Edgeworth Streaming Model
for
redshift space distortions

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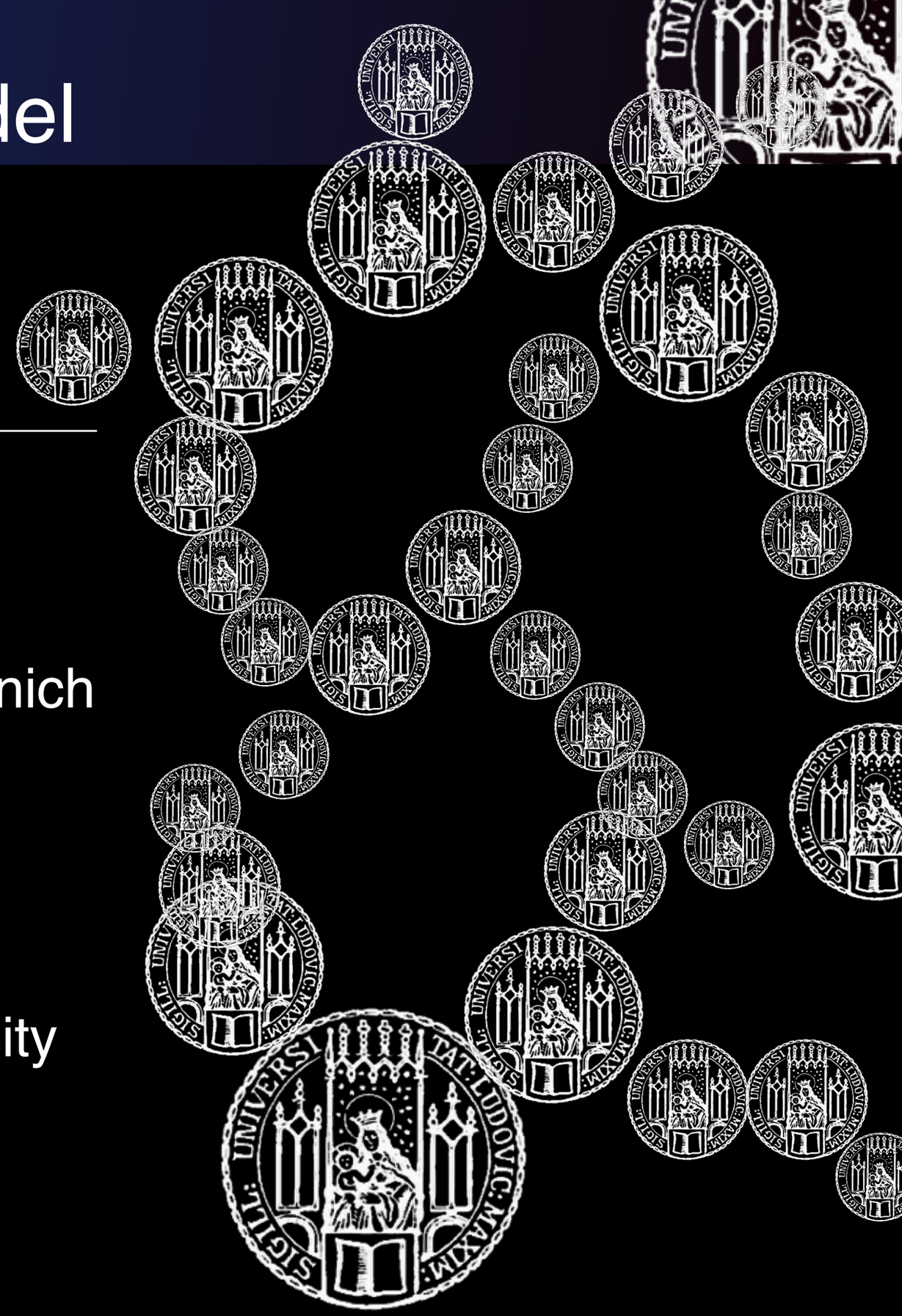


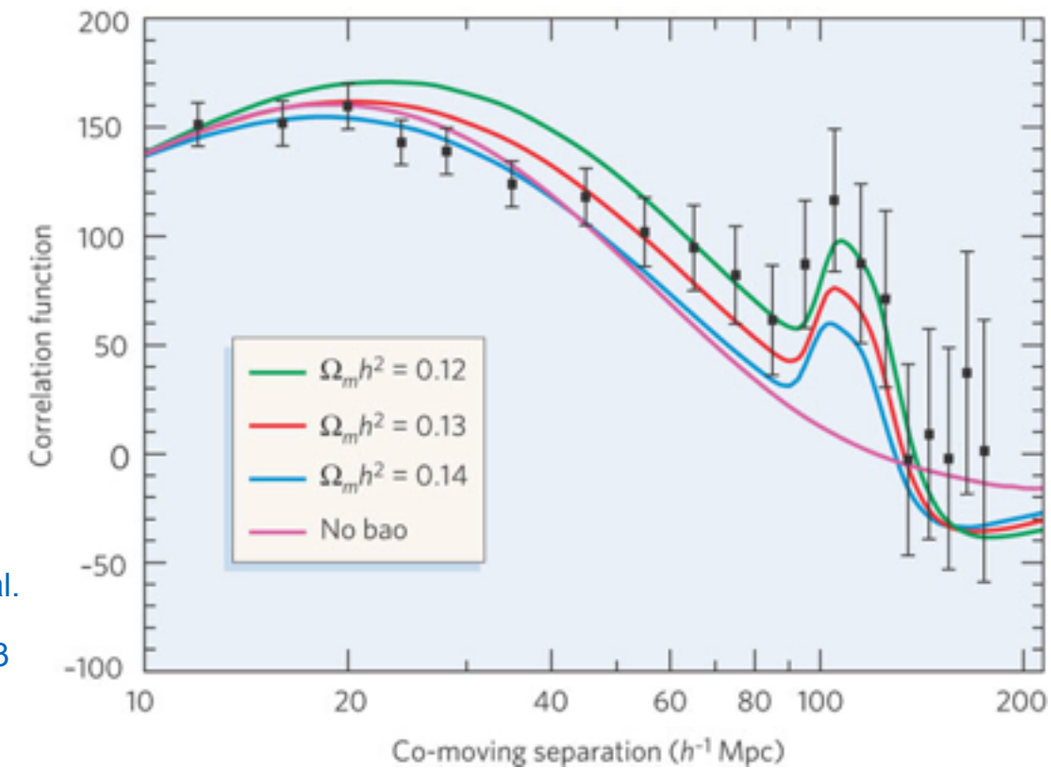
Redshift space correlation function

Correlation function

- measures excess probability

$$1 + \xi_X(s) = \left\langle (1 + \delta_X(s_1))(1 + \delta_X(s_2)) \right\rangle$$

- halos as biased DM tracers
  - input for halo model
  - powerful cosmological probe



Eisenstein et al.

