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LYα EMITTERS AS TRACERS OF PROTO-CLUSTER OF GALAXIES AT $z \sim 2 - 4$

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We propose to use the OSIRIS tunable filters to perform for the first time a systematic study of the environment of Radio Loud and Radio Quiet quasars in windows around a large range of redshifts (z∼ 2 to 4). The aim of our study is (1) to search for the presence of forming clusters of galaxies around quasars, through Lyα emitters, which in turn will allow us to test the current cosmological models, and (2) to investigate any possible relation between the environment of radio loud and radio quiet objects with nuclear activity. These observations will increase our understanding of the early Universe, shedding new light in subjects like primordial starbursts, galaxy evolution, cluster evolution, and AGN formation and fueling, among others. The great capability and flexible nature of the tunable filters make them the most efficient tool for this kind of study.

Constraining the early universe: A search for proto-clusters of galaxies trough Lyα emitting objects

Proto-clusters of galaxies provide the best diagnostic on the formation and evolution of structures in the early Universe. A substantial number of galaxies can be detected at the same redshift, and features in the spectral energy distribution can be studied systematically by shifting the tunable filters to the appropriate wavelengths, proto-clusters are also ideal places for studying galaxy evolution. By comparing proto-cluster galaxies with field galaxies, changes in galaxy properties as a function of the environment can be studied.

Including a large range of redshifts permits to investigate the evolution of all these processes in time, which in turn can constrain the current cosmological models. Several scenarios have been proposed to explain the formation of cosmic structures in the Universe. Among them, the most accepted one is based on inflationary models of Cold Dark Matter (CDM). This model has achieved great success in explaining current observations of our Universe at large and middle scale, including the anisotropy of the background radiation (e.g. Frenk 2002). According to this scenario, galaxies form in the gravitational fields of dark matter halos, which in turn form an ensemble through a hierarchic process, from the smaller structures to the larger ones. Although this model has satisfactory explained the population of galaxies at the present epoch (e.g. Firmani & Avila-Rees 2000), it still needs to explain and predict the structures at the high redshift Universe (z > 2). However, there is still little observational knowledge of the nature and distribution of proto-galaxies and proto-clusters in the early Universe, mainly because the detection of such systems using conventional optical and X-rays techniques is extremely difficult.

According to this scenario, young spheroids are identified with primordial galaxies. Gravitational collapse of the proto-galaxy clouds formed the full stellar content of the spheroids. The duration of the collapse is similar to the free-fall time which, for a mass like the Milky Way, is about one hundred million years. This implies that the star-formation rate was very high (1000 $M_{\odot} yr^{-1}$). During the first starburst, galaxies emit intense UV radiation, and particularly they emit a very strong Ly$\alpha\lambda$1216Å line. The age of the stellar populations of the local spheroids imply that the first starbursts were produced between $2 < z < 7$. The UV spectrum of galaxies at such redshifts is observable in the optical and near-infrared wavelengths.

Emission lines can be much more easily detected than continuum stellar light because the information is concentrated over a narrow wavelength range thereby increasing the contrast relative to the background sky continuum. Therefore, these primordial spheroids, or Lyα emitting galaxies (LEGs) are one of the most efficient ways to trace the distribution of objects in the early Universe.

It is well known that quasars are objects associated with high-redshift galaxies. Therefore, their surroundings represent the best regions to look for the presence of proto-clusters of galaxies, through the LEGs. In fact, this technique has been used to detect LEGs and proto-clusters of galaxies at red-

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shifts up to 4.1 (Fynbo et al. 2003). However, due to the limitations of traditional instruments, only the environments of a few quasars have been observed, and much work is still ahead.

The environment of radio loud and radio quiet quasars

A significant progress in the detection and characterization of the host galaxies associated to QSOs, at low redshift and in some objects at z < 2-2.5 has been achieved during the last decade (see Hutchings 2003 and references therein). On the contrary, studies at high-z are scarce and more difficult due to the enormous light coming from the QSO nuclei. Although, in some cases it has been possible to found that QSOs host galaxies are large, luminous, and sites of star formation and galaxy merging phenomena, that are possibly connected with the ignition of the central engine.

On the other hand, there are also several studies of QSOs that deal with the environment and try to establish the number of galaxy companions associated with these objects. In many cases, it has been noted an apparent connection between galaxy interactions and QSO activity. However, at hizh z, tidal tails are fainter and harder to see. The results of this kind of studies may be image quality-dependent and certainly the use of a 10-meter class telescope as the GTC will provide the quality and resolution needed to improve them. The reality is that environmental studies of QSOs at z > 2 have provide only limited results, and we can found in the literature contradictory results (see for instance de Diego et al. 2003). In a recent paper by Söchting et al. 2004, the authors found that 80% of the RQQ lives in rich clusters, and Fukugita et al. 2004 concluded that the environment of a pair of QSOs at z = 4.25 is indistinguishable to that of normal galaxies.

So, it is evident that there is a lack of homogeneous results as a consequence of a lack of systematical studies.

The redshift range chosen for this work is the more interesting to study the environment because beyond this epoch, we may be closer to the onset of the activity probably driven by interactions. Therefore, any environmental evolution study has to be done at z > 2. Our proposed program represents the first systematic study of quasar environment, and will shed light in important issues of quasar nature like.

A systematic study of LEGs: GTC+OSIRIS TF

In an effort to come up with a better picture about QSO formation and evolution, we are proposing an observational program that studies systematically for the first time the formation of proto-clusters of galaxies associated to the environments of RLQ and RQQ quasars.

In particular, we propose a systematic search for LEGs in the surroundings of a representative sample of 10 RLQ and 10 RLQ QSOs which encompasses 3 different windows in redshift (z = 2, z = 3 and z = 4).

Due to the high redshift, and the expected faintness of the LEGs, it will be necessary to perform the observations with a large size telescope like the GTC. The OSIRIS Tunable Filters (TF) are the best tool for the present study, as they allow to detect LEGs at nearly the redshift of the QSOs, setting the TF at the relevant wavelength.

This will be a great improvement with respect to previous works, that require first imaging and then low resolution spectroscopy to confirm the LEGs associated to QSOs. Furthermore, previous studies require broad and narrow band images, to measure the continuum level and the flux of the Lyα line, which implies large hours of observation.

The charge shuffling capability of the TF will permit a direct background subtraction, and thus a much more efficient detection of the emission line galaxies. This will guarantee the feasibility of our study.

We propose to image a sample of QSOs with TF (width ∼18-20Å) centered on redshifted Lyα. We will take five exposures to include a circle of 6 Mpc around the QSO redshift. This region is the most relevant to measure clustering around galaxies (Krongold et al. 2002). The targets will be compact-spheroidal galaxies of sizes ∼2 arc sec.

From the objects detected in the TF images, we will construct the distribution function for the galaxies in the cluster. This procedure will also reduce to a minimum the number of spurious detections (i.e. objects not associated to the quasar).

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