Outskirts of Galaxy Clusters: Intense Life in the Suburbs
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Infall from peculiar velocities

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Abstract. We perform a statistical analysis to study the infall of galaxies onto groups and clusters in the nearby Universe. The study is based on the UZC/SSRS2 group catalogs and galaxy peculiar velocity data. We find a clear signature of infall of galaxies onto groups in a large range of scales 5 Mpc $h^{-1} < r < 30$ Mpc h^{-1}. We obtain a significant increase of the infall amplitude with group mass derived from virial equilibrium and from the luminosity of the member galaxies. We compare the observational results with mock catalogs derived from numerical simulations of semi-analytical models where we obtain a behavior similar to observations.

1. Introduction

Inhomogeneities in the distribution of matter are the source of the gravitational field in the Universe. As a response to the existence of such a field, objects embedded in it develop peculiar velocities. The enveloping velocity field takes the form of a collapsing streaming motion towards the local density maximum, with a velocity amplitude which depends only on the distance to the mass overdensity (Peebles 1980). In this work we investigate the structure of the peculiar velocity field around groups of galaxies in the nearby universe. We use groups identified from the UZC/SSRS2 catalogs (Merchan et al. 2000) and a recent compilation of galaxy peculiar velocities (CPV) obtained by Giovanelli & Haynes (2004) in order to study directly the infall and the dependence on different group properties.

2. Statistical methods and results

We may describe the mean infall of galaxies onto groups and clusters using galaxy peculiar velocities which give only the line of sight projection of the three dimensional peculiar velocity of a galaxy. This is achieved by:

$$V_{pr}(r,\theta) = V_{infall}(r)\cos\theta, \tag{2.1}$$

where θ is the angular separation between the observer and the galaxy as seen from the group centre. We have neglected in this analysis group peculiar velocities whose effects are expected to cancel out in this study.

We analyse the dependence of galaxy peculiar velocities V_{pr} on $\cos\theta$, in different spherical concentric shells around the individual groups and calculate averages $\langle V_{pr}(\theta)\rangle$ for different bins in $\cos\theta$ for the total group sample.

In Figure 1 we plot $\langle V_{pr}\rangle$ vs $\cos\theta$ at different scales. As it can be seen in the figure, at small scales (panel a) the uncertainties are larger than the mean peculiar velocity. At larger scales, there is a clear infall signature (panels b, c and d). The maximum amplitude occurs between 10 Mpc h^{-1} and 20 Mpc h^{-1}. Only at the largest scales explored (panels e and f) the infall is significantly reduced.

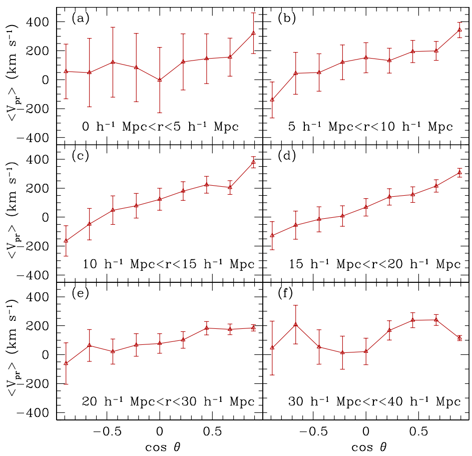

Figure 1. Mean values $\langle V_{pr} \rangle$ as a function of the angle θ for CPV galaxies and UZC groups.

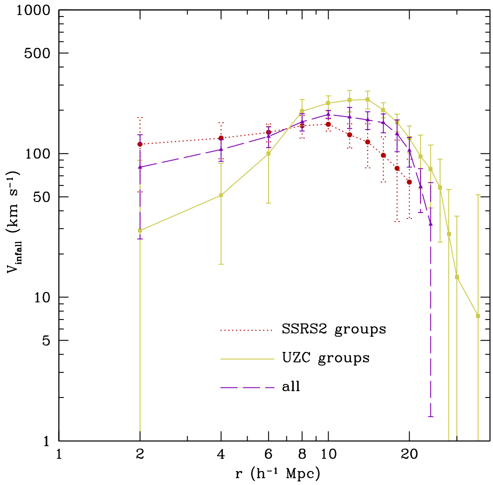

Figure 2. Amplitude of infall velocity of CPV galaxies onto UZC/SSRS2 groups.

