Shapes of Clusters and Groups of Galaxies

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Paz, Lambas, Padilla, Merchán: astro-ph/0509062

Shapes and galaxy flows around Clusters and Groups of Galaxies

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Pivato, Padilla, Lambas, submitted to MNRAS, astro-ph/0512160.
Ceccarelli, Valotto, Lambas, Padilla, Giovanelli, Haynes, 2005, ApJ, 622, 853.

Talk outline

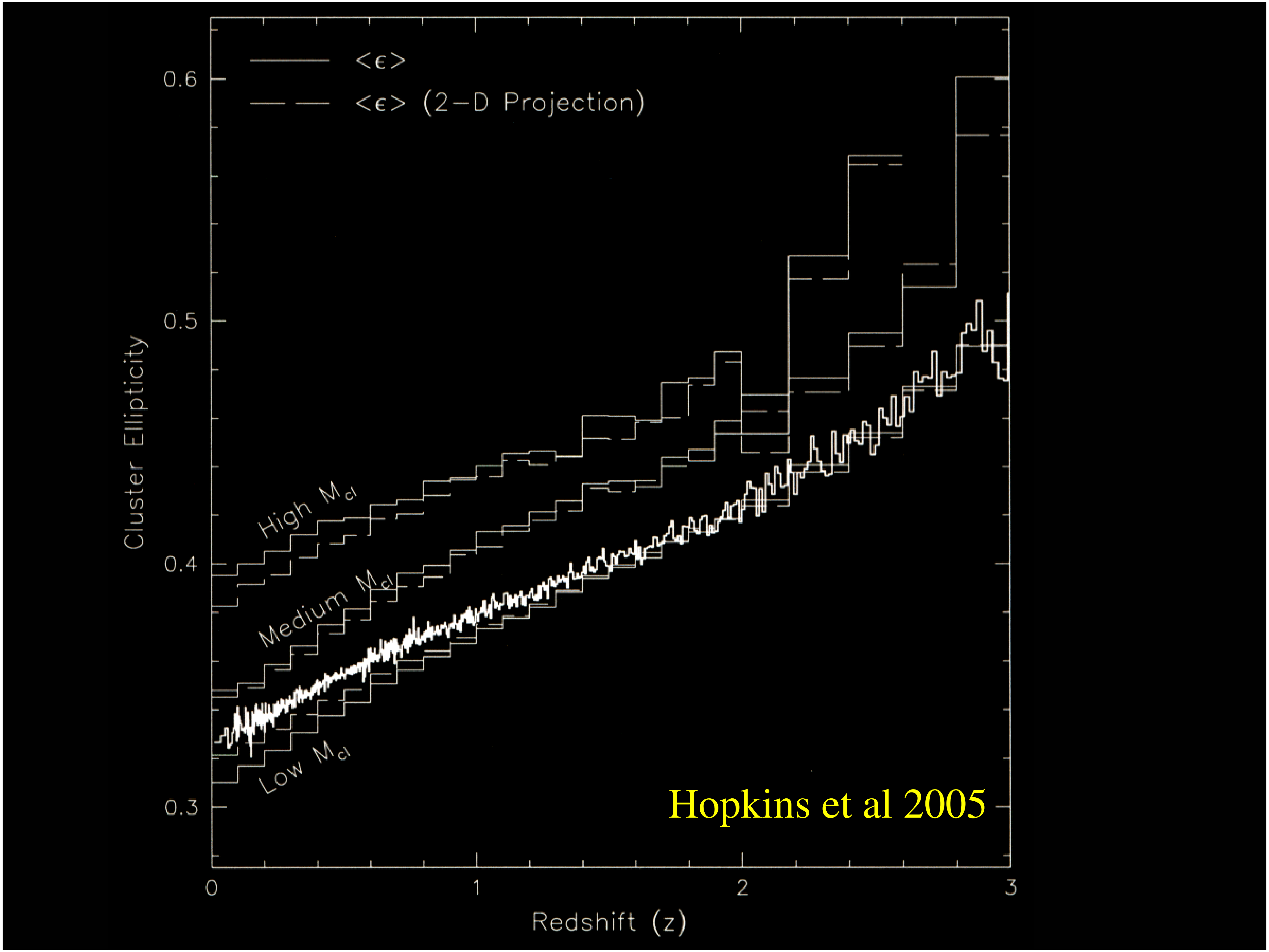
- Shapes of groups in the 2dFGRS and SDSS
  Paz, Lambas, Padilla, Merchán, MNRAS, astro-ph/0509062

- Peculiar velocity fields around groups
  Pivato, Padilla, Lambas, submitted to MNRAS, astro-ph/0512160.
  Ceccarelli, Valotto, Lambas, Padilla, Giovanelli, Haynes, 2005, ApJ, 622, 853.

Shapes of Groups: Why?

- Haloes are aspheric (Frenk White 1987, Warren et al. 1992, Thomas et al. 1998)
- Origin: 1st order, Zeldovich (Bond et al 1996)

  Non linear: Anisotropic accretion (van Haarlem & van de Weygaert 1993, Splinter et al., 1997)



<ε>
<ε> (2-D Projection)
Cluster Ellipticity
0.6
0.5
0.4
0.3
High M_{cl}
Medium M_{cl}
Low M_{cl}
Hopkins et al 2005
0
1
2
3
Redshift (z)

Previous studies:

- In simulations:
  - ✓ Triaxial shapes, independent of environment
  - ✓ Alignments out to 200Mpc/h
  - ✓ Asphericity increases with mass and redshift

- Observational data
  - ✓ X-ray clusters of galaxies (Plionis 2002, Mellot et al. 2001)
  - ✗ Groups in redshift space (Plionis et al. 2004)

