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1546+027: Space VLBI observations of a compact quasar

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Abstract. A 5-GHz space VLBI image of a very compact quasar 1546+027 is presented with a sub-mas angular resolution at this observing frequency. The source has been observed in a broad spectral regime (radio, optical, X-rays) in the recent years. Our image shows changes in the source structure compared with earlier observations. These changes can also be seen at other radio frequencies. The source is a candidate for detecting apparent superluminal motion. We estimate the value of the rest-frame brightness temperature of the source, $T_{\rm B} = 0.46 \times 10^{12}$ K.

1. Introduction

The source 1546+027 (J1549+0237) is one of the brightest and most compact active galactic nuclei found in the VLBI Space Observatory Programme (VSOP) 5-GHz Prelaunch VLBA Survey in 1996 (Fomalont et al. 2000), therefore it is an ideal target for space VLBI observations.

The source 1546+027 was optically identified by Bolton & Wall (1970). Its redshift is $z = 0.412$ (Burbidge & Strittmatter 1972). The optical polarization of the object is greater than 3% (Moore & Stockman 1981), therefore it is classified as a Highly Polarized Quasar (HPQ). Optical monitoring by Smith et al. (1994) has shown that the source has variability range of almost 1 magnitude. The quasar was also observed in X-rays by ROSAT (Brinkmann et al. 1995).

The source has been frequently observed at different radio frequencies. Until 1996, the source did not seem to vary at 22 and 37 GHz (Wiren et al. 1992), and in a radio survey covering the frequency range of 1.5–10.6 GHz (Neumann et al. 1994). At the beginning of 1996, Australia Telescope Compact Array monitoring (1996–1998, S. Tingay et al., in preparation) and other data indicated a prominent flux density outburst (Fig. 1). As well, the source can be found in several imaging radio surveys, for example the 1.64-GHz VLA survey (Murphy et al. 1993), the 5-GHz VSOP Survey (Hirabayashi et al. 2000) and the Radio Optical Reference Frame image database (Fey & Charlot 1997) at 2.3 and 8.4 GHz.

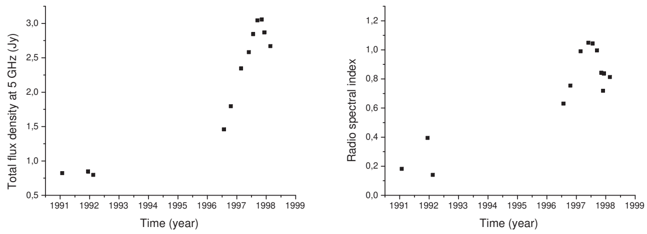

Fig. 1. The 5-GHz total flux density (S, left) and the calculated radio spectral index (α, right) as a function of time. The spectral index is defined as $S \sim \nu^{\alpha}$, where ν is the frequency. The flux density data are taken from S. Tingay et al. (in preparation), Kovalev et al. (1999) and Neumann et al. 1994. Both curves indicate an outburst starting around 1995.

2. Observations, calibration and data reduction

The observations took place on 13 August 2000, with the HALCA satellite (Hirabayashi et al. 1998) and four antennas of the European VLBI Network (EVN), Effelsberg, Hartebeesthoek, Torun and Noto, at 5 GHz. The source was observed for 7 hours in left circular polarization. The data were recorded using 32 MHz bandwidth. The correlation took place at the NRAO correlator in Socorro (NM, USA).

Initial data calibration and fringe-fitting were done using the NRAO AIPS package (Cotton 1995; Diamond 1995). The Caltech DIFMAP package (Shepherd et al. 1994) was used for self-calibration, imaging and determining a brightness distribution model of the source.

3. Results and discussion

At the time of our observations, the total flux density of the source was decreasing, years after the 3-Jy maximum at 5 GHz (Fig. 1). Our 5-GHz space VLBI image of 1546+027 is displayed in Fig. 2. It shows a core-jet structure in N-S direction similar to other VLBI images with lower resolution (e.g. Kellermann et al. 1998). We fitted a brightness distribution model to the source visibility data. The model consists of three elliptical Gaussian components: the core (**a**), and two jet components (**b** and **c**) within 1.5 mas south of the core (Table 1).

