Environmentally dependent two-point auto-correlation function algorithmic speed

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the homogeneous model

- standard model: ΛCDM $(\Omega_{\rm m0} \approx 0.32, \Omega_{\Lambda 0} \approx 0.68)$ homogeneous
- simpler model: EdS $(\Omega_{\rm m0} = 1, \Omega_{\Lambda 0} = 0)$ homogeneous

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$=$ background expands relativistically (Einstein)

$+$ linear density perturbations $\delta := \frac{\rho - \langle\rho\rangle}{\langle\rho\rangle}$, $|\delta| \ll 1$

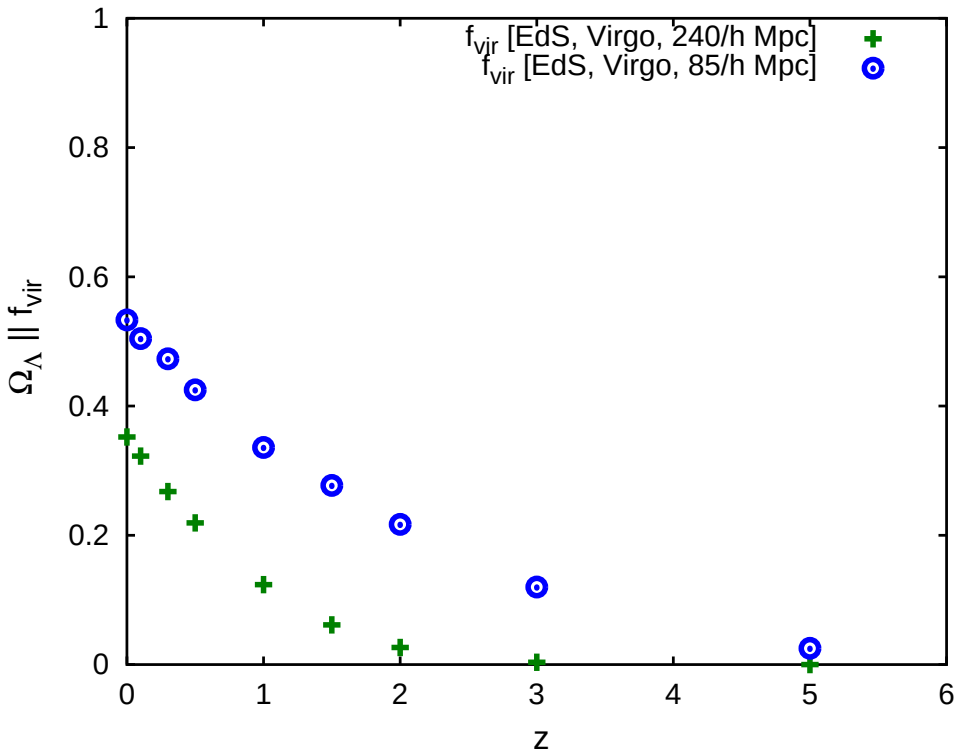
$+$ large-scale structure, galaxy clusters, galaxies $\delta > \Delta_{\rm vir} \gg 1$ (Newton)

$+$ voids $-1 \lesssim \delta \ll 0$ (Newton)

- Newton $\neq$ Einstein $\Rightarrow$ ΛCDM, EdS should fail at $\ll 3\ h^{-1}$ Gpc and $z < 3$

beyond the homogeneous model

- $f_{\rm vir}(z) \ll 1 \Rightarrow \Lambda$CDM, EdS $\sim$ valid
- $f_{\rm vir}(z) \gg 0.01 \Rightarrow \Lambda$CDM, EdS $\sim$ fail



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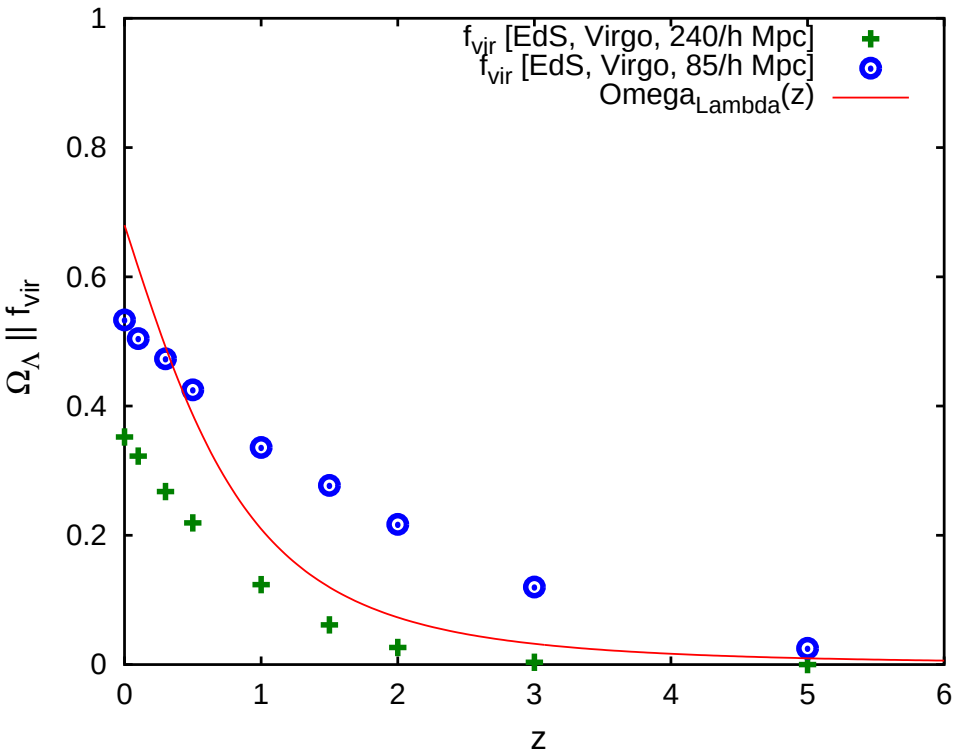

