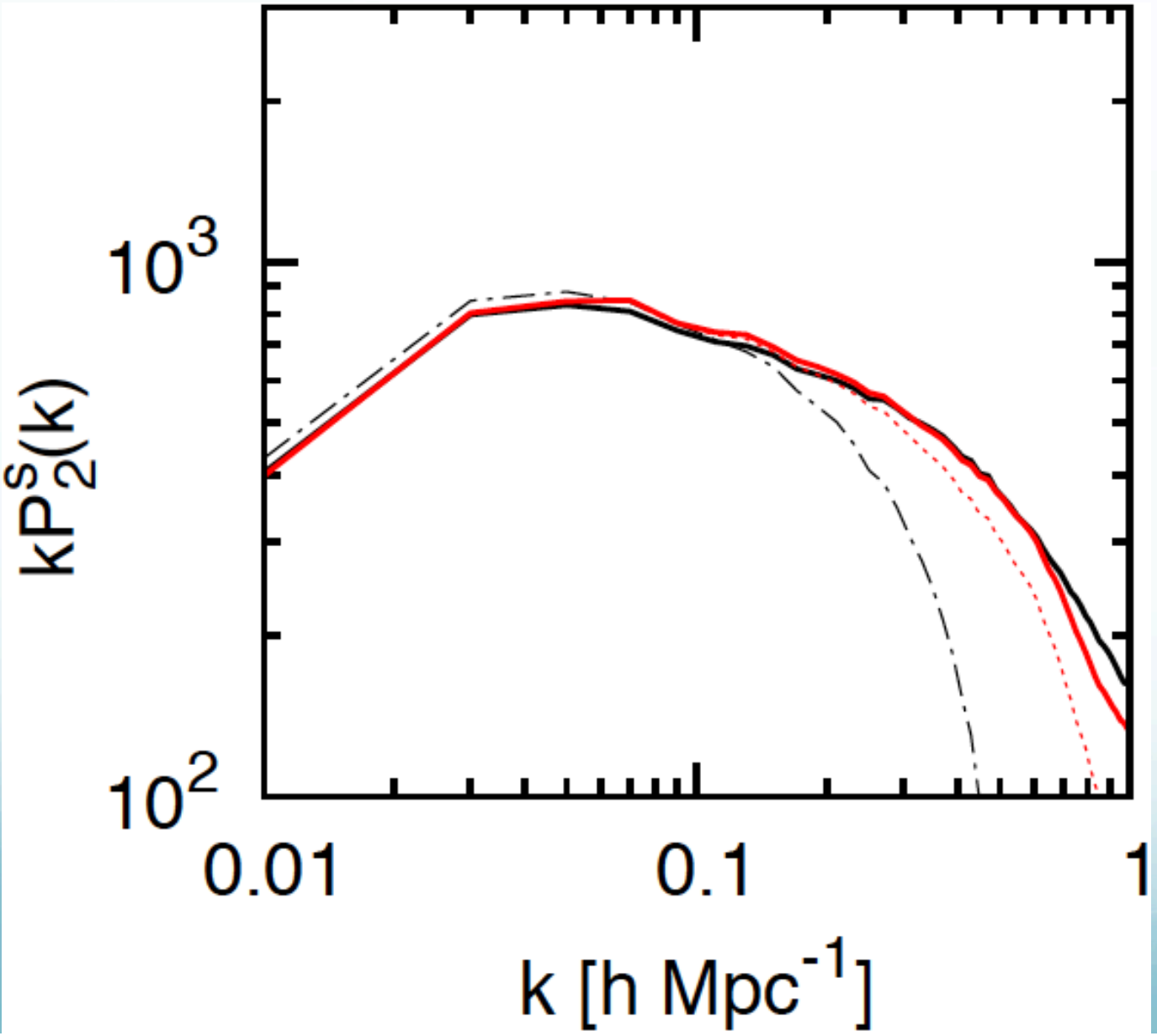


- ~20% of SDSS central LRGs are actually off-centered.
- It causes the residual FoG damping.
- Assuming we can correct for the effect (we could if galaxy-halo lensing is used), the galaxy velocity is replaced by the halo center.

