Proper Motion in the Giant Radio Galaxy B2 1144+35

G. GIOVANNINI[1,2], G.B. TAYLOR[3], L. FERETTI[2]

[1] Astronomy Dpt., Bologna University, [2]Radio Astronomy Inst. CNR Bologna, [3] NRAO Socorro NM

1 Large Scale

The radio galaxy 1144+35 at z = 0.0630 is a giant radio galaxy with a total projected linear size = 0.92 Mpc [a] (Schoenmakers et al. 1999 and Giovannini et al. 1999). The radio core coincides with the optical galaxy. It is the dominant feature in all images. The eastern extended emission shows an 'S' shaped morphology and a uniform low brightness. The western extended emission is elongated in the NS direction and partially confused with an unrelated double radio galaxy.

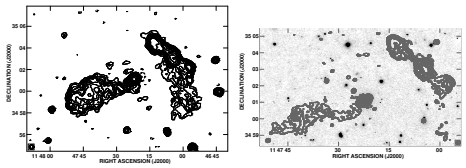

Figure 1 - **left: VLA [b] image of 1144+35 at 1.4 GHz. The HPBW is 20"; right: VLA image at 4.9 GHz of 1144+35 superimposed on an optical image from the POSS**.

[a] H_0 = 71 km sec^{-1} Mpc^{-1}; q_0 = 0.5

[b] VLBA and VLA are operated by NRAO as a facility of the NSF, operated under cooperative agreement by Assoc. Universities, Inc.

2 The milliarcsecond scale

The arcsecond core of 1144+35 is the dominant feature of the radio emission and has long been known to be variable.
The core flux density shows a strong increase since 1974 to 1980 and a smoother flux density increase up to 1990-92. Starting from this epoch we see a fast core flux density decrease with a delay in the decrease at lower frequencies, possibly due to opacity effects (see Fig. 3).
We started to study the milliarcsecond core with VLBI since November 1990 (flux density decreasing phase!)
The mas scale structure is resolved into a few substructures (see Fig. 2):

- Component C - the core source, with a flat radio spectrum (from multi frequency VLBA observations at the same epoch).
- The main jet in SE direction. Many substructures are visible: A, B, and B1 on the bottom side and a more diffuse component (A1) on the top. Near the core a short jet (D) is visible at the same position angle. A large gap is present in between B1 and D. The main jet (A, B, B1, and A1) is moving with an apparent superluminal velocity (β_a = 1.9, see Fig. 3).
- A short counter-jet (E) is present on the opposite side of the main jet. Comparing four VLBA images at different epochs, we measured a counter-jet proper motion with β_a = 0.27 ± 0.05
- The extended complex structure A + B + B1 + A1 is a clear evidence of a limb brightened jet.

References

Giovannini et al. 1999 ApJ 522, 101
Mirabel & Rodriguez 1991 ARAA 37, 409
Schoenmakers et al. 1999 AA 341, 44

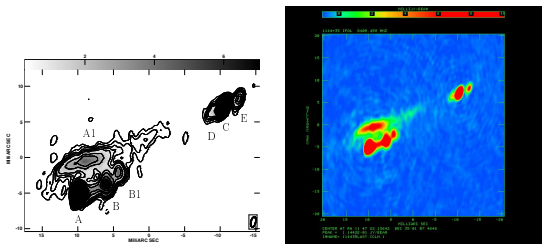

Figure 2 - Left: Global VLBI image at 8.4 GHz of 1144+35. The HPBW is 1.45 × 0.66 in PA -13°. Right: Same as left figure but in colour.

Thanks to new VLBA observations we can now confirm the main jet constant velocity and the detection of a proper motion in the counter-jet

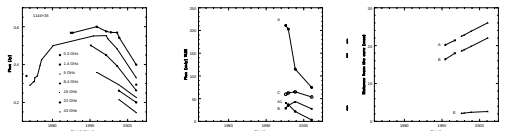

Figure 3 - Left: Arcsecond core flux densities from literature and our data. Center: Core flux densities of VLBI components at 8.4 GHz. Note that the arcsecond core variability is mostly due to the jet component A. Right: Core distance of VLBI components A, B (jet) and E (counter-jet) at different epochs. Note the correlation between the decreasing flux and the increasing distance from the core of A and B components.

3 Jet Dynamic

From the measured proper motion both on the jet and counter-jet, we can derive the source velocity and orientation. According to Mirabel and Rodriguez (1999) we have:
$\beta cos\theta = (\mu_a - \mu_r) \times (\mu_a + \mu_r)^{-1}$ and $\tan\theta = 2D\,(\mu_a - \mu_r)^{-1}\mu_a\mu_r/c$
where μ_a and μ_r are the approaching and receding apparent velocity; β = v/c is the jet velocity; θ is the jet orientation with respect to the line of sight, and D is the source distance assumed = 270 Mpc.
We derive for the 1144+35 jet: θ = 35.7° and β = 0.92

4 Conclusions

- The pc scale jet in 1144+35 shows a well defined structure moving with β = 0.92 and θ = 36°. Assuming a constant velocity this structure started about 50 years ago (1952-55 epoch).
- From 1992 the arcsecond core flux density is decreasing. This variability is not due to the nuclear source but to the jet sub-structures (mainly A component).
- The jet is clearly limb-brightened. The spine low brightness could be explained if it is moving at high velocity (γ = 15), which implies a low Doppler factor (= 0.36). The same effect could explain the gap between D and B1. The lower velocity of the external shear (and its Doppler factor = 1.6) could be due to a strong interaction of the jet with the ISM.