Edgeworth Streaming Model
for
redshift space distortions

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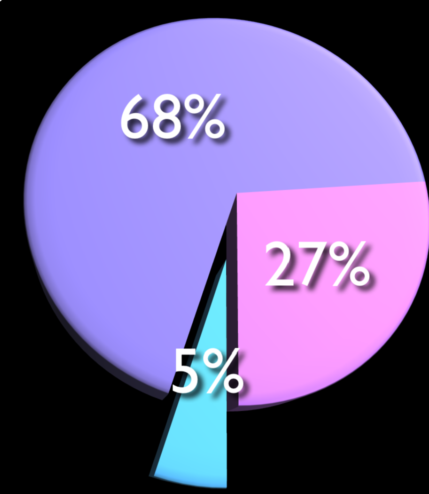
Cosmological Standard Model

ΛCDM



Dark Energy

cosmological constant

baryons

standard model
of particle physics

Cold Dark Matter

collisionless

cold (initially)

⬇

Large Scale Structure (LSS)

dark matter halos

↓

galaxy surveys

constrain parameters

Redshift space correlation function

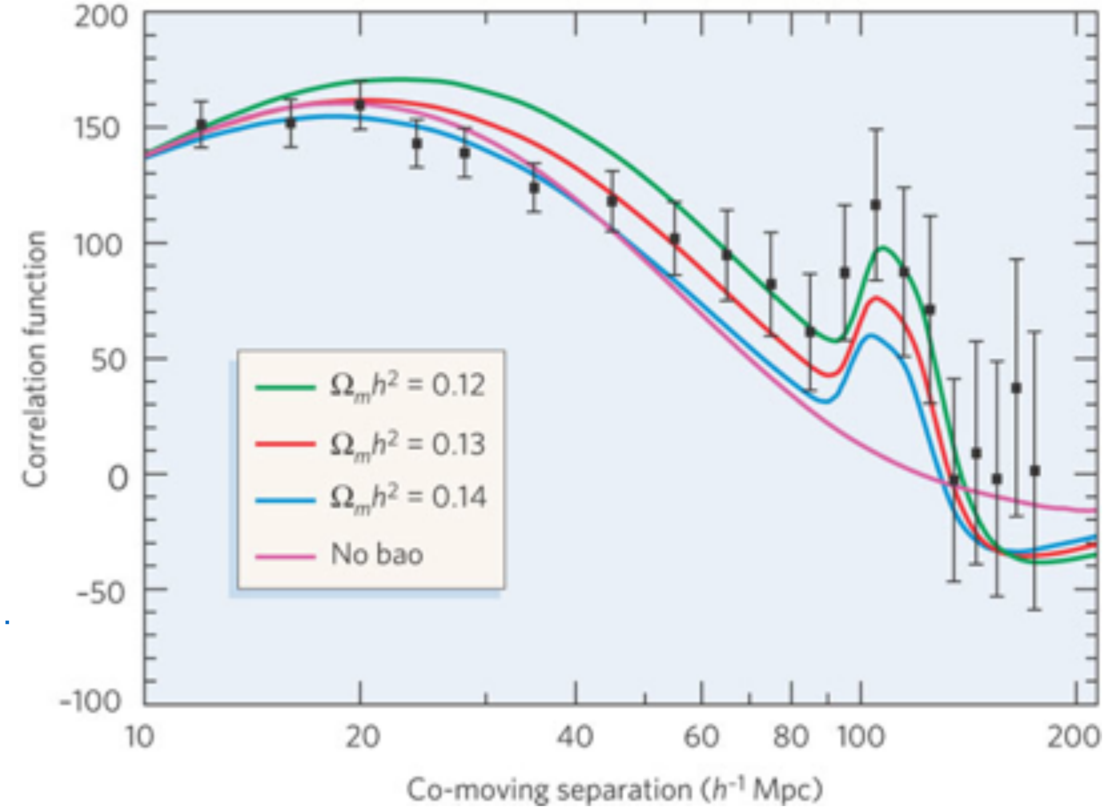
Correlation function

- measures excess probability

$$dP = n[1+\xi(r)]dV$$

- biased CDM tracers: halos or galaxies
  - powerful probe for cosmology

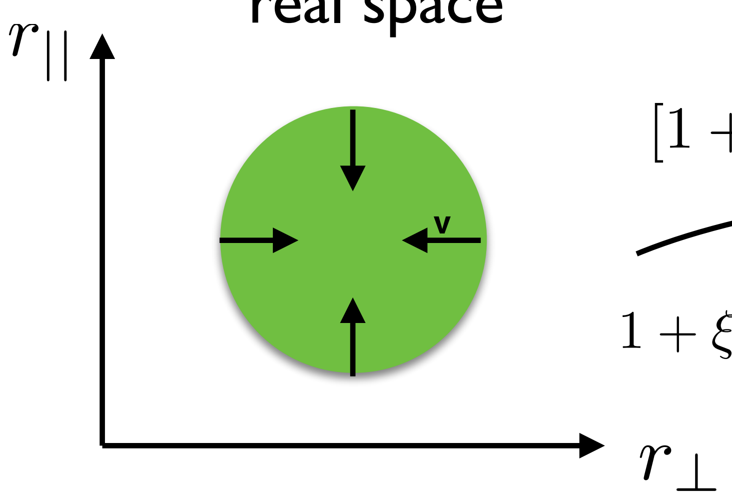
Eisenstein et al.
2005 ApJ, 633



Redshift space distortions

- redshift observations affected by peculiar velocities $s_{||} = r_{||} + v/\mathcal{H} \quad s_\perp = r_\perp$

