Identification of High Redshift Galaxies with Very Large Gaseous Halos

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Over the last several years, considerable efforts have been aimed at understanding the properties of objects at high redshift. The main studies concern optically selected samples of field galaxies (Koo 1986, Koo and Kron 1988, Broadhurst et al. 1988) and rich clusters of galaxies (Gunn and Dressler 1987, Gunn 1988), and radio selected objects first from the 3C sample of bright sources (Spinrad et al. 1985, Djorgovski 1988) and more recently from samples of fainter radio sources (Chambers et al. 1987 and 1988, Koo 1988, Lilly 1989). Our approach is to select high redshift objects with metal-rich, very extended gaseous envelopes giving rise to absorption line systems in quasar spectra. These objects may exhibit properties closer to those of normal galaxies than to those of rather extreme objects associated with powerful radio sources.

Galaxies at z < 1 with Large Gaseous Halos

The early suggestion of Wagoner (1967) and Bahcall and Spitzer (1969) that the absorption-line systems may arise in intervening galaxies was strengthened by statistical analysis showing that the distribution of the number of CIV absorption redshifts per line of sight is Poissonian (Young et al. 1982), and was confirmed by identification of the absorbing galaxies (Bergeron 1986, Cristiani 1987, Bergeron 1988 and references therein). Present searches for absorbing galaxies have only been attempted for $z < 1$ systems. We had estimated that, at these redshifts, the galaxies responsible for Mg II absorption systems should be bright enough ($m_v < 23$) and well separated on the sky from the quasar image ($\theta \sim 0.7$ arcsec at $z = 0.5$) to be easily detectable. These estimates were based on the observed density of Mg II systems per unit redshift assuming a given galaxy luminosity function and a radial-luminosity scaling law (Bergeron 1988).

At present there are 15 identifications of Mg II absorbing galaxies in the redshift range 0.15 to 0.8, most of them done with the ESO Faint Object Camera Spectrograph at the 3.6-m telescope. The galaxies giving rise to $z < 1$, Mg II systems have the following properties:

– they have large gaseous envelopes as implied by the average angular separation of 6.8 arcsec or 2.3 R_H (R_H is the Holmberg radius and equals 22 kpc for $H_0 = 50$ km s^{-1} Mpc^{-1}) for $\bar{z} = 0.44$,
– they are fairly bright, $-22.2 < M_r < -20.2$,
– they all show sign of present or recent stellar formation activity, having a very blue continuum (down to $\lambda_r \sim 2200$ Å) and usually strong [O II] emission with rest equivalent width larger than 15 Å,
– they are mostly field galaxies.

The intervening galaxies are always the resolved object closest on the sky to the quasar. This is not due to an observational bias since galaxies as faint as the LMC could have been detected as an absorber up to $z \sim 0.5$. A deep r image of the field around the quasar Q 2128-123 (Bergeron and Turnshek, in preparation) taken at the Las Campanas 100-inch telescope in condition of good seeing (FWHM = 0.95 arcsec) is shown in Figure 1; as could be seen from the fainter detected objects within the field, there is no absorbing galaxy candidate closer on the sky to the quasar than the galaxy 8.6 arcsec north-east of the quasar identified by Bergeron (1986) as the object giving rise to the $z = 0.4299$ Mg II absorption system.

A general trend found both for field (Koo and Kron 1988, Broadhurst et al. 1988, Dressler 1988) and cluster (Gunn 1988) galaxies is the increasing fraction with redshift of galaxies showing sign of enhanced stellar activity (blue continuum and [O II] emission). For field galaxies the fraction of "active objects" is about 40 % at $z \sim 0.5$ and for galaxies in cluster centres it reaches 20 % at $z \sim 0.9$. Comparison with the properties of Mg II absorbing galaxies suggests that

