Redshift-Space Distortions of the Galaxy Distribution

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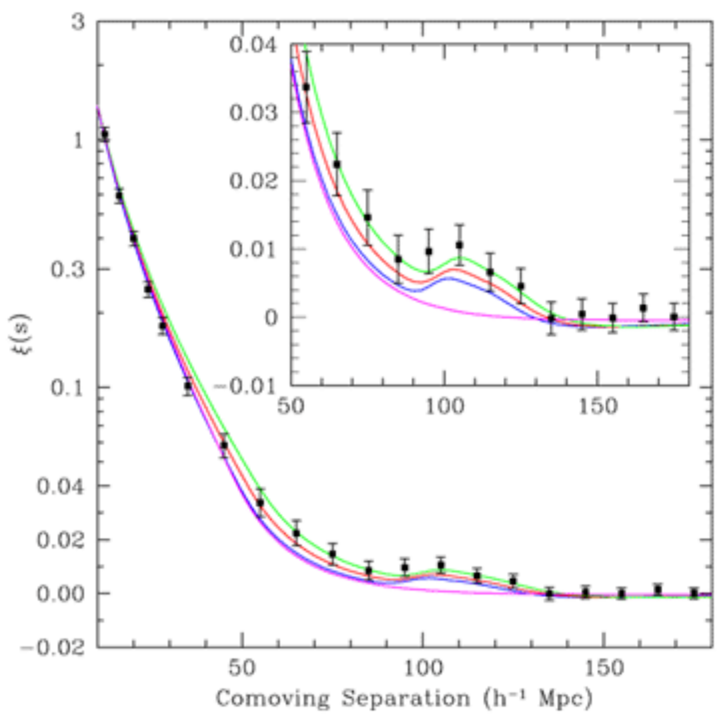
Redshift Space Distortions

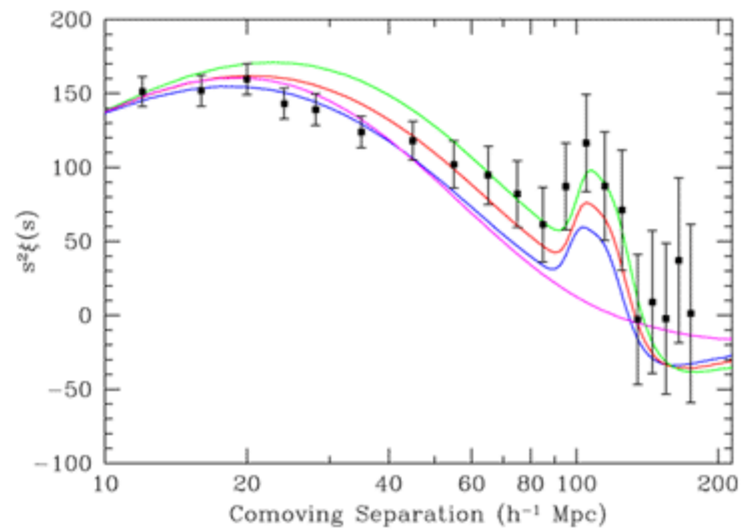
Three different distortions

- Linear infall (large scales)
  - Flattening of the correlations (Kaiser 86)
- Thermal motion (small scales)
  - 'Fingers of God'
  - Cuspy exponential (Davis&Peebles) $P(v_{12}) \propto e^{-|v_{12}|/\sigma}$
- Nonlinear infall (intermediate scales)
  - Caustics

Finding the BAO in SDSS DR4

- Eisenstein et al (2005) – LRG sample





Correlation function

Redshift Space Correlations

$$\xi^{(s)}(r,\gamma) = \left(1 + \frac{2\beta}{3} + \frac{\beta^2}{5}\right)\xi_0(r) - \left(\frac{4\beta}{3} + \frac{4\beta^2}{7}\right)\xi_2(r)P_2(\cos\gamma) + \frac{8\beta^2}{35}\xi_4(r)P_4(\cos\gamma)$$

$$\xi_L^{(n)}(r) = \frac{1}{2\pi^2}\int dk\, k^2 k^{-n} j_L(kr) P(k).$$

- Azimuthal average wipes out the P_2 and P_4 terms, only the real space correlation function remains
- β terms contain a second derivative (Hamilton '92)

$$\frac{2\beta}{3}\left[j_0(kr) - 2j_2(kr)\right] = -2\beta\left[j_0''(kr)\right]$$

