The Broad Line Radio Galaxy J2114+820

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Abstract

In the frame of the study of a new sample of large angular size radio galaxies selected from the NRAO VLA Sky Survey, we have made radio observations of J2114+820, a low power radio galaxy with an angular size of 6\textdegree. Its radio structure basically consists of a prominent core, a jet directed in north-west direction and two extended S-shaped lobes. We have also observed the optical counterpart of J2114+820, a bright elliptical galaxy with a strong unresolved central component. The optical spectrum shows broad emission lines. This fact, together with its low radio power and FR-I type morphology, renders J2114+820 a non-trivial object from the point of view of the current unification schemes of radio loud active galactic nuclei.

Key words: catalogs — galaxies: active — galaxies: individual (J2114+820) — galaxies: jets
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1 Introduction

It is well known that Doppler beaming causes radio samples selected on the basis of a flux density cutoff at high frequencies to be biased towards small

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orientation angles with respect to the observer’s line of sight. In order to properly test unification schemes of radio loud active galactic nuclei (AGN), it is crucial to define samples not affected by such bias in orientation. With this in mind among other motivations, we have defined a new sample of radio galaxies from the NRAO VLA Sky Survey (NVSS) (Condon et al., 1998), selecting as candidates those features apparently related as single objects, with emission over most of their extent, and fulfilling the following restrictions: 

1) declination above +60°; 
2) angular size greater than 4’; 
3) total flux density at 1.4 GHz greater than 100 mJy.

Candidates have been observed with the VLA in its B and C configurations at 1.4 and 5 GHz in order to remove possible random coincidences of nearby unrelated objects, but without overlooking any possible peculiar radio structure, and to sort out the core emission in complex structures, necessary to properly identify optical counterparts. With work almost reaching completion, the sample comprises a total of 85 objects. A detailed description of the sample will be presented elsewhere.

One of the sources in our sample is J2114+820, detected in the NVSS as a 6’ large radio source with a total flux density of 480 mJy. Due to its prominent flat spectrum core, J2114+820 also belongs to the Caltech - Jodrell Bank Flat-spectrum sample (Taylor et al., 1996) and to a sample of optically bright flat spectrum sources (Marchà et al., 1996). It has a redshift of 0.084 (Stickel et al., 1993). Its projected linear size is \( \sim 500 \) Kpc and its total power \( P(1.4 \text{ GHz}) = 6.7 \times 10^{24} \text{ W/Hz} \) (we assume \( H_0=75 \text{ km s}^{-1} \text{ Mpc}^{-1} \) and \( q_0=0.5 \)).

2 Radio Observations and Results

In the frame of the investigation of the radio galaxies in our sample, we have made VLA, MERLIN and EVN observations of J2114+820, mapping its radio structure from kiloparsec to parsec scales.

In Figure 1 we show a VLA map of J2114+820 at 1.4 GHz, resulting from the combination of B and C configuration data obtained on November 1995 and February 1996, respectively. The radio structure is dominated by a prominent and unresolved core. There is a jet extending towards the north-west, and a weaker counter-jet in opposite direction. Both, jet and counter-jet, end up in diffuse lobes of emission with S-shaped morphology. The total power and the radio structure of J2114+820 support its classification as a FR-I type radio galaxy.

The resulting map after calibrating and imaging 1.66 GHz MERLIN data obtained on June 1997 is displayed in Figure 2. Here again we observe a strong
Fig. 1. VLA map of J2114+820 at 1.4 GHz. A Gaussian beam of $12'' \times 9''.7$ in P.A. $11^\circ$ was used for convolution. The lowest contour (at $3\sigma$ of the rms of the image) is 0.369 mJy/beam. The peak of brightness is 174 mJy/beam. Contours increase in powers of $\sqrt{2}$.

