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GIANT LOW SURFACE BRIGHTNESS HALOS IN DISTANT RADIO GALAXIES

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RESUMEN

Presentamos los resultados del estudio cinemático del gas ionizado extenso en la radio galaxia USS0828+193 (z=2.57). Los espectros obtenidos con el telescopio Keck II revelan la existencia de un halo ionizado gigante (∼80 kpc) de bajo brillo superficial y cinemática aparentemente dominada por movimientos gravitatorios. El halo está enriquecido con elementos pesados e ionizado por el continuo emitido por el núcleo activo. Hemos encontrado halos similares en la mayoría de las 11 radio galaxias de la muestra. Se discuten brevemente el origen y la naturaleza del halo.

ABSTRACT

We present results on the spectroscopic study of the extended ionized gas in the distant radio galaxy USS0828+193 at z =2.57. The kinematic analysis of the Keck II spectra reveals the existence of a giant (∼80 kpc) low surface brightness halo of quiescent kinematics consistent with gravitational motions. The halo is enriched with heavy elements and is ionized by the continuum from the active nucleus. We find similar halos in most objects in our sample of 11 high redshift (z ∼2.5) radio galaxies. They might be a common ingredient of this type of objects. We discuss briefly the nature and the origin of these halos.

Key Words: **COSMOLOGY: EARLY UNIVERSE — GALAXIES: ACTIVE — GALAXIES: FORMATION — GALAXIES: INDIVIDUAL: USS 0828+193**

1. INTRODUCTION

Extended Lyα regions are a common feature of high redshift radio galaxies (z >2, HzRG hereafter) and quasars. Most morphological and kinematic studies are based on the high surface brightness regions. These are clumpy, irregular, often aligned with the radio axis (e.g [1]) and show extreme kinematics (e.g. [2]). The observed properties are likely to be strongly distorted by the interactions between the radio jet and the ambient gas [3].

Our work on high S/N Keck spectroscopy of a sample of 11 HzRG has revealed that in addition to these regions, low surface brightness Lyα halos (LSBHs hereafter) are often detected, which sometimes extend beyond the radio structures and which present quiescent kinematics (see some examples in Fig. 1; see also [4]). Such LSBHs are important since they show the gas properties unaffected by kinematic perturbations and they are a potential source of information about the formation process of the galaxy. We present in this paper the results on the kinematic study of the gas in the radio galaxy USS0828+193 (Fig. 1. left) A more detailed discussion can be found in [5] Villar-Martín et al. 2001.

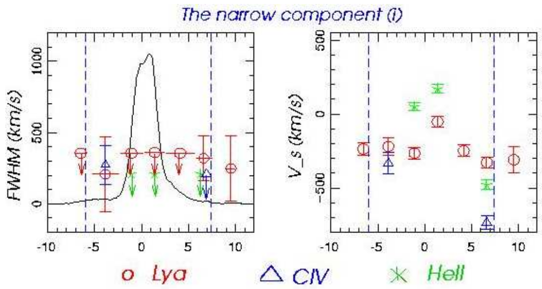

Fig. 2. Kinematic properties of the LSBH. Left: FWHM; right: the velocity shift relative to the HeII emission at the continuum spatial centroid. The dashed vertical lines mark the outer edge of the radio lobes. Arrows indicate upper limits. Notice the uniform kinematic properties across the whole extension of the halo and the similarity with low redshift radio galaxies kinematic properties.

