

Signatures of restarted activity in core-dominated triples

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Abstract. The lobes of radio-loud AGNs are huge reservoirs of energy so even if the central engine turns off, the radio source is still observable for a substantial amount of time. It is quite obvious, however, that the ignition of a new period of activity can occur before the lobes have faded completely. Restarted activity has been observed in several giant radio galaxies but until recently, it has hardly ever been observed in more compact sources. Here we present an early result of a pilot VLBA programme targeted at compact core-dominated triples. It is found that the milliarcsecond structure of the central components in that type of objects normally take the form of core-jets, which in many cases do *not* point toward the relic lobes. Therefore, it looks as if the phenomenon of the restarted activity can occur regardless of the source size and it is often accompanied by a repositioning of the central engine.

1. Introduction

The large linear sizes of the majority of radio sources, which, for some radio galaxies termed Giant Radio Galaxies (GRGs), can be more than 1 Mpc, are a consequence of the constant growth of the radio structures during an appreciable period of time. According to Alexander & Leahy (1987) and Liu et al. (1992) the spectral ages of extended radio sources are $\sim 10^7$ to 10^8 years. However, even in the case of a GRG the spectral age is two orders of magnitude less than the age of the galaxy itself which, in general, can be of the same order as the age of the Universe; the Milky Way Galaxy is a good example of this (Pasquini et al., 2004). It seems that the phenomena collectively called ‘activity’ are episodic — galaxy evolution can be interrupted at some stage and then it can continue after a certain period of time.

If the energy supply from the central engine to the hotspots and the lobes cuts off, the radio source is still observable for a substantial period of time: 10^8 yr (Komissarov & Gubanov, 1994). Therefore, it is quite likely that a new epoch of activity can occur before the lobes have faded completely. The observable effect of this would be the presence of a new, bright component(s) located in or straddling the centre of a larger, double-lobed relic structure. The signature of the renewed activity is most obvious if it takes the form of a smaller, double-lobed radio source giving rise to the so-called double–double structure (Schoenmakers et al., 2000a,b). J0116–473 (Saripalli et al., 2002) and PKS B1545–321 (Saripalli et al., 2003) are also clear examples of double–double radio galaxies (DDRG).

Alternatively, ‘restarted activity’ may result in ‘X-shaped’ radio sources (Rottmann, 2001, and references therein) such as 3C 223.1 or 3C 403 (Dennett-Thorpe et al., 2002). It can be argued that these two sources resemble DDRGs such as J0116–473 or PKS B1545–321 except for a misalignment between the inner (active) and the outer (inactive) parts. The mechanism that triggered the development of the new structure in these two kinds of objects could be the same but that DDRGs are just ‘special cases’ in which the misalignment is (close to) zero.

In principle, different mechanisms could be responsible for activity renewal in particular types of objects, especially if they depend on the presence/absence of the misalignment between the old and the new structures and the magnitude of the ratio of those sizes. However, mergers seem to be the most ‘natural’ explanation of the activity. A review of other possible mechanisms has been given by Schoenmakers et al. (2000a).

All the objects in the examples quoted above are large with linear sizes of the order of several hundreds kpc. It would appear that radio sources have to be quite old for activity renewal regardless of their morphological features. The apparent lack of observable double–double or X-shaped structures in small-scale (i.e. young) sources could mean that there are inherent limits in the mechanism(s) of activity re-ignition known to exist in GRGs. This could make it rare if not impossible for such phenomenon to take place in compact objects. Alternatively, the physical conditions inside the cocoon might not favour the development of the inner lobes for a long time after the initial burst of the activity. According to Kaiser et al. (2000) that timescale could be up to $\sim 5 \cdot 10^7$ years so, even if the activity in a source younger than that actually ceased and then restarted, such events would remain unobservable.

2. A search for compact restarted RLAGNs

So, we are facing an interesting question: do RLAGNs whose activity stops and is restarted on timescales as low as e.g. 10^5 years exist at all? If so, they should be compact and have a clear signature of restarted activity, i.e. a bright core and weak, diffuse lobes without hotspots. The first example of an object of this kind — 0402+379 — was given by Maness et al. (2003). On arcsecond scales this source is a core-dominated Medium-scale Symmetric Object (MSO) with very steep spectrum lobes. The multifrequency VLBA observations carried out by Maness et al. (2003) provide impressive evidence of intermittent activity: the innermost double (~ 30 pc across) has a FR II type structure. However, some hints of a previous active epoch are still preserved. In particular, the diffuse component ~ 200 pc south of the centre seems to be a remnant of the past active

period. Altogether there are three pairs of lobes visible in this source, two ‘dead’ and one ‘alive’. The authors suggest that the intermittency in 0402+379 is caused by the presence of two orbiting black holes, although they find inconsistencies in that model.

The case of 0402+379 is of particular importance. It is only the third example of a Compact Symmetric Object (CSO) possessing a large-scale structure but the first where “large” scale is actually only a kiloparsec scale. The other two are 0108+388 (Baum et al., 1990) and 1245+676 (Marecki et al., 2003). Finding more of these objects would be essential if more light is to be shed on the mechanisms of AGN ignition. Therefore, we started a search programme to find similar sources or at least good candidates for frequently restarting MSOs based on publicly available data. Once candidates had been identified, their detailed structures could be determined using MERLIN and/or VLBI.