2005 ApJ, 633

Redshift space distortions

- redshift observations affected by peculiar velocities

real space

$$1 + \xi_X(r = |\boldsymbol{r}|)$$

isotropic

$$s_{||} = r_{||} + v/\mathcal{H} \quad s_\perp = r_\perp$$

redshift space

$$1 + \xi_X(s, s_{||})$$

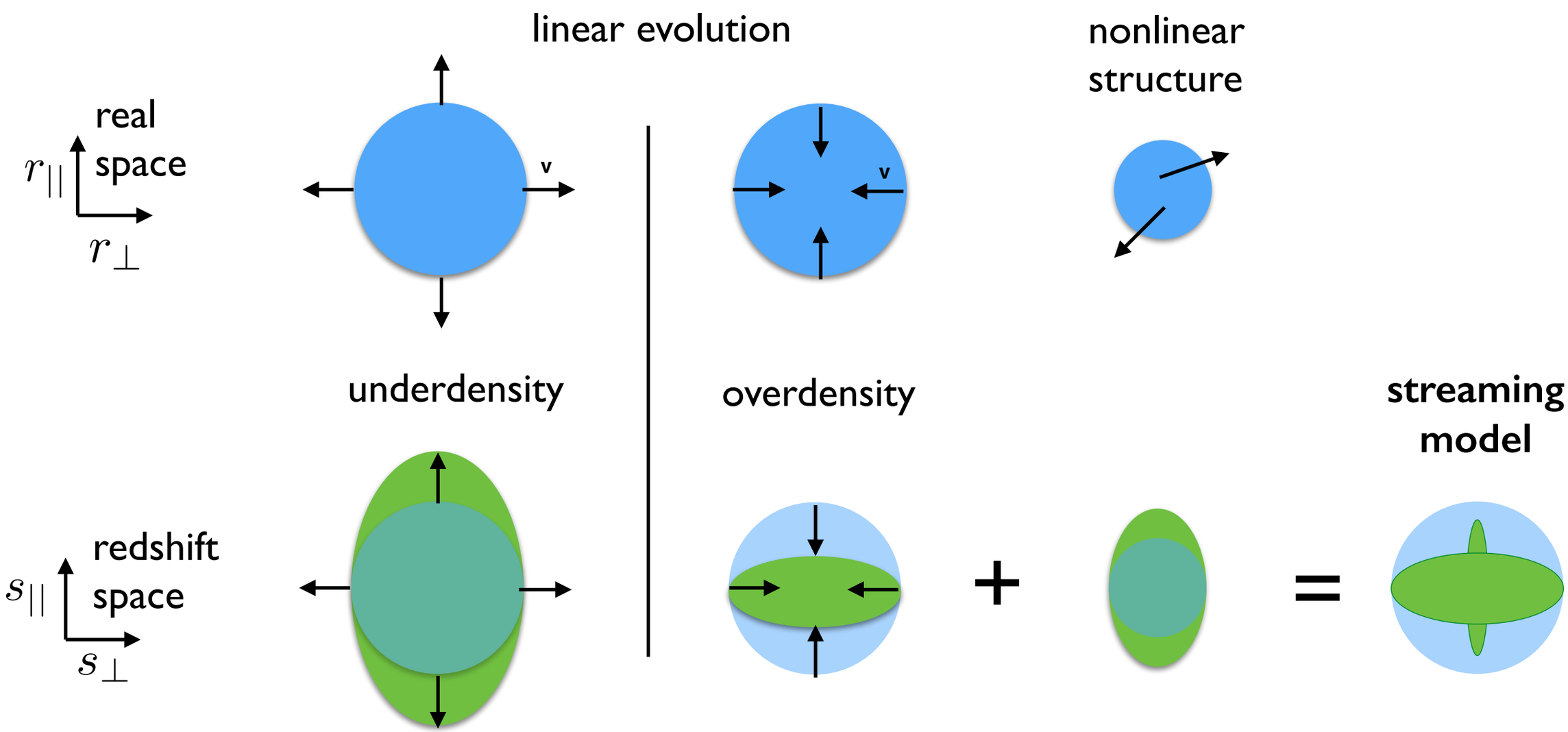
anisotropic

Redshift space correlation function

Redshift space distortions

- observations in redshift space from galaxy surveys
- impact of peculiar velocities along line of sight

$$s_{||} = r_{||} + v/\mathcal{H} \quad s_\perp = r_\perp$$



Streaming model

Gaussian Streaming Model

Gaussian pairwise velocity distribution

real space correlation

mean pairwise velocity & dispersion

$$1+\xi_X(s_{||},s_\perp,t) = \int_{-\infty}^{\infty} \frac{dr_{||}}{\sqrt{2\pi}\sigma_{12}}(1+\xi_X(r,t))\exp\left[-\frac{\left(s_{||}-r_{||}-v_{12}(r,t)r_{||}/r\right)^2}{2\sigma_{12}^2(r,r_{||},t)}\right]$$

Fisher (1995, Astrophys.J. 448,)
Reid & White (2011, MNRAS 417)

- Edgeworth expansion around a Gaussian PDF
- similar as for density δ or velocity divergence θ in SPT

Juszkiewicz, Chodorowski et. al (APJ 442, 39 ,1995)

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CU, Kopp and Haugg (2015, arXiv: 1503.08837)

$$\times\left(1+\frac{\Lambda_{12}}{6\sigma_{12}^3}\left[\left(\frac{\Delta_{srv}}{\sigma_{12}}\right)^3-3\frac{\Delta_{srv}}{\sigma_{12}}\right]\right)$$

first non-Gaussian correction

pairwise velocity skewness

- Edgeworth expansion around a Gaussian PDF
- similar as for density δ or velocity divergence θ in SPT

Juszkiewicz, Chodorowski et. al (APJ 442, 39 ,1995)