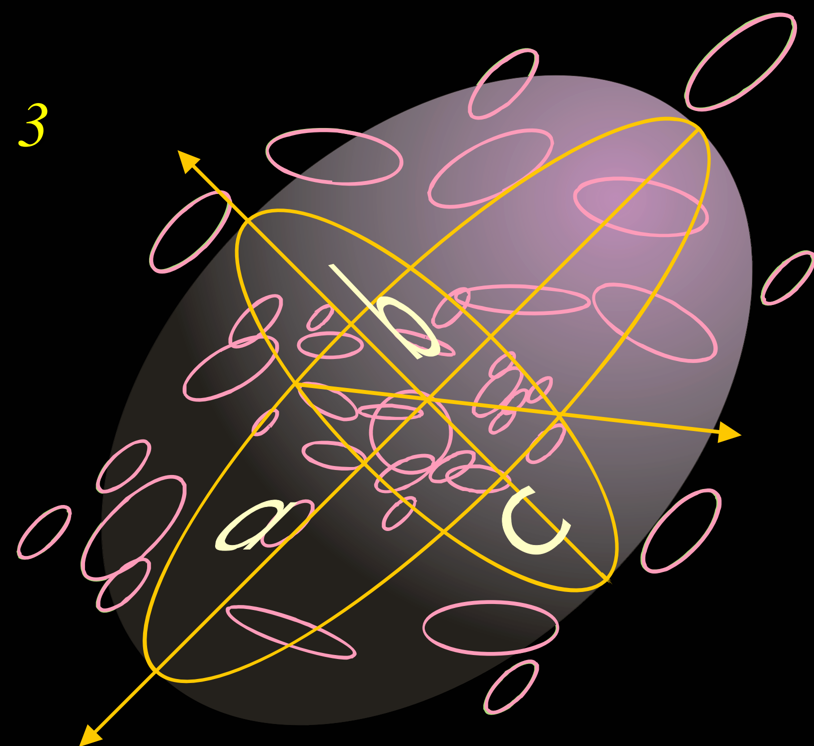
Determination of shapes

$$S_{ij} \propto \sum_{s=1}^{N} X^{i}{}_{s} X^{j}{}_{s} \qquad i, j = 1, 2, 3$$

$$I_{ij} = \sum_{s=1}^{N} r_s (\hat{e}_i \hat{e}_j) + S_{ij}$$

$$R^{-1}{}_{i}{}^{m} S_{lm} R^{l}{}_{j} = S_{ij}$$

