Skewness as probe of BAO

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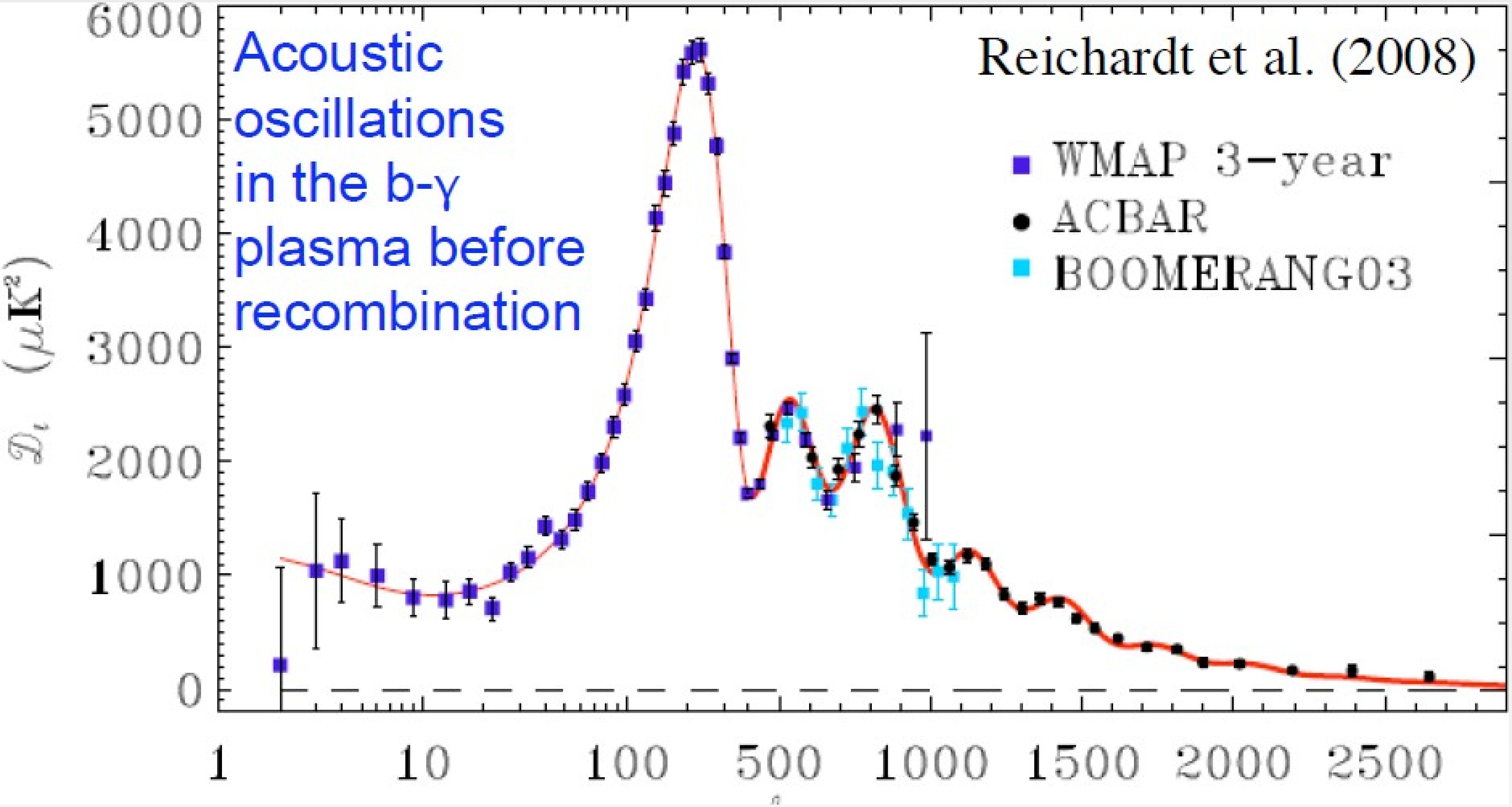
The BAO basics