Streaming model

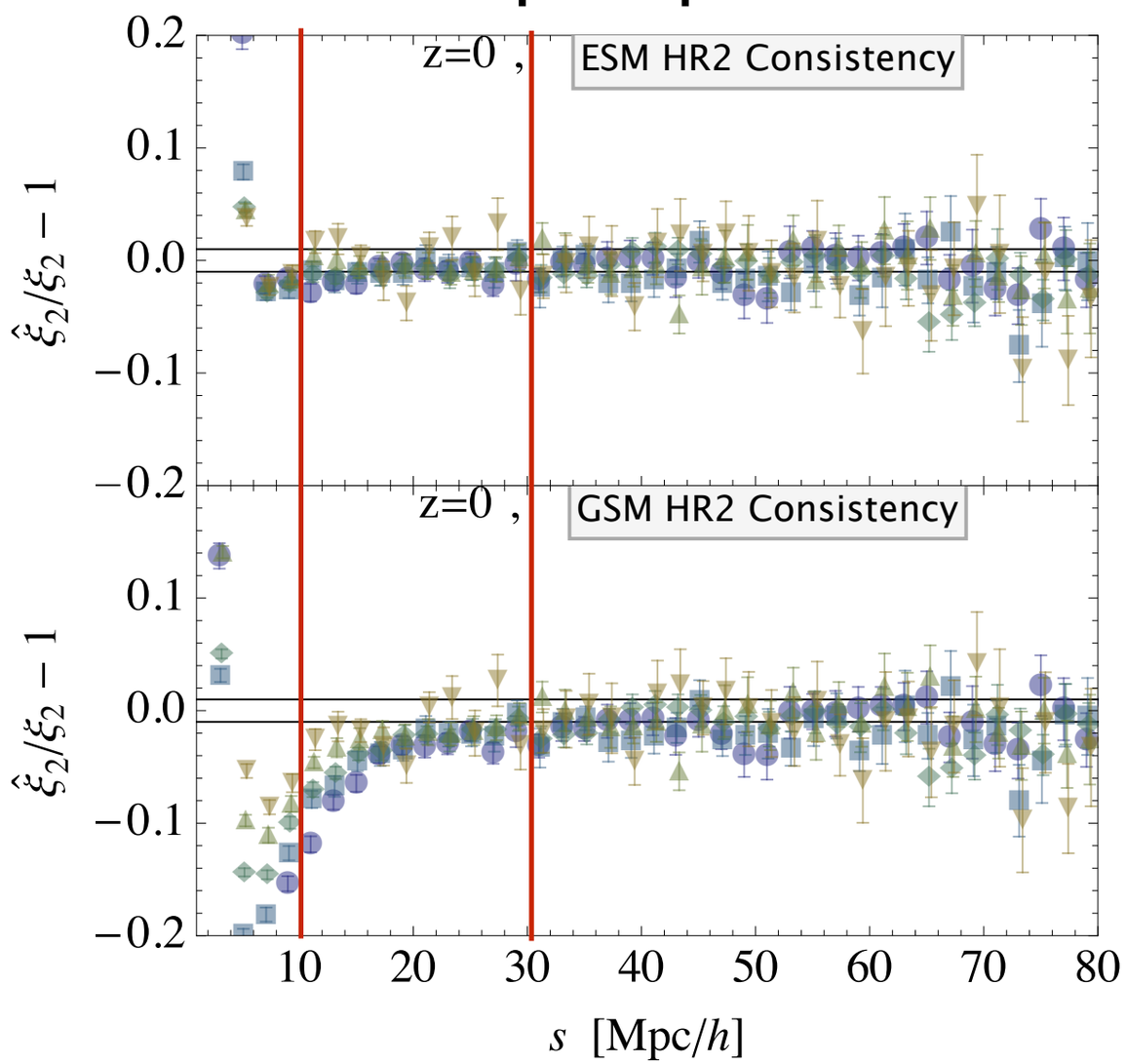
Accuracy of Streaming Models

- compare multipoles of redshift space correlation function
- **model independent**: measure ingredients in halo catalog

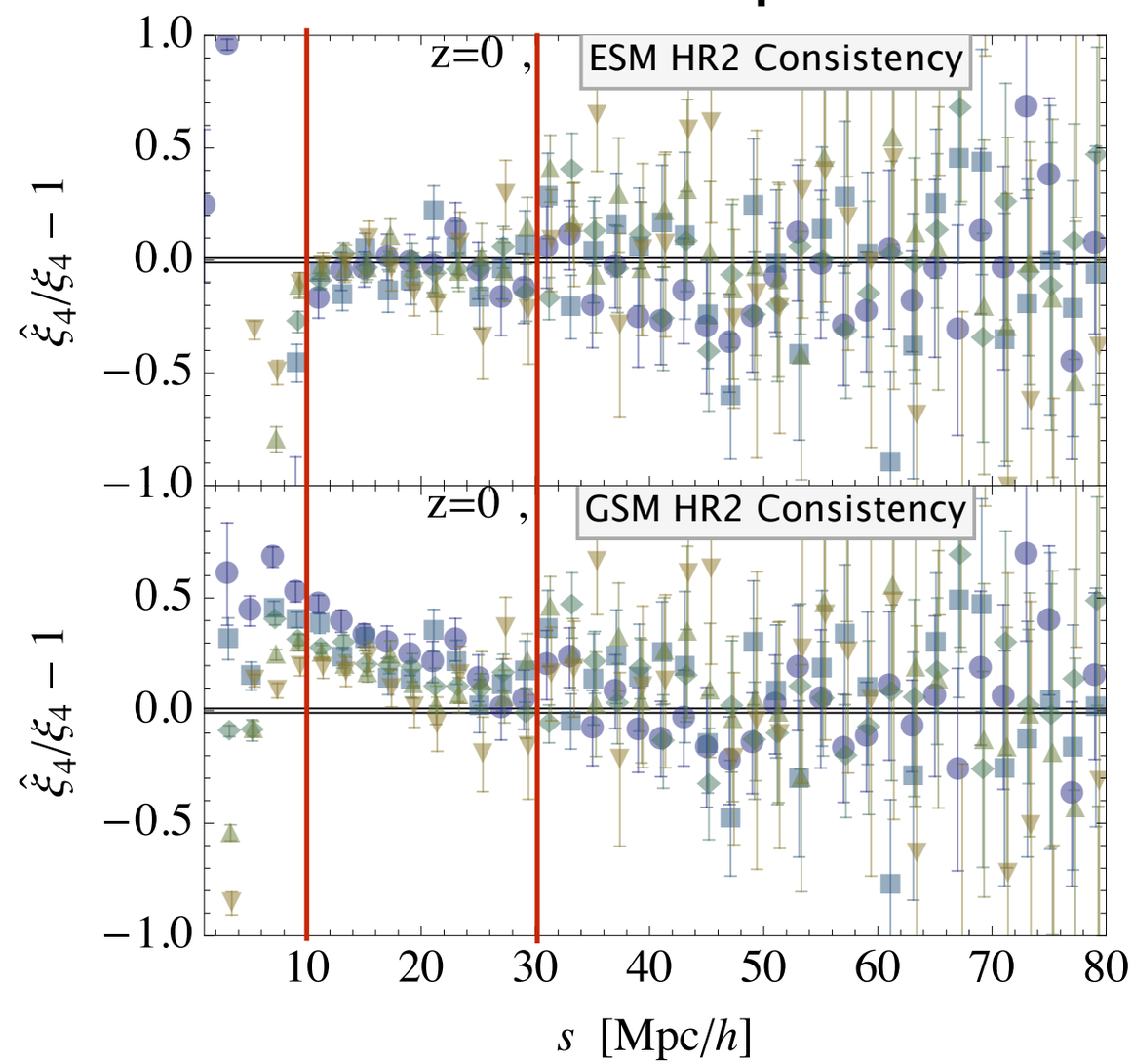
Horizon Run 2
halo catalog
mass range lgM ~ 13 -15

