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LARGE-SCALE STRUCTURES AROUND QUASAR PAIRS AT $Z \sim 1$

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RESUMEN

Hemos usado los telescopios Gemini para estudiar las propiedades fotométricas de 4 campos alrededor de los pares de cuasares QP1310+0007, QP1355-0032, QP0110-0219 y QP0114-3140 a $z \sim 1$ con el objetivo de identificar grupos o cúmulos de galaxias con estructuras a gran escala alrededor de los cuasares. Nuestro análisis revela que QP0110-0219 muestra fuerte evidencia y que QP1310+0007 and QP1355-0032 muestra alguna evidencia de la presencia de cúmulos de galaxias ricos en la vecindad cercana a los pares. Por otro lado, QP0114-3140 podría ser un par aislado en un medio ambiente pobre. Este trabajo sugiere que pares de cuasares a $z \sim 1$ son excelentes trazadores de medios ambientes de alta densidad.

ABSTRACT

We have used Gemini telescopes to study the photometric properties of four fields around the high-redshift quasar pairs QP1310+0007, QP1355-0032, QP0110-0219, and QP0114-3140 at $z \sim 1$ with the aim of identifying large-scale structures –galaxy clusters or groups– around them. Our analysis reveals that QP0110-0219 shows very strong and QP1310+0007 and QP1355-0032 show some evidence for the presence of rich galaxy clusters in direct vicinity of the pairs. On the other hand, QP0114-3140 could be an isolated pair in a poor environment. This work suggest that $z \sim 1$ quasar pairs are excellent tracers of high density environments.

Key Words: galaxies: clusters — large-scale structure of universe — quasars: general — techniques: photometric

1. INTRODUCTION

The study of galaxy populations in high-redshift large-scale structures can give us important clues about the star formation history and galaxy formation process in such environments. However, the detection of distant galaxy clusters is not trivial.

At high redshifts, techniques to trace clustering of galaxies include the detection of the red-cluster sequence (Gladders & Yee 2005), of extended X-ray emission (e.g., Romer et al. 2001), or the Sunyaev-Zeldovich decrement. In this work we consider another possible tracer of the presence of clusters: physically close pairs of quasars. For more details, see Boris et al. (2007).

Quasars are relatively rare astronomical objects and hence, if they are distributed following galaxies, the presence of two or more such objects in a relatively small volume should be a good indicator of a rich environment. Actually, in structure formation scenarios with bias between baryonic and dark matter distribution (e.g., Kaiser 1984) it is expected that high redshift objects form in large high-redshift density fluctuations and, therefore, such correlation between quasar concentrations and clusters is somewhat expected, unless, for some reason, quasars avoid clusters.

Here we present the results of a multi-color photometric study of the field around four quasar pairs at $z \sim 1$, using the instrument GMOS in both Gemini North and South telescopes.

2. RESULTS

We selected four pairs from Véron-Cetty & Véron (2001) quasar catalog considering redshifts between 0.9 and 1.0, redshift differences between the quasars smaller than 0.01, and projected angular separations smaller than 300 arcsec.

We have studied the environment traced by these quasar pairs using images in g', r', i', and z' bands obtained with GMOS at Gemini North and South (Boris et al. 2007). Our photometry is complete to a limiting magnitude of $i' \sim 24$ mag (corresponding to $\sim M^*_{i'} + 2$ at the redshift of the pairs).

In order to identify galaxies in a redshift interval close to that of the quasar pairs, we have estimated photometric redshifts with a Locally Weighted Regression algorithm, using ACS-GOODS data as a training set. The rms dispersion of the difference

