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A Sharper View into the Parsec-Scale Jet of 3C 345

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Abstract

We present images from VSOP observations of 3C 345 at 6 cm, for two epochs separated by 1 year. In the VSOP images, the inner jet of 3C 345 is resolved into several components, which cannot be disentangled from each other in the ground VLBI images. The components show superluminal motions, with different trajectories and large variations in the flux densities. These observations help us to obtain better constrains for the models of 3C 345.

1 Introduction

The quasar 3C 345 (16^{m}, z=0.595) is an archetypical source for studies at superluminal motions. Several partially resolved enhanced emission regions (components) are observed in the jet, after being ejected from the core at apparent speeds of $2c$–$20c$ along strongly bent trajectories (e.g. Zensus et al. 1995). This may be caused by a periodic process driven by Kelvin-Helmholtz instabilities (Hardee, 1987, Steffen et al., 1995, Qian et al., 1996) or a binary black hole system (Lobanov 1996). The ejection angles of the components vary, and the component trajectories differ significantly. The curvature of the component trajectories increases near the core, while the trajectories appear to straighten farther away from the core. This makes the innermost region a better indicator of the jet kinematics. It is therefore important to investigate the behaviour of the jet components at a very early stage of their evolution in order to constrain the kinematics of the jet components. This makes 3C 345 a prime candidate for high-resolution imaging with VSOP.

2 Observations and Imaging

We present here images from two out of 8 observations made for our VSOP monitoring program of 3C 345 (see Table 1). The observations presented here were made at 6 cm in 1998.57 and 1999.50. 3C 345 was observed for 14 h and 10 h, respectively. The data were processed at the NRAO[1] VLBA correlator in Socorro, New Mexico, USA. Calibration and fringe-fitting were done in AIPS, and imaging was performed using Difmap. Model fitting by elliptical Gaussian components was applied to quantify the flux densities and positions of the jet components.

Table 1: VSOP monitoring program of 3C 345

Epoch	λ (cm)	Pol.	Array
1998.22	6	No	HALCA, VLBA, EB, Y
1998.22	18	No	HALCA, VLBA, GO, Y
1998.57	**6**	**No**	**HALCA, VLBA, EB, Y**
1998.66	18	Yes	HALCA, VLBA, EB, Y
1999.50	**6**	**Yes**	**HALCA, VLBA, EB**
1999.50	18	Yes	HALCA, VLBA, EB, GO, RO
1999.69	6	Yes	HALCA, VLBA, Y
1999.69	18	Yes	HALCA, VLBA, GO

EB: Effelsberg, Y: phased VLA, GO: Goldstone, RO: Robledo

3 Evolution of the Jet Components

The baselines to HALCA are about 3 times larger than the longest ground baselines, leading to a likewise improvement in image resolution. At $\lambda = 6$ cm, the interferometric beam including the space baselines in east-west direction is ~ 0.34 mas (1st epoch) and ~ 0.37 mas (2nd epoch) while the ground array yields only $\sim$ 1 mas resolution. With this improved image resolution, we are able to identify the synchrotron self-absorbed core and three inner jet components (C9, C8 and C7) to the west (Figure 1, left). In the ground-array image the core and these components appear blended into a single one.

To compare both epochs, we have restored both images with a circular beam of 0.4 mas, and we have also modelled the visibilities with Gaussian components. The big change of the inner few parsecs within one year is evident (Figure 1, right). The flux of the core has more than doubled (from 0.8 Jy to 1.8 Jy), while its shape became slightly elongated in east-west direction in 1999.50. At this epoch, the single-dish flux density at 6 cm has also increased (UMRAO) which, according to the

[1]The National Radio Astronomy Observatory (NRAO) is operated by Associated Universities, Inc., under cooperative agreement with the National Science Foundation.

flare model of Lobanov & Zensus (1999), is a reliable hint that a new jet feature (C10) has been recently emitted from the central region. Our later VSOP observations should help to identify the expected new jet feature.