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- $f_{\rm vir}(z)$ strongly correlates with $\Omega_\Lambda(z)$
  Roukema, Ostrowski, Buchert, 2013, JCAP, 10, 043;
  Roukema 2013, IJMPD, 22, 1341018;
- Is $\Omega_\Lambda(z)$ an artefact of ignoring virialisation?

EdS + virialisation approx

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- Newton : constant spatial curvature of structures + voids
  Friedmann equation:
  $$\Omega_{\rm m} + \Omega_\Lambda + \Omega_{\rm k} = 1.$$
- Einstein : hyperbolic voids
  Buchert : volume-weighted means

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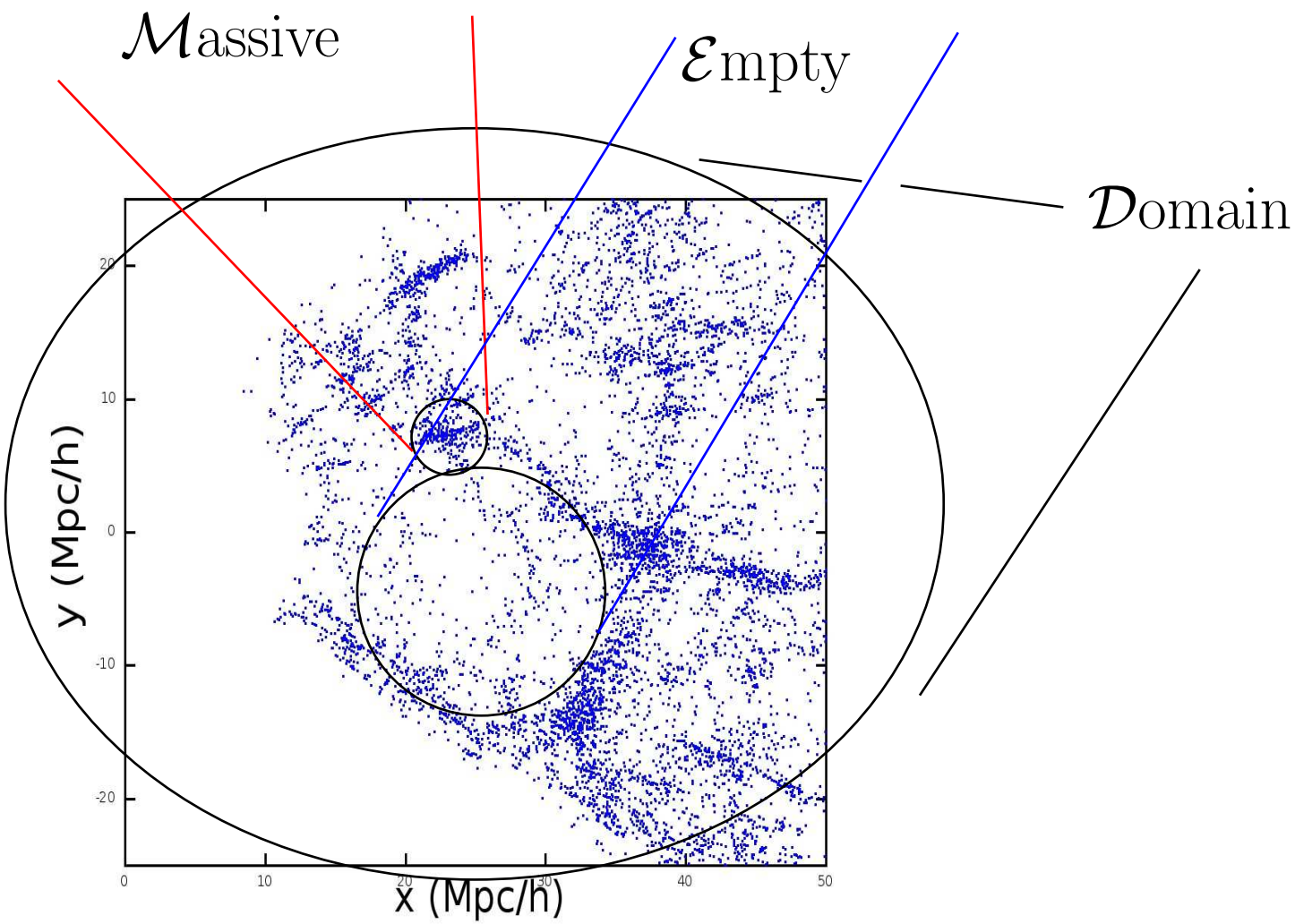

