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Study of the parsec-scale jet in the blazar 3C 66A with VLBA

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Abstract. We report 4-epoch VLBA observations of 3C 66A at 22GHz. The resulting images show a typical core-jet structure. We combine our results with some previous results to investigate the proper motions of the jet components. The kinematics of 3C 66A is quite complicated; mildly superluminal motions as well as apparent inward motions have been detected for some components. The inward motions may imply position change of the observed core.

Keywords. Radio continuum: galaxies— galaxies: individual (3C 66A)— galaxies: jet

1. Introduction

3C 66A (B0219+428, NRAO 102, 4C +42.07) is a well-known blazar which is further sub-classified as an intermediate synchrotron peaked BL Lac object (IBL) in terms of its SED (Abdo *et al.* 2010). At radio wavelengths, previous Very Long Baseline Interferometry (VLBI) images from 2.3 to 43 GHz revealed a typical core-jet structure on parsec scales (e.g. Jorstad *et al.* 2001 (hereafter J01), Marscher *et al.* 2002, Cai *et al.* 2007 (hereafter C07)). The kinematics of 3C 66A jet has been studied via multi-epoch VLBI observations (e.g. Jorstad *et al.* 2005 (hereafter J05), Britzen *et al.* 2008) and superluminal motions as well as apparent inward motions have been reported. Here we re-visit these properties over a relatively longer period with the VLBA at 22 GHz. In this work, we adopt a redshift of z=0.444 for 3C 66A. With $H_0 = 71$ km s $^{-1}$ Mpc^{-1}, $\Omega_M = 0.27$, and $\Omega_\Lambda = 0.73$, we have 1 mas = 5.69pc.

2. Observations and Data Reduction

3C 66A was observed as primary phase-reference calibrator for the VLBA project BS144 (Sudou & Iguchi. 2011). 22 GHz observations were successfully carried out at all 4 epochs (2004.80, 2005.05, 2005.35, 2005.54). The total on-source time of 3C 66A at each epoch is about 40 min. The data were recorded in VLBA format with 4 Intermediate Frequency (IF) bands, 8 MHz each. Data correlation was done with the VLBA correlator in Socorro. The data reduction was performed with the NRAO AIPS and Caltech DIFMAP packages. Amplitude and phase calibrations were made in a standard way given in AIPS COOKBOOK, with residual phase delays and delay rates calibrated using global fringe-fitting. Bandpass calibrations were performed using 0133+476 for all epochs. The output data were then read into DIFMAP for hybrid mapping and model fitting. Circular Gaussian models were used in model fitting.

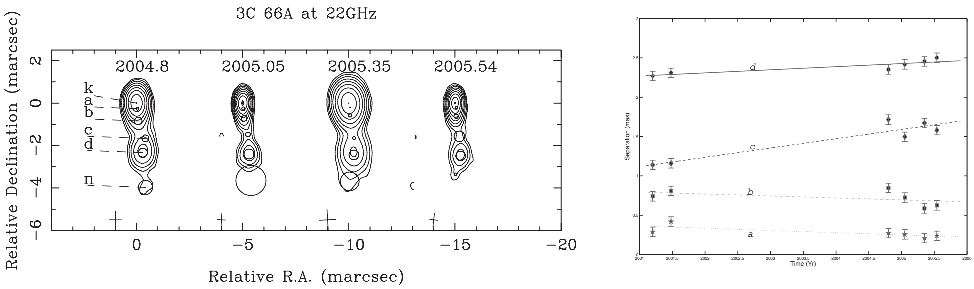

Figure 1. Left: The naturally-weighted maps of 3C 66A at 22 GHz.The crosses represent the restoring beams; Right: Proper motions of the jet components at 22 GHz. The apparent speed of each component: a: -0.76c, b: -0.67c, c: 3.16c, d: 1.06c.

3. Results and Discussion

Our VLBI maps of 3C 66A (see Fig. 1 left) show a typical core-jet structure which is similar to previous results (e.g. J01, J05, C07). The northmost component is identified as the core because it is the brightest and the most compact. Multi-frequency results show that it has a relatively flat spectrum (Zhao *et al.* in preparation). The jet is a smooth continuous jet roughly towards the south. The jet bends at about 1.2 mas. According to J05, the bending is continuous from 1.2 to 3 mas which might be due to the decrease of the viewing angle leading to increase of the Doppler boosting effect. The flux densities of components k-d in our maps support such an argument.

We combine our results with that in C07 so we could study the kinematics of the jet over a much longer time-interval, from 2001.20 to 2005.54 (see Fig. 1 right). The jet components show very complex proper motions, indicating the complex nature of this blazar. The inward motions detected for components a and b may be attributed to the position change of the observed core. This may be due to opacity change or the motions of the inner-most jet components which cannot be separated from the core under current resolutions. Multi-frequency studies show the core shift may change in this source, which could be related to the possible core position change in this source (Gao *et al.* in preparation). Components c and d show mildly superluminal motions. More detailed multi-frequency study of the morphology and kinematics of 3C 66A can be found in Zhao *et al.* (in preparation).

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