Table 1. Fitted Gaussian model components of 1546+027.

Component	a	b	c
Flux density [Jy]	0.688	0.280	0.082
Separation* [mas]	0.05	0.81	1.51
Position angle [°]	-22	179	179
Major axis [mas]	0.56	0.52	0.30
Minor axis [mas]	0.18	0.15	0
Major axis position angle [°]	-11	-27	-48

* Separation from phase center

Using the fitted model components, we can estimate the rest-frame brightness temperature of the core as

$$T_{\rm B}[{\rm K}] = 1.22 \times 10^{12} \frac{S}{\theta_{\rm maj}\theta_{\rm min}} \frac{1+z}{\nu^2},$$

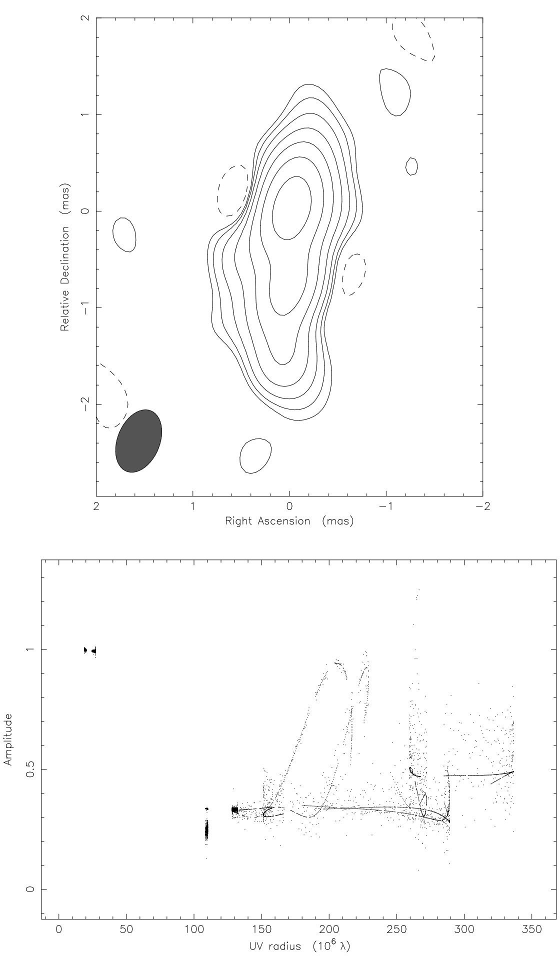

Fig. 2. Top panel: Clean image of the source 1546+027 with a clear N-S core-jet structure. The contours are drawn at −1, 1, 2, 4, 8, 16, 32 and 64% of the 0.535 Jy/beam peak brightness. The total flux density is 1.1 Jy. The restoring beam FWHM is 0.675×0.437 (mas) at $-22°$. Bottom panel: The correlated flux density as a function of projected baseline length. The solid curve represents the clean component model.

where S is the flux density of the component in Jy, $\theta_{\rm maj}$ and $\theta_{\rm min}$ are the major and minor axes of the component in mas, respectively (assuming optically thick Gaussian brightness distribution), ν is the observing frequency (in GHz) and z is the redshift. We obtain $T_{\rm B} = 0.46 \times 10^{12}$K for the core brightness temperature. This value is close to the inverse Compton limit, in agreement with independent estimates of $T_{\rm B}$ based on earlier data.

The linear core-jet distance between components **a** and **b** (Table 1) is $2.8/h$ pc (where h is the dimensionless Hubble constant; the Einstein–de Sitter cosmological model is assumed, $q_0 = 0.5$). According to the total flux density monitoring data (Fig. 1), an outburst occured at about the end of 1995. If we associate component **b** with this outburst, then this change in the linear core-jet separation implies an apparent speed of $2c/h$ (c is the speed of light). This can be considered as marginal evidence for a moderately superluminal motion that could be verified with future high resolution VLBI observations.

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