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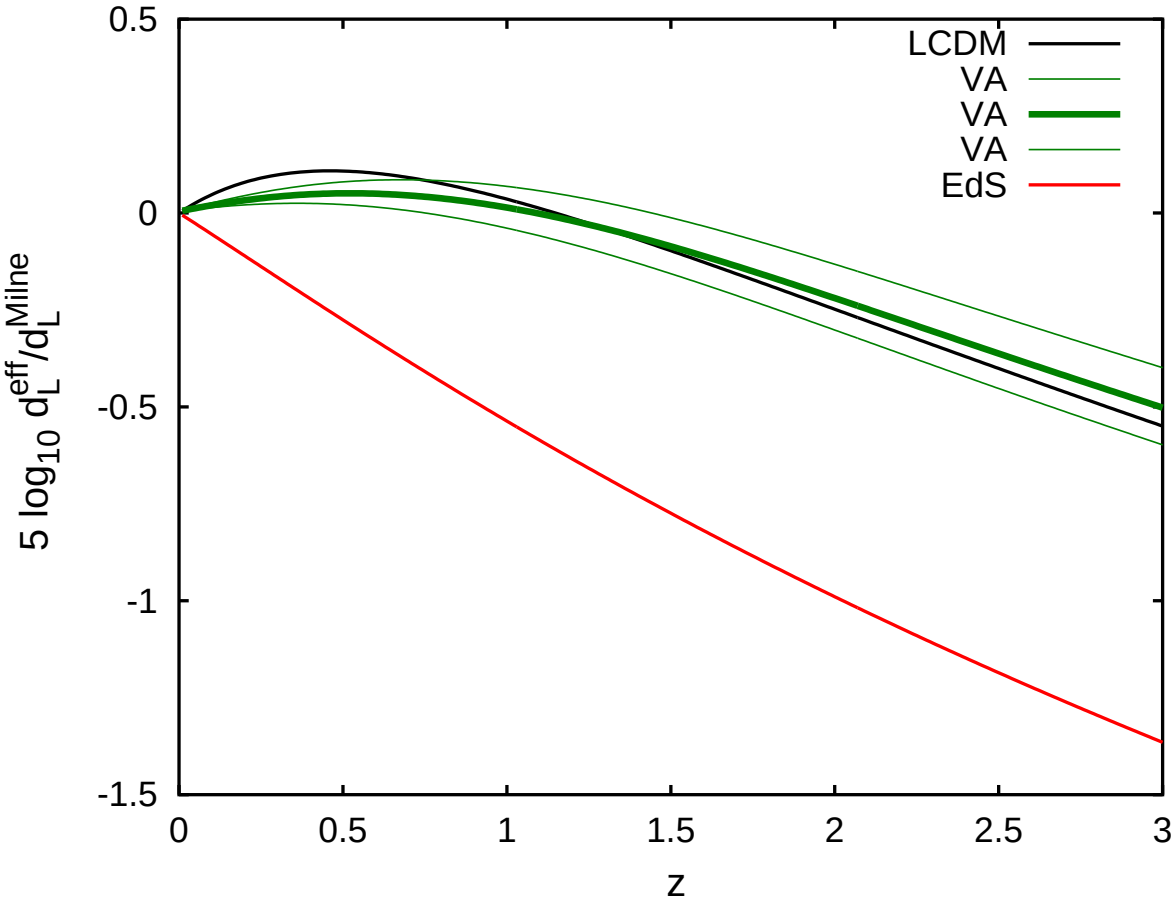
  Buchert : volume-weighted means on domains $\mathcal{D} := \mathcal{M} \cup \mathcal{E}$
  generalised Friedmann equation (Hamiltonian constraint):

$$\Omega^{\mathcal{F}}_{\rm m} + \Omega^{\mathcal{F}}_\Lambda + \Omega^{\mathcal{F}}_{\mathcal{R}} + \Omega^{\mathcal{F}}_{\mathcal{Q}} = \frac{H^2_{\mathcal{F}}}{H^2_{\mathcal{D}}} \ , \quad \text{where } \mathcal{F} \in \{\mathcal{M}, \mathcal{E}, \mathcal{D}\}$$

EdS + virialisation



metric template

- expected homogeneous model failure $\sim \Omega_\Lambda(z)$
- remove free param $(\Omega_{\Lambda 0})$; assume EdS background $(\Omega_{\rm m}=1, \Omega_\Lambda=0)$ at early times $(z \gg 3)$
- add GR (scalar averaging): virialisation approximation:
  2 obs inputs: $H^{\rm eff}(z=0)=74\pm1.6$ km/s/Mpc;
  $H^{\rm com}_{\rm pec}(z=0)=36\pm3$ km/s/Mpc;
- background model + virialisation
  $\Rightarrow$ void-dominated neg. curvature + inhomogeneous expansion $\Rightarrow$
  $\Omega^{\rm eff}_{\rm m}(z=0)\sim 0.3$
  distance modulus $m-M$ vs z : EdS+VA $\sim \Lambda$CDM
- dark energy $\sim$ virialisation-epoch negative curvature
  Roukema, Ostrowski, Buchert 2013 JCAP, 10, 043 (arXiv:1303.4444);
  Roukema 2013, IJMPD, 22, 1341018 (arXiv:1305.4415)