$$S_{jk} d_l{}^{k} = \lambda_l d_l{}^{j}$$



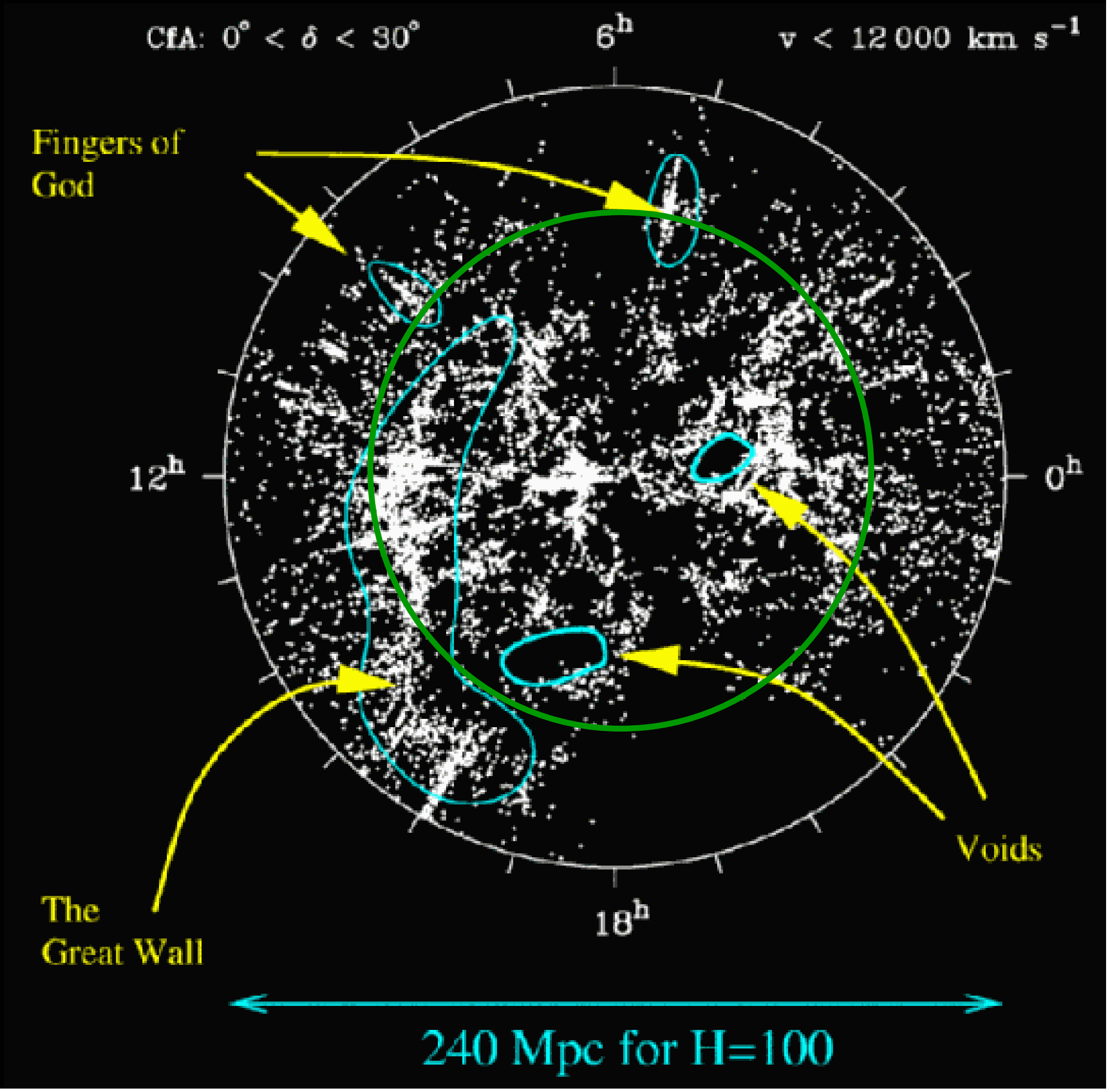
$$a > b > c = \sqrt{\lambda_l}$$

2D analysis

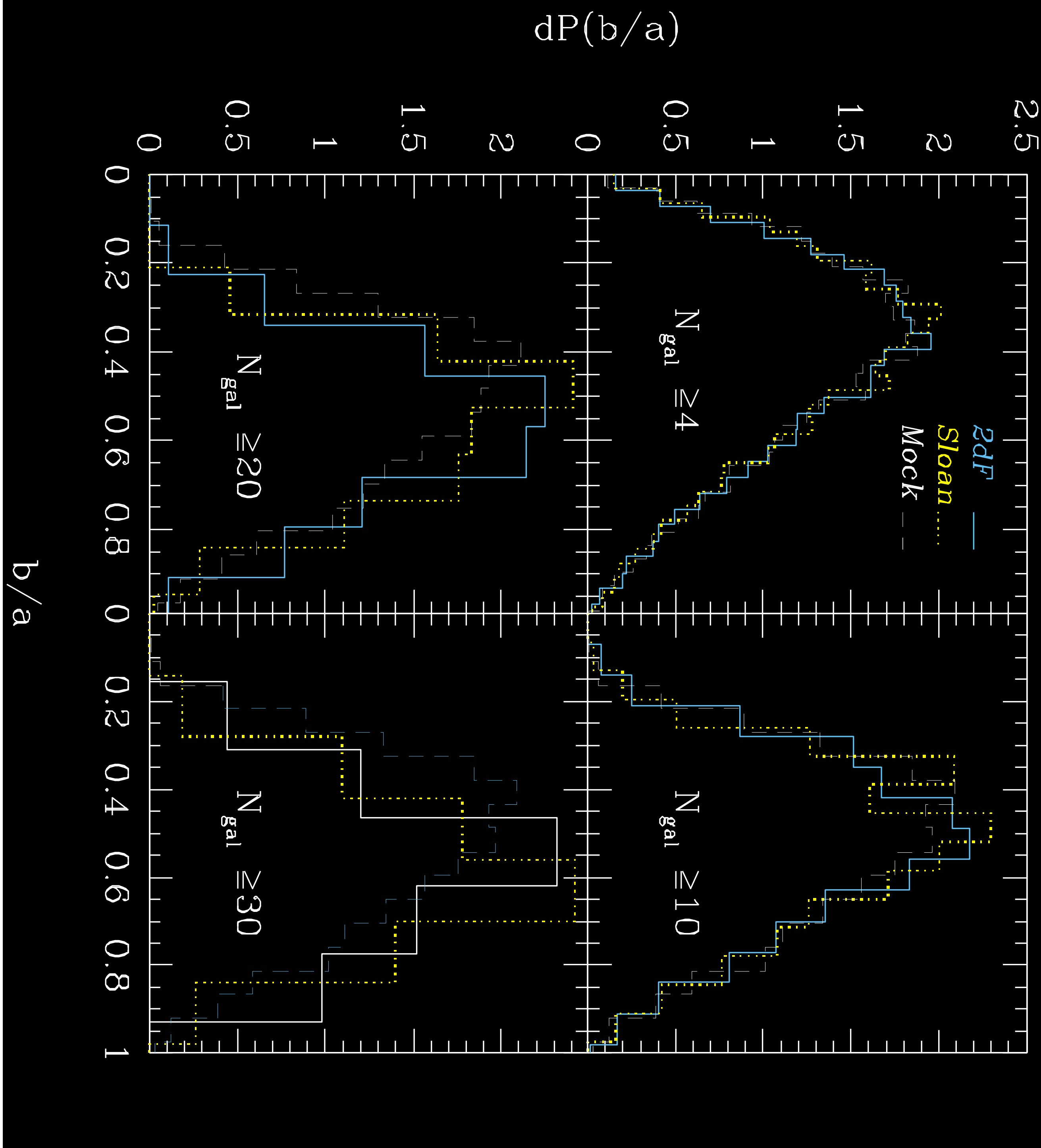
$$S_{ij} \propto \sum_{s=1}^{N} X^{i}{}_{s} X^{j}{}_{s}$$

