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The IDV Source BL Lac 0716+714, is it Fast or Slow ?

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Abstract. We investigate the structural evolution of the IDV source BL Lac 0716+714 from 10 epochs of global VLBI and VLBA observations. Our study reveals two possible component identification schemes, in which the jet components move either slow or fast. Although the fast motion would fit better to the observed IDV, the quality of our data does not allow a final decision between the slow and the fast picture.

1. Introduction

5 GHz VLBI studies during 20 years reveal 0716+714's core-dominated and northward oriented jet. Assuming a redshift $z \geq 0.3$ (Wagner et al., 1996) the source is most likely superluminal. 0716+714 shows correlated broad-band Intraday Variability (IDV). Simultaneous variations between X-ray, optical and radio strongly suggest an intrinsic origin of this variability. This would result in an apparent brightness temperature as high as $T_b = 10^{17}$ K. It therefore could be expected that the intrinsic Lorentz and Doppler factor in 0716+714 also is quite high and that the source should display rapid superluminal motion. In order to test this idea, we analyzed global VLBI observations from five epochs at 1.3 cm, two epochs at 2 cm and three epochs at 3.6 cm between 1993 and 1996.

2. Results

2.1. Morphology

Our studies reveal 0716+714's one-sided core-jet structure on scales of 0.1 to 10 pc: a strongly dominant core and more than 4 weaker knots in the jet. The position angles of the jet component gradually decrease with increasing core-separation, indicating bending of the VLBI-jet to the north towards the arcsecond VLA-jet which is oriented along p.a. $\simeq 300^0$.

2.2. Superluminal motion

With VLBI it always is difficult to accurately cross-identify VLBI components of AGN detected from multiple epoch and multiple frequency imaging. The limited time sampling, differences in the observing conditions and spectral effects in the source (opacity shifts, spectral fading) often make the component identification ambiguous. The analysis of the ten available data sets indicates that there are two possible identification scenarios for the jet components in 0716+714: one in which the components separate from the core with relative fast speed (0.25 mas/yr), another one in which the components are moving slower (0.02 mas/yr). In the latter scenario the motion of the components appears not monotonic (components accelerate and decelerate). We therefore favour the simpler (but faster) scheme, in which components 'linearly' separate from the core.

In this scenario, the apparent velocities of the source range between 3 and 8 c (H_0=100), for some components much faster than previously published (Fan et al. 1996; Gabuzda et al. 1998). VLBI studies dating back in the mid 1980's gave a limit of the apparent velocity of $\beta h \leq 2.3$ (Schalinski et al. 1992), in 0716+714, but this is based only on two epochs of observations at 5 GHz. We therefore conclude that in 0716+714 most likely a single jet speed does not exist and that different jet components move with different speeds. The possibility of the existence of faster speeds in 0716+714 indicates that the bulk Lorentz-factor is higher than previously assumed. This would help to reduce the apparent discrepancy to the observed rapid IDV and high brightness temperature.

2.3. Physical parameters from the relativistic beaming model

If the observed pattern velocity reflects the velocity of the bulk jet material, then the angle to the line of sight and the Lorentz factor can be derived from the superluminal motion. Using the apparent velocities of $3c$ - $8c$ from our fast identification scheme, we calculate the lower value of the Lorentz factor γ_{min} ($= \sqrt{\beta_{app}^2 + 1}$) $\sim 3.16 - 8.06$. The angle θ_0 $(1/\gamma_{min})$ at which the apparent component speed would be maximized then is $\sim 7.1^0$ - 18.5^0. Using the synchrotron self-Compton model, Ghisellini et al. (1993) derive a lower limit to the Doppler factor $\delta \sim 2.1$. This is consisistent with $\delta = 6 - 16$, which we derive from our measurements. The Doppler factor could even be higher, if the angle to the line of sight is ≤ 7 degrees. A Doppler-factor of $\delta = 40 - 50$ would bring the IDV-brightness temperature down to 10^{12} K. Such high Doppler-factor can be obtained, if the innermost part of the jet is inclined at $1.1 - 1.4$ degrees. A consequence of such jet bending would be that the apparent velocity on sub-mas scales must be slower than on mas-scales. This could solve the apparent contradiction between the before mentioned velocity measurements and would be easy to check by future VLBI observations.

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