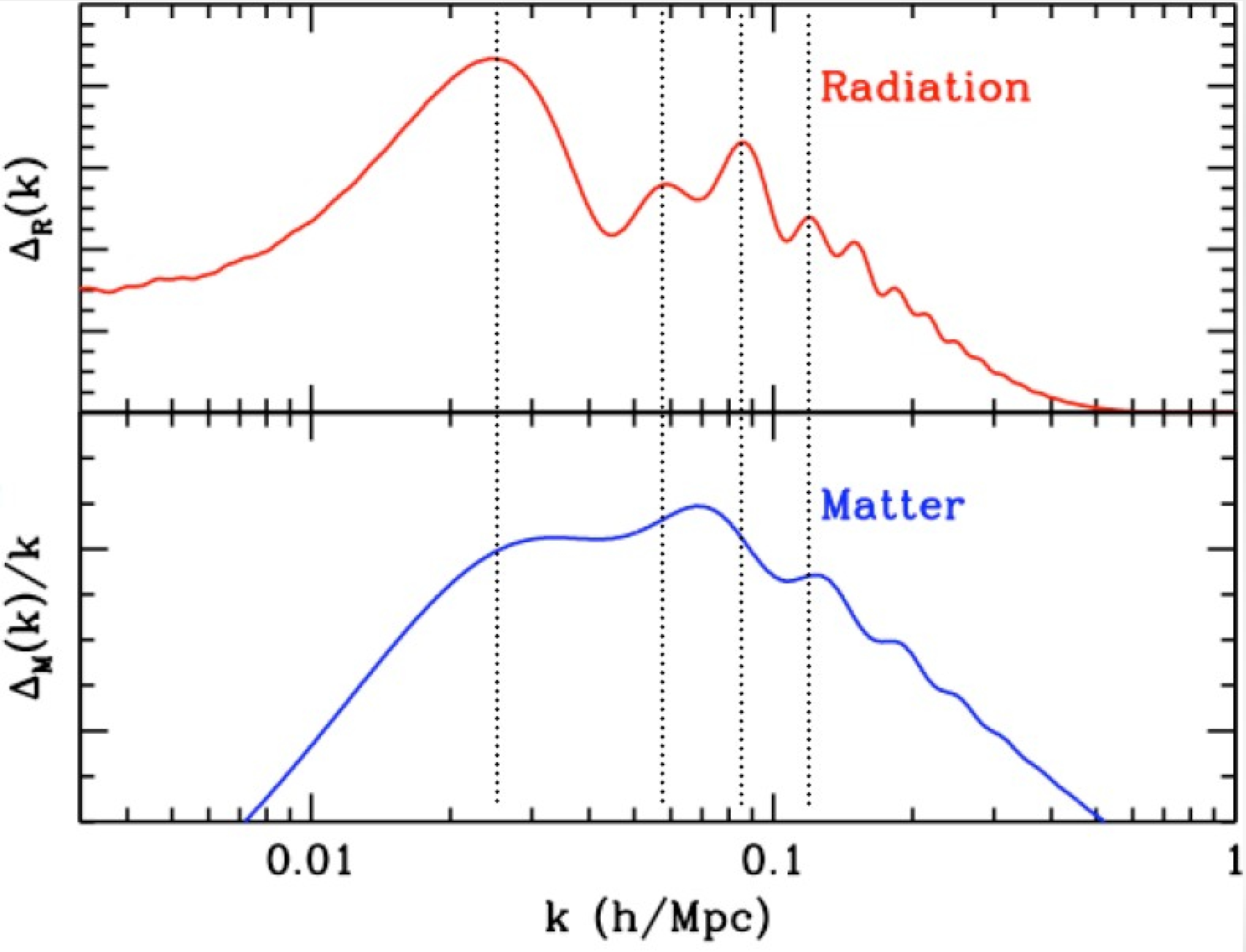
- Sound waves that propagate in the opaque early universe imprint a characteristic scale in the clustering of matter, providing a “standard ruler” whose length can be computed using straightforward physics and parameters that are tightly constrained by CMB observations.
- Measuring the angle subtended by this scale determines a distance to that redshift and constrains the expansion rate.
- The detection of the acoustic oscillation scale is one of the signature accomplishments of the SDSS, and even this moderate signal-to-noise measurement substantially tightens constraints on cosmological parameters.
- But, very large surveys are required to attain high statistical precision.

The CMB power spectrum



- The sound horizon scale ($s \sim c_s t_{ls}$) at the last scattering sets the location of the acoustic peaks. High accuracy for that one measurement – but only for one z.

