Transverse motions in CSOs?

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The measurement of proper motions in CSOs is a powerful tool to determine the dynamical evolution of the newly born extragalactic radio sources. We observed 3 CSOs with the VLBA in 2004 and in 2006 to monitor changes in their structure and measure the separation velocity of the hot spots. It is important to increase the size of the samples of CSOs with measured expansion velocity to test the existence of frustrated objects, and put stringent constraints on the current models. We found for all the three objects observed a transverse motion of the hot spots, and we suggest as the more likely explanation a precession in the jet axis. This behaviour likely inhibits or at least slows down the radio source growth because the head of the hotspot continuously hits new regions of the ISM. Therefore these radio sources may represent an old population of GPS/CSOs.

1 Introduction

Compact Symmetric Objects (CSOs) are radio sources with sub-kpc size with a morphology and radio luminosity similar to the classical doubles, which are typically 1000 times larger. The integrated radio spectrum is generally convex, with the peak frequency around a few GHz. The projected linear size generally never exceeds 1 kpc, and some sources are a few tens of pc in size only.

A key issue in the study of these sources is their age. They could be rather young (< 10⁴ yr) or substantially older (> 10⁶ yr).

It has also been suggested that many CSOs are short lived objects who die before reaching large sizes (Readhead et al. 1994).

At present there is large support to the youth scenario. Expansion speeds detected are in agreement with estimated radiative ages to give to CSOs an age of a thousand to ten thousand years (Murgia et al. 1999, Polatidis and Conway 2003, Gugliucci et al. 2005). Still there are the sources with upper limits to their expansion speed, and it is not demonstrated that all the sources are growing fast. In this context monitoring new CSOs increases the number of measurements of proper motions and improves the statistics.

2 The selection of new target CSOs

We searched CSOs sources fulfilling the following requirements:

- Simple double or triple structure on mas scale;
- High declination, allowing a better sampling of the UV plane;
- High flux density at 8.4 GHz, where the VLBA has the best combination of sensitivity and resolution;
- Size between 10 and ~100 mas, to fully exploit the spatial frequencies sampled by the VLBA.
- Not already studied or under study for this purpose.

Not many sources satisfied all these requirements. A search in the literature and among the VLBI databases available online was carried out to select suitable sources belonging to the samples of GPS radio sources and CSOs (Snellen et al. 1998, Stanghellini et al. 1998, Dallacasa et al. 2000, Dallacasa et al. 2002a). From the candidate sources we chose as the best suitable, the 3 objects listed in Table 1, which satisfy the above requirements. Two objects do not have a measured redshift, but they belong to GPS samples with planned/ongoing optical studies (e.g. Dallacasa et al. 2002b), and in any case a rough redshift can be estimated for one of them (J1335+5844) by its optical magnitude as it is known that optical magnitudes of GPS/CSOs correlate well with redshift (O’Dea et al. 1996, Snellen et al. 1996).

| source | m_r | z | RA(J2000) | DEC(J2000) |
|--------|-----|---|-----------|------------|
| J0706+4647 | -   | - | 07 06 48.147 | +46 47 56.21 |
| J1335+5844 | 22.0 | 0.57 | 13 35 25.928 | +58 44 00.29 |
| J1823+7938 | 16.7 | 0.224 | 18 23 14.109 | +79 38 49.00 |

Table 1: Information on the observed radio sources

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3 Observations, data reduction, and results

We observed these 3 radio galaxies with the VLBA in two epochs for 24 hours each. Observations for the first epoch took place in 2 observing sessions in January and March 2004, while observations for the second epoch took place about 2.5 years later, always in two separate observing sessions in September and November 2006.

At each epoch each source was observed 6/8 hours at 8.4 GHz in single right polarization.

The calibration and mapping has been done in a standard way using the NRAO AIPS software. Once the final images have been obtained, we used the DIFMAP data reduction package to model-fit the radio sources with a few discrete pointlike or gaussian components on the fully calibrated visibilities.

The typical resolutions of the images (FWHM) are $\sim 0.8$ mas.

In J0706+4647 and J1335+5844 a very weak radio core is detected for the first time at the center of the double structure. Such detection is truly important to confirm the classification of the radio source as a Compact Symmetric Object (CSO) and possibly to refer the hot spot motion to the center of activity. In the present observations however, even if detected, the position of the cores are not well constrained, and referring the position of the Hot-Spot respect to the core gives too large errors.

Therefore the relative position of the 2 hot-spots have been measured in all the three objects modelfitting the data in the UV plane with several gaussian components. We considered as hot-spots the two strongest and more compact components derived from the modelfit. The estimate of the accuracy and precision of this measures is usually a diffi-
cult task, but given the high dynamical range of the images it is much better than the beam size. In the assumption of a linear motion the errors can be estimated by the scatter of the data themselves, which is not possible in our case with only two epochs. In a previous work on OQ208 we could be able to estimate a 1 sigma error of 0.02 mas based on the scatter of the data, and we use the same value for the present data, which are of the same type (Stanghellini et al. in preparation).

Table 2  Hot-spot relative position in the 2 epochs. The position of the southern hot-spot relative to the northern one is indicated in polar coordinates in columns 3 and 4. The difference in position from first and second epoch is given in column 5 and 6.

| source       | epoch  | r      | θ      | r    | θ     |
|--------------|--------|--------|--------|------|-------|
| J0706+4647   | 2004   | 52.126 | 109.35 |      |       |
| J0706+4647   | 2006   | 52.059 | 109.45 | 0.11 | -145.79|
| J1335+5844   | 2004   | 12.964 | -164.84|      |       |
| J1335+5844   | 2006   | 12.891 | -165.18| 0.11 | 61.41 |
| J1823+7938   | 2004   | 15.765 | -115.60|      |       |
| J1823+7938   | 2006   | 15.745 | -115.38| 0.06 | -7.20 |

To make the motion visible, in Fig. 1, 2, and 3 we show the extrapolated motions in 500 years for the radio source J0706+4647 ($v \sim 0.4c$, assuming $z=0.5$), in 100 years for J1335+5844 ($v \sim 0.4c$, photometric $z=0.57$), and in 150 years for J1823+7938 ($v \sim 0.15c$, $z=0.224$). The arrows do not show the exact position of the components after that time, because we do not know if the motion is constant and which is the period of the jet precession (if this is the real nature of the motion). It is only shown to make it possible to evaluate by eye the direction and the velocity of the motion.

It seems surprising that we find these first cases of transverse motions in all the three objects observed, but we are not aware of any bias we could have put in our selection criteria. These objects deserve to be observed again together with other candidates of the original list, and it is important to monitor all CSOs of a complete sample to find how frequent tranverse motions are, but we are confident we revealed a real phenomenon.
4 Conclusions

We suggest a scenario where the jet precession strongly influences the size and morphology of a radio source. When the precession is negligible the radio source expands normally to become an FRI or an FRII. When the jet precession is small the jet is able to travel through the channel, void of ISM particles because the transverse shocks it created, and the hot spot has a slow transverse motion, as in the objects presented in this work. When the jet precession is large, the jet hits the ISM at a shorter distance and an S shape is formed, as sometime seen in GPS radio galaxies (e.g. B0500+019, Stanghellini et al. 2001).

Rapid precession is likely to inhibit or slow down at least the radio source growth because the head of the hotspot continuously hits new regions of the ISM. These objects with a precessing jet may represent population of CSOs older than those with expansion speed measured so far, and may help to explain the higher fraction of CSOs in samples of radio galaxies with respect to the predictions of the models (Snellen et al. 2000, Alexander et al. 2000).

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