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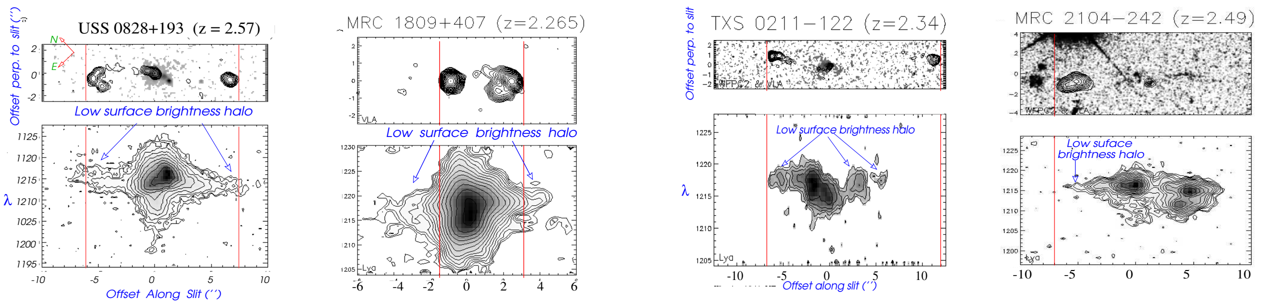

Fig. 1. The top panels show the overlay between the HST images (when available) and the radio VLA contours of four high redsfhit radio galaxies. The 2-dimensional spectrum of the Lyα emission line (bottom panels) is spatially aligned with the radio/optical images. The spatial zero is the position of the continuum centroid measured on the Keck spectra. The vertical lines indicate the outer edges of the radio lobe. Notice the extended low surface brightness halos with more quiescent kinematics than the high surface brightness regions.

2. OBSERVATIONS

The spectra were obtained with the Low Resolution Imaging Spectrometer with its polarimeter at the Keck II 10 m telescope in December 1997 ([10]). We used a 300 line mm^{-1} grating and 1 arcsec wide slit which provide a dispersion of 2.4 Å pixel^{-1} and an effective resolution of FWHM$\sim$10.5 Å . The exposure time was 5 hours and the seeing was $\sim$1.0 arcsec. The slit was oriented along the radio axis, with PA 44°.

3. DATA ANALYSIS AND DISCUSSION

The kinematic analysis of the extended gas in USS0828+123 (see [5] for a detailed description) reveals the presence of highly perturbed gas as typically found in HzRG. In addition, a narrow kinematic component (FWHM<400 km s^{-1}) associated with the LSBH is detected across the whole extension of the object and beyond the radio structures ($\sim$80 kpc). Its kinematic properties (Fig. 2) are consistent with being gravitational in nature and they are similar to those of low redshift radio galaxies. The LSBH also emits CIV and HeII lines. It is the first time that lines other than Lyα are detected from the LSBH in a HzRG. The LSBH is therefore ionized (probably by the continuum from the active nucleus) and it has been enriched with heavy elements. We propose that the LSBH surrounds the central object completely. The gas inside the ionization cones is seen in emission. The gas detected in absorption by [3] could be part of the same halo, with this gas located outside the ionization cones.

There are gaseous structures around other types of galaxies which might have the same origin as the LSBHs associated with distant radio galaxies.

* Galactic envelopes ($R \sim$100 h^{-1} kpc) found in studies of quasar absorption line systems (e.g. [6]).

* Giant Lyα halos associated with Ly break galaxies ([7])

* Large scale ($\geq$several tens of kpcs) HI disc like structures found in low redshift radio ([8]) and elliptical ([9]) galaxies.

Therefore, giant gaseous halos are found to be often associated with galaxies in general: active and non-active, of different morphological types and luminosities and at different epochs. The origin and nature of such halos is not clear (deposition by galactic winds? cooling flows? galactic satellites? other?). An interesting possibility is that these halos have a similar origin as the LSBHs found in HzRG related to the formation process of the galaxies.

4. SUMMARY AND CONCLUSIONS

We have found a very extended ($\sim$80 kpc) reservoir of ionized gas in the distant radio galaxy USS0828+193, whose kinematics is apparently gravitational. The gas is ionized by the continuum from the active nucleus and enriched with heavy elements. We have found similar halos in other distant radio galaxies. The origin and nature of the halos have been briefly discussed here.