The mean infall amplitude $V_{infall}(r)$ as a function of scale r is derived from the least square method applied to the observed $\langle V_{pr} \rangle$ vs $\cos\theta$. Figure 2 shows the resulting V_{infall} as a function of r where it can be seen that in the range of scales 5 Mpc $\mathrm{h}^{-1} < r <$ 20 Mpc h^{-1}, the amplitude of the infall velocities is in the range 100 km/s to 200 km/s.

It is expected that the amplitude of the infall velocities increases monotonically with group mass. To estimate group masses we have used either the virial mass M_V or the total group luminosity in the B band L_g. For groups with $M_V < 10^{13} M_\odot$, we obtain $V_{infall} \simeq 200$ km/s whereas for $M_V > 10^{13} M_\odot$ a larger infall is observed, $V_{infall} \simeq$ 350 km/s. For groups with $L_g < 10^{15} L_\odot$ we obtain $V_{infall} \simeq 190$ km/s whereas for $L_g > 10^{15} L_\odot$, $V_{infall} \simeq 490$ km/s. The results are shown in Figure 3 where it can be seen that, by dividing the sample into two roughly equal number subsamples by virial mass or luminosity, the difference in the amplitude of infall velocities is larger when dividing by luminosity than by mass.

The mock catalogues used to compare the results of the observations were extracted from a high resolution N-body simulation populated with galaxies using a semi-analytic model, by the theory group at the University of Durham. The simulation uses standard ΛCDM parameters and we have added observational constraints to construct suitable mock samples corresponding to both UZC groups and CPV galaxies.

We have tested the dependence of the amplitude of infall velocity on group virial mass and luminosity in the mock catalogues using the same procedure applied to the observational data. The mean infall velocities obtained are plotted in Figure 4, where we can see that the results from the mock samples are in qualitative agreement with those of observational data which indicates that galaxies and groups in semi-analytic models within the ΛDCM scenario provide a suitable agreement with the observations.

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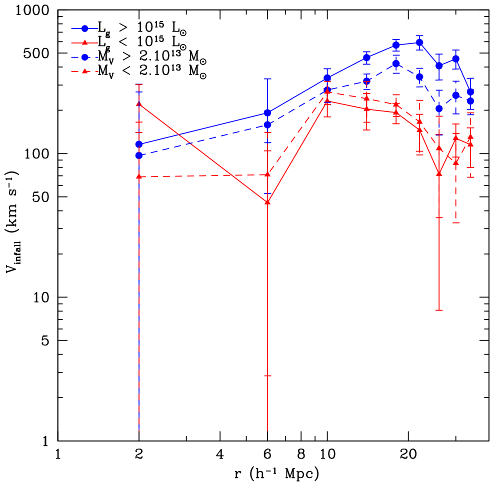

Figure 3. Mean infall velocity onto subsamples in UZC galaxy groups.

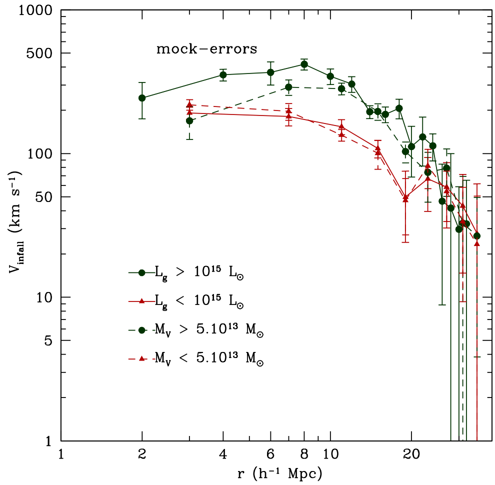

Figure 4. Mean infall velocity onto subsamples in mock catalogs.

3. Discussion

We find a clear signature of infall of galaxies onto groups in a large range of scales from galaxy peculiar velocity data. The amplitude of the infall velocities is of the order of few hundreds km/s. There is a significant dependence of the infall amplitude on group virial mass and in a similar fashion the total luminosity of the groups is an important parameter that determines the infall amplitude. We observe a larger difference in the infall amplitude for groups samples divided according to luminosity than to virial mass. We obtain a similar behaviour for the infall of galaxies onto groups in the numerical models which provides galaxy formation through semi-analytic prescriptions. The results for different virial mass and luminosity thresholds are consistent with those of the observational data, indicating that the models are suitable to reproduce the observations.

References

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