$$I_{ij} = \sum_{s=1}^{N} r_s (\hat{e}_i \hat{e}_j) + S_{ij}$$

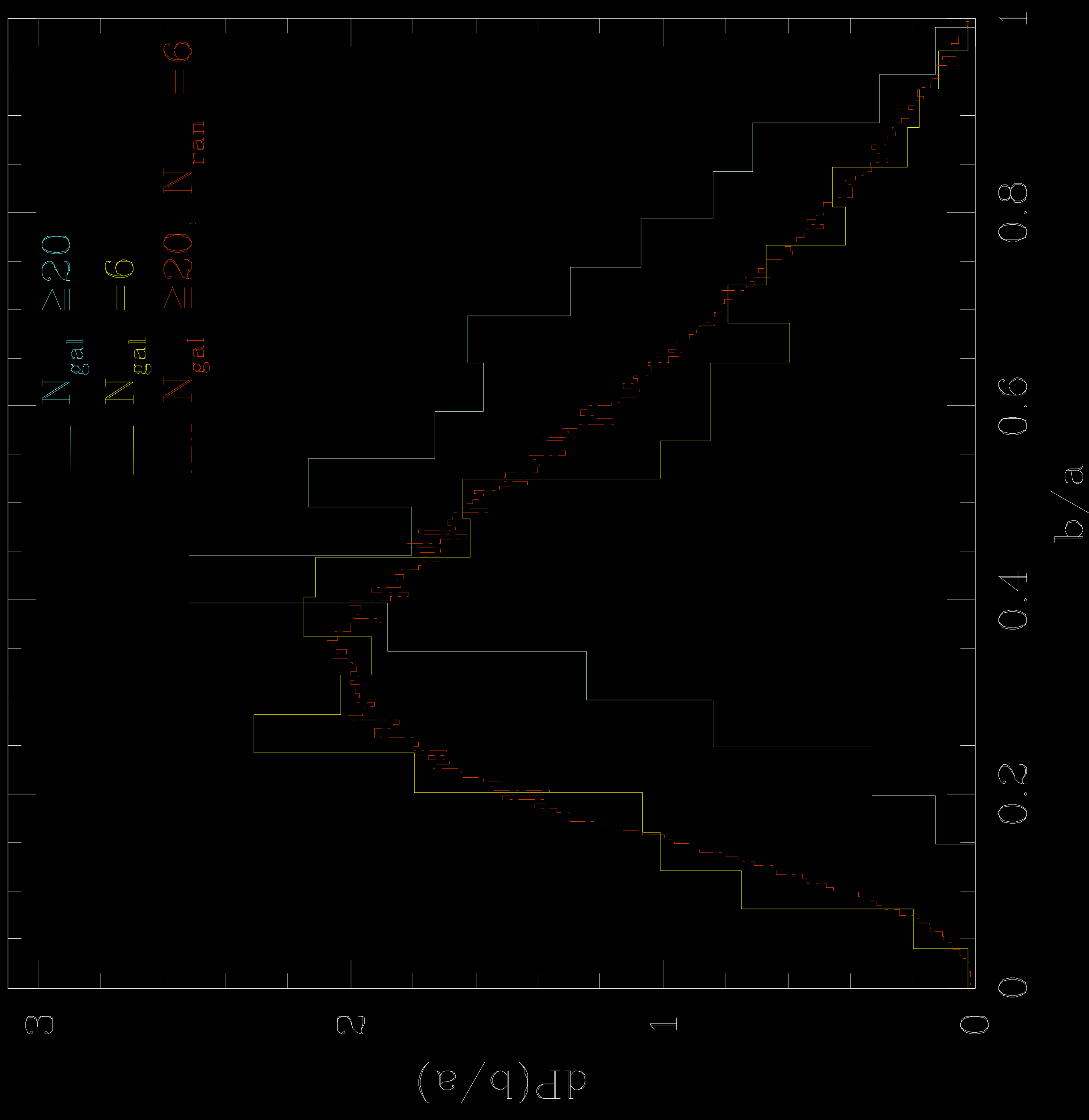
$i, j = 1, 2$

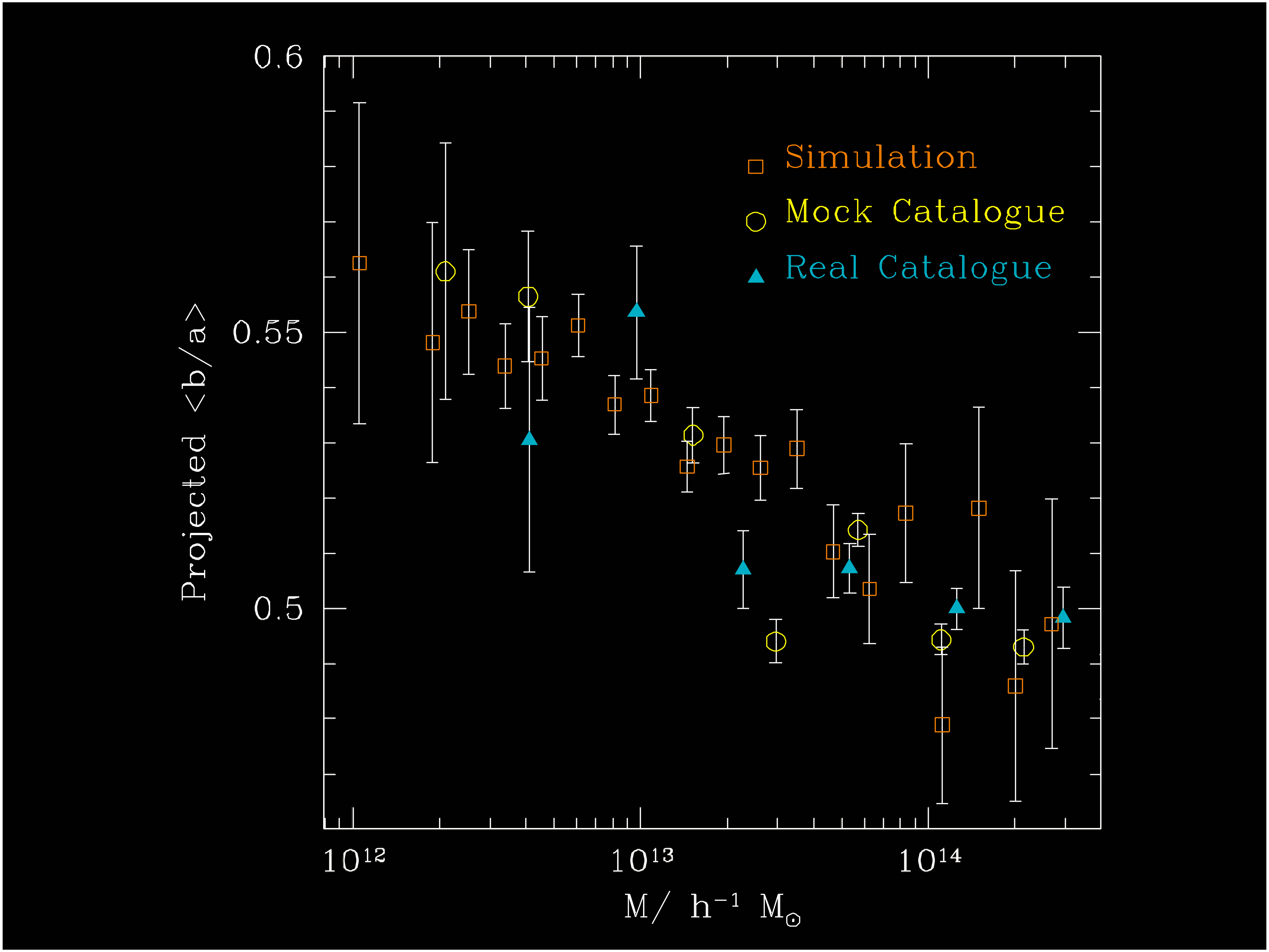


Number of members vs. b/a



Discreteness effect




Simulation
Mock Catalogue
Real Catalogue
Projected <b/a>
0.6
0.55
0.5
10^12
10^13
10^14
M/ h^-1 M_⊙

Dynamics around groups

Theoretical expectations in linear theory

$$V_{inf}^{lin} = -\frac{1}{3} H_0 \Omega_0^{0.6} r \delta(r),$$

In non-linear theory (Yahil, 1985),