- 2% down to 10 Mpc/h (ESM) vs. 30 Mpc/h (GSM)

quadrupole



hexadecapole



Streaming model ingredients

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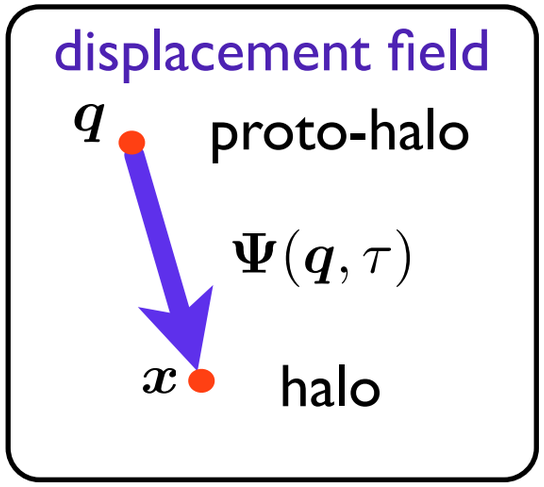
Wang, Reid & White (2014, MNRAS 437)

Lagrangian Perturbation Theory

+ local Lagrangian bias: $\xi \rightarrow \xi_X$

- **Zel'dovich approximation** Zel'dovich (1970, A&A 5, 84)
  - 1st order Lagrangian PT
  - physically motivated resummation of SPT



- **Post Zel'dovich approximation**
  - higher order Lagrangian PT
  - partial resummation: Convolution LPT

Carlson et al. (2012, MNRAS 429)

Streaming model ingredients

Gaussian Streaming Model

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- **Why smoothing?**
  - implement halo size in fluid description
  - improves Zel'dovich predictions in N-body

- **truncated Zel'dovich approximation**
  - Zel'dovich with smoothed input PS
  - improves agreement with N-body

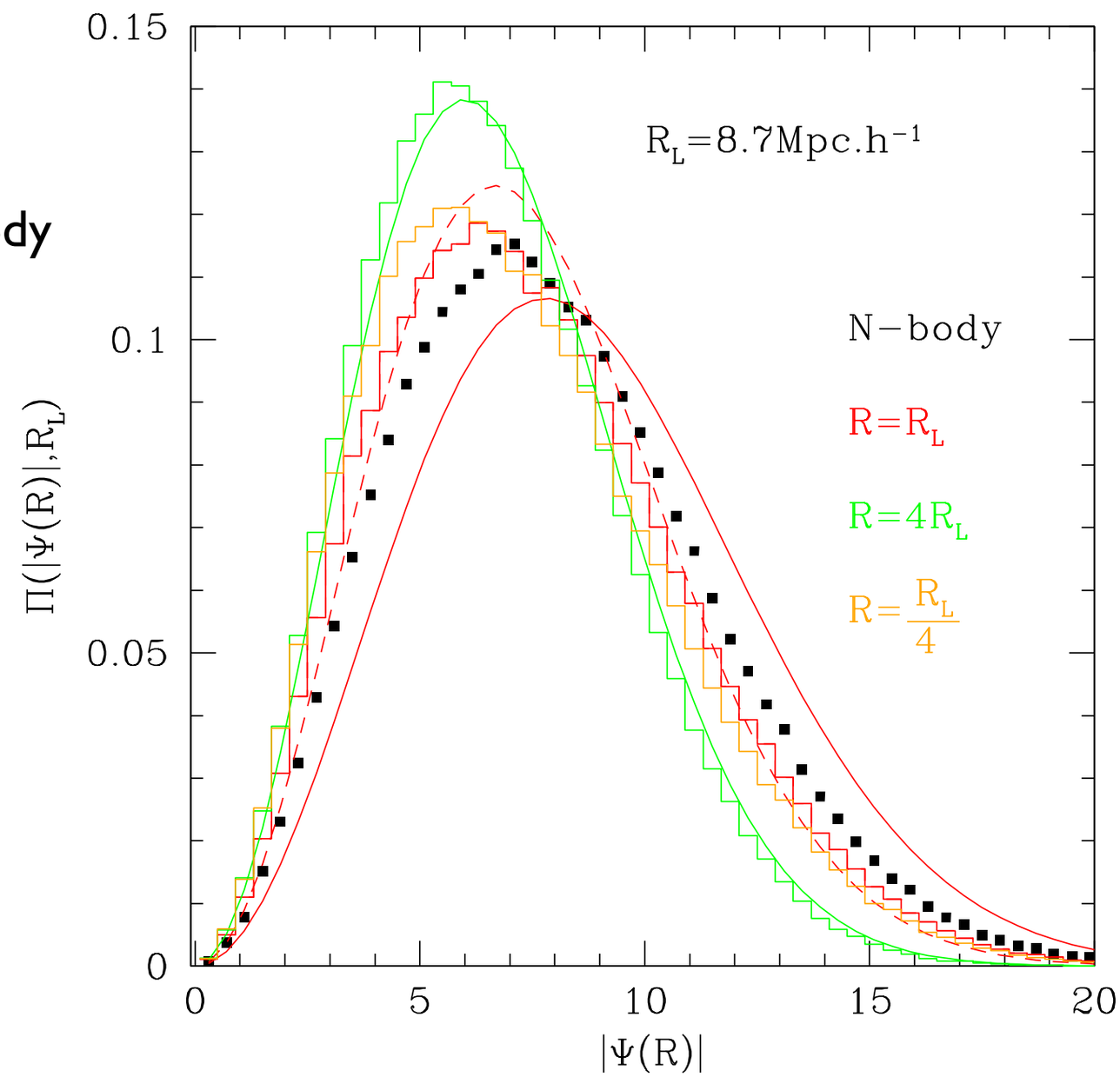
Coles, Melott, Shandarin (1993, MNRAS 260)

coarse-grained dust model

CU, Kopp & Haugg (arXiv: 1503.08837)

truncated CLPT

Kopp, CU & Achitouv (in preparation)