BAO peak—SDSS DR7

subset	D	R	ref
LRGs:			
dim	61899	3082871	Kazin2010 arXiv:0908.2598
bright	30272	1521736	Kazin2010
superclusters:			
dim + bright	235		NH2013 arXiv:1310.2791
$z < 0.6$	2701		Liivamägi arXiv:1012.1989
voids:			
dim + bright	83		NH2013

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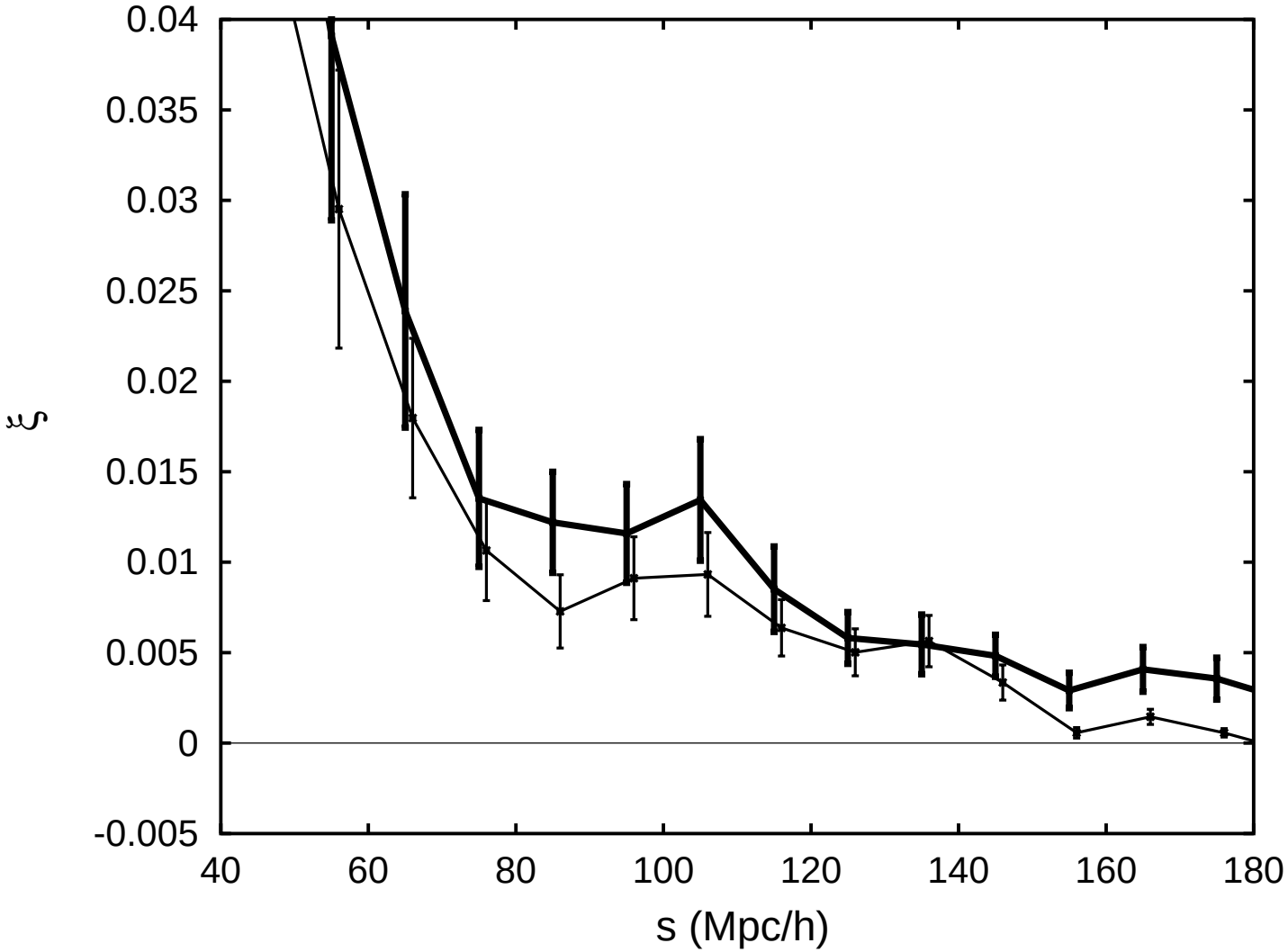