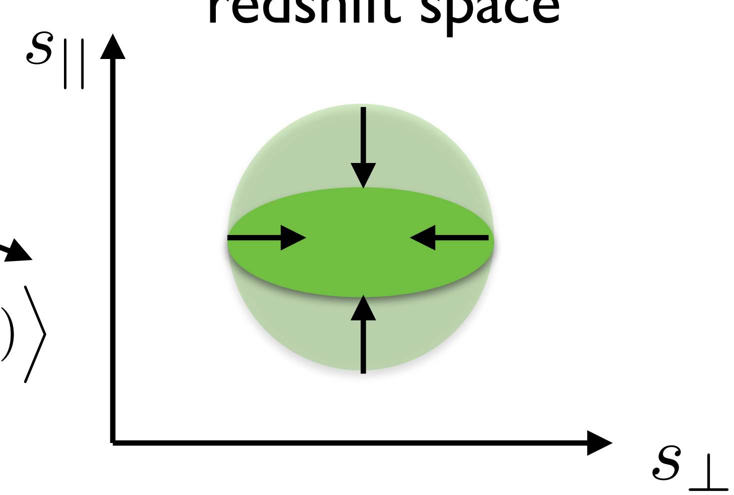
real space



$$[1+\delta_X(\boldsymbol{r})]d^3r = [1+\delta_X(\boldsymbol{s})]d^3s$$

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

redshift space



Redshift space correlation function

Gaussian Streaming Model

real space correlation

Gaussian velocity distribution

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)

Redshift space correlation function

Edgeworth Streaming Model

real space correlation

Gaussian velocity distribution

mean pairwise velocity & dispersion

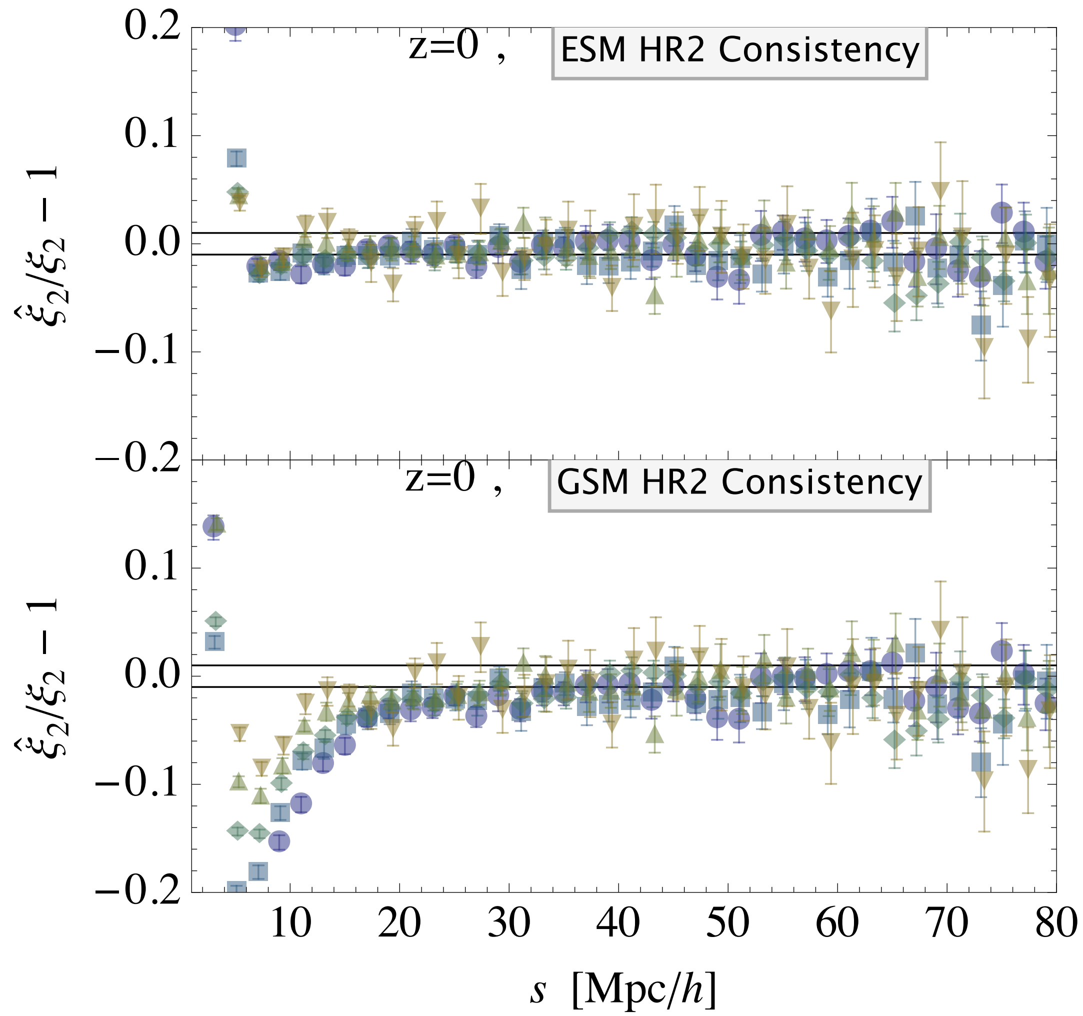
$$1 + \xi_X(s_{||}, s_\perp, t) = \int_{-\infty}^{\infty} \frac{dr_{||}}{\sqrt{2\pi}\sigma_{12}} (1 + \xi_X(r,t)) \exp\left[-\frac{\left(s_{||} - r_{||} - v_{12}(r,t) r_{||}/r\right)^2}{2\sigma_{12}^2(r, r_{||}, t)} \right]$$

