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Research Note

Is 3C287 a precessing radio source?

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Abstract. We present a 5 GHz VLBI image of the compact steep spectrum (CSS) quasar 3C287. The source has been one of the candidate precessing CSS sources. Both static features and large structural changes are observed since the earliest VLBI experiments. The overall picture does not seem to support a precessing jet scenario.

Key words: galaxies: active – radio continuum: galaxies – quasars: individual: 3C287

1. Introduction

3C287 is a compact steep spectrum (CSS) quasar at a redshift of z=1.055. It was observed from 22.5 to 0.6 GHz with conventional interferometry (van Breugel et al. 1984, 1992) and VLBI technique (Nan et al. 1988, 1991a; Fanti et al. 1985, 1989; Dallacasa et al. 1998). The source does not show any structure with the VLA, its overall extent is less then 100 mas. The observed structure at VLBI scales is complex, indicative of a helical core–jet morphology (Fanti et al. 1989). There is a faint, filamentary halo to the W–SW at 1.6 GHz (Fanti et al. 1985, Nan et al. 1988) which becomes more dominant at 0.6 GHz and extends to E-NE, too (Nan et al. 1991a).

In the class of CSS sources there are some potential precessing candidates reported in earlier works: 3C119 (Fanti et al. 1986; Nan et al. 1991b), 3C287 (Fanti et al. 1989), 3C343 (Sanghera et al. 1997) and 3C380 (Kus et al. 1993). Precessing jets may indicate the presence of double black holes in the the center of these objects (e.g. Hardee et al. 1994 and references therein), though an alternative twisted accretion disk model also exists (Appl et al. 1996). Precession may also occur in merging galaxies, a scenario proposed to explain the complex structure of some CSS sources (van Breugel et al. 1988). In the present paper we show a new 5 GHz VLBI image of 3C287 and discuss its morphology.

2. Observations, calibration and data reduction

The observation took place on 23-24 February 1997 with 7 antennas of the European VLBI Network (EVN) at 5 GHz. Parameters of the radio telescopes are shown in Table 1. 3C287 was observed over 10.5 hours using left circular polarization. Data were recorded with MkIII recording system in mode B, which results in 28 MHz bandwidth. Correlation took place at the Max Planck Institute for Radio Astronomy in Bonn, Germany.

Initial data calibration was done using the NRAO AIPS package (Cotton 1995; Diamond 1995). Instrumental delay errors were corrected using 0804+499 calibrator source which is unresolved with the western EVN. The data were fringe–fitted in AIPS using 13 minutes solution time. We used the measured antenna system temperatures and gains for initial amplitude calibration, while complex bandpasses were calibrated using 0804+499. Data were averaged using 1 minute integration time. The Caltech DIFMAP package (Shepherd et al. 1994) was used for self–calibration and imaging. First a preliminary image was made with the western EVN antennas using a point source starting model. The clean components of this map formed the starting model of the final imaging process involving the whole dataset.

3. Results

Our image of 3C287 at 5 GHz is shown in Fig. 1. Plots of self–calibrated correlated flux densities as a function of projected baseline length are shown in Fig 2. We used 5 mas circular restoring beam as there is a large gap in the uv–coverage from 25 to 100 Mλ and the phases are very noisy for the longest baselines. Despite the fact that there were no intermediate baselines present, we were able to reconstruct the source structure well at 5 mas scale. The observed flux density distribution of the source is in agreement with earlier results at 5 GHz (Fanti et al. 1989). As expected, correlated flux density on the shortest (Effelsberg–Westerbork) baseline was 1.6 Jy, about 50% of the total flux density. Model CLEAN components of our image also contain 1.6 Jy which implies that about half of the total flux density is missing from our map and probably associated with the extended, low surface brightness halo visible in Fanti et al. (1985) and Nan et al. (1988, 1991a). The source is only marginally detected on the longest baselines, and therefore no compact radio core is present at a flux density level of 5 mJy.