full br/dim

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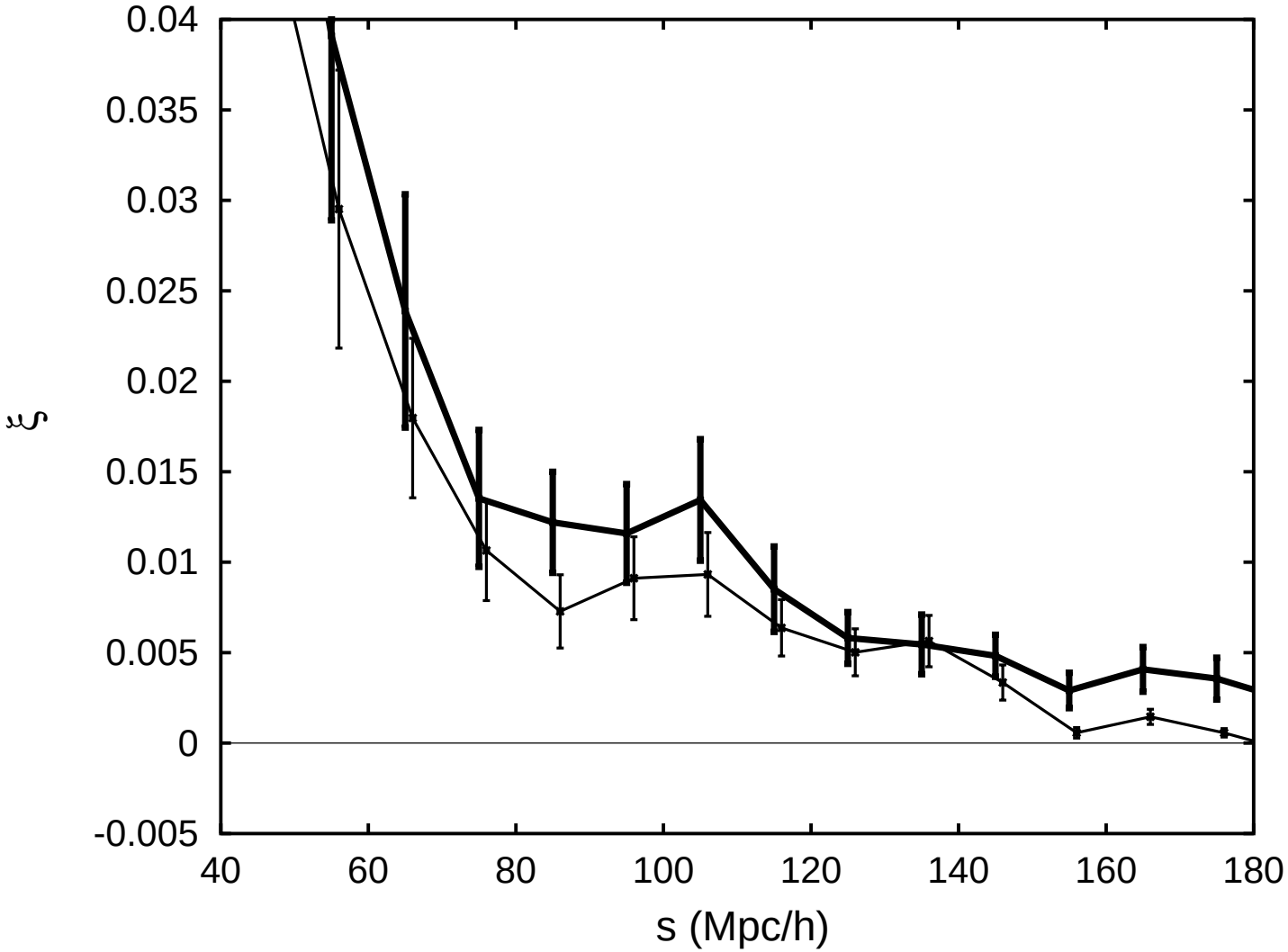