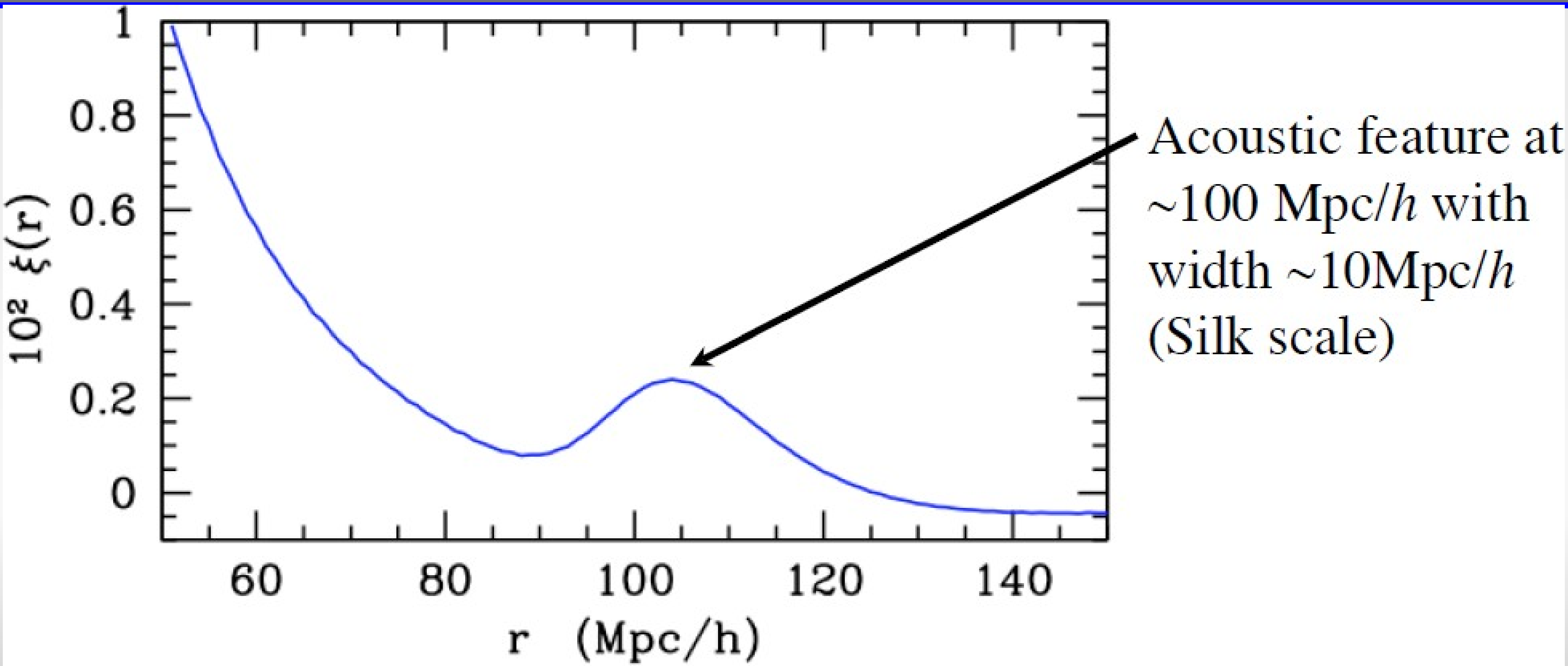
The baryon acoustic oscillations



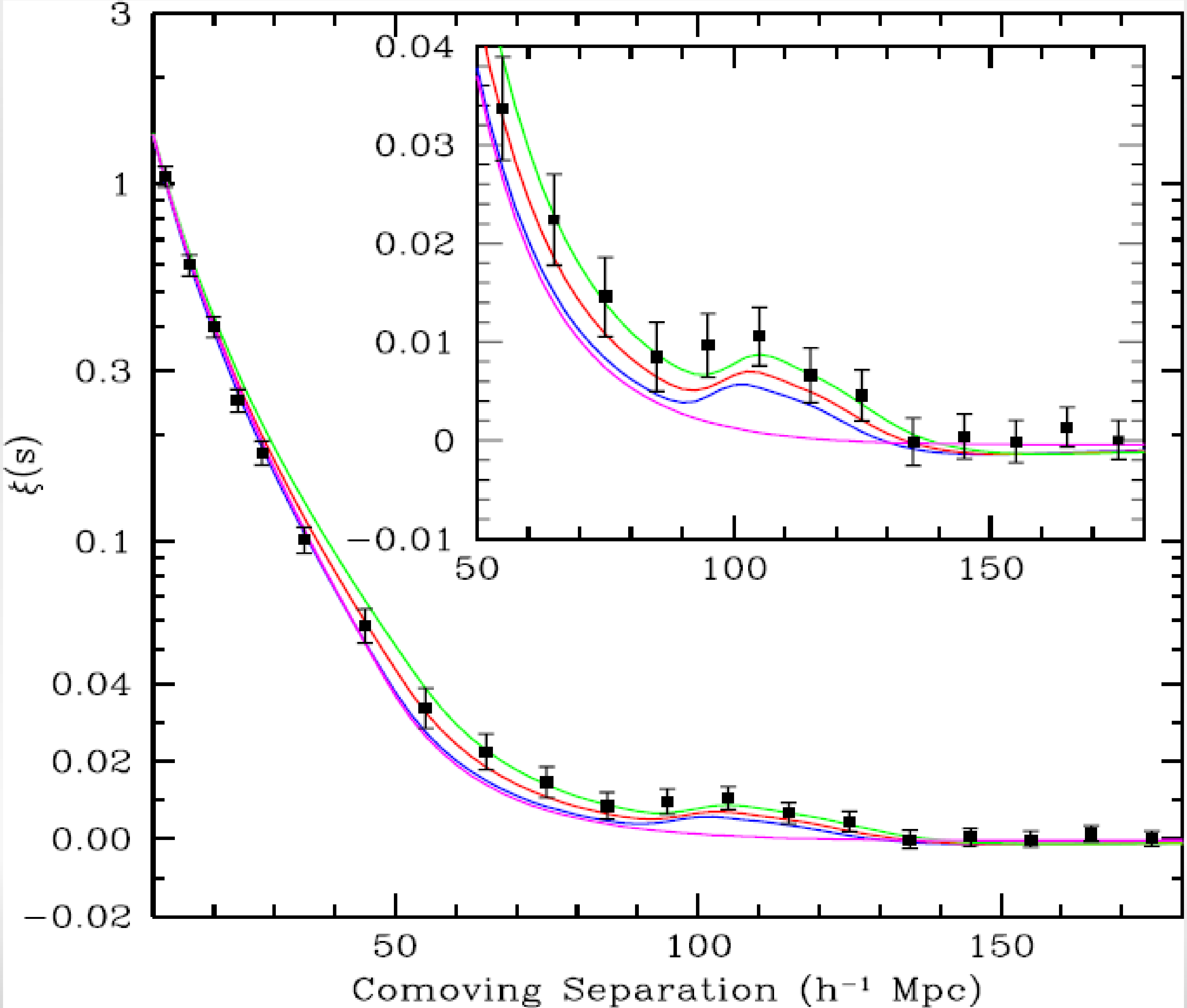
“borrowed” from M. White presentation

The configuration space

• These features are frozen into the matter power spectrum and provide a known length scale (standard ruler) with which to measure dA(z) and H(z) as a function of z. Both dA and H constrain DE.
• In Fourier space, a damped (almost) harmonic series of peaks in P(k).
• In configuration space a narrow feature in ξ(s) at the sound horizon