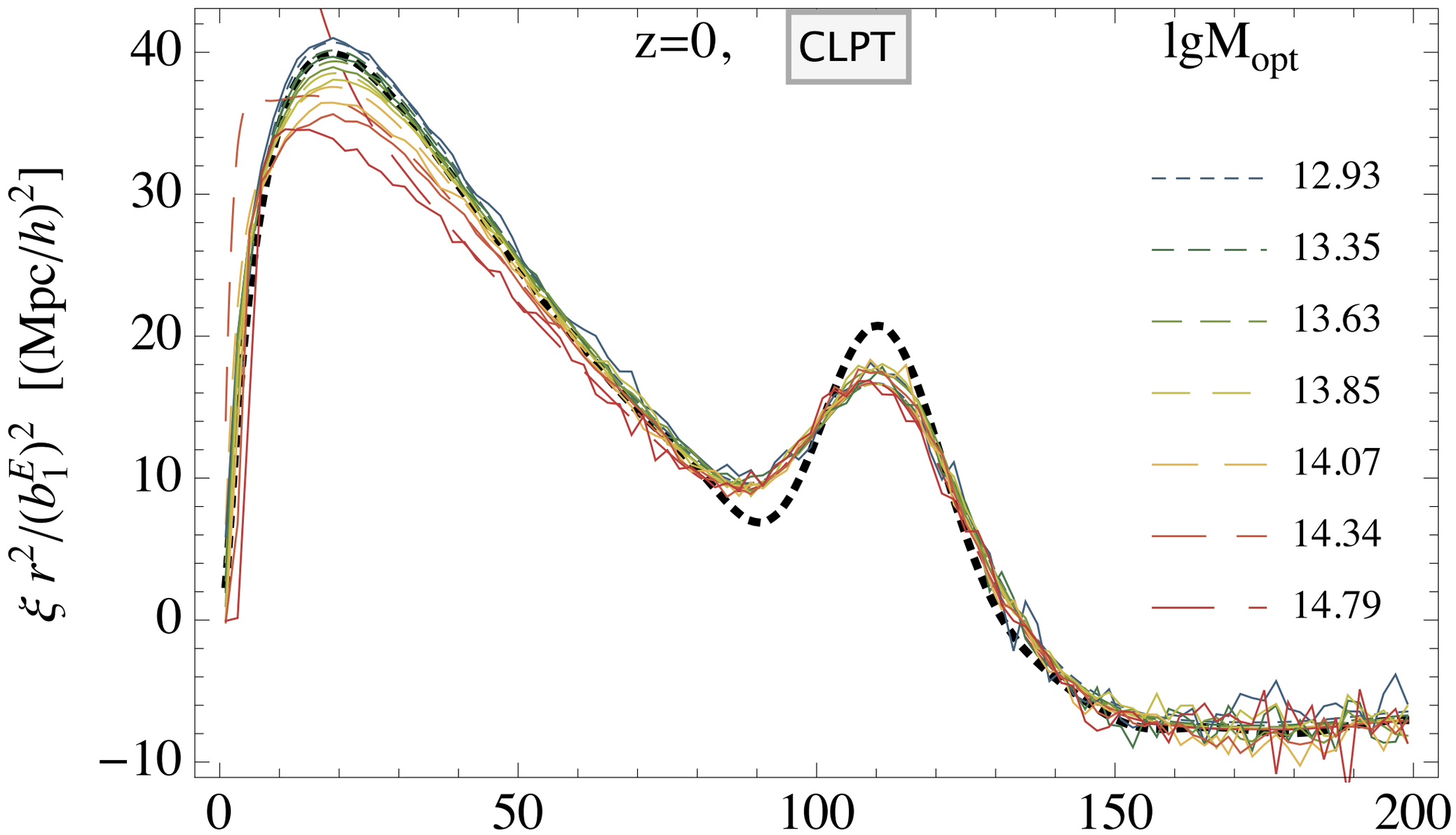


Redshift space distortions

Streaming parameters from truncated CLPT

Real space halo correlation ξ(r): best agreement for 1 Mpc/h

- smoothing in R(M) worse: need to include peak bias **Baldauf, Desjacques & Seljak (arXiv: 1405.5885)**