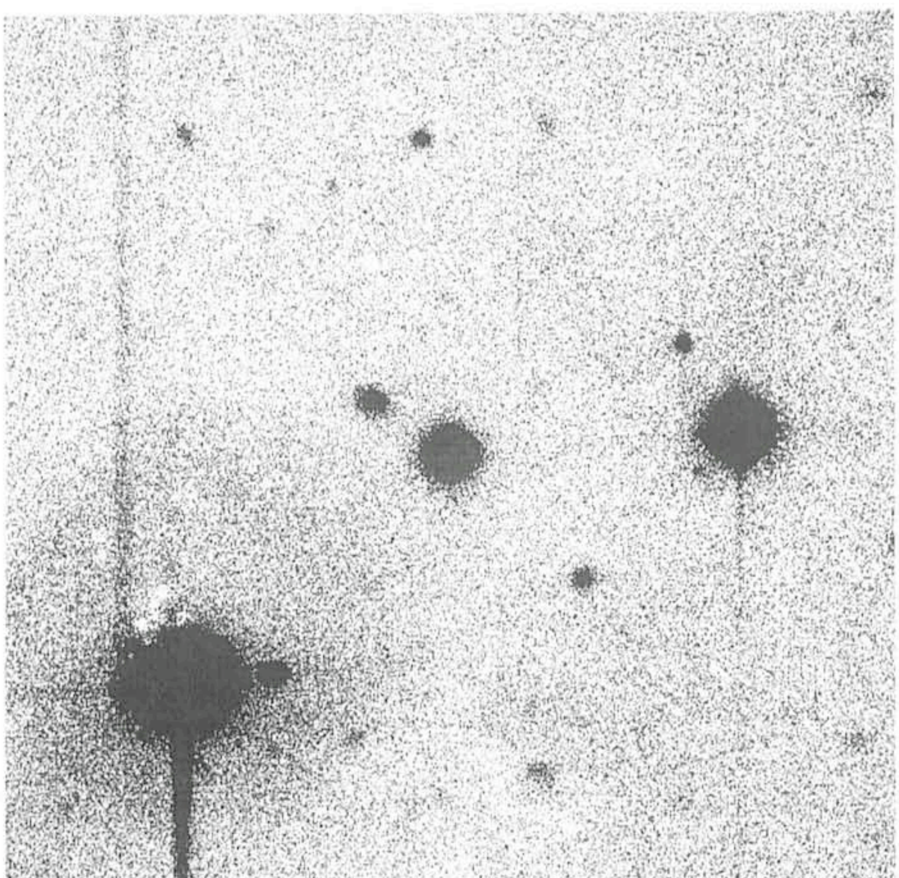

Figure 1: *r image of an 80 × 80 arcsec field centred on the quasar Q 2128-123. North-east is at the top left corner. The Mg II absorbing galaxy is the resolved object 8.6 arcsec north-east of the quasar. The spatial resolution is FWHM = 0.95 arcsec.*

at z ~ 0.5 about 1/3 of field galaxies have very large gaseous envelopes. Such a large fraction is also implied by the very similar values found for the gaseous halo dimensions from direct observations and from statistical analysis of Mg II absorption line samples, since for the latter we had assumed that half of the galaxies are gas-rich and with large halos.

Galaxy Surveys at z > 1

Almost all the galaxies that have been identified so far at z > 1 are associated with powerful radio sources (Spinrad et al. 1985, Djorgovski 1988, Lilly 1989). The extreme cases discovered are at z = 3.4 with a dominant older stellar population (Lilly 1988) and at z = 3.8 for steep radio surces (Chambers et al. 1989). These high redshift galaxies are intrinsically bright with M_V absolute magnitudes in the range −22.0 to −24.5. They have a very high rate of star formation and an extremely disturbed morphology. Therefore, they constitute a special class of galaxies which cannot be directly compared to the z < 1 galaxy samples to derive properties such as the galaxy luminosity evolution. The aim of another ESO Key Programme "A Study of the Most Distant Radio Galaxies" by G. Miley and collaborators is to extend the identification of radio sources to larger and fainter samples of ultra-steep spectrum radio sources. There is also an on-going identification survey of weak radio sources which has revealed a few galaxies at z ~ 1.2–1.5 all with emission lines of [C II, C III] and [Ne IV] (Koo 1989). The cluster survey done by Gunn and collaborators also contains potential candidates at z > 1 with on-going spectroscopic identification but no result has been communicated so far.