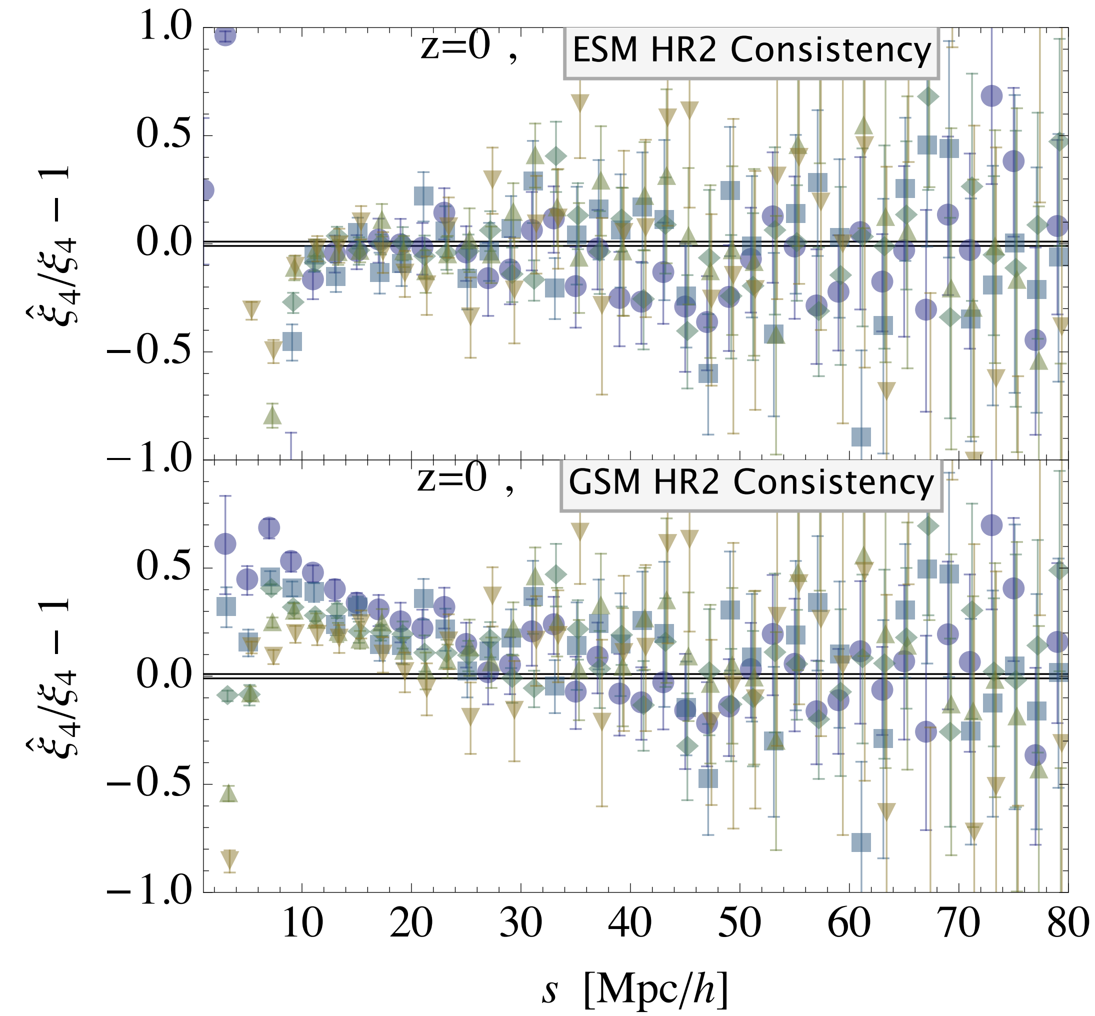
$$\times \left(1 + \frac{\Lambda_{12}}{6\sigma_{12}^3} \left[\left(\frac{\Delta_{srv}}{\sigma_{12}} \right)^3 - 3 \frac{\Delta_{srv}}{\sigma_{12}} \right] \right)$$