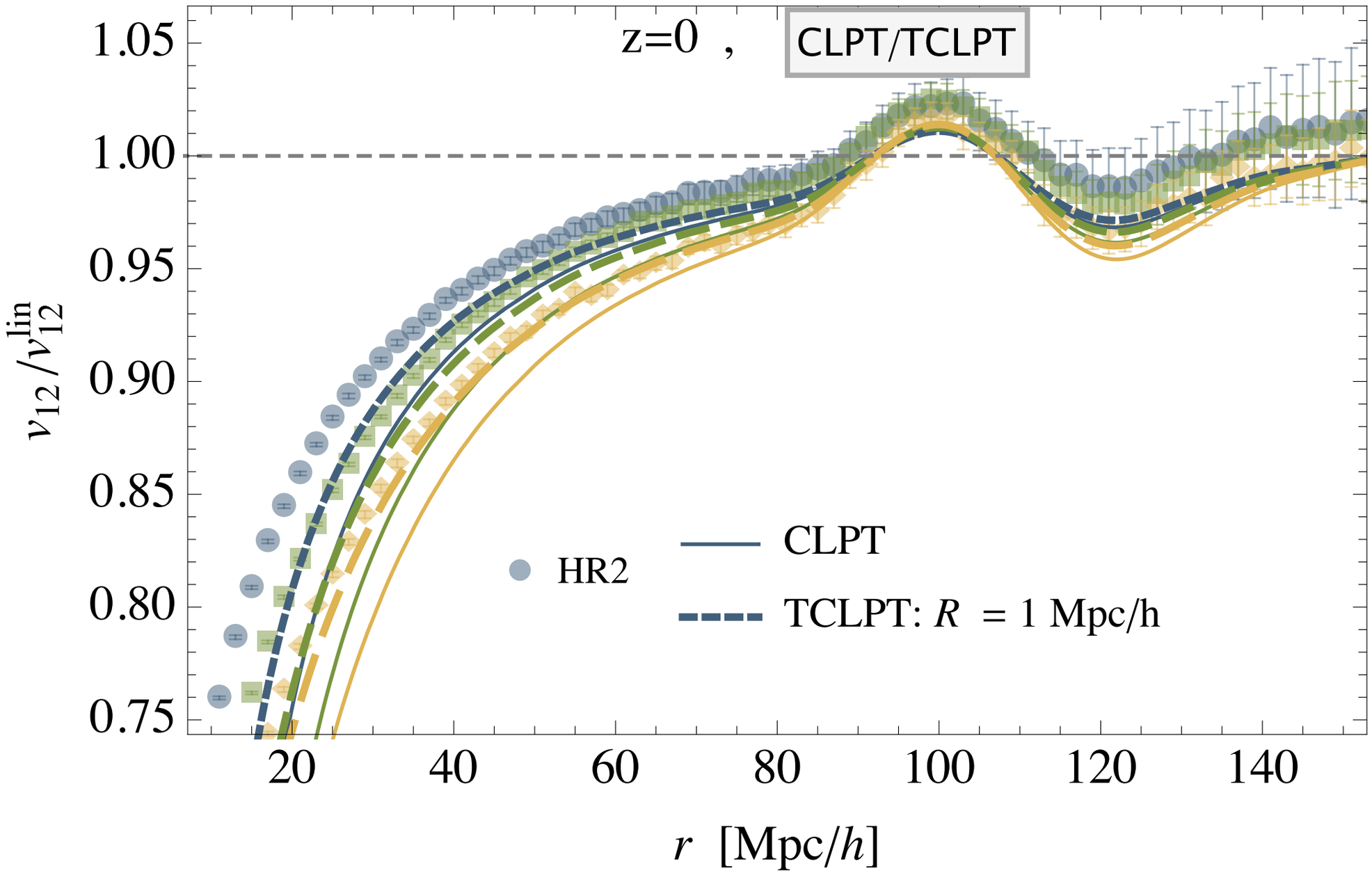


Redshift space distortions

Streaming parameters from truncated CLPT

Pairwise velocity $v_{12}(r)$: best agreement for 1 Mpc/h

- smoothing in R(M) worse for high M - velocity bias?

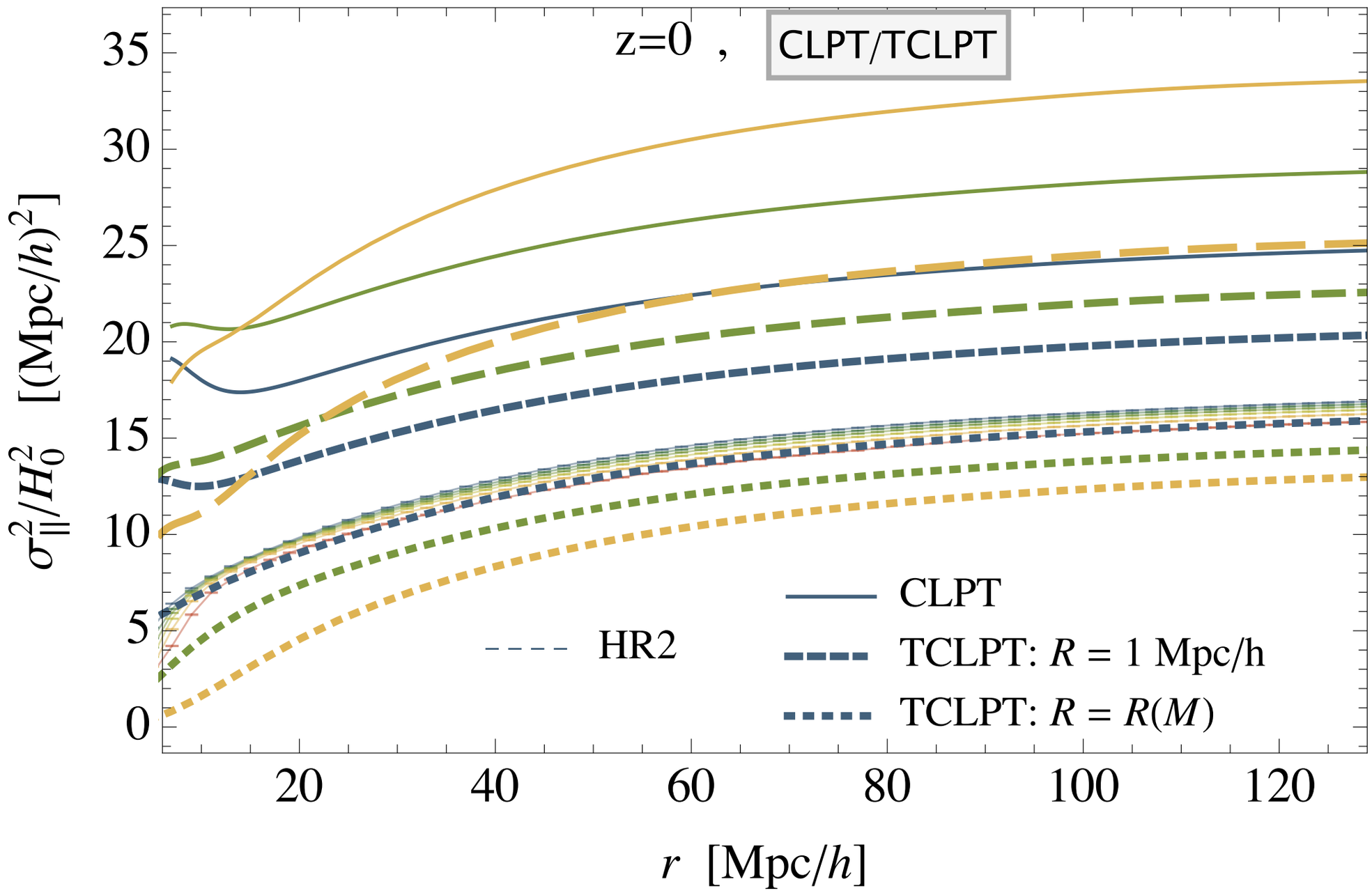


Redshift space distortions

Streaming parameters from truncated CLPT

Pairwise velocity dispersion $\sigma_{12}(r)$: best agreement for R(M)