Applying CiC to mock galaxies at z=0.5

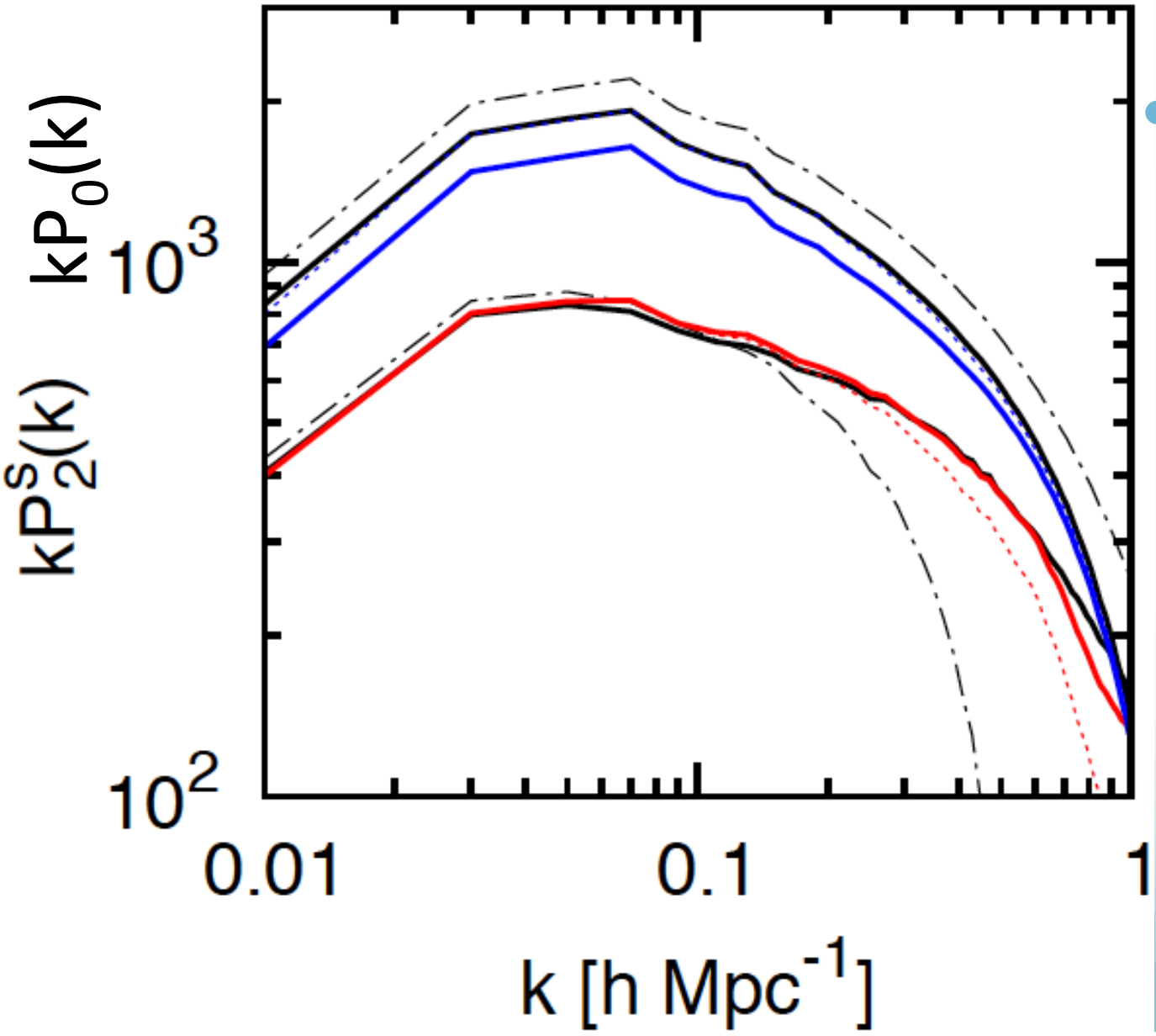


Applying CiC to mock galaxies at z=0.5



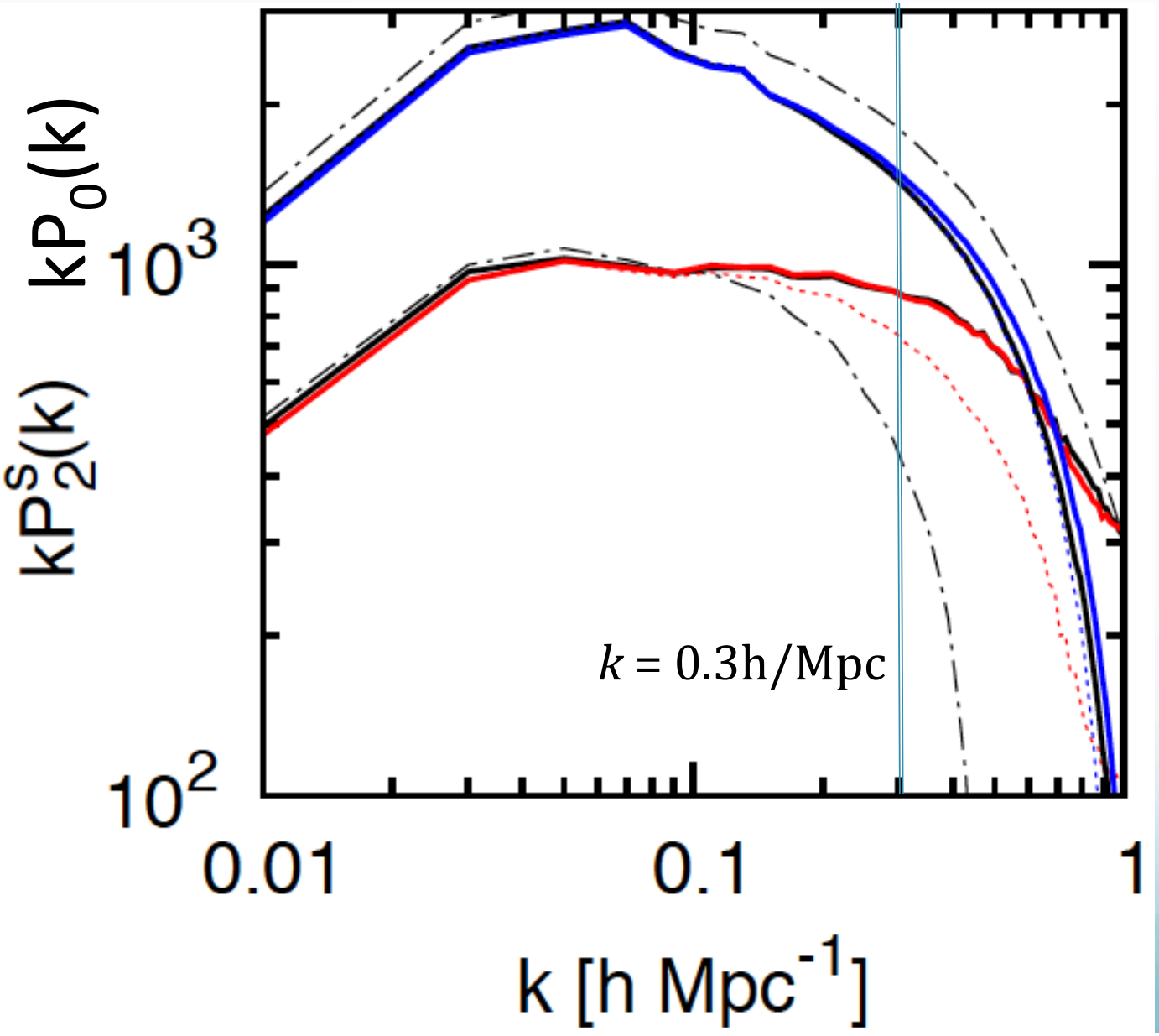
- The original halo qudrupole is recovered up to high k!

Applying CiC to mock galaxies at z=0.5



- However, note that the clustering loss due to window is corrected using the real-space quadrupole (coming only from cylinder anisotropy).

Applying CiC to mock galaxies at z=0.5



- Reduce number density to
- $n_g \sim 1.0\times10^{-4}$ $_{(h/Mpc)^3}$
  - Related to clipping method
- Monopole + quadrupole with galaxy-halo lensing work up to k~0.3h/Mpc for BOSS sample.

Conclusions

- We have developed a method to reconstruct halo power spectrum from observed redshift-space galaxy distribution using CiC and halo exclusion correction.
- It works pretty well for BOSS-type galaxy sample, particularly when we reduce the number density by a factor of 3 close to SDSS LRG.
- Up to $k \sim 0.3$ h/Mpc for both Monopoles and quadrupoles, if galaxy off-centering effect is corrected for using galaxy-halo lensing.
- We can extract cosmological information from the BOSS survey using theoretical model for halos.
- Can be extended to eBOSS, HETEX, PFS, DESI,…