Radio Structure of the Quasar 0202+149 on Subarcsecond Scale

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Abstract We present the results of MERLIN observations at 5 GHz and VLBA observation at 1.67 GHz for the γ-ray bright quasar 0202+149. Two images on subarcsecond scales first reveal that 0202+149 contains two mini-lobes separated about 200 mas, located on both sides of a bright radio core. The northeast lobe is resolved into two hot knots by the VLBA observation. Combining multiepoch multifrequency VLBI images, we investigate the spatial evolution of the radio jet on scales from 0.5 mas to 0.5 arcsecond. The γ-ray quasar 0202+149 maybe be the first superluminal source with two-sided jet structure on subkiloparsec scale. We rule out the possibility that 0202+149 is a Compact Symmetric Object (CSO). We prefer 0202+149 has stronger bent jet structure on scales from parsec to subkiloparsec rather than a compact F doubles.

Key words pulsar-mode change-spectrum

1 Introduction

The source 0202+149 (J0204+1514, 4C +15.05) is a flat-spectrum quasar with redshift $z = 0.833$ (Herbig & ReadHead 1992; Stickel et al. 1996). It was detected by EGRET as a γ-ray source (von Montigny et al. 1995) and identified as a variable source with a high level of probability in the second EGRET catalog (Mattox et al. 1997). However, unlike general γ-ray sources, 0202+149 has little radio variability (Piner & Kingham 1998) and low radio polarization (Perley 1982).

The γ-ray quasar 0202+149 has been observed and imaged in the radio band. A VLA observation at 1.4 GHz presented an unresolved component on the kpc scale (Perley 1982; also see Murphy et al. 1993). Higher resolution observations showed that 0202+149 is a core-dominated structure with a faint jet in the northwest direction on pc scale and the jet component is stationary (Bondi et al. 1996; Piner & Kingham 1998; Pyatunina et al. 2000). A 22 GHz VLBI observation (Moellenbrock et al. 1996) measured a brightness temperature of 0202+149 in excess of the inverse Compton limit ($10^{12}K$) for synchrotron radiation, indicating the likelihood of relativistic beaming in this source. 43 GHz VLBA observations (Pyatunina et al. 2000) revealed a inner bent jet and proposed a proper motion of 0.18 ± 0.01 mas/yr, corresponding to an apparent superluminal velocity $(8.1 \pm 0.3)c$ (where $q_0 = 0.1$, $H_0 = 65\,\mathrm{km\,s^{-1}Mpc^{-1}}$).

In this paper, we will present the results obtained from MERLIN observations at 5 GHz, VLBA observation at low frequency of 1.67 GHz. We investigate the spatial evolution of 0202+149 on scales from 0.5 mas to 0.5 arcsecond.

2 Observations and the results

The γ-ray bright quasar 0202+149 was observed with MERLIN on 12th Nov 1998. The participating antennas of MERLIN are Cambridge, Darnhall, Defford, Tabley and Knockin, but the antenna Tabley was failed in the observation. The source was also observed with Very Long Baseline Array (VLBA) as a part of a EGRET-detected AGNs monitoring campaign (Hong et al. in preparation) on 17th Feb 2000 at wavelength of 18 cm (1.67 GHz) in "snapshot" mode. The primary data reduction of the VLBA data were done in the NRAO Astronomical Imaging Processing Software (AIPS) package (Cotton 1995; Diamond 1995). For MERLIN data, the amplitude calibration was done with d program by Dr. Garringtonin in Jodrell bank observatory. The imaging of 2 epochs data were performed with AIPS or the package DIFMAP (Shepherd et al. 1994).

The MERLIN image at 5 GHz and the VLBA image at 1.67 GHz are displayed in Figure 1.

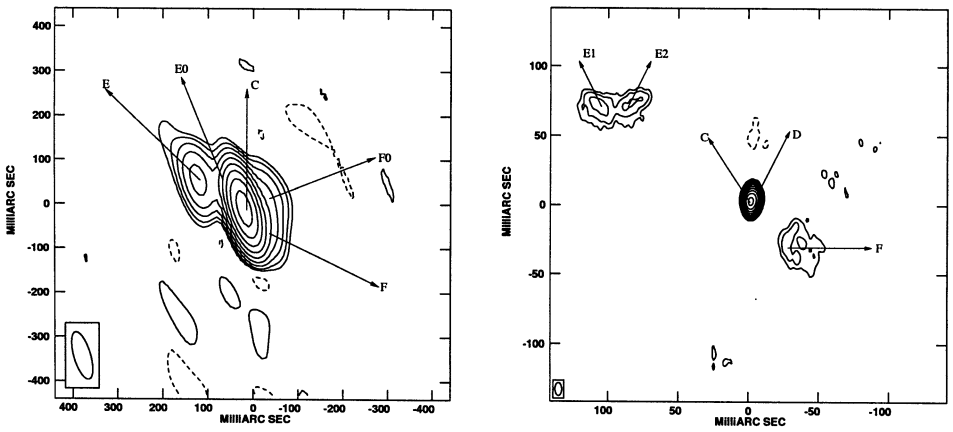

Fig. 1 Left: the MERLIN Image at 5 GHz on epoch 1998.87. Contour peak flux =2.31 Jy/beam. Levs=6 mJy/beam × (-1, 1, 2, 4, 8, 16, 32, 64, 128, 256), Beam FWHM: 110 × 37.2 mas at 16deg. Right: the VLBI image with VLBA at 1.67 GHz on epoch 2000.10. Contour peak flux =1.22 Jy/beam. Levs=3.7 mJy/beam × (-1, 1, 2, 4, 8, 16, 32, 64), Beam FWHM: 10 × 4.99 mas at 1.27deg.