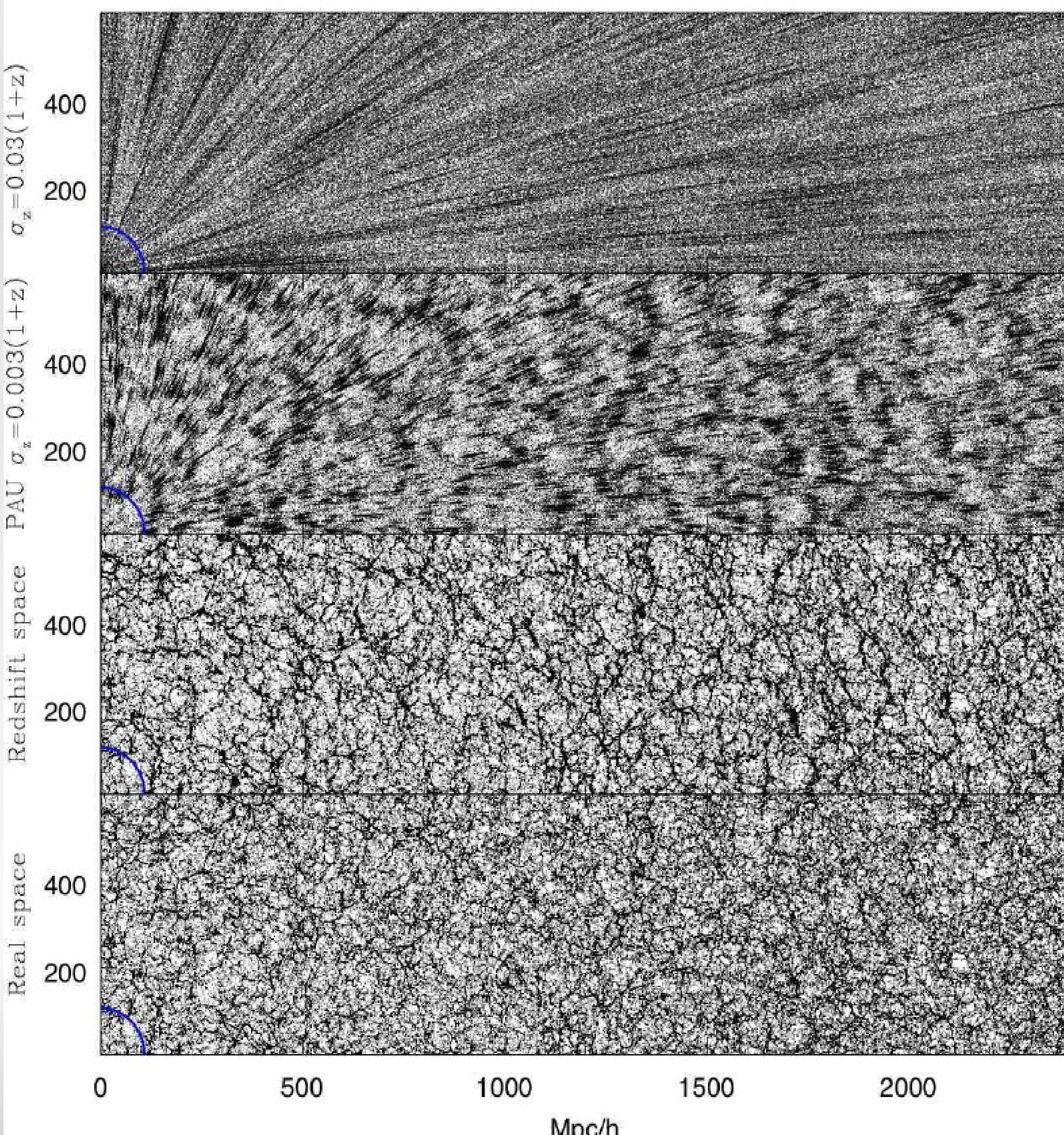
The measured signal in SDSS LRG



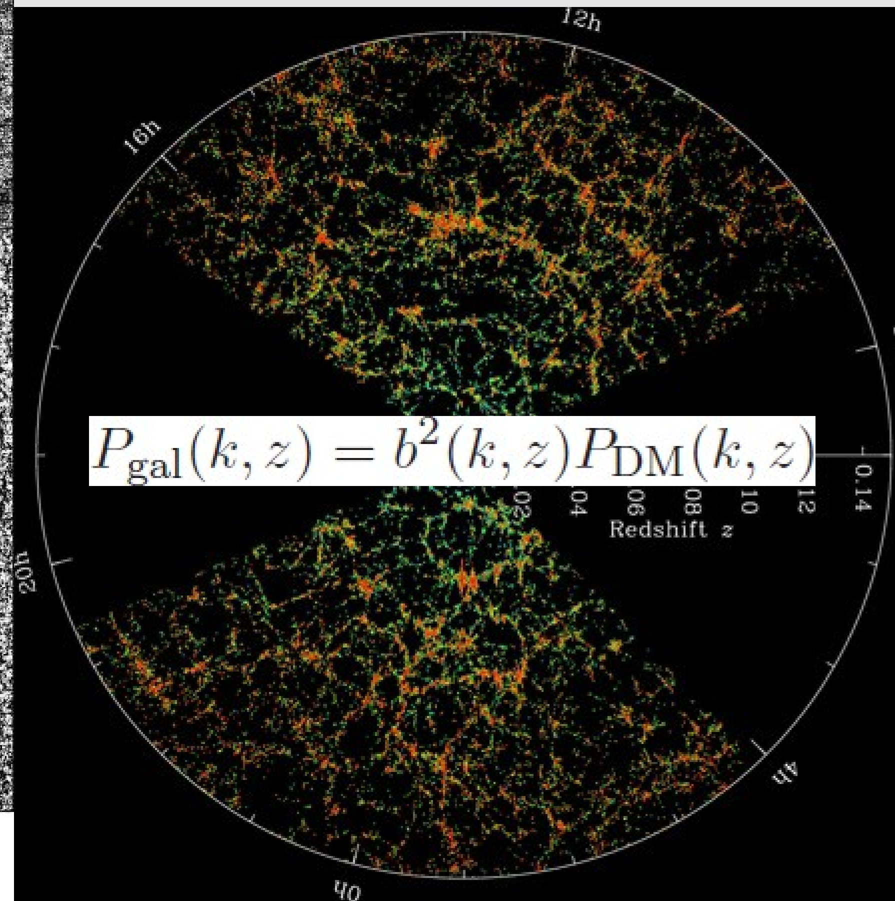
From Eisenstein et al. 2005

Main source of errors

Bassett and Hlozek, 2009



On top of a whole bunch of possible systematic errors, the measurements of ξ(r) are plagued by two major sources of errors: **redshift space distortions** and **galaxy bias**



$$P_{\rm gal}(k,z) = b^2(k,z) P_{\rm DM}(k,z)$$

The skewness

- The reduced third moment S_3 of the density filed – the skewness is linear bias free and also is affected only weakly by the redshift space distortions (e.g. Hivon et al. 1995) for linear and mildly non-linear scales
- The basic setup:
- We assume the fair-sample hypothesis and then can express volume-averaged J-point correlation function as:

$$\bar{\xi}_J = V_W^{-J} \int_S d\mathbf{x_1}...d\mathbf{x_J} W(\mathbf{x_1})...W(\mathbf{x_J}) \xi_J(\mathbf{x_1}, ..., \mathbf{x_J}), \quad (1)$$

