TRIPLETS OF QUASARS AT HIGH REDSHIFT: ENVIRONMENTAL ANALYSIS

Georgina Coldwell, Ilona Söchting, M. V. Alonso, M.G. Smith & D.G. Lambas

IATE, Instituto de Astronomía Teórica y Experimental, (CONICET, OAC), Córdoba, Argentina
Departamento de Física, Universidad de La Serena, La Serena, Chile
University of Oxford, Astrophysics, Denys Wilkinson Building, Keble Road, Oxford OX1 3RH
Cerro Tololo Inter-American Observatory (CTIO), La Serena, Chile

Abstract

In this work we present preliminary results of our analysis of Optical (COSMOS) and IR (ISPI) data on the galaxy environment of 3 triplets of quasars at z ∼ 1.5. The results are consistent with those found at low redshift. The quasars at z > 1 are not in the center of galaxy overdensities and they appear to follow the large-scale structure. Moreover, the neighbourhoods of the triplets on smaller scales seem to have bluer galaxies.

Introduction

Quasar and AGN environments at low redshifts have been well studied in recent years. Several works have shown that galaxies hosting a black hole are located, on average, in density regions similar to those around normal galaxies (Coldwell & Lambas 2006). However, on small scales ($r_p \leq 1\ h^{-1}$ Mpc, $\Delta V = 500$ km s^{-1}) the quasar environment is overpopulated by blue disk galaxies having a strong star-formation rate with respect to typical galaxy neighbourhoods (Coldwell & Lambas 2003, 2006). These results are in agreement with those of Söchting et al. (2002, 2004) in the sense that low-redshift quasars follow the large-scale structure traced by galaxy clusters but they are not located near the center of clusters. These quasars are mainly found in the periphery of such structures or between two, possibly merging, clusters.

Following these results, groupings of quasars can be expected to trace systems in formation and regions of enhanced star-formation activity. Triplets of quasars are very rare objects and they are probed to be "lighthouses" of galaxy clusters at z < 0.2 (Söchting et al 2008). In this work we show some preliminary results of the study of the environment of 1.3 < z < 1.7 triplet of quasars.

The cosmological parameters adopted throughout this work are: $\Omega_m = 0.3$, $\Omega_\lambda = 0.7$ and $H_0 = 100h$ km s^{-1} Mpc^{-1} with $h=0.7$.

Large-scale structures with COSMOS

Triplet 5 (TR5) is within the COSMOS field (COSMOS is a 2-deg^2 deep galaxy survey with accurate photometric redshifts measured with 30 filters, Ilbert et al. 2009). This allows us to explore the large-scale structures around this triplet.

In addition, a galaxy-cluster catalogue was obtained, from COSMOS, by Söchting et al. (2009) by using the Voronoi-Tesellation algorithm. We selected galaxy clusters with more than 7 members in the redshift slice 1.472 < z < 1.552, in the whole COSMOS area, to analyse the spatial distribution of galaxy clusters and groups with respect to TR5. In Fig. 1 (left pannel) it can be appreciated, from the distribution of galaxy clusters (red squares), that there are three galaxy clusters within projected distances of approximately 5 Mpc < r_p < 10 Mpc. One of them, is the highest-density galaxy cluster within the given redshift range. Fig. 1 (right top pannel) shows the density map for the galaxy cluster closest to the triplet, which has 17 galaxy members. Also, the overall redshift distribution of the galaxy cluster catalogue is presented (Fig. 1, right bottom pannel). This last shows the peak of the distribution around the mean redshift of the triplet indicating the existence of an overdensity.

Furthermore, a sample of 7 quasars from the LQAC catalogue is also shown in Fig. 1 in the given redshift slice for the COSMOS field. The LQAC (Souchay et al. 2009) is a new catalogue which includes 12 of the largest quasar catalogues (from radio to opical surveys) such as: SDSS, 2Qz, Vèron-Cetty & Vèron, First, etc. We observe that the majority of the quasars are in the field, following the large-scale structures traced by the galaxy clusters; however they avoid the center of the clusters. These results indicate that the environment of quasars at high redshift appears to be similar to that at low redshift.