$$V_{inf}^{non-lin} = -\frac{1}{3} H_0 \Omega_0^{0.6} r \frac{\delta(r)}{[1+\delta(r)]^{0.25}};$$

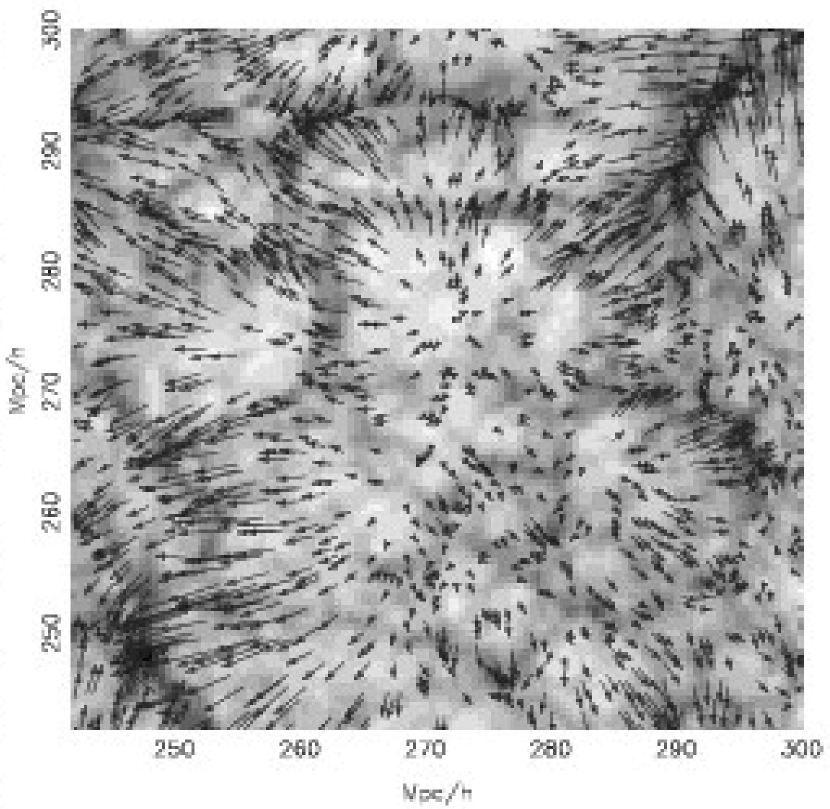


Figure 1. Infall pattern in a slice, $60h^{-1}$ Mpc a side and $10h^{-1}$ Mpc thick, of the VLS simulation box. The particle density is plotted in a logarithmic gray-scale, smoothed using a top-hat function ($R = 1h^{-1}$ Mpc). The black solid arrows show the peculiar velocity field.

Pivato, Padilla, Lambas, submitted to MNRAS, astro-ph/0512160.