3 Morphology and Structural Evolution

Both MERLIN and VLBA images exhibited that the source 0202+149 has extended mini-lobes straddling the core. In the MERLIN image, the core component was labelled C and the extended mini-lobes were labelled E and F respectively (See the left in Figure 1.). Two other components were detected. The component E was resolved with two hot spots labelled E1 and E2 in the VLBA image (See the right of Figure 1). In fact, Bondi et at. (1996) found the VLBI map accounts only for 50% of the flux density measured by the Effelsberg 100 m telescope and predicted that there must be an extended component on a scale of hundreds of mas. Our results confirm the prediction. Moreover, the results show that 0202+149 clearly has an extended component on the other side of the core. Our observations first reveal that the γ-ray quasar 0202+149 contained with symmetric mini-lobes straddling

the bright core on subarcsecond scale.

On the basis of the results and the previous publications (Bondi et al. 1996; Murphy et al. 1993; Perley 1982; Piner & Kingham 1998; Pyatunina et al. 2000), we can investigate the spatial evolution of the radio jet of 0202+149 from small scale to large scale. The redshift of 0202+149 indicated the source located at a distance of 100 Mpc (so 1 mas $\sim$ 3.6 pc). The morphology features of 0202+149 includes the followings:

(1) Multiepoch VLBA observations at 43 GHz clearly showed the jet structure of the inner ($r < 1$ mas) region of 0202+149, suggesting either strong curvature or complex cross-sectional structure (Pyatunina et al. 2000). Based on 4 epochs high resolution 43 GHz VLBA images, Pyatunina et al. (2000) revealed the superluminal motion of component of the inner jet with an apparent superluminal velocity $(8.1 \pm 0.3)c$. This is consistent with that the γ-ray sources are strongly beamed (von Montigny et al. 1995).

(2) The VLBI observations on mas scale revealed a core-dominated structure with a diffuse jet out to $\sim$ 7 mas (Bondi et al. 1996; Pyatunina et al. 2000; Piner & Kingham 1998). The outer jet structure ($r < 10$ mas) showed that the extended jet component at a distance $\sim$ 5 mas and PA $\sim$ 60 deg is stationary.

(3) The MERLIN and VLBA observation in this paper revealed the triple jet structure on the intermediate scale ($r < 0.5$ arcsecond). The two components on either side of the bright core are probably mini-lobes. And the two mini-lobes have similar flux density.

(4) 0202+149 was unresolved on scales greater than 1 kpc (Perley 1982; Murphy et al. 1993).

4 Discussion and Conclusions

Figure 1 shows that 0202+149 has the outer mini-lobes separated by 720 pc, straddling the core. Considering compactness of 0202+149 on kpc scale, we easily think that it is a CSO (Pearson & Readhead 1988; Conway et al. 1994). The γ-rays loud emission of 0202+149 imply that the source is strongly beamed (von Montigny et al. 1995). Pyatunina et al. (2000) has also detected the superluminal motion on pc scale for 0202+149. This contrasts with the radio properties of CSOs in which relativistic beaming does not play a major role (Wilkinson et al. 1994). Moreover, the flux density of the core at low frequency should be weaker for CSOs. From Figure 1 and 2, the core of 0202+149 is obviously brighter than mini-lobes. So we don't think that the source 0202+149 is a CSO.

Piner & Kingham (1998) suggested 0202+149 as a new compact F double source. The reasons included (1) 0202+149 contains with a resolved core and a stationary extended jet component on mas scale; (2) little or no radio variability; (3) no detectable structure on the scale of kpc. Conway et al (1994) indicated that the compact F doubles generally show flatter high-frequency spectra and are associated with an apparently one-sided radio jet. However the MERLIN and VLBA images show that 0202+149 have two-sided radio jets on subkpc scale. We need more evidence and the spectral information to decide whether 0202+149 can be classified as a compact F doubles.

The phenomena of the γ-ray emission and the superluminal motion show that 0202+149 is relativistic beamed. This means that the jet components are very close to the line of sight. Because of relativistic beaming, the counter-jets are not visible on the mas scale. This is consistent with the structure on the pc scale. The triple structure on subarcsecond implies that 0202+149 might have two-sided radio jets structure. This suggests that the direction of the jet components is strongly changed from pc scales to subkpc scales. So both advancing and receding jets could still be visible on subkpc scale. But it is difficult to decide how the pc scale jet is connected to the mini-lobes on subarcsecond scale. Lacking of the obvious

evidence connecting the jet component on pc scale to subkpc scale, we cannot rule out that the mini-lobes are the jet components previously ejected from the core.

In this paper we have reported an ongoing work aimed to investigate the spatial evolution of the radio jets of 0202+149 on scales from submas to subarcsecond. The γ-ray quasar 0202+149 maybe be the first superluminal source with two-sided jet structure on subkiloparsec scale. We also suggest that the γ-ray quasar 0202+149 tend to have strong bent-jet structure on scales from pc to sub-kpc.

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