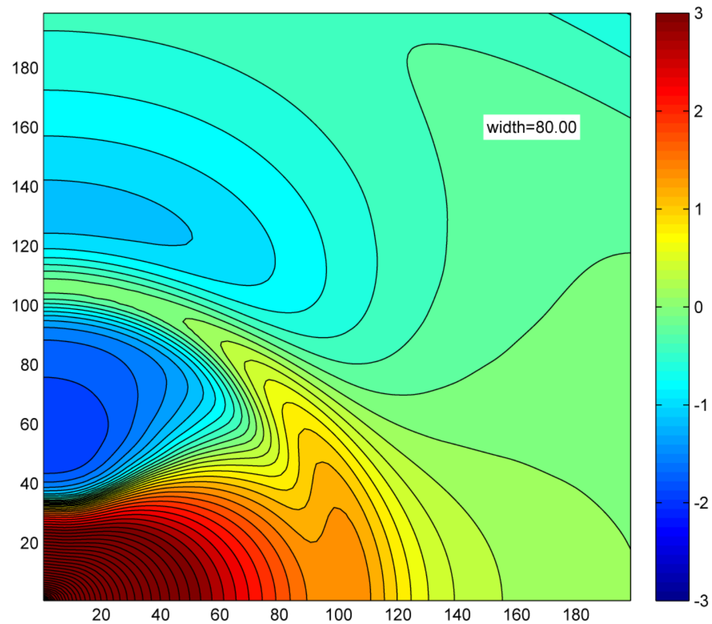
- Interesting effect on power spectra with sharp features: redshift-space distortions make features even sharper!
- Baryon Acoustic Oscillations !!!