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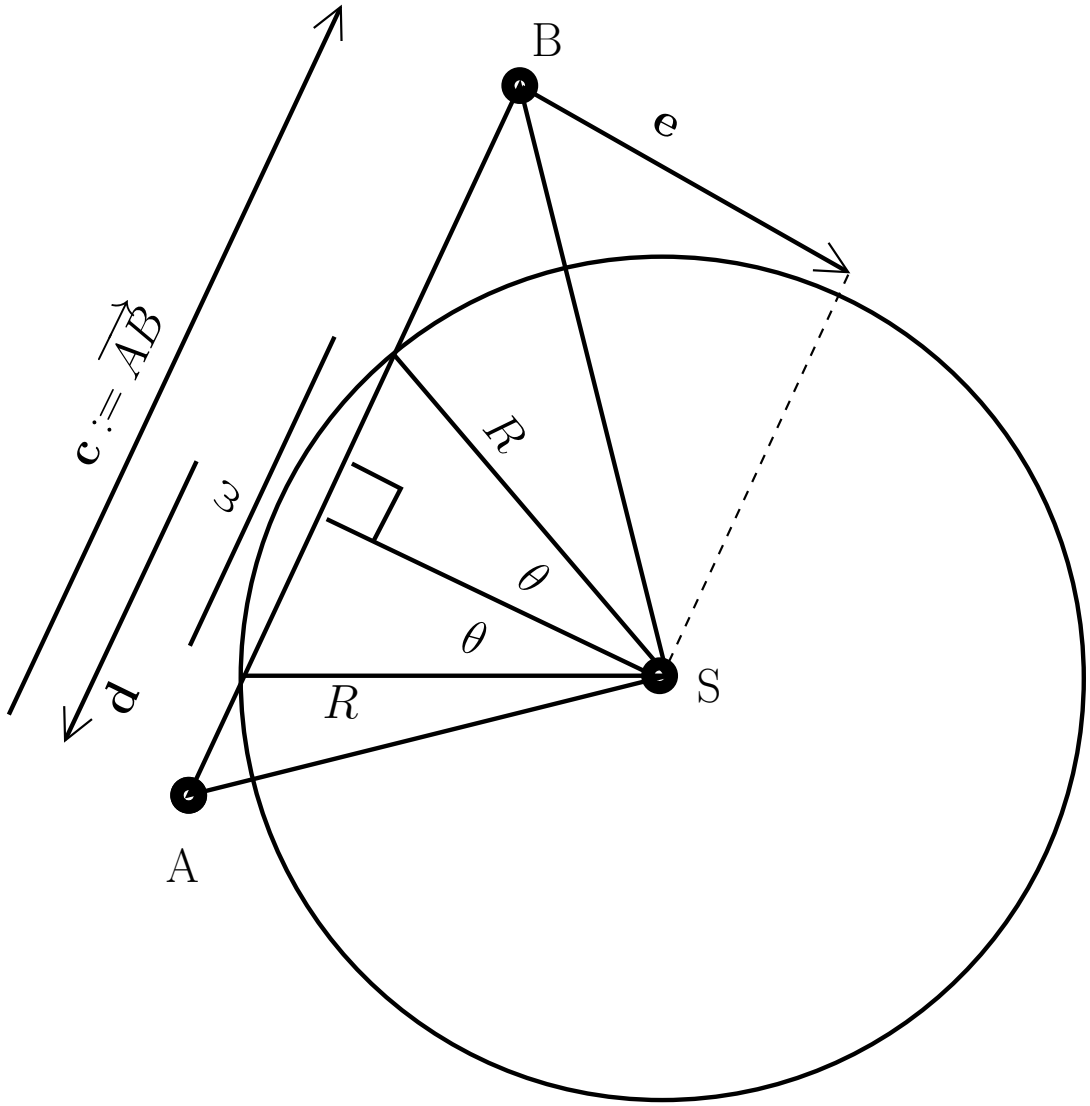
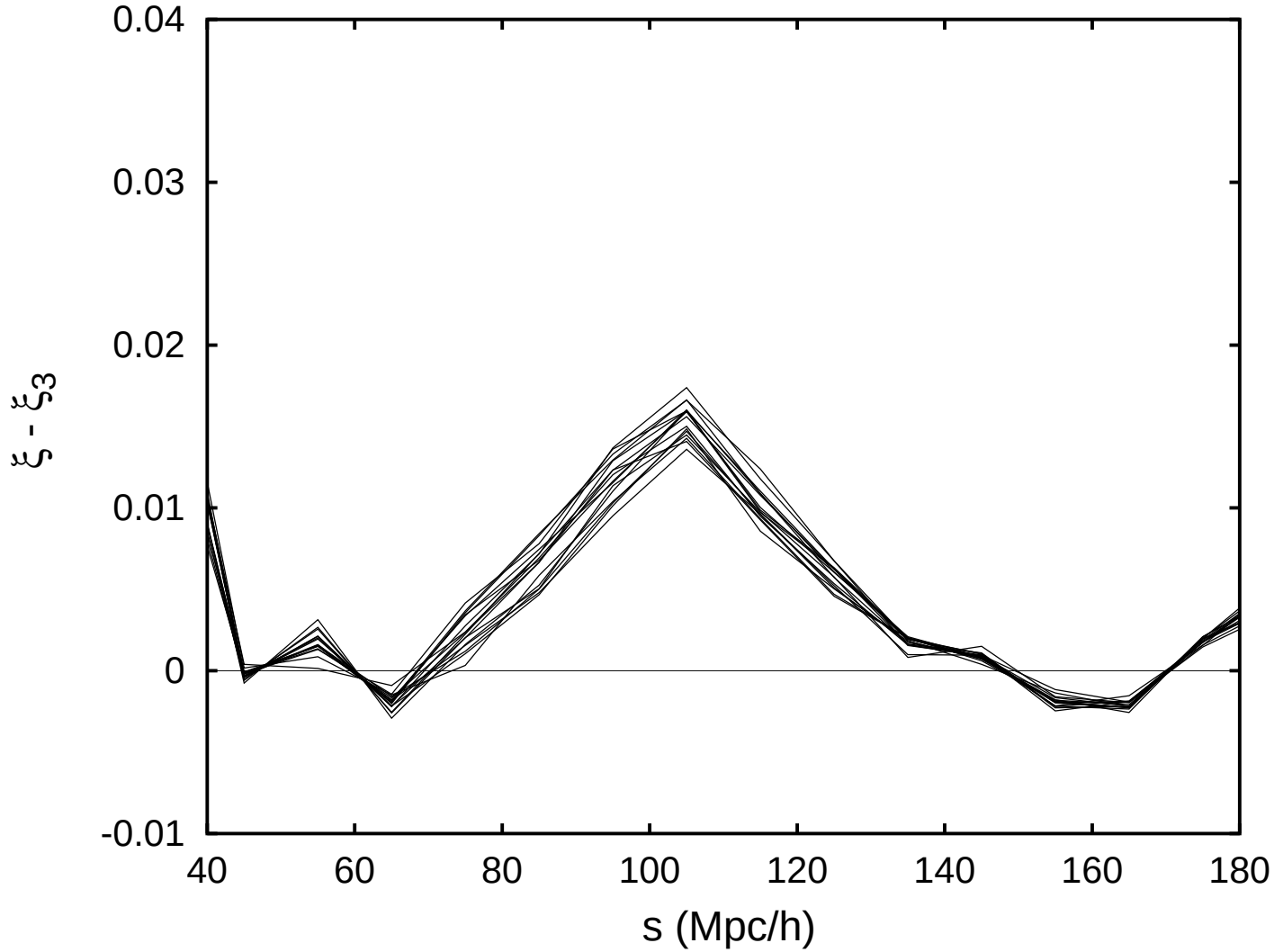
peak better defined in bright (bigger scale) sample

