

VLBI OBSERVATIONS OF B2 1144+35: A PECULIAR RADIO GALAXY

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ABSTRACT.

The radio galaxy B2 1144+35 shows some peculiar characteristics being a core dominated FR I radio galaxy with an extended radio structure and showing an apparent superluminal motion on mas scale. New VLA, MERLIN and VLBI observations suggest that this radio galaxy consists of two components: an extended relic component on the plane of the sky, and a compact, more recent emission oriented near the line of sight where the apparent superluminal motion have been found.

1. Introduction

The low power radio galaxy B2 1144+35 is identified with a faint ($m_{pg} = 15.7$) Zwicky galaxy (ZW186.48) in a medium-compact cluster with a redshift of 0.0630 (Colla et al., 1975). An isocontour map taken from the PSS shows that the optical galaxy has a boxy shape which according to Binney and Petrou (1985) may occur in systems that have cannibalized low luminosity galaxies. A nearby faint companion is imbedded in its external region but optical spectroscopy is necessary to confirm a real connection between the two galaxies. In a recent optical study of bright flat radio spectrum sources, Marcha et al. (1996) classify 1144+35 as a BL Lac candidate even if its spectrum shows $H\alpha$ and [NII] emission lines. From a comparison between the measured line equivalent width and the contrast they suggest that 1144+35 could be a diluted BL Lac.

In this paper we will use a Hubble constant $H_0=50 \text{ km sec}^{-1} \text{ Mpc}^{-1}$ which corresponds (for B2 1144+35) to a factor of 1.62 pc/mas or 1.62 kpc/arcsec.

2. The large scale

The large scale radio structure of 1144+35 consists of 3 different regions (fig. 1): the core region, the East and the West extended emissions. The radio peak (core region) in the map coincides with the optical position of the galaxy identified with 1144+35 and it is the dominant feature in all the maps. The West extended emission can be divided in two regions: the northern one is an unrelated double galaxy with a central emission and two extended symmetric lobes. In the south of this radio galaxy is present one more

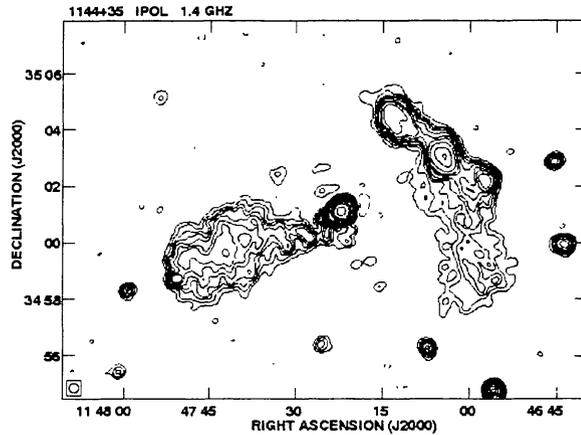


Fig. 1. VLA map at 1.4 GHz. The HPBW is $20''$ and the noise level is 0.06 mJy/beam. The peak flux is 539.4 mJy/beam and contour levels are: -0.2 0.15 0.3 0.5 0.7 1 1.5 2 3 5 7 10 30 50 100 300 mJy/beam.

extended emission which cannot be attributed to the near field galaxy because of the strong asymmetry and the lack of any evident connection. It is on the opposite side with respect to the East emission of 1144+35 and we tentatively identify this emission as the West lobe of 1144+35. The East lobe is clearly connected to the central region and it shows the typical morphology of extended lobes in low power radio galaxies. If 1144+35 is a giant double radio galaxy, it has a linear size of $\approx 13'$ corresponding to ≈ 1.3 Mpc.

The central region of 1144+35 exhibits a flat ($\alpha \approx 0.1 - 0.2$ with $S(\nu) \propto \nu^{-\alpha}$) spectrum while in the East and West lobes it is in general very steep. In particular the East lobe spectral index distribution shows that near the central structure α is ≈ 0.7 with no continuity with it; from here the spectrum steepens reaching $\alpha \approx 2 - 2.5$ in the more external regions.

3. The small scale

At 8.4 GHz the parsec scale structure is resolved in 4 main substructures: two compact components (A and B in fig. 2) separated by 2-3 mas. On the North of both components a faint extended emission is visible (A1), clearly extended in the direction of the component C, while A and B are misaligned with respect to C. The fourth component C is at a distance of ~ 20 mas and shows a symmetric extension in direction of the A1 feature.

Simultaneous multi-frequency VLBA observations show that C has an inverted spectrum (peaked around 8.4 GHz), while A and B have a steep spectrum typical of radio jets. Therefore we identify from the spectral index properties the component C as the real core of the source 1144+35 while other components are the inner part of a jet-like structure.