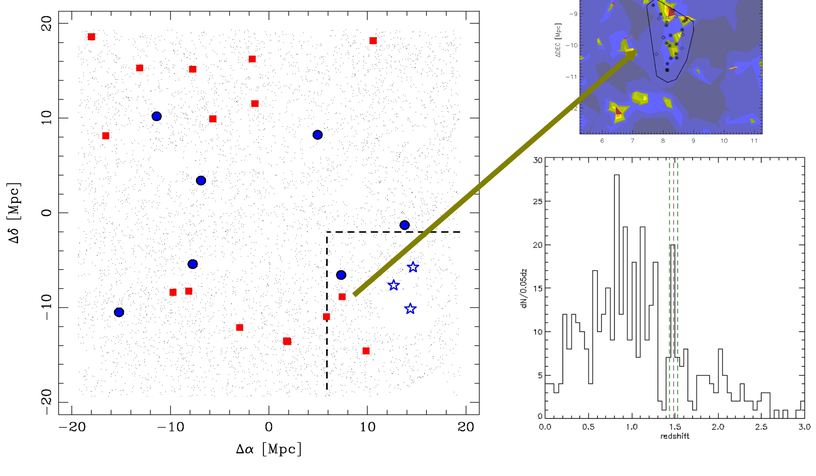

Fig 1: Left: Spatial distribution of galaxy clusters (red squares), LQAC quasars (blue circles), and the triplet quasars (blue stars) in the COSMOS area for 1.472 < z < 1.552. The black dots correspond to the whole COSMOS galaxy sample at the given redshift slice. The black dashed line indicate the region of overlap with the Mosaic observations.

Right (Top): Density map of the galaxy cluster closest to TR5. The filled diamonds correspond to the cluster galaxy members and the open diamonds to the all "possible" members.

Right (Bottom): Redshift distribution of the overall cluster catalogue (black solid line). The dashed line corresponds to the redshift range spanned by the closest galaxy cluster to TR5.

Data

The sample of triplets of quasars was defined from the SDSS-DR4 (Schneider et al. 2003) and Veròn-Cetty & Vèron (2003) quasar and AGN catalogues. We used the friend-of-friend, three-dimensional percolation algorithm (Huchra & Geller 1982) with percolation longitudes of 2 h^{-1} Mpc and 2000 km s^{-1} (approx. twice the typical radius and velocity dispersion of rich galaxy clusters).

The total sample consists of 12 triplets of quasars: 3 with z < 0.2 and 9 within the range 0.9 < z < 2.5. The subsample of triplets of quasars with z < 0.2, is discussed in detail by Söchting et al. (2008). For some of our triplets at higher redshifts, we performed multicolor photometry of their neighbour galaxies with the CTIO 4m telescope using two instruments: MOSAIC II for the optical and ISPI for the near IR. Table 1 shows the observed triplets used in this analysis, including the triplet ID, mean coordinates and redshift, and the total exposure time observed for each filter.

Triplet	α (J2000)	δ (J2000)	redshift	R	Z'	J	Ks
Triplet 5	10:02:30	01:55:12	1.512	1.34hs	0.67hs	___	3.34hs
Triplet 6	12:09:19	00:30:41	1.319	1.84hs	0.67hs	8.1hs	3.34hs
Triplet 7	23:54:17	-28:47:19	1.674	____	____	6.5hs	2.92hs

The galaxy catalogues obtained from the observations have limiting magnitudes R=24.5, z'=22.5, J=20.5 and Ks=19.0 (in the Vega System). For details of the observations, data reduction and galaxy identification criteria, see Alonso et al. (2008).