The components C9 and C8 appear almost merged into one single component. However, a detailed analysis shows that the distance between C9 and C8 became smaller — only about 0.11 mas. The bigger effect is the change of the flux density. The flux of C9 increased from 2.6 Jy to 3.0 Jy, while the flux of C8 dropped from 2.4 Jy to only 1.3 Jy. With a component distance of 0.55 mas and a beam size of 0.37 mas, the big flux difference between C9 and C8 causes the apparent dominance of the brighter feature over the fainter. C8 has an angular speed of only 0.18 mas/yr, which corresponds to an apparent speed of $3.6\,h^{-1}c$ (for a flat universe cosmology, with $H_0 = 100h\,\mathrm{km\,s^{-1}Mpc^{-1}}$). The trajectories of C9 and C7 show faster proper motions, of 0.3 mas/yr ($5.8\,h^{-1}c$) and 0.28 mas/yr ($5.5\,h^{-1}c$). Also, the proper motion of C7 along 1996 was 0.35 mas/yr $\widehat{=}\ 6.8\,h^{-1}c$ (Ros et al. 2000), at the same core distances as C8. The observed relative weakness of C8 may arise from its lower observed speed. A detailed analysis of the kinematics and the component evolution will be presented in Klare et al. (in preparation).

4 Conclusions and Future Work

The VSOP observations provide a good opportunity for high resolution imaging and allow us to trace the components in the vicinity of radio source cores better than ground VLBI. We have successfully imaged 3C 345 at 6 cm with the VSOP. The observations presented here, combined with the other epochs (Table 1, data reduction in progress) and also at the other wavelength (18 cm), and adding polarimetric imaging should help us to constrain the models of 3C 345.

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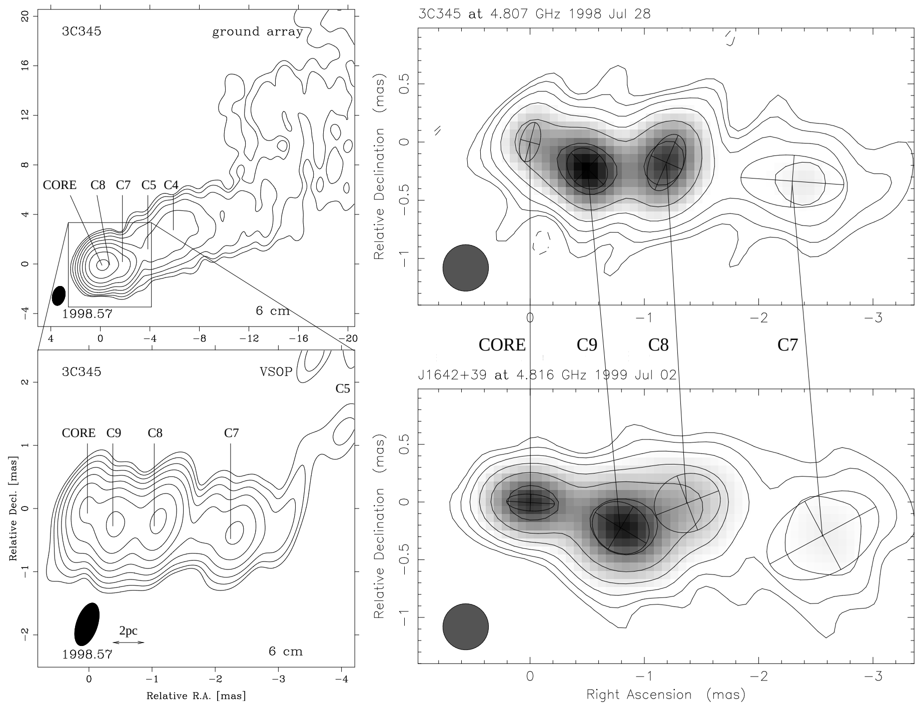

Figure 1: Total intensity flux images of 3C 345 - Left: VSOP resolves the core into several components (see also Colour Figure 1). Right: Evolution of the inner jet components, epochs 1998.57 and 1999.50

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