Now the reduced third moment – the skewness will be:

$$S_3 = \frac{\bar{\xi}_3}{\bar{\xi}_2^{\,2}} = \sigma^{-4} \bar{\xi}_3 \quad (2)$$

The skewness and PT

- Juszkiewicz et al. 1993 showed that the skewness of the field smoothed with the spherical top-hat window is estimated by:

$$S_3 = \frac{34}{7} + \gamma_1, \tag{3}$$

well known result for an unsmoothed field (Peebles 1980)

Gamma term – depended on the local shape of P(k)

- The gamma is the logarithmic slope of the variance:

$$\gamma_1 = -(n+3) = \frac{d \log \sigma^2(R)}{d \log R}\ , \tag{4}$$

$$\sigma^2(R) = \sigma^2(R) = \frac{1}{2\pi^2}\int_0^\infty dk\ \ k^2 P(k) W^2(kR), \tag{5}$$

The skewness and PT

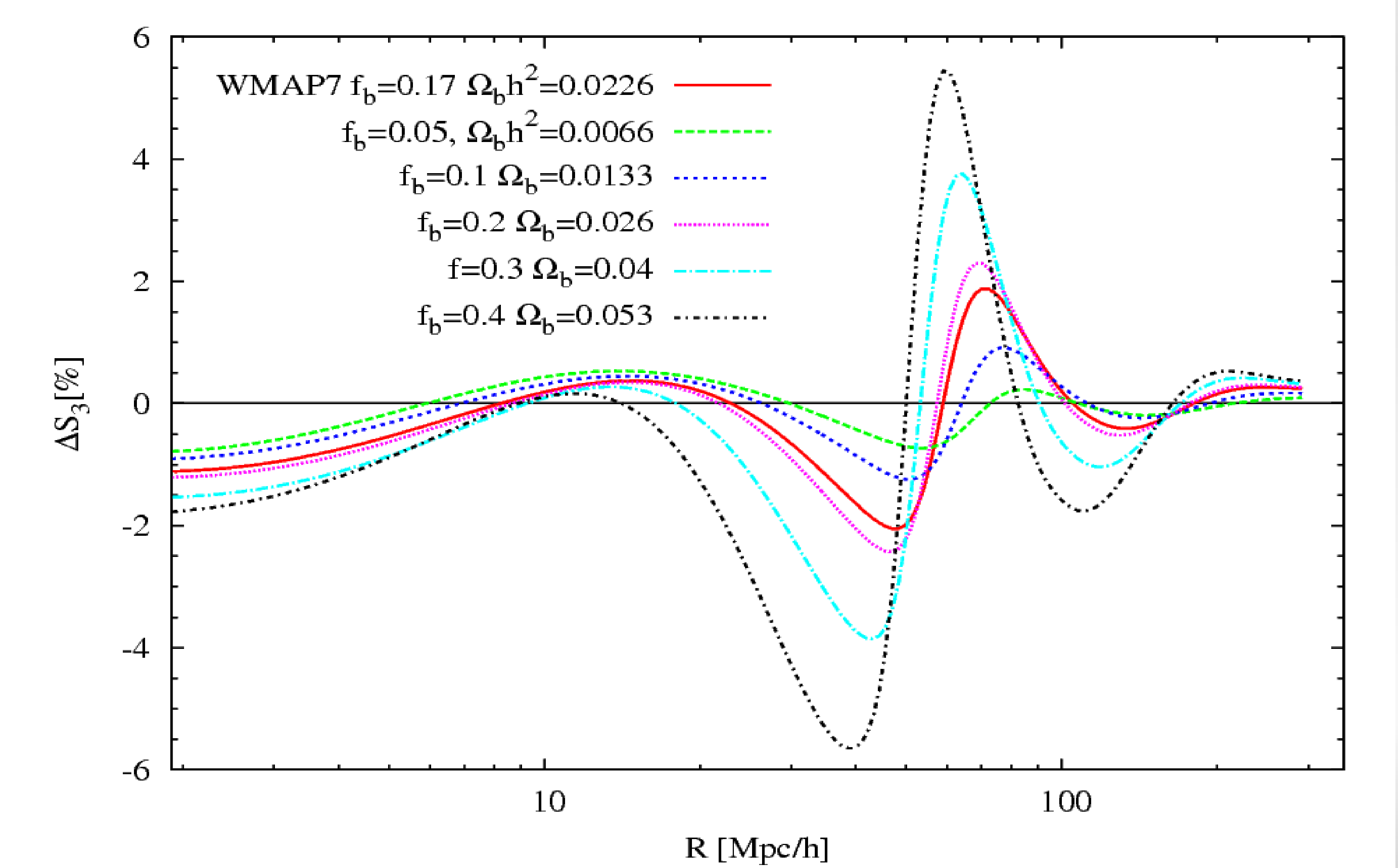
- Finally Juszkiewicz,Hellwing & van de Weyagert (in prep.) report that according to PT the gamma factor can be expressed as:

$$\gamma_1(R) = 2 - \frac{2\int_0^\infty \mathrm{d}k P(k) j_1(kR) kR \left[j_0(kR) - 2j_2(kR)\right]}{3\int_0^\infty \mathrm{d}k P(k) j_1^2(kR)}\,, \quad (9)$$