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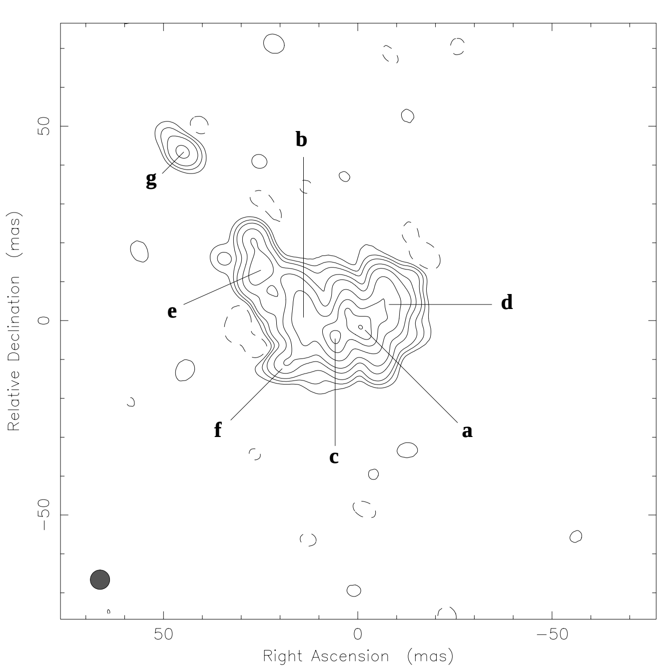

Fig. 1. Natural weighted image of 3C287 at 5 GHz. Contour levels are −0.4, 0.4, 1, 2, 5, 10, 25, 50, 75, 99 % of the 183 mJy peak flux density. The restoring beam is 5 mas

Table 1. EVN telescopes involved in the experiment and their characteristics at 5 GHz

Radio telescope	Diameter (m)	SEFD[a] (Jy)
Effelsberg	100	20
Jodrell Mk2	26	320
Torun	32	220
Medicina	32	296
Onsala	25	780
Shanghai	25	520
Westerbork	93[b]	108

[a] system equivalent flux density
[b] the telescope was used in phased array mode; an equivalent diameter is given.

We performed model fitting in DIFMAP using self–calibrated uv-data. The complex structure is fitted well with 7 components listed in Table 2.

4. Discussion

An EVN+MERLIN map of 3C287 at 5 GHz is presented by Fanti et al. (1989). They found that the most compact A component – which is the brightest one – is in the centre of the source. The source brightness decreases smoothly along the curved jet, and has a secondary maximum at 15 mas to East and 45 mas to North from the centre. This component marked with C in their paper. The two point spectral index between 18 cm and 6 cm