- huge improvement of the overall amplitude



Streaming model predictions

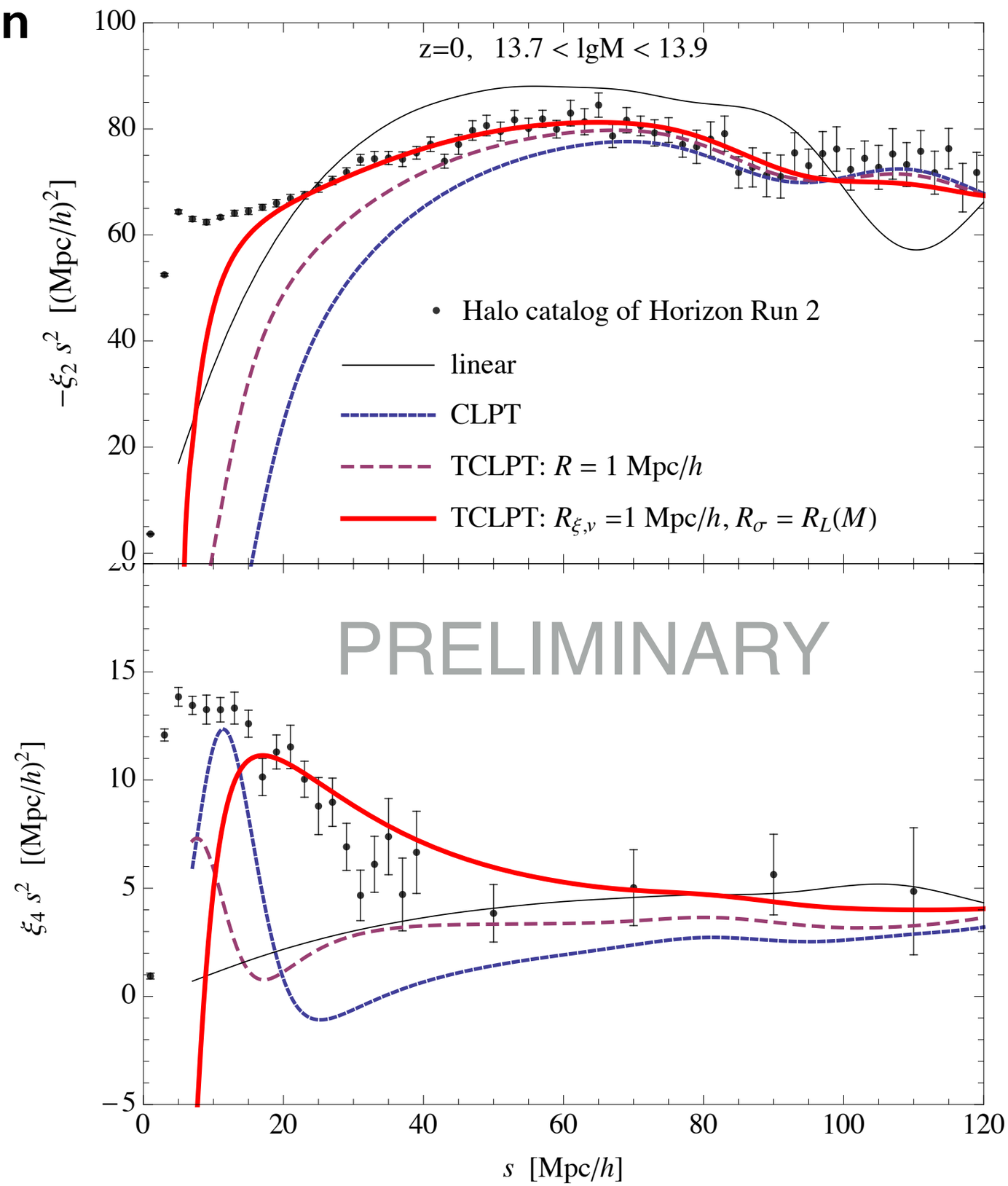
Redshift space correlation function

Kopp, CU & Achitouv (in preparation)

- plug streaming model ingredients in obtain redshift space multipoles
  - monopole $\xi_0(s)$
  - **quadrupole $\xi_2(s)$**
  - **hexadecapole $\xi_4(s)$**

- TCLPT outperforms CLPT
  - simultaneously improves all higher redshift-space multipoles

- optimal: two-filter TCLPT smoothing
  - $\xi(r)$ & $v_{12}(r)$: 1 Mpc/h
  - $\sigma_{12}(r)$: Lagrangian scale R(M)