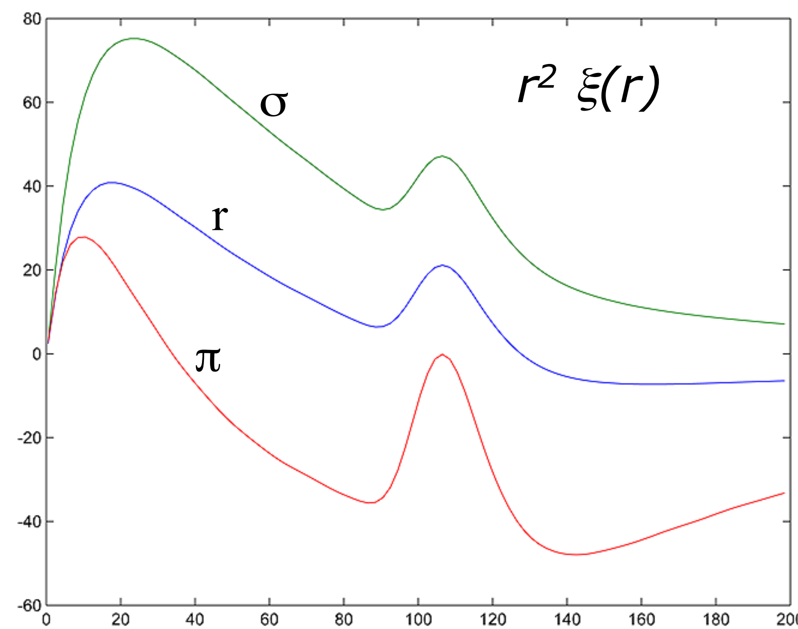
$\xi(r)$ from linear theory + BAO

- Mixing of ξ_0 , ξ_2 and ξ_4
  - Along the line of sight

$$\xi_n(r) = \frac{1}{2\pi^2}\int_0^\infty dk\, k^2 j_n(kr) P(k)$$

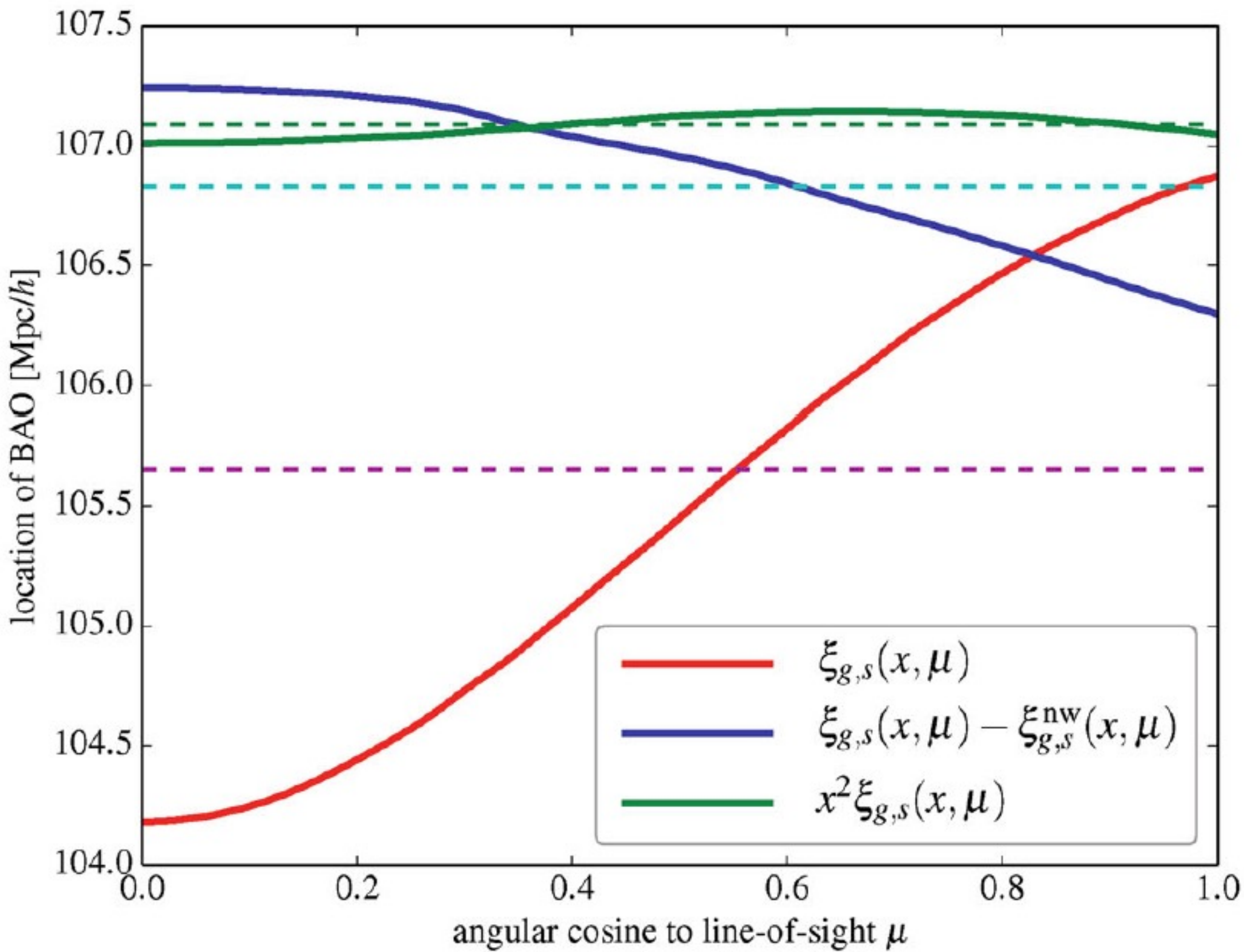
$$\xi^{(s)}(r) = \left(1 + \frac{2\beta}{3} + \frac{\beta^2}{5}\right)\xi_0(r) - \left(\frac{4\beta}{3} + \frac{4\beta^2}{7}\right)\xi_2(r) + \frac{8\beta^2}{35}\xi_4(r)$$





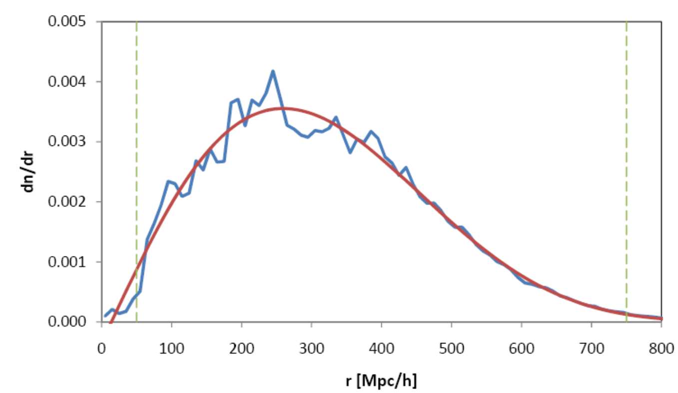
Shift of the BAO Scale with μ?