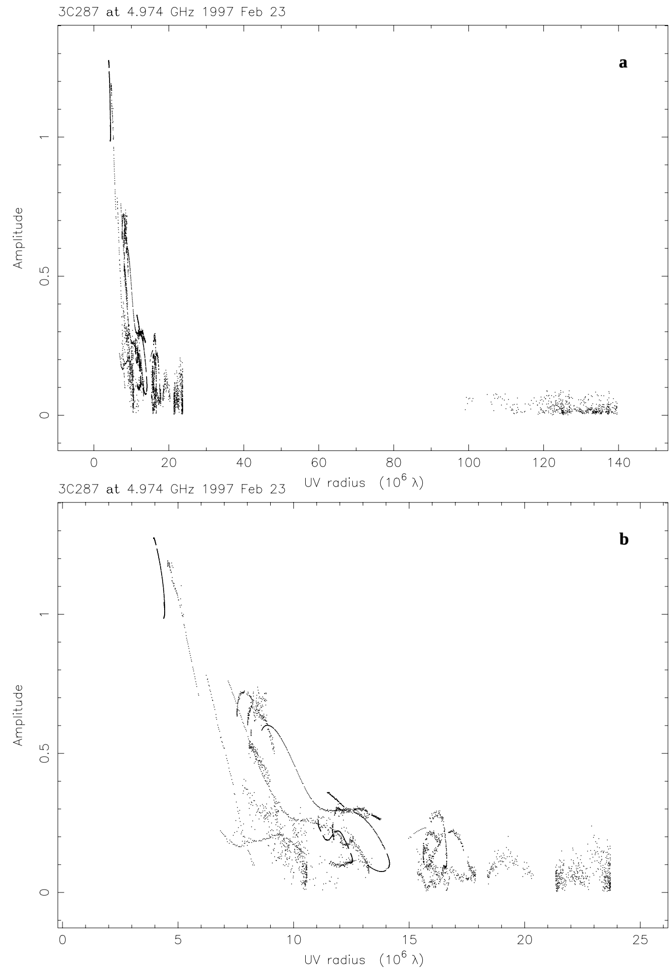

Fig. 2a and b. Correlated flux density (Jy) versus projected baseline length: **a** all data including baselines to Shanghai telescope, **b** the western EVN, 0–25 Mλ u–v range

($S \sim \nu^{\alpha}$) changes from −0.5 to −1.5 near the brightness minimum, then flattens again up to −0.5 in the C component (Fanti et al. 1989).

The most remarkable difference between the map of Fanti et al. (1989) and our results is that we cannot find emission above the 3 σ noise level (1 mJy) at 15 mas to East and 45 mas to North from the center in Fig. 1. Our array did not include MERLIN which is very powerful in mapping faint, extended emission. However, the peak brightness of component C was 55 mJy/beam using 7 mas beam (see Fig. 3 of Fanti et al. 1989) and the corresponding feature was clearly identified at lower frequencies as well (Fanti et al. 1985; Nan et al. 1988, 1991a). If present at the epoch of our observation, such a bright feature should have been identified in our map as well. We also note that the baseline sensitivity in our experiment was a factor of four better than that of Fanti et al. (1989) due to the larger bandwidth used.

The near circular track of the jet bridge line suggested earlier by Fanti et al. 1989 was based on their C component. 1.6 GHz observations support this regularly curving jet scenario (e.g. Nan et al. 1988). Unfortunately, we cannot decide whether component

Table 2. Fitted elliptical Gaussian model parameters of the source structure

Component	S (mJy)	r (mas)	Θ ($^\circ$)	a (mas)	b/a	Φ ($^\circ$)
a	774.3	0.0	–	11.3	0.8	16
b	412.0	14.8	88	14.4	0.6	14
c	235.5	7.8	119	6.8	0.7	-7
d	162.1	10.2	-50	9.2	0.1	15
e	107.3	30.2	62	11.6	0.4	13
f	21.4	25.6	118	3.3	0.3	17
g	17.9	63.9	47	5.4	0.0	41

Notes to Table 2:
S flux density, r angular separation from the centre,
Θ position angle, a, b component major and minor axes,
Φ component major axis position angle,
Position angles are measured from north through east.

C moved away or faded below our 3 σ image noise. Observation of moving discrete 'bullets' of jet material would help us to study the jet kinematics. On the other hand, by comparing the observed structures in more details, we can identify features that cannot be explained by simple precession models. All of the VLBI maps published earlier show two features which do not follow the curving jet ridge line. These correspond to our components *f* and *g* in Table 2. (see also Fig. 1.).

Recent VLBA observations at 8.4 GHz also failed to detect component C (Dallacasa et al. 1998). There is no compact core at a few mJy level even at this frequency. Component *f* is identified just above the image noise, while component *g* also appears at about 1 mJy/beam contour level using 7 mas restoring beam (Dallacasa 1998, priv. comm.).

5. Conclusion

The observed complex structure and the lack of a well defined radio core in 3C287 indicate that simple precession models cannot describe the source. Both short baselines and quasi–simultaneous multi–frequency observations are needed in order to map the faint surface brightness emission and locate a possible radio core at higher frequencies. These further observations would help us to get a better understanding of the nature of 3C287.

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