Infall velocity and velocity alignment

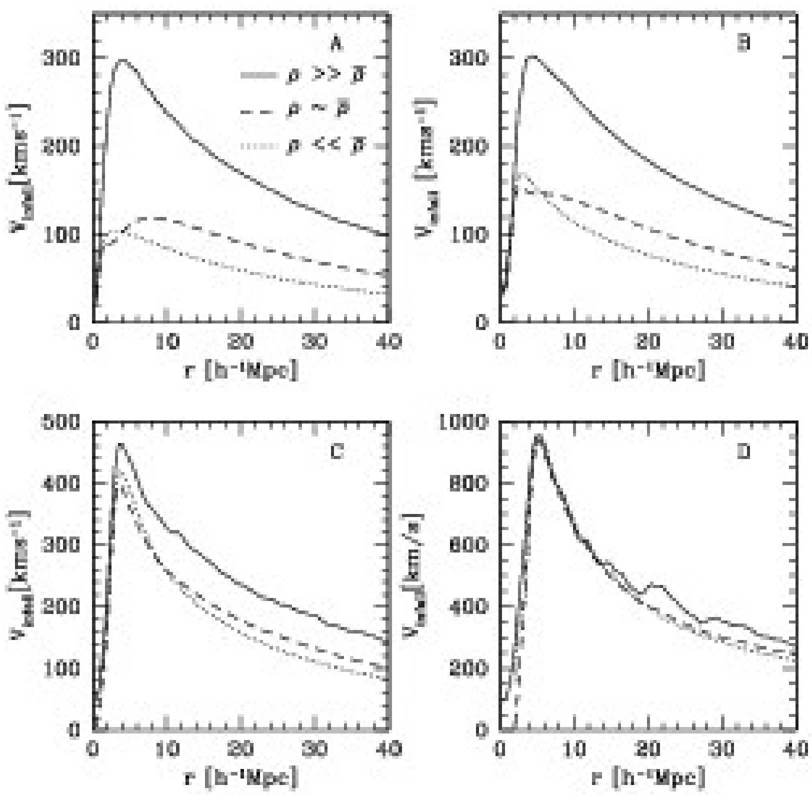


Figure 7. Mean infall velocity as a function of scale. Halo samples correspond to S1, S2, S3 and S4, and are defined in Table 1 (panels A, B, C and D). The different lines show the average infall patterns of particles in regions with density $\rho >> \bar{\rho}$ (solid line), $\rho \sim \bar{\rho}$ (dashed line) and $\rho << \bar{\rho}$ (dotted line).

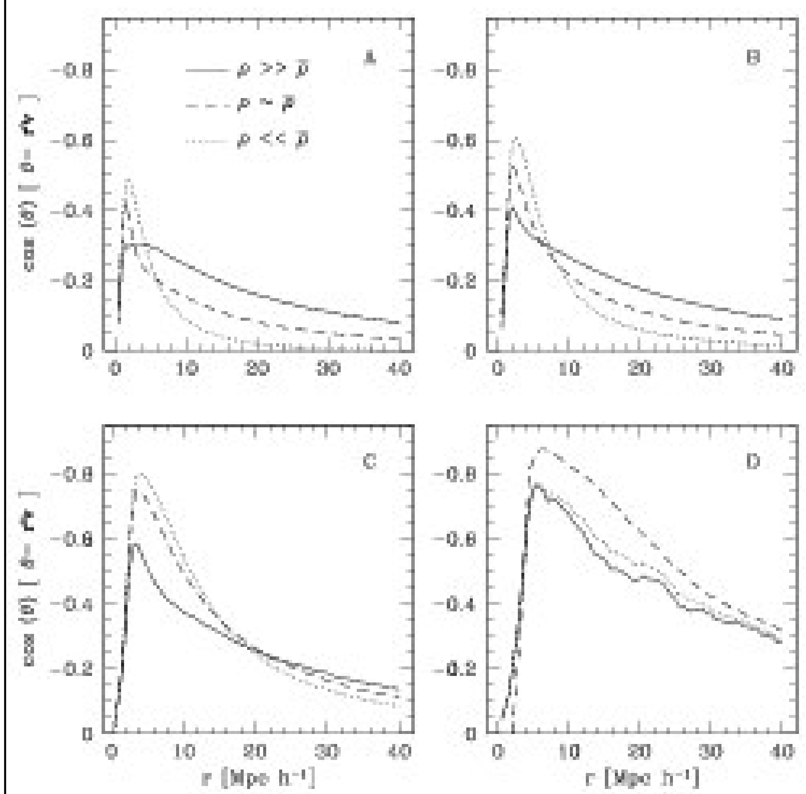
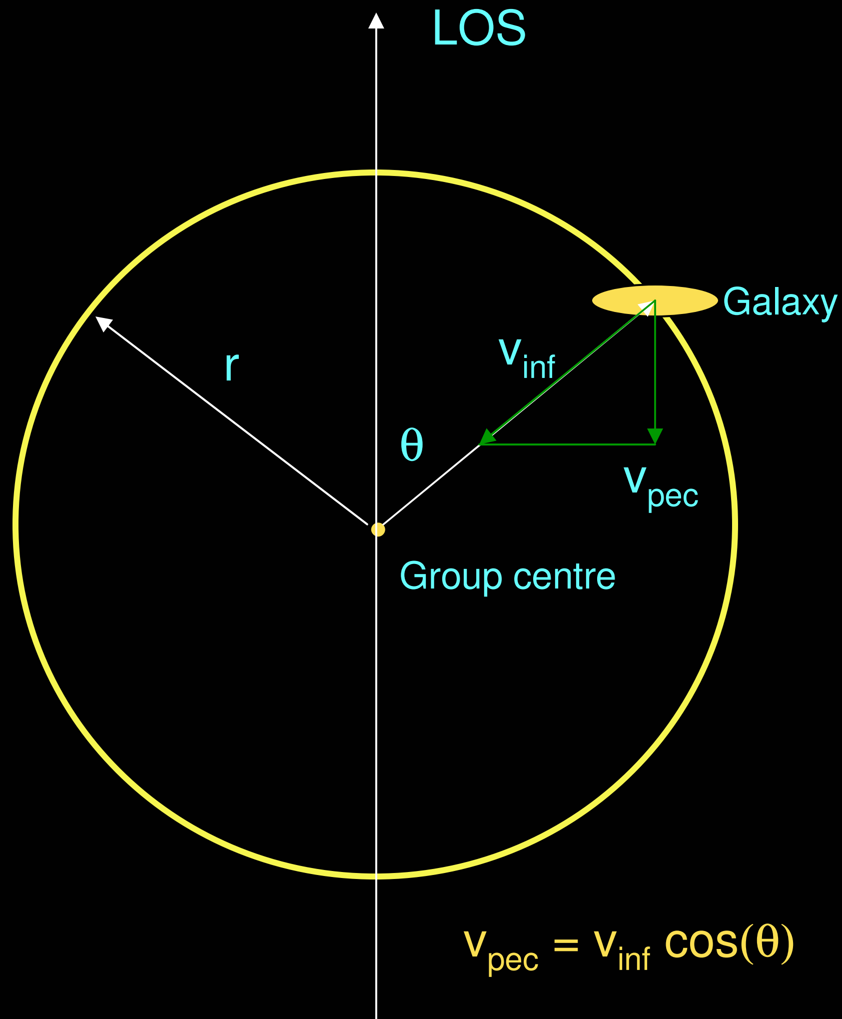