Position of the BAO peak is sensitive to how we measure it
(Jeong, Dai, Kamionkowski, Szalay 2015)



Analyzing the Main SDSS Sample

- SDSS DR7 MGS, Stripes 9 through 37, Northern Cap only
- 0.1<z<0.18, zConf>0.9, zErr<0.1
- Remove all objects in the incomplete areas
- 300K objects
- 17M random galaxies
- Slices:



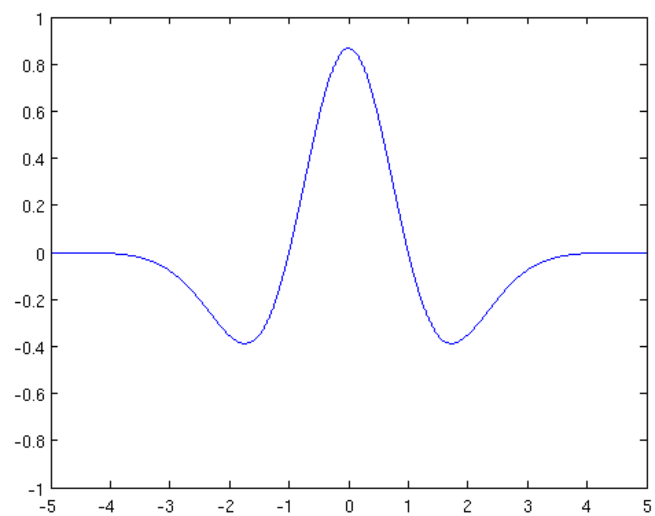
From 0 to 165°, 15° increments, 12 angular orientations, 2.5° thickness, 20°<width<80°, 661 slices total

Tian, Neyrinck, Budavari, Szalay (2011)

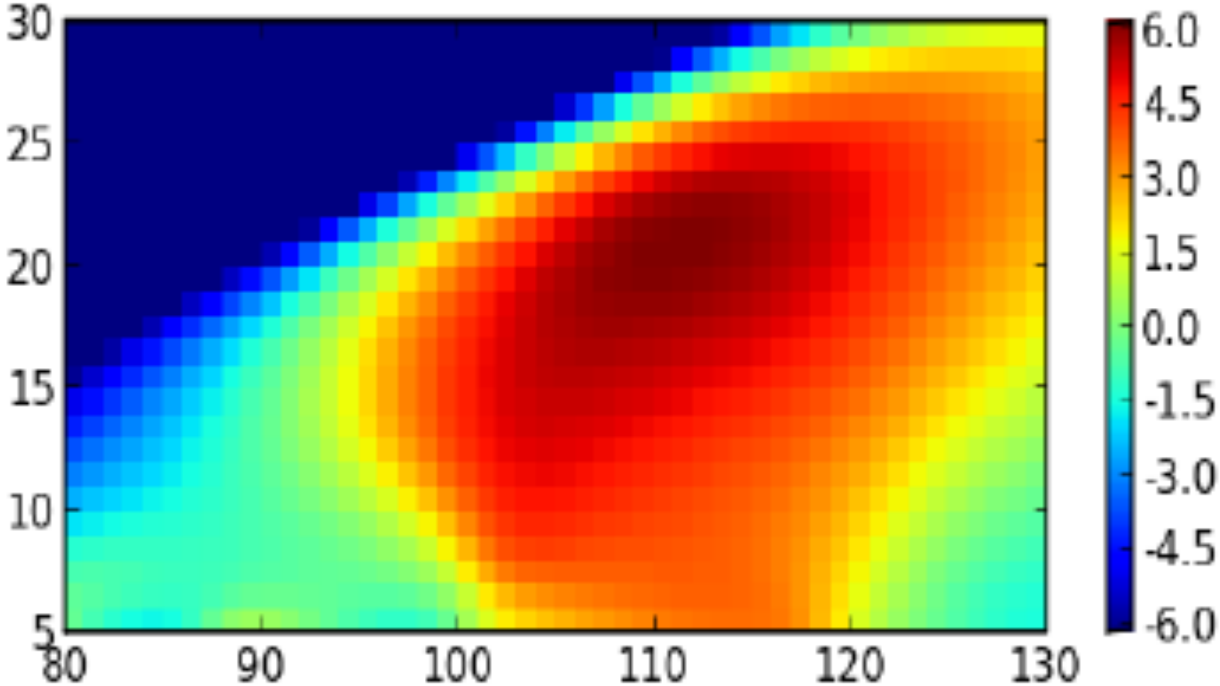
300-750 Mpc/h only, LOS

Wavelet Transform

- Mexican hat wavelet transform
  - Compensated filter
  - Enhances localized "bump"
- Zero signal for constant background
- Decreases correlations among bins