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

- improves accuracy on small scales
- 2% down to 10 Mpc/h (ESM) vs. 30 Mpc/h (GSM)

pairwise velocity skewness





Streaming model ingredients

Gaussian Streaming Model

real space correlation

Gaussian velocity distribution

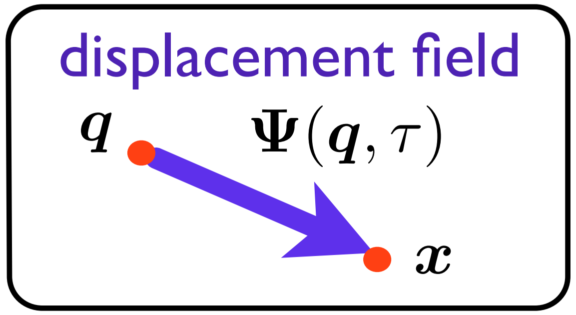
mean pairwise velocity & dispersion

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

Wang, Reid & White (2014, MNRAS 437)

Lagrangian Perturbation Theory
\+ local Lagrangian bias

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



- **truncated Zel'dovich**
  - Zel'dovich with smoothed input power spectrum
  - improves agreement with N-body

  Coles, Melott, Shandarin (1993, MNRAS 260)

implementation coarse-grained dust model

CU & Kopp (arXiv: 1407.4810)
coarse-graining in Eulerian space
\+ mapping to Lagrangian space

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

  Carlson et al. (2012, MNRAS 429)

Streaming model ingredients

Truncated CLPT

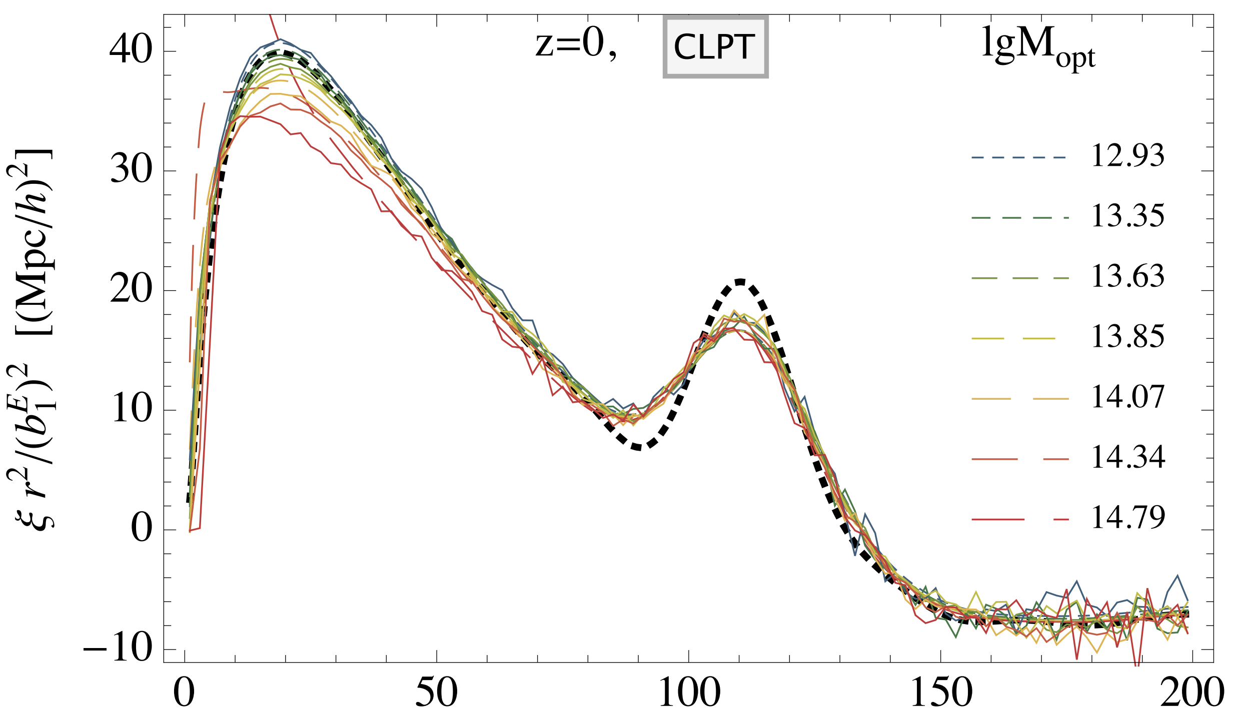
Kopp, CU, Achitouv & Haugg (in preparation)