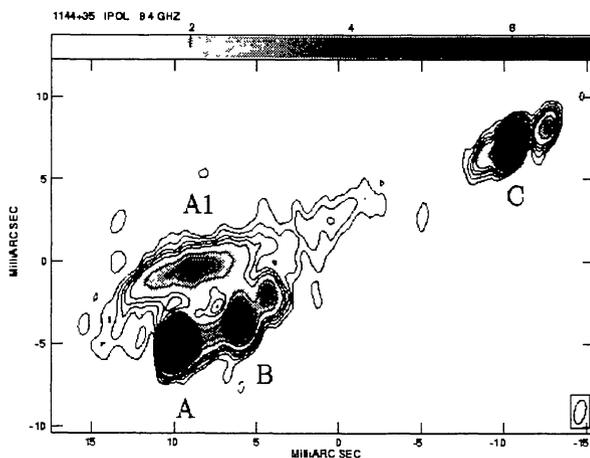


Fig. 2. VLBI map at 8.4 GHz of 1144+35. The HPBW is 1.45×0.66 mas in PA -13° . The noise level is 0.05 mJy/beam. The peak flux is 114.4 mJy/beam. Contour levels are: -0.2 0.15 0.3 0.5 0.7 1 1.5 2 3 5 7 10 30 50 100 mJy/beam.

We used multi-epoch observations to measure the apparent proper motion with respect to the core component C. In fig. 3 we give the angular distance of A and B components from C with respect to the time. Both components show a well defined motion from the core C in direction to the main jet in the large scale structure with a constant velocity. The average velocity for component A is $2.78 c$ and $2.62 c$ for component B. Assuming a proper motion of the extended structure of $\approx 2.7c h_{50}^{-1}$ we can derive that the 1144+35 jet has to move at a minimum intrinsic velocity of $\approx 0.94 c$ and that the orientation angle with respect to the line of sight (θ) has to be smaller than 40° . Moreover assuming an intrinsic symmetry for the 1144+35 structure we find a jet/counter-jet ratio larger than 500 for the A component. This implies a value for $\beta \cos(\theta) \gtrsim 0.85$: the intrinsic velocity has to be larger than $0.85 c$ and θ is smaller than 32° . Even if the proper motion and the j/cj ratio refers to two different velocities (pattern and bulk velocity) we find a general agreement and we can conclude that the 1144+35 jet has an intrinsic high velocity $\approx 0.9 c$ or higher and it is at a small angle with respect to the line of sight (30° or smaller).

In high resolution maps, the core component C shows a short two sided emission. No proper motion has been found on both sides with respect to the core C, moreover the two-sided emission is very symmetric. These results imply either that the jet velocity near C is low ($< 0.2 c$) or that $\theta \approx 90^\circ$. We consider unlikely a low jet velocity near the core because of the high speed of components A and B therefore we conclude that θ has to be $\approx 90^\circ$.

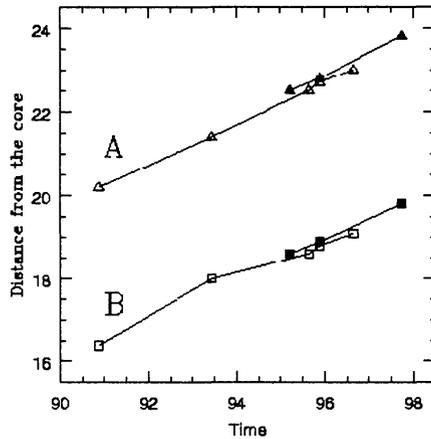


Fig. 3. Core distance versus time of the A and B components. Empty symbols refer to 5 GHz data, filled symbols to 8.4 GHz data.

4. Discussion

The different morphology and spectral index of the kpc emission with respect to the nuclear emission suggests that the kpc scale emission is a relic emission. Given its large size, it should be oriented on the plane of the sky. The arcsecond core is a young re-started emission oriented at a small angle with respect to the line of sight as deduced from the parsec scale morphology and the superluminal motion. Therefore the orientation of the radio emission is very different in the two epochs of radio activity. Such a large change in the jet direction could be related to a merger event as suggested by the optical morphology.

On the parsec scale A and B components are at a small angle with respect to the line of sight (superluminal motion) while near the core (C component) the emission is expected to be on the plane of the sky (two-sided jets).

We consider very unlikely to have in a source two very large changes in the jet emission direction, one of which very near to the core. Despite the large amount of data available for this source we have to conclude that the interpretation of its morphology and properties is still puzzling.

References

- Binney J., Petrou M., 1985, *Mon. Not. R. Astr. Soc.* **214**, 449.
 Brinkmann W., Siebert J., Reich W., Furst E., Reich P., Voges W., Trumper J., Wielebinsky R., 1995 *Astron. Astrophys. Suppl. Ser.* **109**, 147.
 Colla G., Fanti C., Fanti R., Gioia I., Lari C., Lequeux J., Lucas R., Ulrich M.H., 1975, *AAS* 20 1.
 Fanaroff, B.L., Riley, J.M.: 1974, *Mon. Not. R. Astr. Soc.* **167**, 31.
 Marcha M.J.M., Browne I.W.A., et al., 1996, *Mon. Not. R. Astr. Soc.* **281**, 449.