S/N of the Wavelet Transform

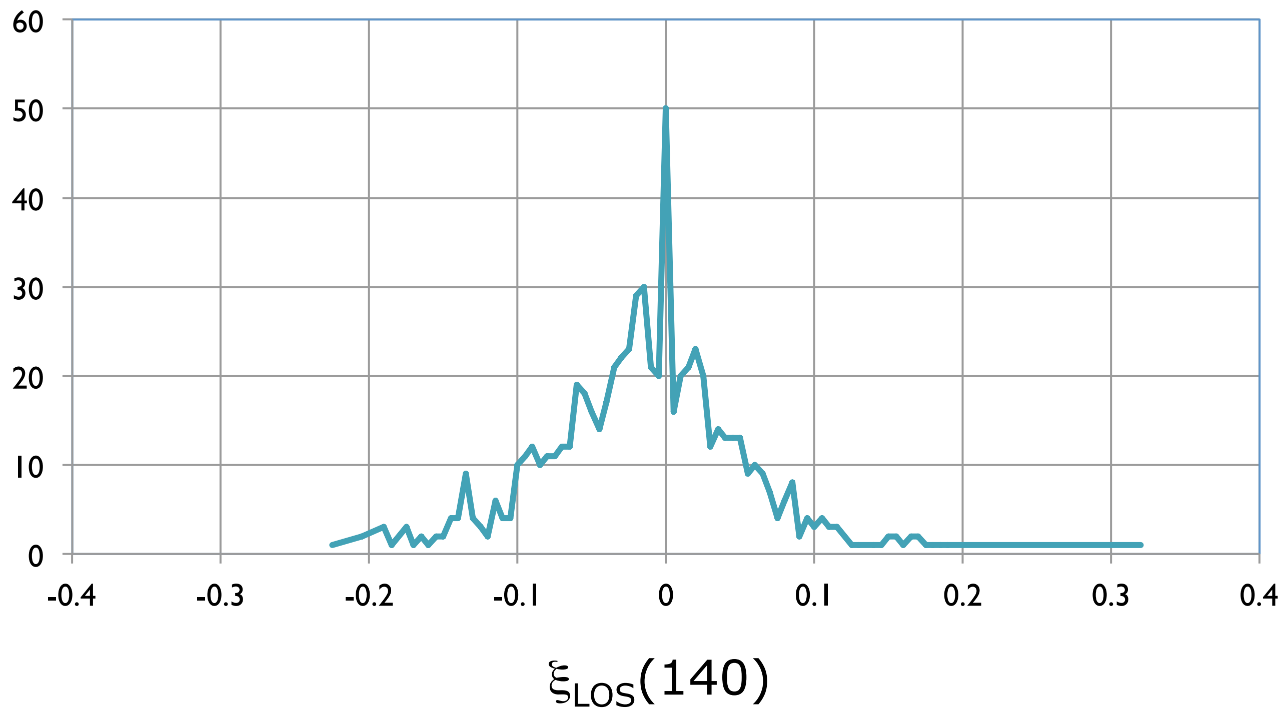


Flat theta weighting

Noise estimated from slices, corrected for correlations

Far Side Infall (140Mpc)