Real space halo correlation ξ(r)

- best agreement for 1 Mpc/h
- smoothing in R(M) worse

  need to include peak bias

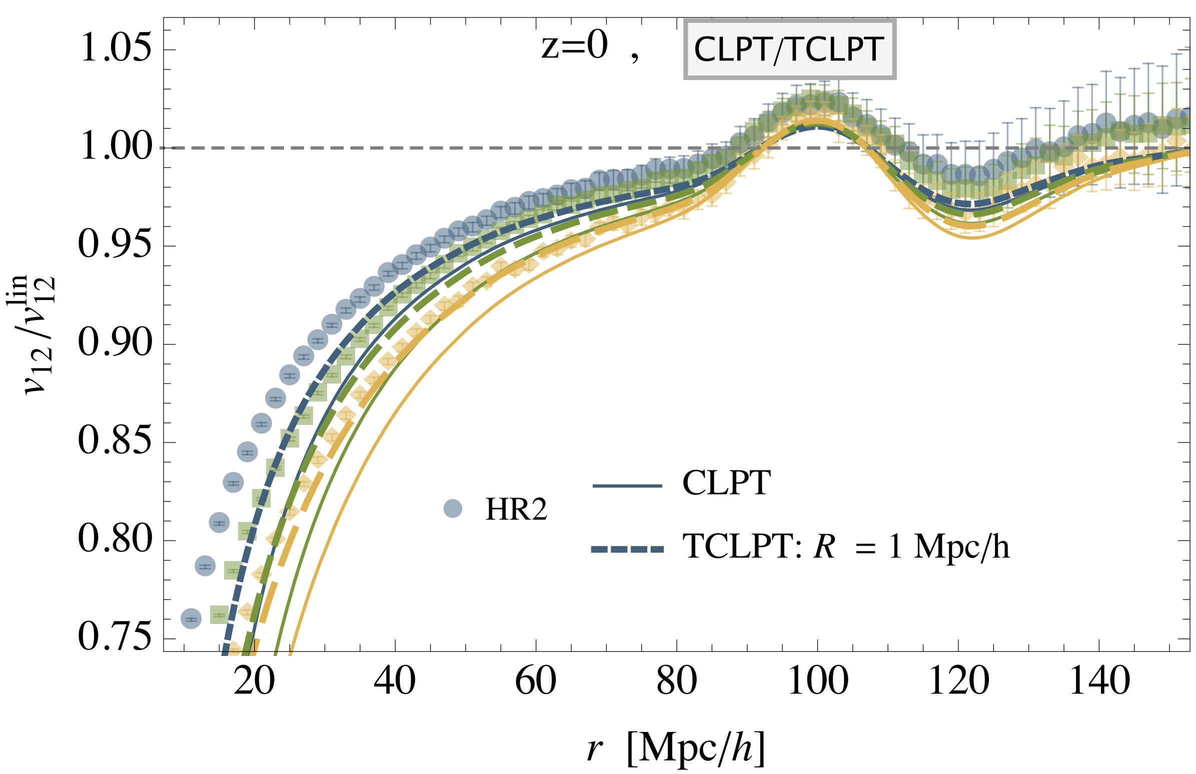
  Baldauf, Desjacques & Seljak (arXiv: 1405.5885)