BAO peak—environment



overlap defn

BAO peak: NH superclusters



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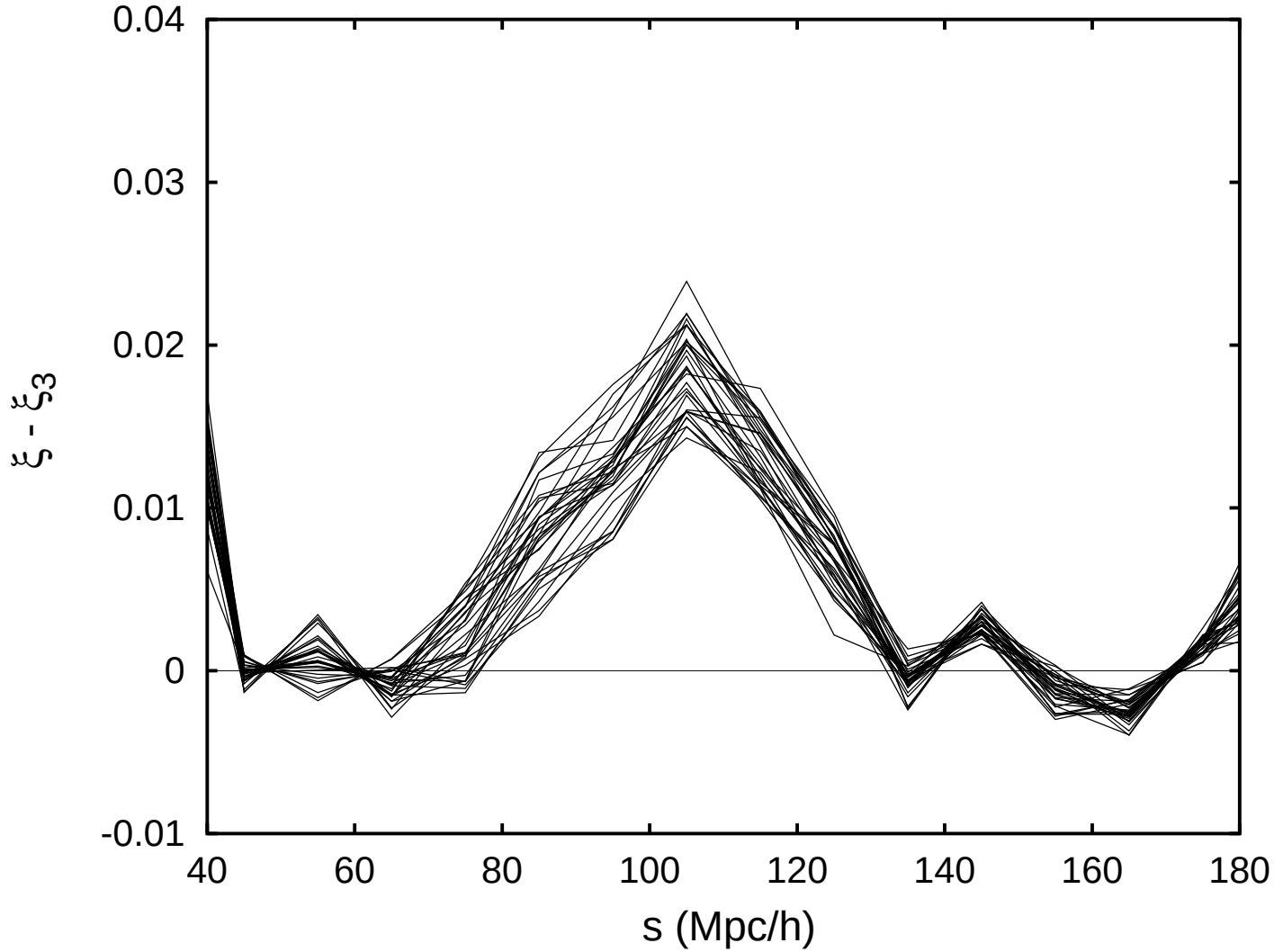