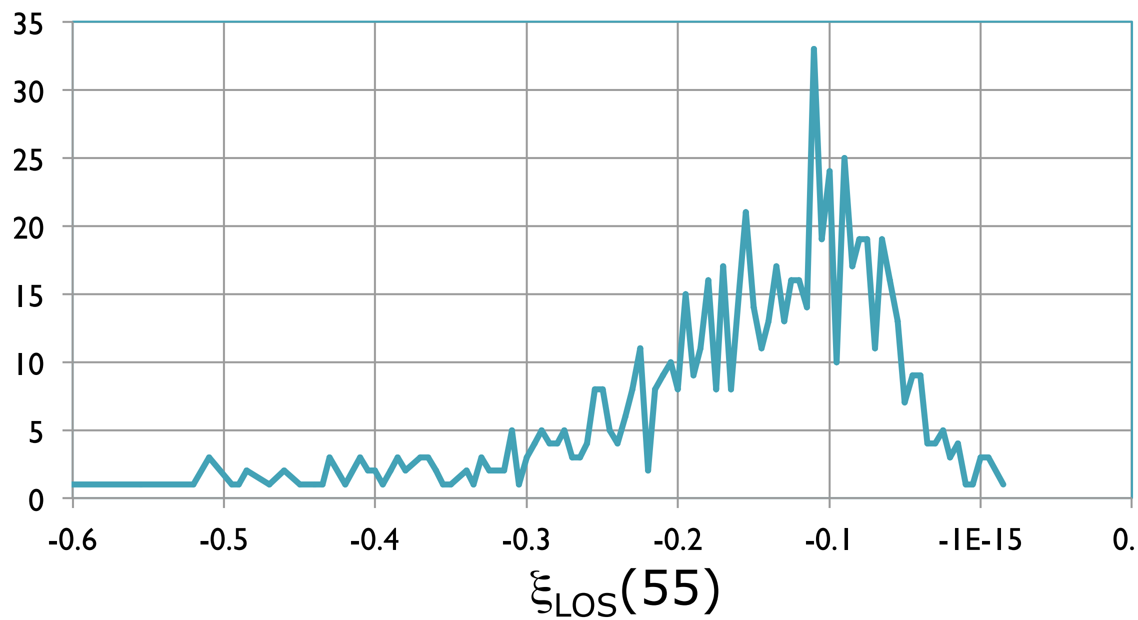
- Center: 140 h^{-1}Mpc, width: 25 h^{-1}Mpc
- Still shows some skewness



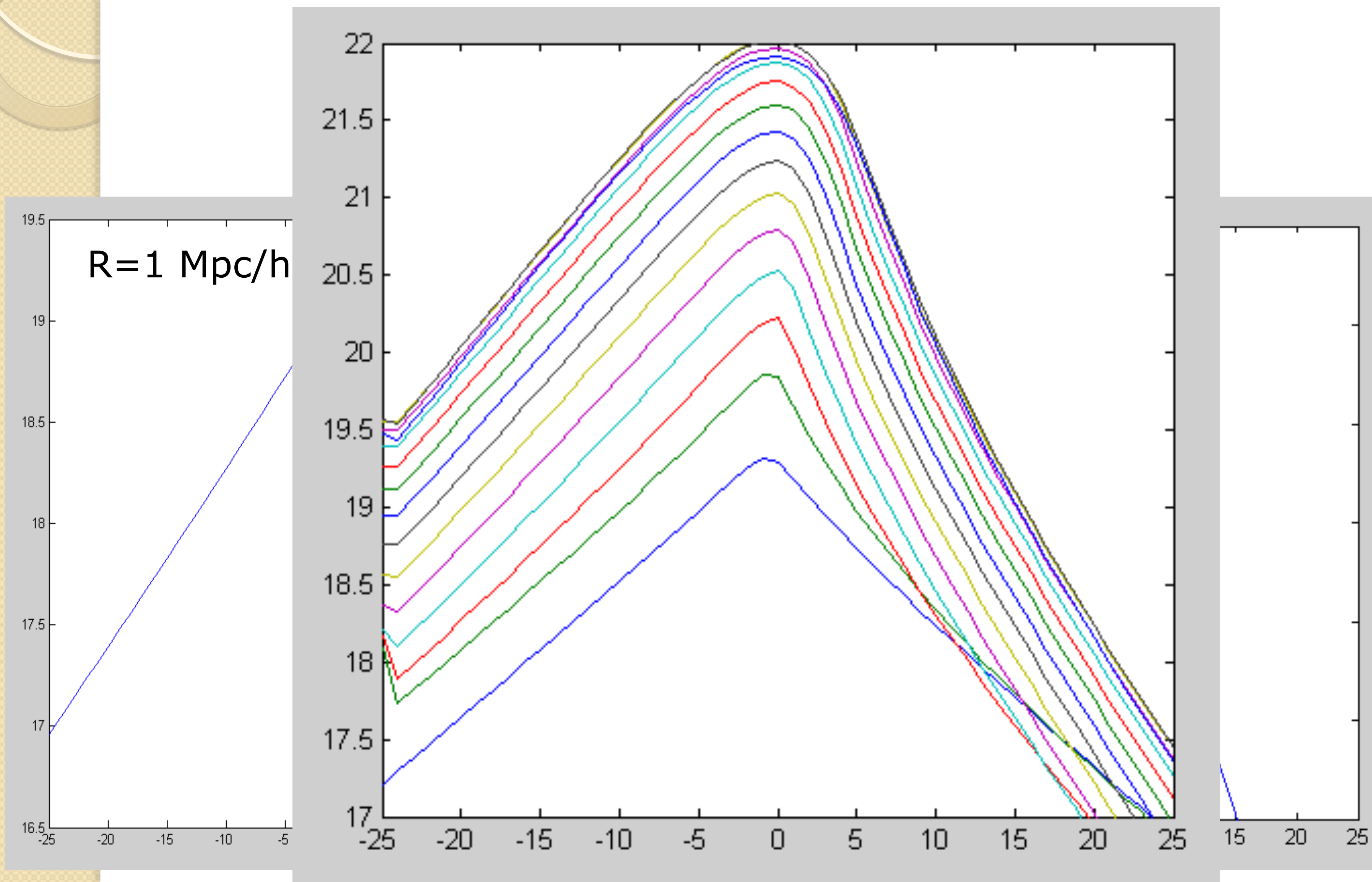
Strong Non-Linear Infall (55Mpc)