Pairwise velocity $v_{12}(r)$

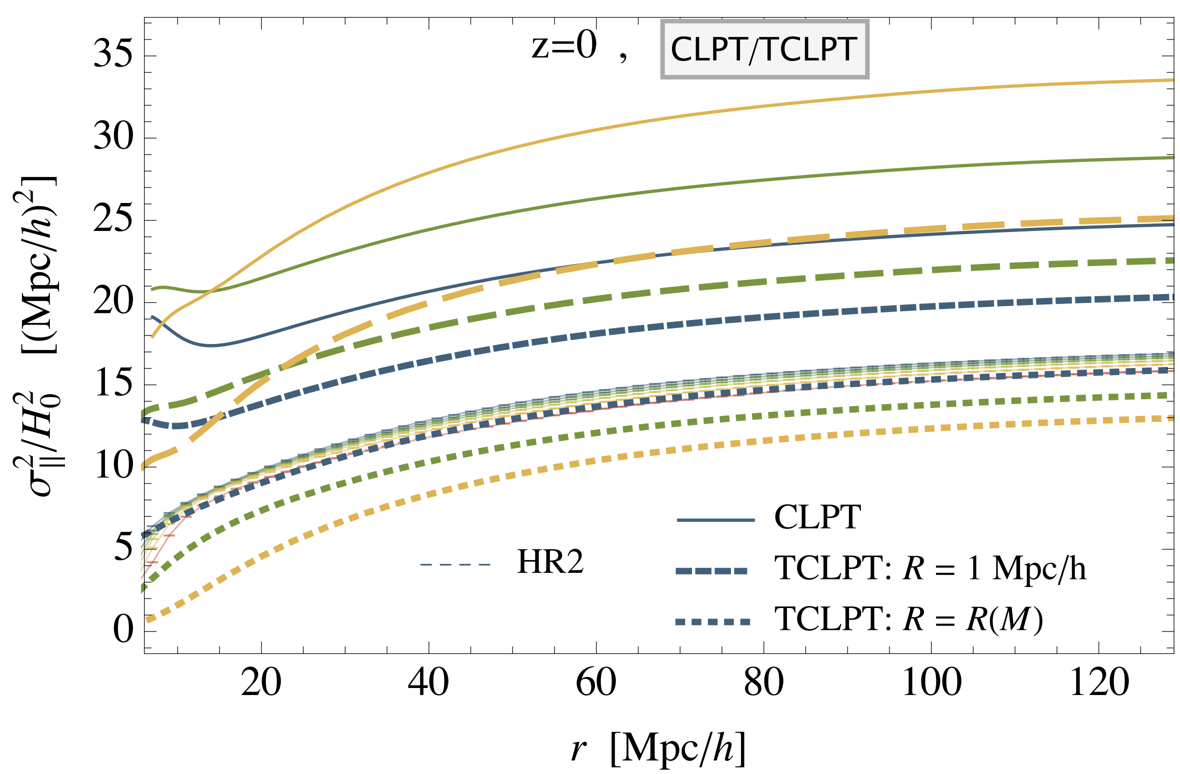
- best agreement for 1 Mpc/h

  similar as for DM CU & Kopp (arXiv: 1407.4810)



