The General Assembly of Galaxy Halos: Structure, Origin and Evolution
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Halo Mass Estimation for Galaxy Groups: The Role Of Magnitude Gaps

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Abstract. We find that for the galaxy groups, the luminosity gap between the brightest and the subsequent brightest member galaxies in a halo (group) can be used to significantly reduce the scatter in the halo mass estimation based on the luminosity of the brightest galaxy alone. These corrections can significantly reduce the scatter in the halo mass estimations by ∼ 50% to ∼ 70% in massive halos.

1. Introduction

Galaxy groups provide an important step in understanding processes in galaxy formation and cosmology. There are many methods to identify galaxy groups. Yang *et al.*(2005a) developed a halo-based group finder which has been successfully applied to 2dFGRS (Yang *et al.* 2005a), SDSS DR4 and DR7 (Yang *et al.* 2007). One of the key steps in the halo-based group finder is the estimation of halo masses of candidate galaxy groups. Usually, group total luminosity (e.g. Yang *et al.* 2005a; 2007) is considered to be a reliable halo mass indicator. Unfortunately, for shallow and high redshift surveys, only a few brightest member galaxies can be observed in each dark matter halo. In case the survey volume is difficult to calculate because of the bad survey geometry, the halo mass estimation based on the total luminosity may become unachievable.

To estimate the halo masses for poor galaxy systems, one may make use of the central-host halo relation. As shown in Yang *et al.* (2008), for massive halos $L_c \propto M_h^{\sim 0.25}$, the typical scatter is about 0.15. The central (or the brightest) galaxy alone cannot provide a reliable estimation. Thus we improve this relation by using luminosity gap, defined as $\log L_{\rm gap} = \log L_c - \log L_i$, where L_i is the luminosity of the i-th brightest member galaxies.

2. Overview

We make use of four sets of mock galaxy catalogs obtained from conditional luminosity function, the subhalo abundance, and semi-analytical model respectively. In Fig. 1, blue open circles show the median and the 68% confidence levels (error bars) of halo masses, $\log M_h$, as a function of central galaxy luminosity $\log L_c$. We fit the median $M_h(L_c)$ relations with the following functional form:

$$\log M_h = \exp(\log L_c - \log M_a) + \log M_b \,. \tag{2.1}$$

To tighten the errorbars by using luminosity gap, we formally write

$$\log M_h(L_c, L_{\rm gap}) = \log M_h(L_c) + \Delta \log M_h(L_c, L_{\rm gap}) \,, \tag{2.2}$$

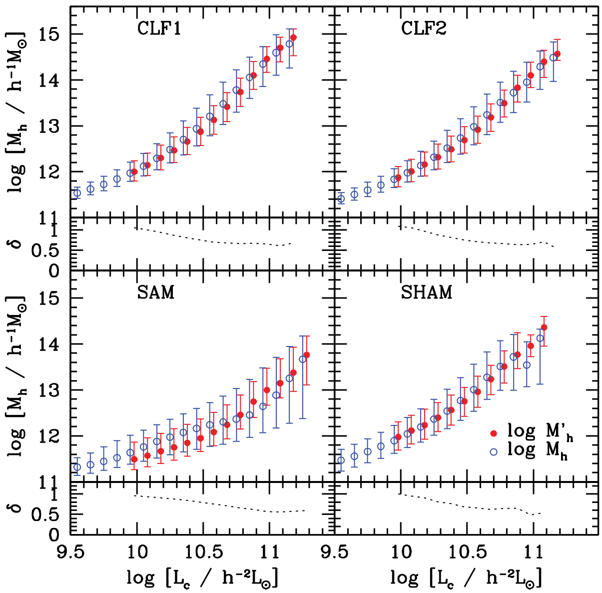

Figure 1. The comparison between the scatter in the original $\log M_h(L_c)$ relation and the new $\log M_h(L_c, L_{\rm gap})$ model.

where the first term on the right side is the empirical relation described by Eq. (2.1). And the 'luminosity gap' here, defined as the luminosity ratio between the central and the second brightest member galaxies in the same dark matter halo, $L_{\rm gap} = L_c/L_2$. We use the following functional form to model $\Delta \log M_h(L_c, L_{\rm gap})$,

$$\Delta \log M_h(L_c, L_{\rm gap}) = \eta_a \exp(\eta_b \log L_{\rm gap}) + \eta_c \,, \tag{2.3}$$

where parameters η_a, η_b and η_c may all depend on L_c:

$$\begin{aligned} \eta_a(L_c) &= \exp(\log L_c - \beta_1) \\ \eta_b(L_c) &= \alpha_2(\log L_c + \beta_2)\,, \\ \eta_c(L_c) &= -(\log L_c - \beta_3)^{\gamma_3} \end{aligned} \tag{2.4}$$

which in total has five free parameters. For comparison, we define a 'pre-corrected' halo mass

$$\log M'_h = \log M_h - \Delta \log M_h(L_c, L_{\rm gap})\,, \tag{2.5}$$

and check if the scatter in the $M'_h(L_c)$ relation is significantly reduced relative to that in the $M_h(L_c)$. If the correction by $\Delta \log M_h(L_c, L_{\rm gap})$ were perfect, the scatter in the $M'_h(L_c)$ would be reduced to 0.

In Fig. 1, we define the ratio between the corrected and original errorbars as δ in the sub-panels. It is clear that the scatter in $M'_h(L_c)$ is significantly reduced, especially for massive halos/groups where the scatter is reduced by about 50%.

References

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