Distribution of LOS Mexican Hat wavelet coefficients over the 660 slices,

- Center at 55 h^{-1}Mpc, width 25 h^{-1}Mpc

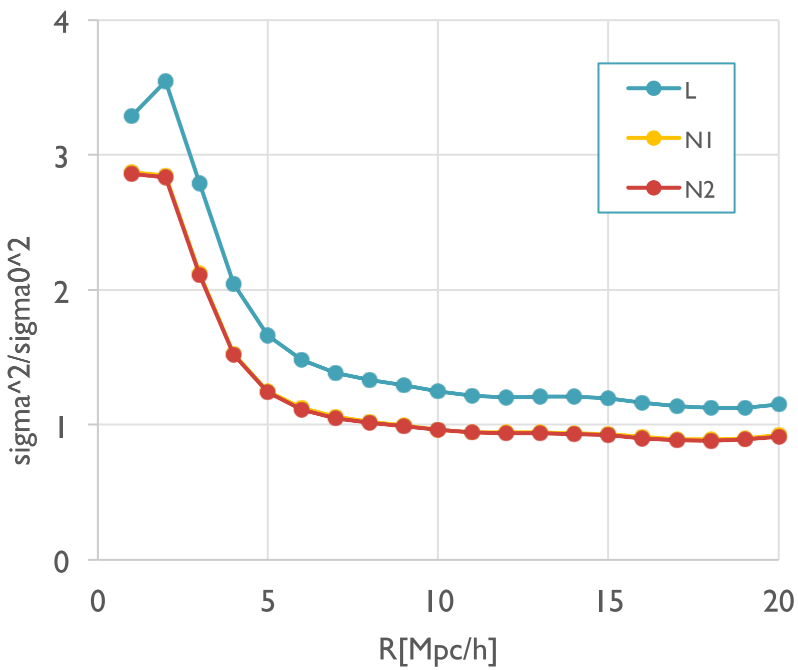


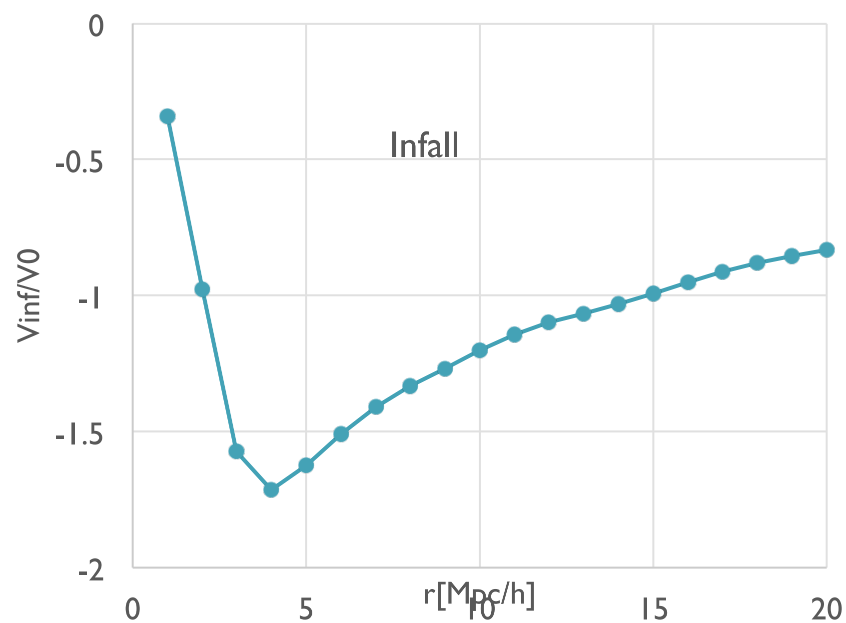
Pairwise Velocity Distribution



Pairwise Velocity Moments

- Longitudinal 2nd moment 25% more elongated than transverse
- Infall has a maximum at around 4Mpc/h