Figure 8. Dependence of $\langle cos(\theta) \rangle$ on local density for our four mass groups samples. Panel A: $\langle cos(\theta) \rangle$ for groups in mass sample S1, computed for particles in regions with $\rho >> \bar{\rho}$ (solid line), $\rho \sim \bar{\rho}$ (dashed line) and $\rho << \bar{\rho}$ (dotted line). Panel B: same as A, for groups in sample S2. Panel C: r groups in sample S3. Panel D: groups in sample S4.

Infall velocities from SFI Peculiar velocity data (From Giovanelli & Haynes 2002)

The difficult task can be achieved by measuring the projected infall toward the group centres onto the line of sight.

This method is tested using mock SFI and UZC group cagalogues.



$v_{pec} = v_{inf} \cos(\theta)$

Ceccarelli, Valotto, Lambas, Padilla, Giovanelli, Haynes, 2005, ApJ, 622, 853.

Actual measurements:

$$v_{pec} = v_{inf} \cos(\theta)$$

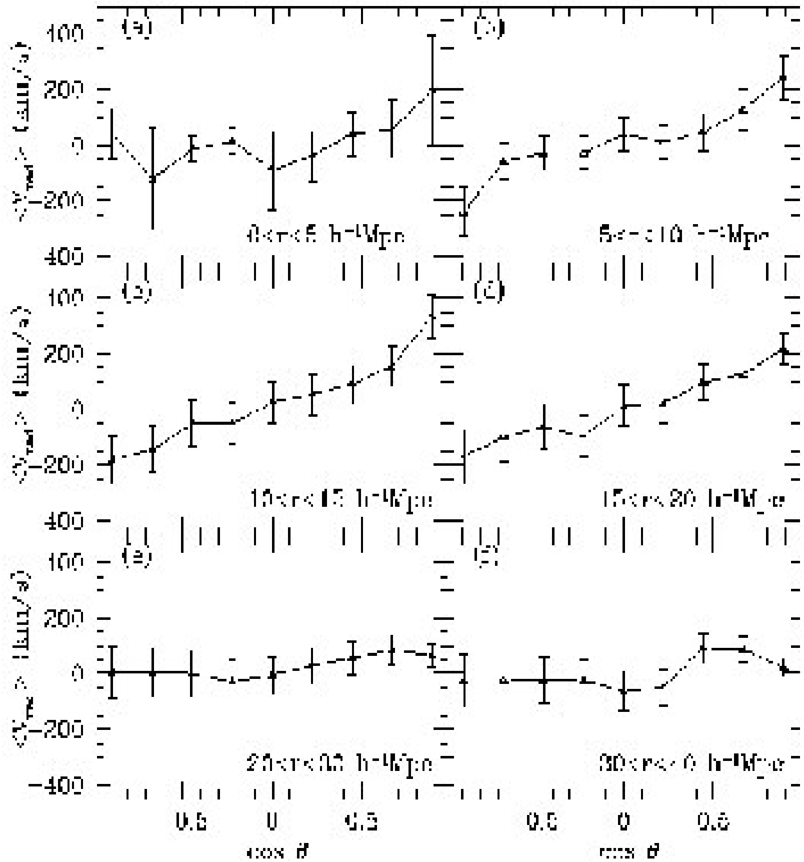
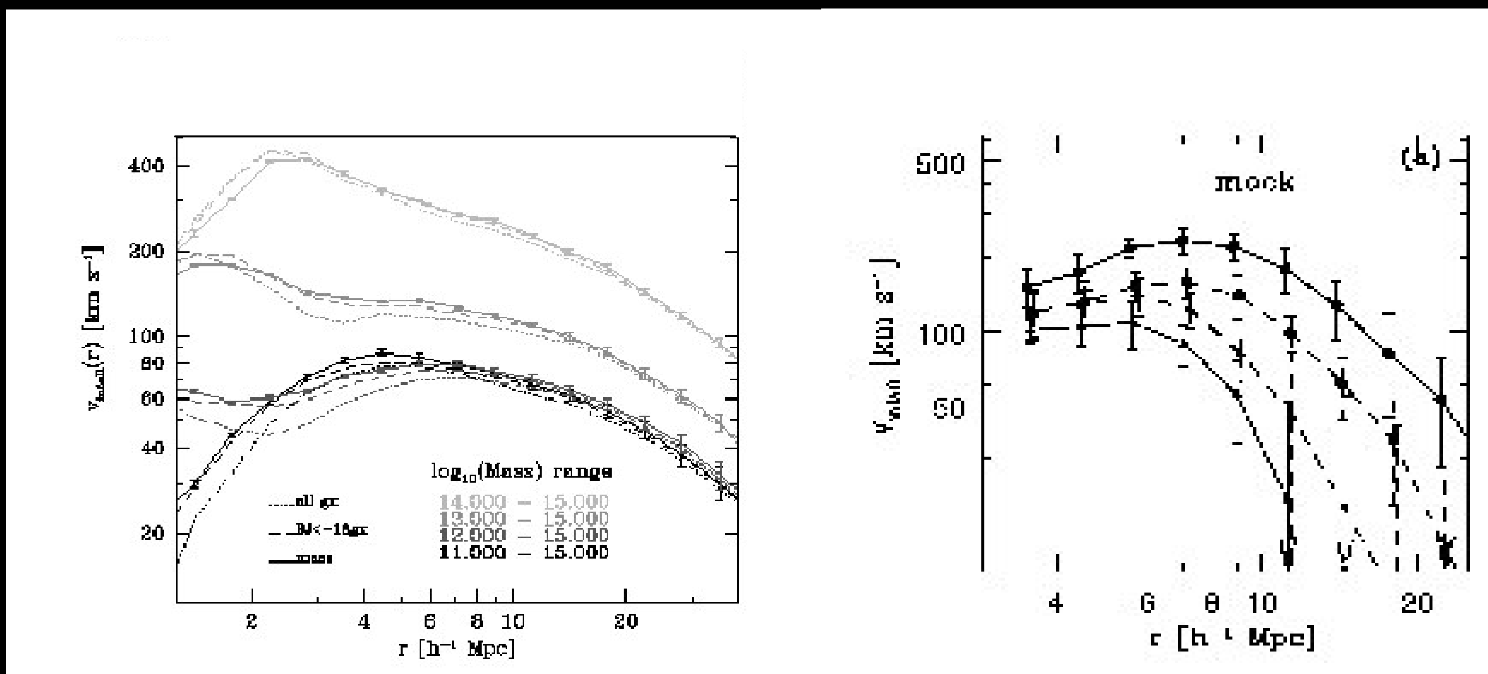