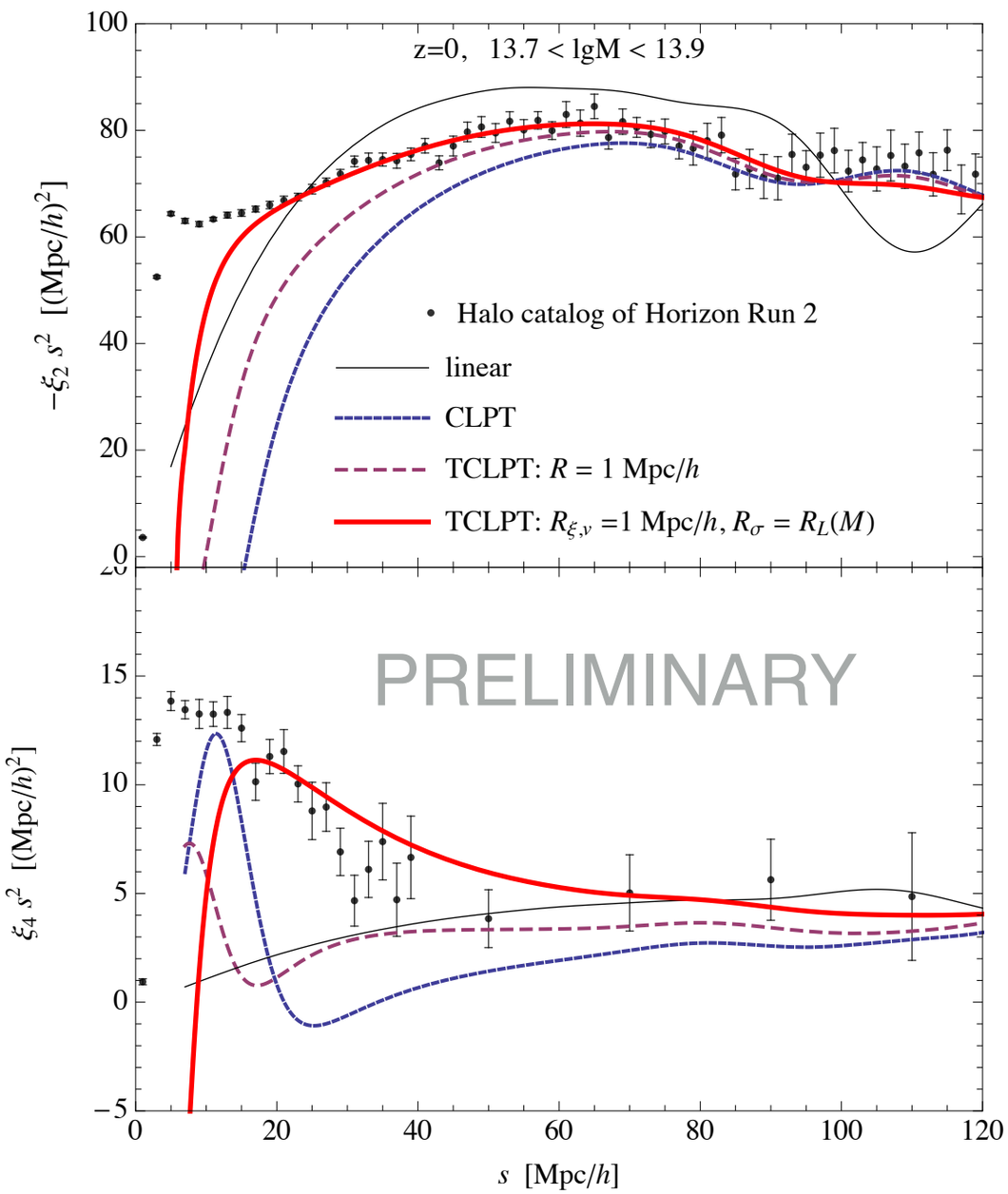


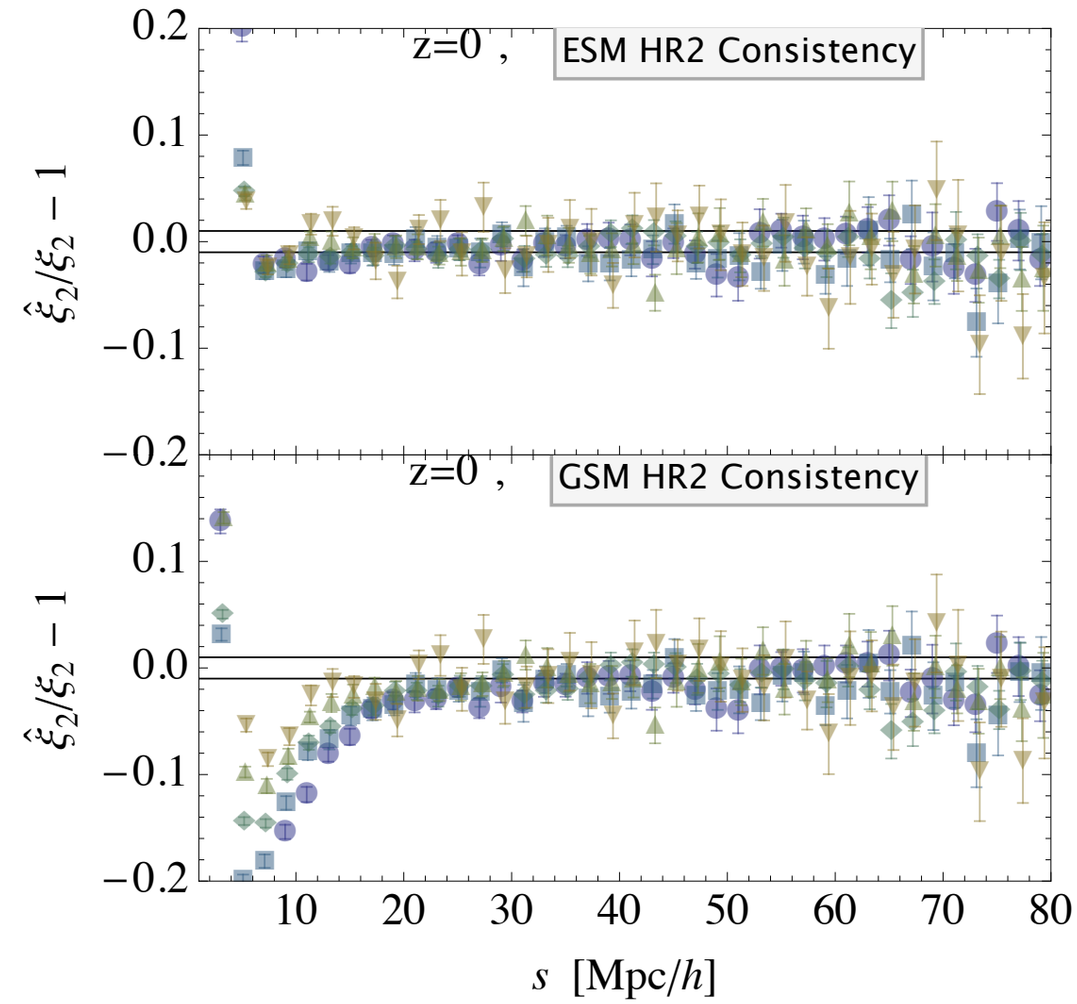
Summary

Edgeworth streaming model

- generalization of Gaussian streaming model
- pushed 2% accuracy from 30 down to 10 Mpc/h

CU, Kopp and Haugg (2015, arXiv: 1503.08837)





Truncated Zel'dovich approximation

- truncated Post-Zel'dovich approximation (TCLPT)
  - optimal with two filters: 1 Mpc/h & R(M)
  - consistent results for $\xi_0, \xi_2, \xi_4(s)$

    Kopp, CU & Achitouv (in preparation)
  - peak bias effects relevant