NH non-sc

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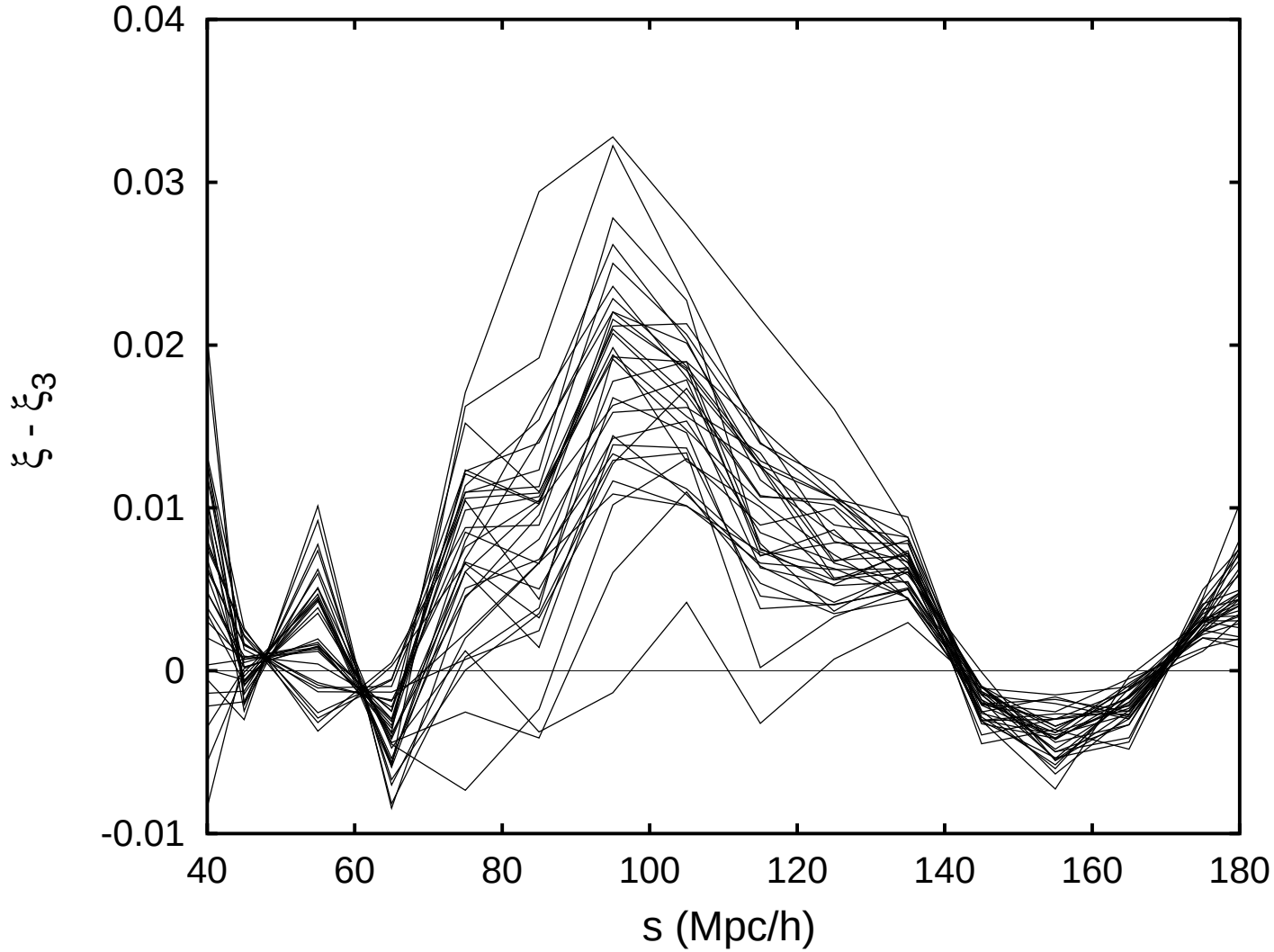

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- kd tree approach (not yet implemented).

Summary

catalogue	$r_\perp^0 - r_\perp^{\rm sc}$	$r_\perp^{\rm non-sc} - r_\perp^{\rm sc}$	$r_\perp^0 - r_\perp^{\rm void}$	$r_\perp^{\rm non-void} - r_\perp^{\rm void}$
N&H	4.3 ± 1.6	6.6 ± 2.8	-0.2 ± 4.0	-1.1 ± 5.5
LTS	3.7 ± 2.9	6.3 ± 2.6	all in h^{-1} Mpc	

- BAO comoving ruler compressed by $\approx 6\%$ for supercluster-overlapping pairs
- similar result for both NH2013 and Liivamägi2012 supercluster catalogues
- effect too noisy for void-overlapping pairs
- unpredicted in FLRW; expected from scalar averaging
- Roukema, Buchert, Ostrowski & France 2015 MNRAS, 448, 1660 — thanks to **grant 197 @PSNC**