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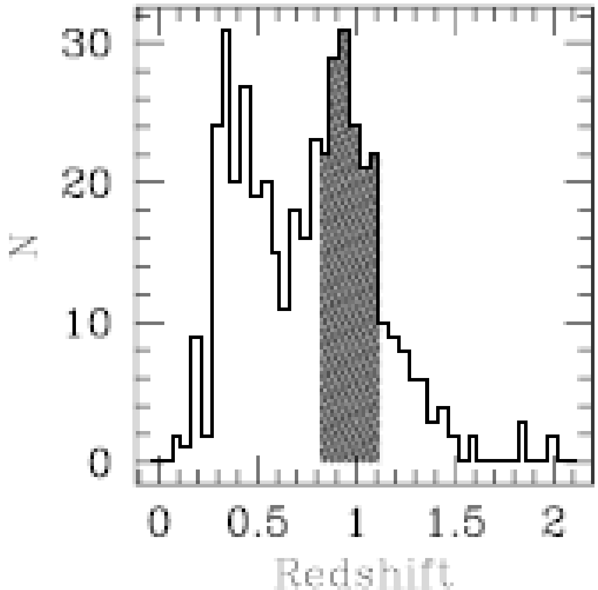

Fig. 1. Distribution of photometric redshifts in the field of QP0110-0219. Notice the peak at the redshift of the quasars.

between our photometric redshift and the spectroscopic redshift in the training set is $\sigma_z = 0.16$. We have adopted the interval $z = z_{\rm pair} \pm \sigma_z$ for the analysis of the pair environment. Figure 1 shows the photometric redshift distribution of QP0110-0219.

When compared with the HHDFN region, all fields show a significant overdensity in the redshift interval of the pair. In all cases this excess is larger than 3.5σ.

We investigated the clustering of the galaxies near the pair by estimating a confidence level that the galaxies are more concentrated than in a uniform distribution. We have also estimated the richness of each redshift interval with a variant of Abell's criterion, as well as by the number of bright galaxies. We verified whether a red sequence is present and the form of the projected distribution of red galaxies.

The pair in the richest environment is QP0110-0219, with quasars at redshifts of 0.956 and 0.958. The red galaxies present a filamentary-like distribution and there is a galaxy excess around the radio-loud quasar. These results indicate that QP0110-0219 is indeed a rich cluster. Moreover, we have verified that it has been serendipitously detected (but unreported) in X-ray with a pointed *ROSAT* PSPC observation of 6.6 ks (see Figure 2). We have estimated the bolometric X-ray luminosity assuming that all detected flux (background corrected) comes

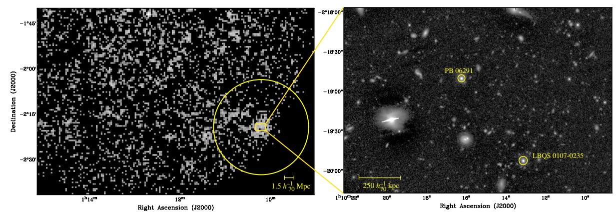

Fig. 2. Left: *ROSAT* PSPC serendipitous observation of QP0110-0219. Right: GMOS image of the same field, with identification of the two quasars.

from the ICM: $L_{X,\rm bol} \sim 5 \times 10^{45}$ ergs s^{-1}. Such luminosity is well above a typical cluster X-ray luminosity and may be contaminated by the X-ray emission from one or both quasars. On the other hand, the typical quasar X-ray luminosity [2–10 keV] is around 10^{44} erg s^{-1}, thus the quasars in the pair may not account for all X-ray emission. Besides, the total emission [0.5–8.0 keV] within 3 arcmin is about 10 times higher than the typical quasar emission in this band; therefore the observed X-ray flux is consistent with emission from quasars and a possible cluster around them.

Our analysis indicates that probably three out of our four quasar pairs are members of galaxy clusters. For one of the pairs we did not find strong evidence for it: QP0114-3140 could be in a poor cluster, group, or in the neighborhood of a cluster, since our fields are smaller than Abell's radius.

Taken at face value, this result shows that quasar pairs are indeed good tracers of the large scale structure at high z. However, with only four quasar pairs in our sample we are not able to say at what level targeting a quasar pair increases the probability of finding a rich galaxy cluster as compared to targeting a single quasar. A study of larger and homogeneous samples would be necessary to clarify this point.

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