- This allows as to draw prediction on the theoretically expected signal of BAOs in volume-averaged skewness.

The skewness and BAO

- The sound horizon (the peak scale in ξ_2) depends both on Ω_m and f_b – the same is for S_3



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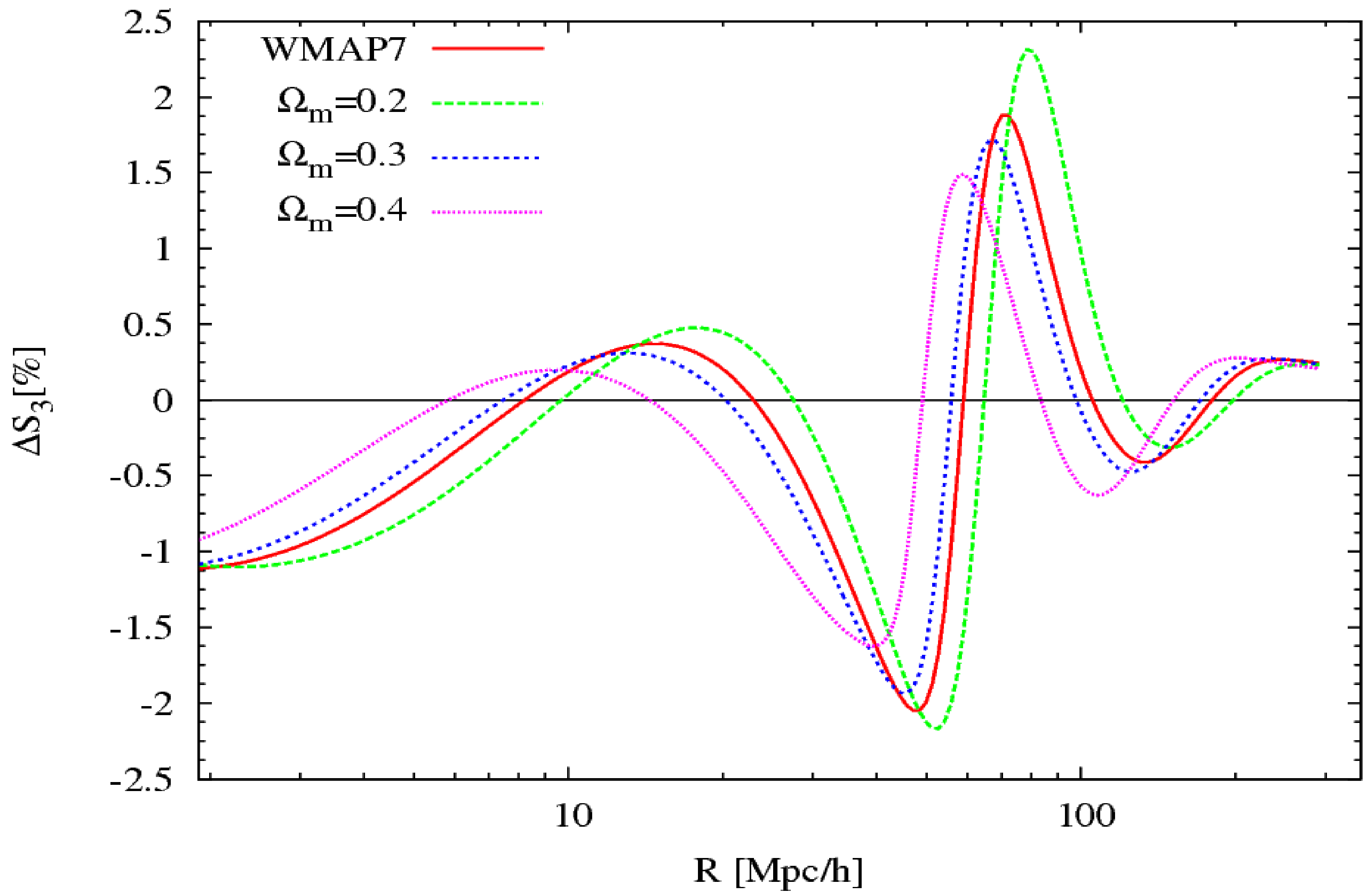
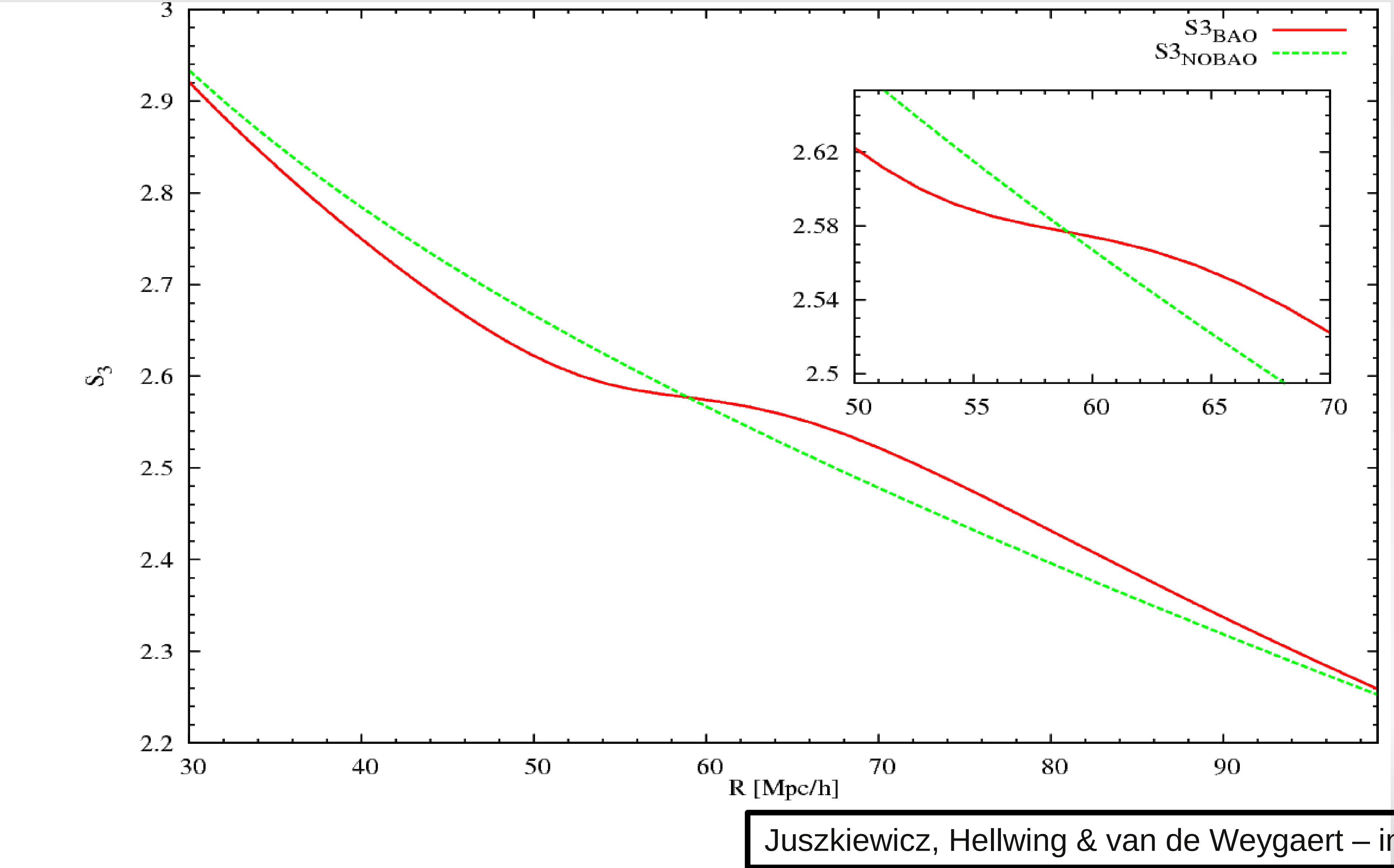


The final effect (from PT)

- In the configuration space the BAO peak in the skewness should be “visible” like this:



Juszkiewicz, Hellwing & van de Weygaert – in prep

The conclusions

- The BAO and BAP scale are universal measuring rods choice of XXI century cosmology
- Precise (below 1-2%) measurements of BAO can provide powerful DE and cosmology parameters constrains
- This calls however for a very large redshift surveys and still when applied for ξ_2 alone has to challenge the redshift-space distortions and possible galaxy bias
- We propose that a possible new/old source of rich cosmological information might be considered – the skewness
- In principle with a large-enough survey at hand it should be possible to measure BAO peak in the skewness
- The question remains: is that feasible? As “observationally-disabled” theorist I have no clue!