Pairwise velocity dispersion $\sigma_{12}(r)$

- best agreement for R(M)
- consider cumulant not moment



Streaming model predictions

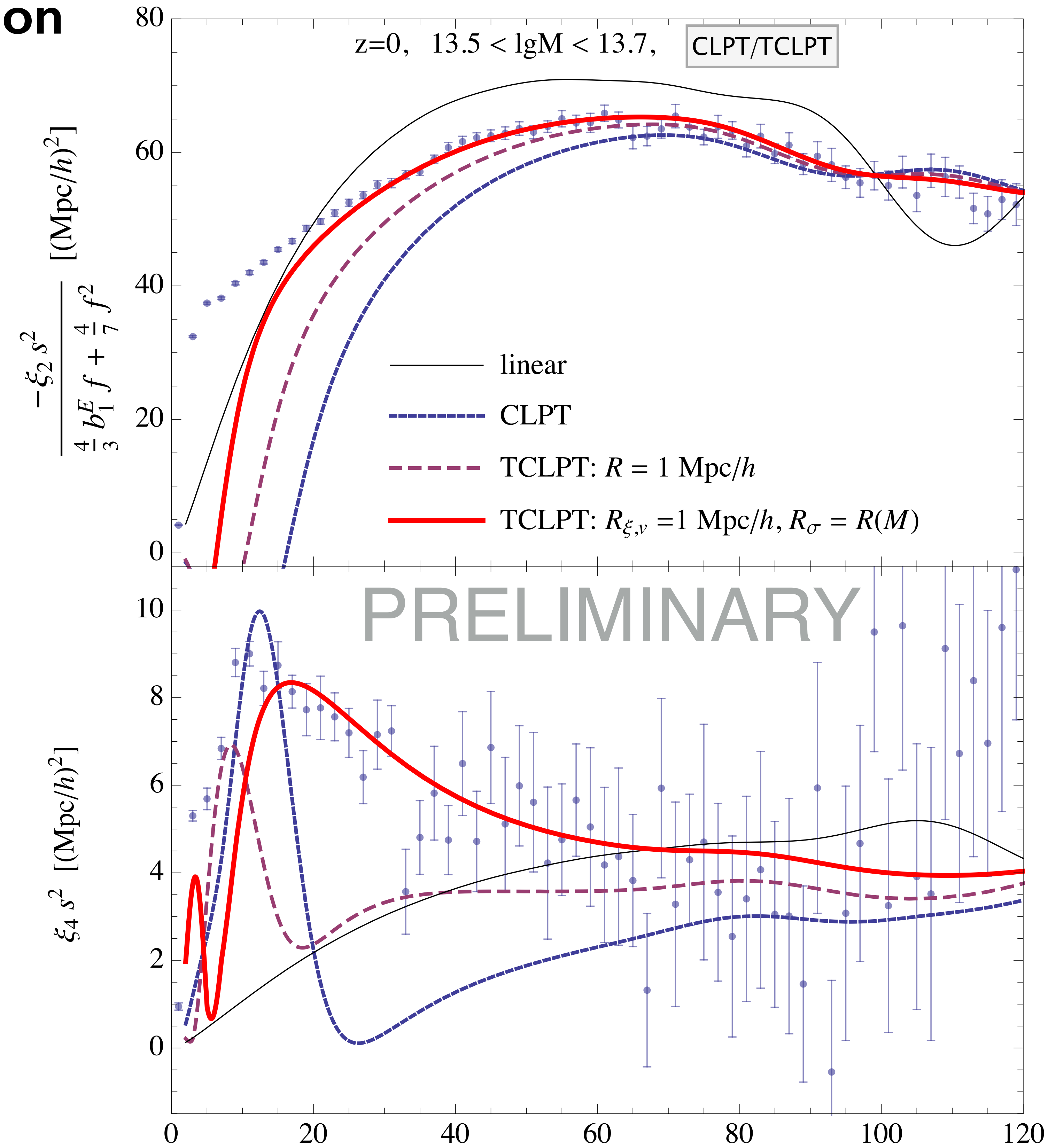
Redshift space correlation function

Kopp, CU, Achitouv & Haugg (in preparation)

- plug streaming model ingredients 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

- best: TCLPT with hybrid smoothing
  - $\xi(r)$ & $v_{12}(r)$ on 1 Mpc/h
  - $\sigma_{12}(r)$ on Lagrangian scale R(M)