Fig. 2. MERLIN map of J2114+820 at 1.66 GHz. A circular Gaussian beam of $0''.3$ was used for convolution. The lowest contour (at $3\sigma$ of the rms of the image) is 0.355 mJy/beam. The peak of brightness is 142 mJy/beam. Contours increase in powers of 1.5.
and unresolved core, with a very faint and slightly bent jet directed towards the north-west. The jet is not smooth, but dominated by two main components at distances of 5".6 and 10".5 from the core, respectively. Simultaneously with MERLIN, the EVN observed J2114+820 also at 1.66 GHz, with antennas at Effelsberg (Germany), Simeiz (Ukraine), Medicina and Noto (Italy), Onsala (Sweden), Westerbork (The Netherlands), Torun (Poland), Cambridge and Jodrell Bank (U.K.). The EVN map, in Figure 3, shows a compact structure slightly elongated in the direction of the main jet. Data can be fitted with two Gaussian components (Table 1), in a manner fully consistent with results from VLBA observations at 5 GHz (Taylor et al., 1996). Combination of EVN and MERLIN data does not add more information since the jet appears completely resolved at the intermediate angular resolution provide by the combination of both interferometers.

![Fig. 3. EVN map of J2114+820 at 1.66 GHz. A circular Gaussian beam of 10 mas was used for convolution. The lowest contour (at 3σ of the rms of the image) is 0.92 mJy/beam. The peak of brightness is 91.5 mJy/beam. Contours increase in powers of 2.](image)

**Table 1**

Gaussian fit parameters of the compact (EVN) structure of J2114+820

| Component | S   | D    | P.A. | L   | r   | Φ   |
|-----------|-----|------|------|-----|-----|-----|
|           | (mJy) | (mas) | (deg) | (mas) | (deg) |
| 1         | 80.6 | –     | –    | 4.8 | 0.1 | -14 |
| 2         | 34.9 | 5.1   | -23  | 9.3 | 0.3 | -30 |
3 Optical Observations and Results

We made observations of the optical counterpart of J2114+820 with the 2.2 m telescope at the Calar Alto observatory (Spain) on September 1997, making use of the direct imaging and spectroscopic capabilities of the Calar Alto Faint Object Spectrograph (CAFOS). The R-filter image of the field of J2114+820 after a 300 second exposure in Figure 4 shows a bright galaxy coincident with the radio core position (the seeing is \(\sim 1''\)). The brightness profile of this galaxy is consistent with that of an elliptical (\(r^{1/4}\)) harboring an unresolved central component associated with the active nucleus. There are also hints of interaction of this galaxy with one (or maybe two) dwarf galaxy in the surroundings. Atmospheric conditions prevented us from obtaining a reliable photometric calibration of our data.

![R-filter image of J2114+820 taken at the 2.2 m telescope in Calar Alto.](image)

Fig. 4. R-filter image of J2114+820 taken at the 2.2 m telescope in Calar Alto.

The spectrum of J2114+820 is displayed in Figure 5. We confirm the redshift and main features of the spectrum reported in Stickel et al. (1993). J2114+820 exhibits strong broad Balmer lines, but not only in the core region, but also at distances up to 4 Kpc from the center, indicating the existence of high velocity gas over large extensions of the galaxy.

4 Discussion

J2114+820 can be classified as a low power FR-I radio galaxy. According to current unification schemes of radio loud AGN’s (e.g. Urry & Padovani).
1995), FR-I radio sources constitute the parent population of Bl-Lac type objects, which are characterized by the absence of broad emission lines (at most, only weak broad lines have occasionally been observed in Bl-Lac type objects (e.g. Vermeulen et al., 1995)). In consequence, FR-I sources should not show such emission lines, contrary to what we observe in J2114+820. In this sense, J2114+820 hardly fits the requirements of unification schemes. Another peculiarity of this galaxy is the evidence of high velocity gas at distances as large as 4 Kpc from the core, a fact not common in elliptical galaxies which are relatively poor in gas. New observations are being analyzed in order to bring J2114+820 into a coherent scenario.

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