Fig. 4.— Mean values $< V_{pr} >$ as a function of the angle θ subtended by the group-galaxy and group-observer directions for the CPV galaxies and UZC groups. The units of r are h^{-1} Mpc. The different panels correspond to different distances to the group center: (a) $0 < r < 5$; (b) $5 < r < 10$; (c) $10 < r < 15$; (d) $15 < r < 20$; (e) $20 < r < 30$; (f) $30 < r < r40$

Comparison between simulation and mock results



Using the relation between Infall velocities and δ we find the overdensities within spheres of different radii around the group centres (both in the mock catalogues and real data).

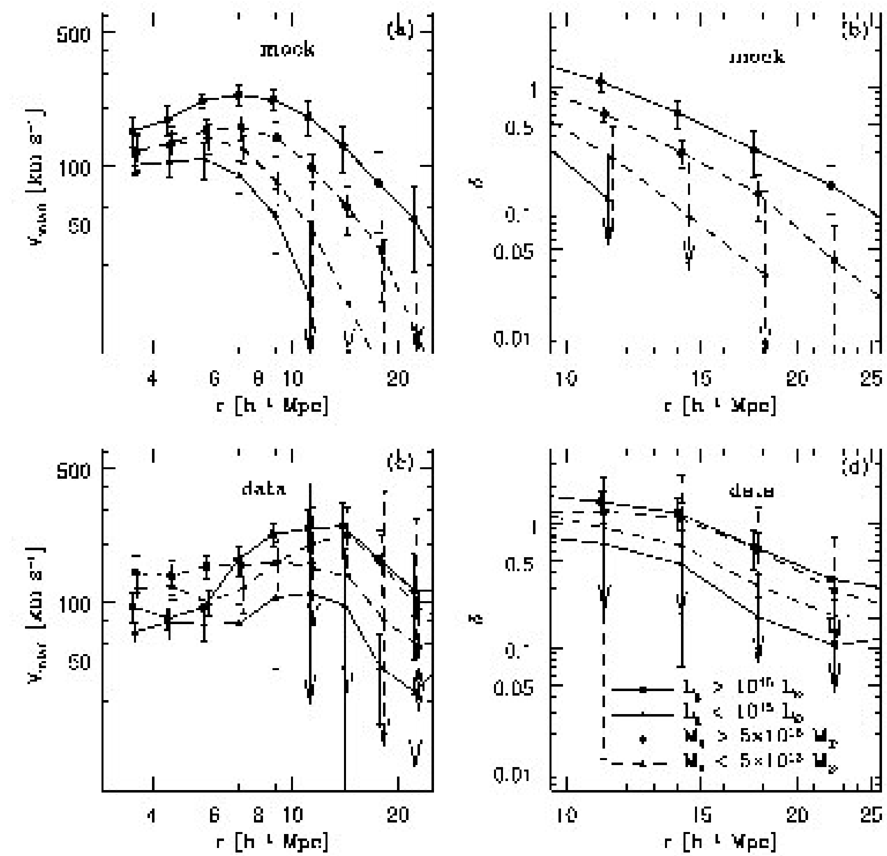


Fig. 10.— Results from mock (a,b) and observational (c,d) data. In all four panels, solid lines indicate subsamples divided by luminosity, whereas dashed lines indicate subsamples divided by virial mass. (a) Mock infall velocity corrected by distance errors. (b) Integrated mass overdensity as function of radius derived from linear theory. (c) Corrected infall velocity from observational data. (d) Integrated mass overdensity as function of radius derived from linear theory. Errors are derived from the scatter in several mock catalogs.

Conclusions

- Shapes of 2dFGRS groups: consistent with rounder systems for lower masses, as seen in numerical simulations.

  (Paz, Lambas, Padilla, Merchán: astro-ph/0509062)

- Infall onto dark matter haloes strongly dependent on local DM density.
- Alignments of infall around DM haloes out to larger distances than increase in infall velocities. Also important differences in alignments as a function of local density.

  (Pivato, Padilla, Lambas, submitted to MNRAS, astro-ph/0512160)

- First direct measurements of infall velocities toward centres of groups using UZC groups and SFI peculiar velocity data.

  (Ceccarelli, Valotto, Lambas, Padilla, Giovanelli, Haynes, 2005, ApJ, 622, 853).