Searching for the intervening galaxies responsible for z > 1 absorption systems will provide an independent sample of high redshift galaxies, whose properties can be directly compared to those of z < 1 absorbing galaxies. Our proposed survey will allow to determine the evolution of galaxies with gaseous halos, more specifically:

- to find the evolution of the halo size with redshift,
- to confirm that the correlation between strong stellar formation activity and the presence of gaseous halos holds at z > 1 and find if this stellar activity increases with the size and mass of the gaseous envelopes,
- to derive the luminosity function of galaxies with large gaseous halos and its evolution with redshift.

Detecting z > 1 intervening galaxies in a Vri imaging survey should not be an impossible task, since the galaxies are expected to be neither extremely faint, nor very close on the sky to the quasar. Extrapolating our results obtained at z ~ 0.5–0.8, we expect, in the assumption of no luminosity evolution, that intervening galaxies at z ~ 1.6 will have r magnitudes of about 24. Further, at z ~ 1.6, the average sizes of the absorbers derived from statistical analysis of CIV (Young et al. 1982, Sargent et al. 1988) and Mg II (Lanzetta et al. 1987, Sargent et al. 1989) absorption line samples are larger than those at z = 0.5 (Mg II) by factors of 1.9 and 1.4 respectively. Therefore, the angular distance between the quasar and the absorbing galaxies should be on an average the same for Mg II systems at z = 0.5 and 1.6, i.e. around 7 arcsec.

At z > 1 the redshift of the intervening galaxies can be identified from the [Ne IV] λ 2424, C II] λ 2326, C III] λ 1909 emission lines and also from He II λ 1640 and CIV λ 1549 at z > 1.5. The Mg II λ 2799 doublet is also observable but it may be in absorption, as for two emission line galaxies of our z < 1 sample, thus more difficult to detect.

The Sample

From our lower redshift survey, we have found that low excitation (Mg II) absorbers are associated with bright galaxies of high central surface brightness. Since we do not know whether this also applies to high excitation (CIV) absorbers, we first primarily select low excitation Mg II and/or Fe II absorption systems. The latter also usually show CIV absorption at the Mg II or Fe II redshift. These low excitation systems constitute about 1/5 to 1/4 of the metal-rich absorbers at z = 1.5 (Lanzetta et al. 1987, Sargent et al. 1988 and 1989, Caulet 1989).

Selecting specific quasar fields is of crucial importance if less than one absorber is expected on an average for a given redshift range. This is the case for Mg II absorption systems at z < 2. From high redshift Mg II absorption surveys, one finds that the average number of Mg II absorbers expected per (quasar) line of sight in the redshift range 1.0–1.5 is 0.36. To increase further our chances of detection we will give higher priority to multiple absorption systems spanning more than 500 km s^{-1}, which suggests the presence of a cluster along the line of sight, and to quasars with several Mg II absorption systems at very different redshifts from unrelated intervening galaxies.

The proposed sample is based on data published by Young et al. (1982) Bergeron and Boissé (1984) Boissé and Bergeron (1985) Foltz et al. (1986) Lanzetta et al. (1987) Sargent et al. (1988 and 1989) and Bergeron (unpublished), and it will be updated when new absorption line surveys become available. It includes 53 quasars all with Mg II and/or Fe II absorption at z < 2, out of which there are 8 quasars with low excitation multiple systems, 11 quasars with at least 2 low-excitation systems in the redshift range 1.0–1.5 and 2 quasars with a low-excitation system at the quasar emission redshift.

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