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WEAK GRAVITATIONAL LENSING ANALYSIS OF A SAMPLE OF 50 MASSIVE GALAXY CLUSTERS

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ABSTRACT

Weak gravitational lensing is an efficient technique for detecting galaxy clusters and probing their mass distribution. We present a weak gravitational lensing analysis of a large sample of galaxy clusters. We have built a nearly complete sample of 50 optically rich clusters, located in the redshift range $0.1 < z < 0.6$ and observed in the Canada France Hawaii Telescope Legacy Survey (CFHT-LS). We used weak gravitational lensing to measure, for each galaxy cluster, the density radial profile, the total mass and the mass-to-light ratio (by comparing with the total luminosity of the member galaxies). This project is a preliminary step towards the next analysis of the weak lensing galaxy clusters in the surveys KiDS and VOICE, which are currently collecting data with the VLT Survey Telescope, in Chile.

Key words: weak gravitational lensing : galaxy cluster

1. INTRODUCTION

Galaxies are not smoothly distributed in space and usually they belong to gravitational systems that span a wide range in mass and size: groups, clusters and superclusters. Galaxy clusters are the most massive, gravitationally bound systems in the Universe, and their study provides important information about the formation of cosmic structures. Therefore, galaxy clusters have an important role in observational cosmology. Broadly speaking, galaxy clusters consists of three components: dark matter, hot intracluster medium and galaxies.

In this project, we used weak gravitational lensing to study the dark matter component of a large sample of ∼1200 galaxy clusters (Covone et al. 2014) and built a nearly complete sample of 50 rich galaxy clusters in order to determine the scaling relation of the mass-to-light ratio with the physical properties of the clusters: total light, total mass and redshift.

2. WEAK GRAVITATIONAL LENSING

Gravitational lensing provides a direct method to probe the distribution of matter in clusters of galaxies and, therefore, the relationship between baryonic and dark matter. General Relativity predicts that the light travelling through the gravitational field of a massive system is deflected. In the so called strong lensing regime, we observe multiple images and evident deformation of the images. In our work, we are interested in the weak lensing regime. In this case, only weak deformations of the source morphology are observable. Therefore, it is not possible to detect the lensing event from the study of single sources: it is necessary to use a statistical approach and a very accurate data analysis of wide sky regions around the gravitational lens.

We used the well-known Navarro-Frenk-White density profile (NFW, Navarro et al. (1996)) to describe the total mass distribution in galaxy clusters. NFW profiles accurately describe the mass distribution of dark matter haloes (e.g., Jing & Suto 2002). The NFW density profile is given by

$$\rho(r) = \frac{\delta_c \rho_c}{(r/r_s)(1 + r/r_s)^2} \quad (1)$$

where r is the distance from the cluster center and $\rho_c = 3H^2(z)/8\pi G$ is the critical density at the redshift (z) of the halo, $H(z)$ is Hubble's parameter at the same redshift and r_s is the scale radius. The concentration c is defined as $c \equiv r_{200}/r_s$, where r_{200} is the viral radius defined as the radius inside which the mass density of the halo is equal to 200 times critical density.

3. DATA ANALYSIS

We have used the public shear data of the CFHT Lensing Survey (CFHT-LenS), based on the optical data collected with MegaCam at the Canada-France-Hawaii Telescope (CFHT). The whole survey covers more than 170 square degrees of sky in 5 bands. Next, we selected the background galaxies by using a color-color

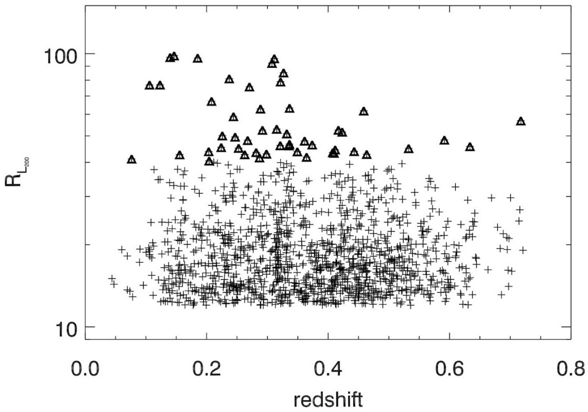

Figure 1. Distribution of the optical richness as a function of redshift. Triangles denote the sample of 50 richest clusters.