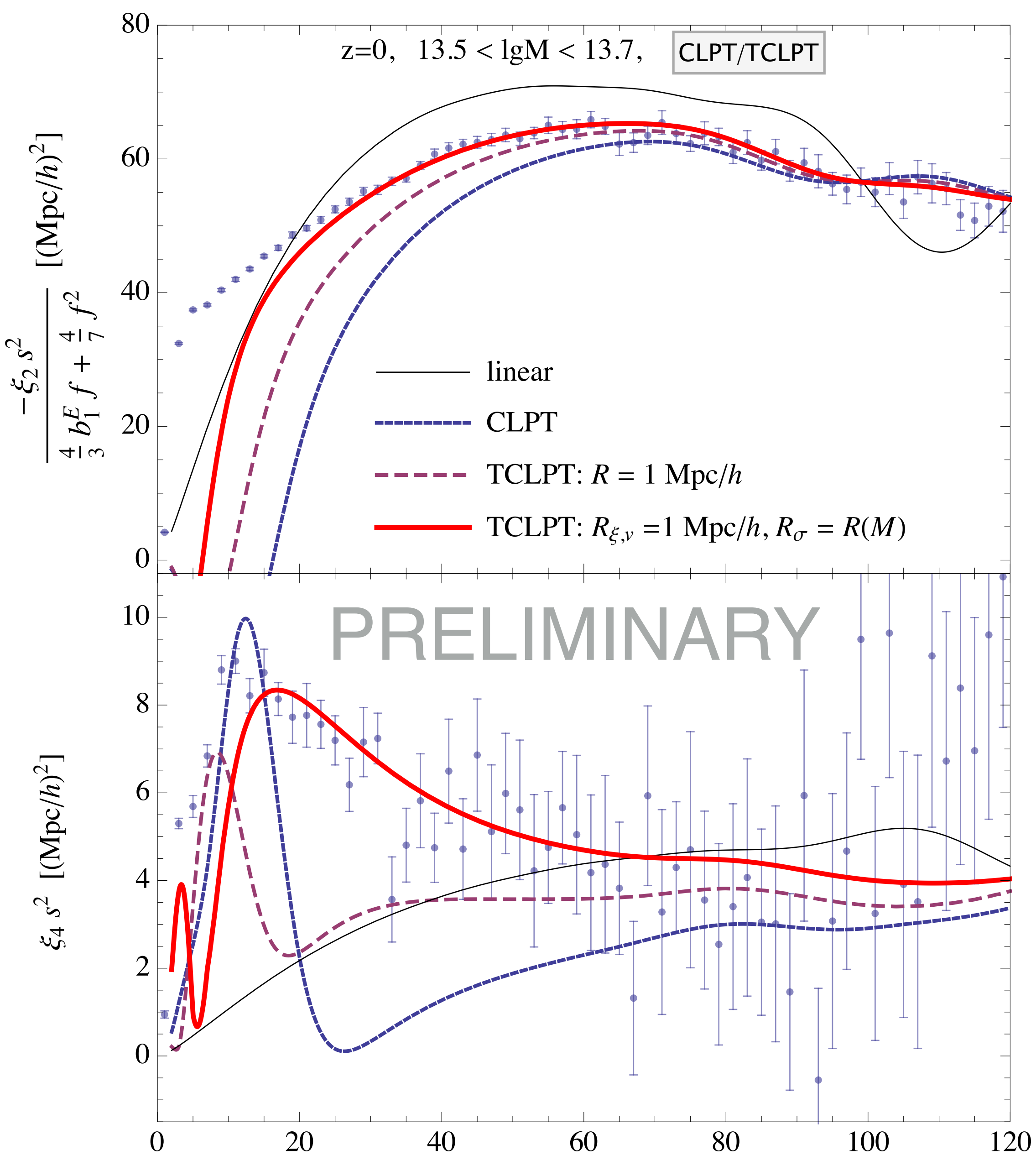


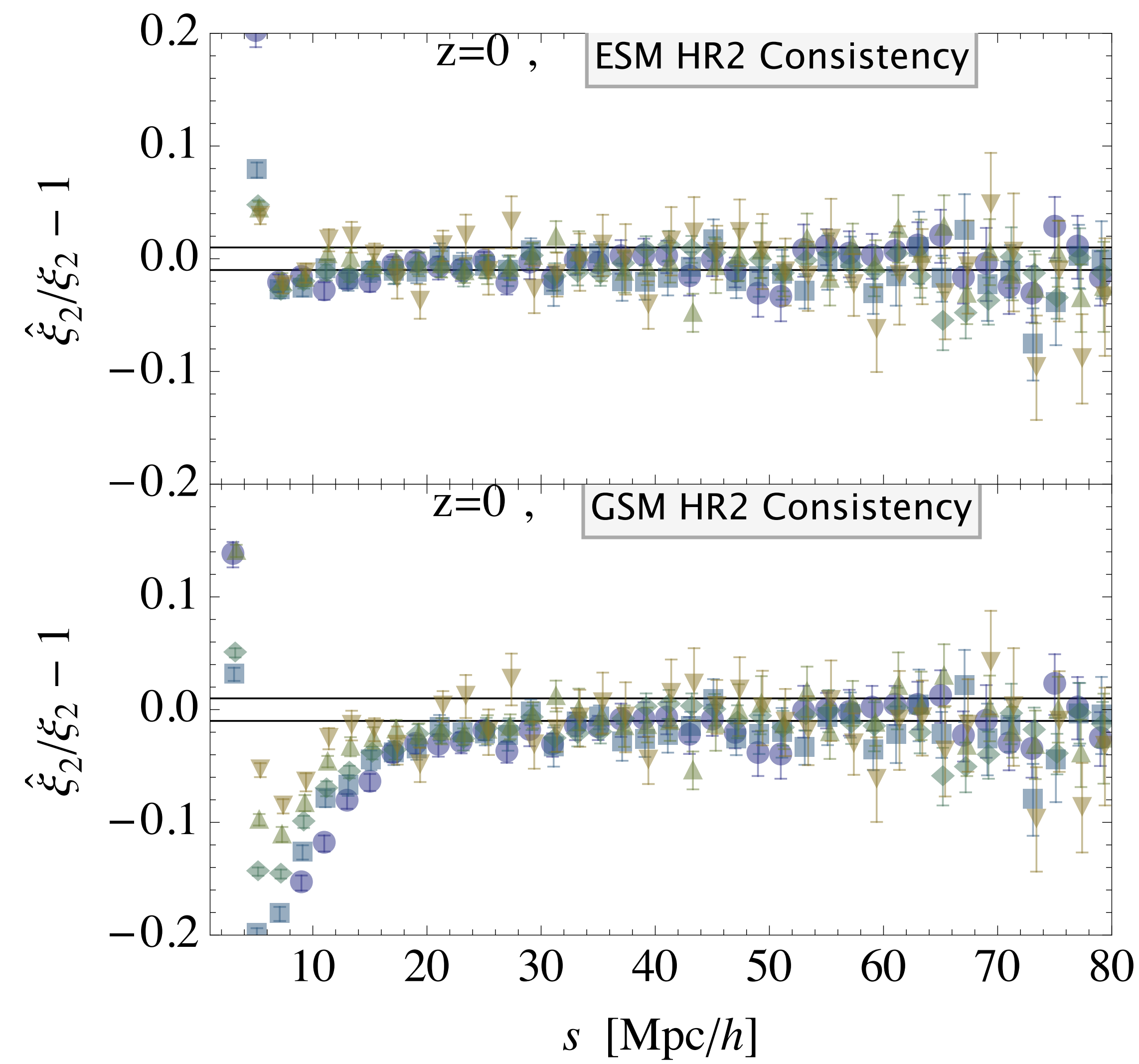
Summary

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)





Redshift space halo correlation function

- coarse-graining in Eulerian vs Lagrangian space

  CU, Kopp and Haugg (2015, arXiv: 1503.08837)
- truncated Post-Zel'dovich approximation (TCLPT)
  - use two smoothing scales: 1 Mpc/h & R(M)

  Kopp, CU, Achitouv & Haugg (in preparation)