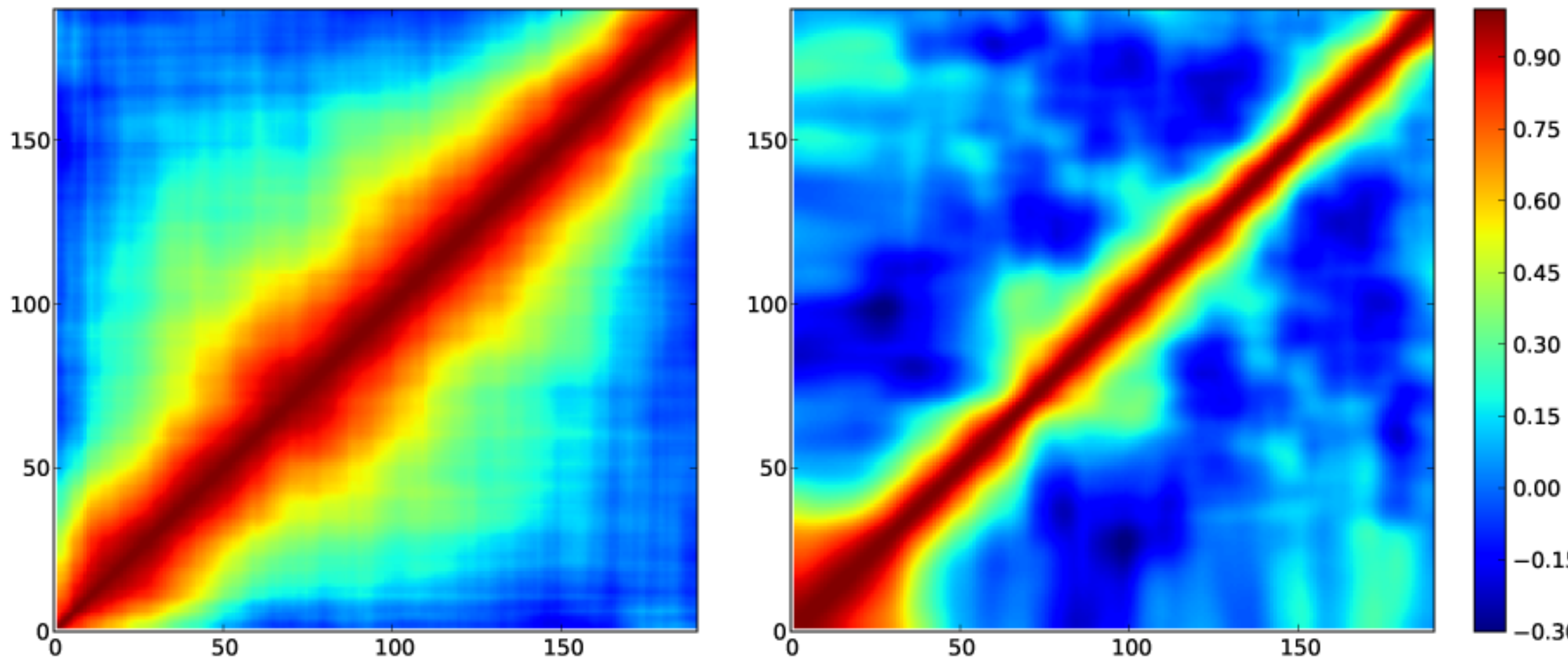




Using the Indra simulations (see B. Falck's talk)

Covariance matrix of

From the Indra simulations *Nuala McCullagh (2015)*



Real space Line of sight

Conclusion

- Redshift space distortions amplify and sharpen BAO features along the line of sight
- Near and far side infall onto the BAO bump
- Angular averaging wipes out most of this effect
- Evidence for BAO in SDSS DR7 MGS at ~110 h^{-1}Mpc, potentially constraining the equation of state at low z
- Trough at 55 h^{-1}Mpc indicates effects of strong nonlinear infall on these scales
- Nonlinearities important even on BAO scales!
- Fingers of God are quite anisotropic