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A MULTI-WAVELENGTH STUDY OF THE FORMING CLUSTER AROUND THE Z=2.16 RADIO GALAXY MRC 1138-262

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We present multi-wavelength observations of a forming cluster around the z=2.16 radio galaxy MRC 1138-262. We study the populations of Lyα and Hα emitters, extremely red objects and X-ray sources. The field of the radio source MRC 1138-262 has been observed at several wavelengths, including deep imaging through narrow band filters corresponding to Lyα and Hα at z$\sim$2.16 (with FORS and ISAAC respectively), several optical and near-IR broad bands (B, R, I, J, H and K), and finally radio and X-ray emission.

We had initially selected about 50 candidate Lyα emitters from the NB observations and we spectroscopically confirmed 15 of them (Pentericci et al. 2000), resulting in an over-density of galaxies which we interpreted as a forming cluster around the central radio source. Subsequently about 60 Hα emitters were selected and 8 of them have been confirmed to be part of the protocluster (Kurk et al. 2002b). Interestingly, the populations of Lyα and Hα emitters being have very different properties: first is their spatial distribution, with the Hα emitters much more concentrated towards the central part of the field, around the radio galaxy (see Fig. 1). Second, the Lyα/Hα ratios of the sources are such that the Hα emitters must be quite dusty objects, while the Lyα emitters are almost dust free, as expected (otherwise the Lyα emission would be heavily depressed). This can only be partially explained by the selection criteria. Furthermore, from the K-band flux which samples the optical rest-frame emission, we find that the Hα emitters are a few times more massive than the Lyα emitters, while the range of star formation rates derived from the emission line flux (mostly between 1 and 60 $M_\odot\ yr^{-1}$), is similar for all emitters All these properties seem to indicate that the emitters are two different populations and not just the opposite tails of a single population with a broad range of properties. One possibility is that the Hα galaxies are on average older that the Lyα emitters, therefore they are more massive and their distribution is more relaxed (Kurk et al. 2002a).

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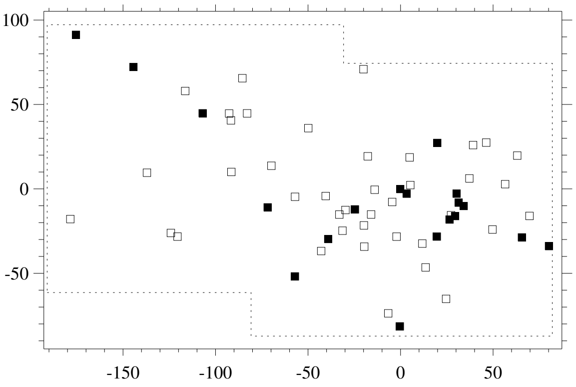

Fig. 1. The positions of the 62 (18) Hα candidate emitters with $EW_0 > 25$ (50) Åindicated by open (filled) squares. The radio galaxy is at the origin. The dotted box shows the 2 ISAAC fields.

In the field we have also found many sources with very red colors (I-K> 5 or even I-K>6), the so called EROs. They have colors expected for passively evolving elliptical galaxies and dusty starburst galaxies at redshift > 1.5. The density of these objects in higher than in field searches and again they tend to be more concentrated towards the center of the field, around the radio galaxy. We therefore speculate that some of these EROs might also be part of the protocluster, but further observations are needed to confirm it.

Finally, we have also observed the field with the Chandra X-ray observatory: besides the radio galaxy we detect emission from 17 other sources, down to a flux of 10^{-15} erg cm^{-2} s^{-1} (Pentericci et al. 2002), about 50% more than what is expected from Chandra deep field counts. We have optically identified all the emitters in the field. Few of these sources coincide with Lyα, Hα candidates or EROs and could actually be AGNs in the protocluster. Two of them have been spectroscopically confirmed: they are AGNs showing broad emission lines at a redshift similar to that of MRC 1138-262.

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