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PROBING CLUSTER GALAXIES WITH BACKGROUND QSOS

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RESUMEN

Presentamos los resultados del primer censo de absorbentes de Mg II asociados con cúmulos de galaxias a alto corrimiento al rojo. Hemos investigado la incidencia (dN/dz) de Mg II en cúmulos del *Red-Sequence Cluster Survey* a $\langle z \rangle = 0.6$ y encontrado que, mientras que los sistemas intensos ($W_0 > 1.0$ Å) son hasta 10 veces más frecuentes que en la estadística del campo, los más débiles ($W_0 < 0.3$ Å) se ajustan a ésta última. Sostenemos que tal dicotomía puede ser explicada si los halos que dan origen al Mg II débil están truncados debido a efectos medioambientales en el cúmulo.

ABSTRACT

We present the results of the first survey of intervening Mg II absorption systems associated with high-z cluster galaxies. We investigated the incidence (dN/dz) of Mg II absorbers in $\langle z \rangle = 0.6$ cluster galaxies from the Red-Sequence Cluster Survey. While strong ($W_0 > 1.0$ Å) absorbers show a significant excess (up to 10×), weak ($W_0 < 0.3$ Å) absorbers conform to the field statistics. We argue that this dichotomy could be explained if cluster galaxies that give rise to weak Mg II absorption have their cold halos truncated as a consequence of environmental effects.

Key Words: galaxies: clusters: general — quasars: absorption lines

1. INTRODUCTION

Galaxy clusters trace the densest environments in the Universe. They thus constitute the best laboratories to study galaxy evolution since (1) they contain a large number of galaxies at essentially the same cosmic time, (2) their environment is extreme compared to the field so galaxy transformations are constantly present, and (3) they can be traced to large look-back times.

In this report we present the first spectroscopic survey of background quasars having foreground clusters in the line of sight. The survey is aimed at probing metal absorbers possibly associated with the cluster galaxies, similarly as it has been done for field galaxies. We concentrate on the incidence of the redshifted Mg II $\lambda\lambda$ 2796,2803 Å doublet, an excellent tracer of high-redshift galaxies for which extensive field surveys exist.

2. SAMPLE AND OBSERVATIONS

We have used the candidate clusters from the Red-Sequence Cluster Survey, a 100 sq deg two-band imaging survey conducted with the CFHT and CTIO 4 m telescopes in the northern and southern skies, respectively. Clusters are detected as overdensities of red galaxies in the parameter space of color and position. Cluster redshifts, z_c, are estimated from the color of the red-sequence to within $\delta z = 0.1$. We have cross-correlated these clusters with background QSOs from the SDSS DR3 producing a total sample of 442 QSO-Cluster pairs, for which the impact parameter is smaller than 2 Mpc from the cluster center.

To study the incidence of Mg II in cluster galaxies we define —similarly to an unbiased QAL survey defined by $W_0^{\rm min}$— the redshift number density of absorbers in galaxy clusters, $(dN/dz)_c$, as the number of hits per unit cluster redshift:

$$(dN/dz)_c(W_0, z_1, z_2) \equiv \frac{N_{\rm hits}(W_0, z_1, z_2)}{\Delta z_{\rm c}(W_0, z_1, z_2)}\,, \qquad (1)$$

and its distribution, $n_c(W_0) \equiv \frac{d^2N}{dW\,dz}$, as the number of hits per unit cluster redshift per unit equivalent width, such that:

$$\int_{W1}^{W2} n_c(W_0, z_1, z_2)dW = (dN/dz)_c\,. \qquad (2)$$

An absorber is called a ‘hit’ when $z_{\rm abs}$ is in a ‘cluster redshift interval’, i.e., within $z_{\rm c} \pm \delta z$. We therefore define a ‘cluster redshift path density’, $g_c(W_0^{\rm min}, z_i, d)$, as the function that gives the number of cluster redshift intervals within a LOS-cluster distance d, in which a $W_0 > W_0^{\rm min}$ Mg II system at redshift z_i might have been detected. The cluster redshift-path $\Delta z_{\rm c}$ between any two redshifts z_1 and