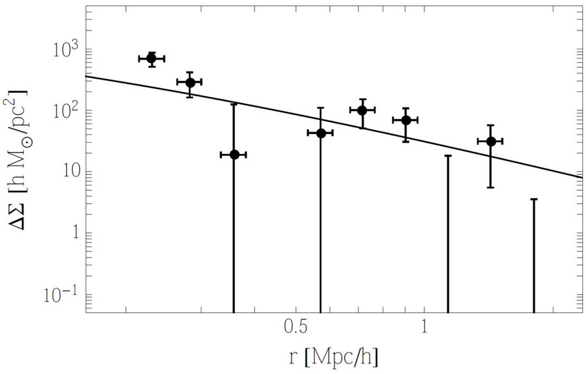

Figure 2. An example of the shear radial profile with the NFW fit.

selection, slightly modifying the technique of Oguri et al. (2013) in order to enlarge the number of background sources. Then, we used the cluster catalog from Wen et al. (2012), whose galaxy cluster catalog is complete to more than 95% for cluster masses $M_{200} > 10^{14}\,M_\odot$ in the redshift range of $0.05 < z < 0.42$. We selected 1176 galaxy clusters in the CFHT-LenS region and used the information about the optical richness R_{L_*} reported by Wen et al. (2012) to select the 50 optically richest galaxy clusters (see Fig. 1). The optical richness is defined as the ratio of the total r-band luminosity L_{200} to the characteristic galaxy luminosity $L_*(z)$.

4. FIRST RESULTS

We performed a weak lensing analysis of all the galaxy clusters (by fitting a NFW profile, see Fig. 2) to determine the total mass of the clusters and to study the scaling relations. As a first step, we measured the mass-to-light ratio of the selected clusters. Therefore, we also determined L_{200}, i.e. the total r-band luminosity of galaxy clusters (within the virial radius r_{200}), using the parametric function for the evolution of L_* proposed by Blanton et al. (2003). The results are shown in Fig. 3, where we compare the M/L ratio of massive clusters (triangle) with the average values from the whole sample of

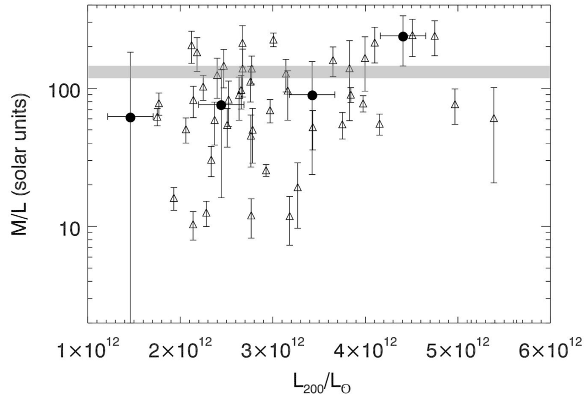

Figure 3. The M/L is calculated in the r-band of our samples compared to the the mean cosmological value (gray band) obtained by Bahcall et al. (2014). Triangles: the average values of M/L ratio for all the clusters. Points: the 50 massive galaxy clusters.

1176 systems (binned). We find an excellent agreement with Bahcall et al. (2014), after converting their i-band measurements to the r-band by using the average colors of passively evolving galaxies at intermediate redshift. There is no strong evidence of a variation of the M/L as a function of the cluster mass. Our results also show that the typical M/L of massive clusters is very close to the mean cosmological value. As noted by Bahcall et al. (2014), this supports the hypothesis that most of the dark matter is located in the halos of individual galaxies, while galaxy clusters appear to have the same dark matter fraction of massive galaxies.

5. CONCLUSIONS

The study of massive galaxy clusters via weak gravitational lensing is a fundamental tool for investigating their inner structure and constraining the cosmological parameters (e.g., Allen et al. 2014). Here we presented the measurement of the mass-to-light ratios in a large, nearly complete sample of massive clusters. Details of the work presented here will be presented in a master thesis report (Phriksee 2014). In the next steps, we plan to study in detail the scaling relations between cluster mass and optical luminosity and richness.

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