Local Environment

At low redshift, the results show that galaxies in the local environment of quasars are bluer, even, than typical galaxies (Coldwell & Lambas 2006). A colour analysis of galaxies in the field of the triplets of quasars gives us some understanding of the population properties around the triplets at high redshift.

By using the galaxy catalogues obtained from our multicolour photometry, we show in Fig. 2 (top panels) the IR colour-magnitude diagram for the galaxies in the fields of TR6 and TR7. The dashed lines indicate the predicted colours for elliptical gallaxies at the triplet redshifts and allow us to divide the blue from the red galaxy population in J-Ks=2. As a reference, a sample of spectroscopic members of galaxy clusters at z ∼ 1.4 from Stanford et al. (2005) and Hilton et al. (2009) are plotted in the diagram showing the red sequence for J-Ks ∼ 2. The spatial distribution of the galaxies around the triplet (Bottom panels) show some grouping of red galaxies near the triplet while there is a lack of red galaxies very close to the quasars. In Fig. 3 a marginal excess of blue galaxies is observed at r_p <250 Kpc from the quasars with respect to the J-Ks distribution of all galaxies.

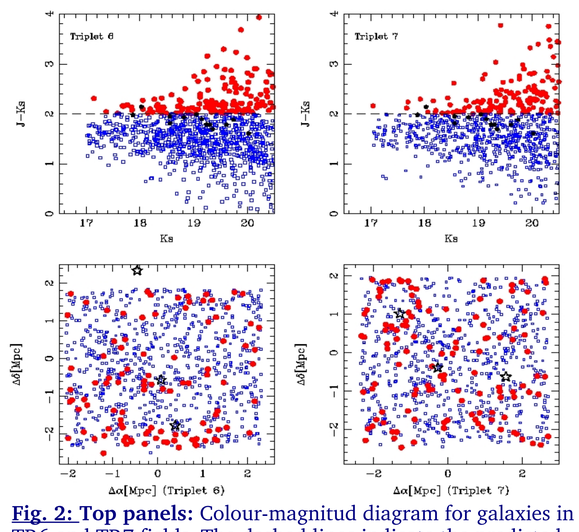

Fig. 2: Top panels: Colour-magnitud diagram for galaxies in the TR6 and TR7 fields. The dashed lines indicate the predicted colours of elliptical galaxies at the triplet redshift and the black circles are members of high redshift galaxy clusters
Bottom panels: Spatial distribution of galaxies. Red filled circles represent to the red galaxies (J-Ks > 2), the blue open squares to the blue galaxies (J-Ks < 2) and the black stars to the quasar triplet members, respectively.

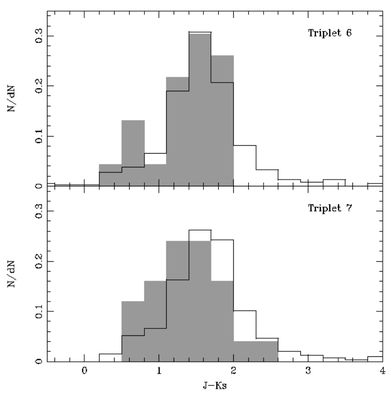

Fig. 3: J-Ks distribution for all galaxies in the triplet fields (black solid lines) and for galaxies within r_p < 250 Kpc of each triplet member (shadow histograms)

Summary

This preliminary analysis shows that triplets of quasars at high redshift inhabit environments similar to that found at z < 0.2. From COSMOS data a rich galaxy cluster was detected at ∼ 5 Mpc from TR5. Furthermore, the quasars in the redshift slice appear to follow the large-scale structures but are not in the center of the clusters.

The observational results for TR6 and TR7 show regions where a grouping of red galaxies could be studied in more detail in order to detect cluster candidates at high redshift. The spatial and colour distributions of galaxies suggest that the triplets of quasars at higher redshift appear to prefer to have blue galaxies in their local environment. All these results are biased by projection effects and spectroscopic observations are needed in order to make stronger conclusions.

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