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z_2 is thus

$$\Delta z_c(W_0^{\rm min}, z_1, z_2, d) = \int_{z_1}^{z_2} g_c(W_0^{\rm min}, z, d) dz\,. \quad (3)$$

We used the sample by Prochter et al. (2006) of strong ($W_0 > 1$ Å) Mg II systems in SDSS DR3 spectra, and our own high-resolution sample of 19 quasars to deal with the weaker absorbers. The total redshift paths were $\Delta z_c = 57.0$ and 6.3, for both samples, respectively.

We compared the W_0-distribution measured in clusters with field Mg II surveys by Nestor et al. (2005, 2006), Churchill et al. (1999), and Narayanan et al. (2007). These surveys have found that weak and strong systems show different W_0-distributions: weaker systems are fitted by a power-law while stronger systems are better described by an exponential, with the transition at $W_0 \approx 0.3$ Å. This effect would hint at two distinct populations of absorbers (e.g., Nestor et al. 2005).

3. RESULTS

We find a 3σ excess of *strong* Mg II absorbers in bright QSO spectra whose line-of-sight is within 2 Mpc from the center of clusters of galaxies at $z_c = 0.3-0.9$, when compared to those found in the field. This excess is more significant for the subsample of pairs with impact parameters to the cluster center lower than 1 Mpc, and also for the sub-sample of pairs having the richest clusters (Lopez et al. 2008).

The *weak* absorbers, on the other hand, do not show such an excess. In fact, the W_0-distribution in clusters is consistent with that found for the field for $W_0 < 0.3$ Å, and it shows an enhancement only for $W_0 > 1$ Å (Figure 1). The naive interpretation for this result is that field galaxies have an extended halo where the weak Mg II absorption can occur, while cluster galaxies have been stripped from this outer halo and only the strong absorbers survived. The excess found for the strong absorbers is naturally explained as an overdensity of galaxies in the cluster environment (about 10× for the clusters being considered here), while for the weak absorbers the field statistics is recovered along Δz_c due to the lack of them in the clusters.

From these results it follows that the stronger systems correlate more strongly with galaxies: strong

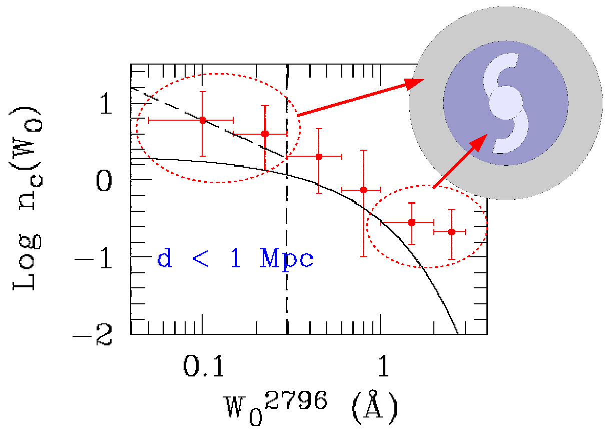

Fig. 1. Equivalent width distribution of Mg II absorbers in $\langle z \rangle = 0.6$ clusters (corrected by the cluster redshift path) with an impact parameter lower than 1 Mpc. The solid and broken lines indicate the distributions of field absorbers. The distribution for $W_0 < 0.3$ Å is consistent with that of the field, while for $W_0 > 1.0$ Å there is an excess of up to 10×. The cartoon on the top-right corner shows the location in the cluster galaxies where the two equivalent-width regimes could occur.

systems in our sample show more clustering with clusters than weak systems. This seems to go in the opposite direction of the results by Bouche et al. (2007), who find that stronger systems occur in galaxies associated with less massive dark-matter halos ($M \sim 10^{11}\ M_\odot$) than weaker systems ($M \sim 10^{12} M_\odot$). The Bouche et al. (2007) data, however, reaches only $W_0 = 0.3$ Å, while with our technique we probe much deeper in equivalent width.

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