There are several possible ways to find candidate sources. What we did was to inspect the maps of ‘rejects’ i.e. sources not suitable to be used as calibrators as they did not appear pointlike in the Jodrell Bank–VLA Astrometric Survey (JVAS) (Patnaik et al., 1992; Browne et al., 1998; Wilkinson et al., 1998). We found 13 objects (Table 1) in which there was a dominant core straddled by (nearly) symmetric outer components which are the putative lobes pertinent to a previous stage of activity.

Table 1. Candidates for restarted RLAGNs among JVAS rejects

J0458+2011	J1708+0035	J1848+3244
J1012+3309	J1756+2914	J1857+3104
J1520+5635	J1803+0934	J2005+1825
J1628+2247	J1843+3225	J2218+4146
J1647+2705		

There were no published VLBI maps of the sources listed in Table 1 but as JVAS provided a basis for the VLBA Calibrator Survey (VCS, Beasley et al., 2002) a check was made using the VCS server¹ to see if any of the sources, although being JVAS rejects, had been mapped with the VLBA and the resulting images included in the VCS. As expected, quite a few had been included and one of them — J1708+0035 — seemed to be particularly interesting.

3. The case of J1708+0035

J1708+0035 is a galaxy located at a redshift of $z = 0.449$. In the JVAS map (Browne et al., 1998) it appears as a core-dominated aligned triple at P.A. $\approx 25^\circ$ (Fig. 1). Its projected linear size is $\sim 10 h^{-1}$ kpc.

The quality of the VCS maps is rather poor and it is unclear whether this particular source is either a double or a core-jet. Nevertheless, whatever the structure actually is, there is a hint in the VCS maps that it might be *misaligned* with respect to that seen in the JVAS map (Browne et al., 1998). Therefore, we observed J1708+0035 with the VLBA at two frequencies

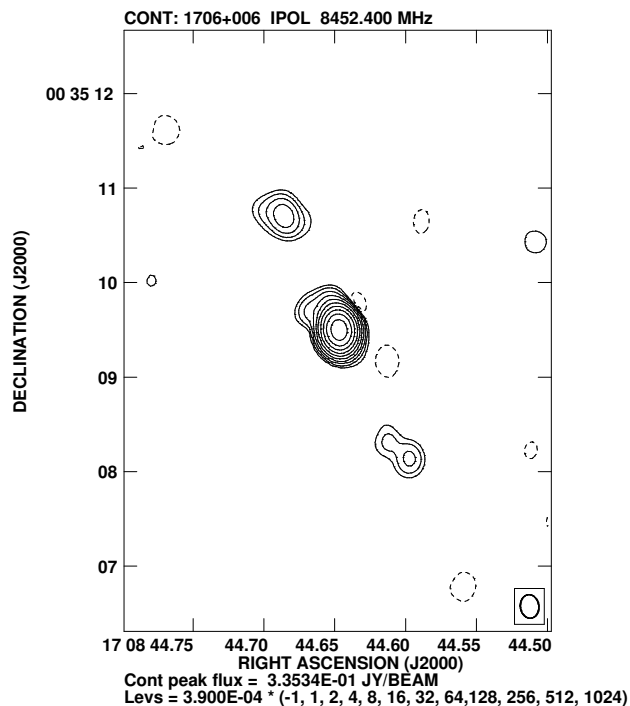


Fig. 1. JVAS map of J1708+0035 acquired with the VLA in A-configuration at 8.4 GHz.

(5 GHz and 15 GHz) and, using standard reduction techniques with phase referencing followed by self-calibration, produced the maps shown in Fig. 2. At 15 GHz the source is a core-jet whereas at 5 GHz an additional steep-spectrum part of the jet is also visible. The whole milliarcsecond structure points to P.A. $\approx -25^\circ$ confirming the existence of a large misalignment between the arcsecond and milliarcsecond structures, tentatively suggested by the VCS maps.

4. Discussion

The phenomenon of misalignments between milliarcsecond- and arcsecond-scale structures in radio sources is well known and has, in fact, been thoroughly investigated — see Appl et al. (1996) for a review. Based on a large collection of observational material, they have concluded that, although it is possible to apply a helical jet model to individual sources, it is difficult to find a single mechanism responsible for the observed distribution of misalignments indicated by a statistically significant peak at $\Delta PA \approx 90^\circ$. This peak is particularly well defined for BL Lac objects. One way to interpret the misalignments is to adopt a complicated twisted helical jets model. This has been done for example by Attridge et al. (1999) for the quasar TXS 1055+018 where the jet is pointing exactly perpendicular to the whole structure of the radio source. More recently, Cassaro et al. (2002) carried out VLBI observations of several BL Lac objects in 1-Jy Sample, in order to investigate the spatial evolution of radio jets from a few tens to hundreds of milliarcseconds, and to search for helical jets in this class of sources. Their EVN and MERLIN observations of bent radio

¹ http://magnolia.vlba.nrao.edu/vlba_calib.

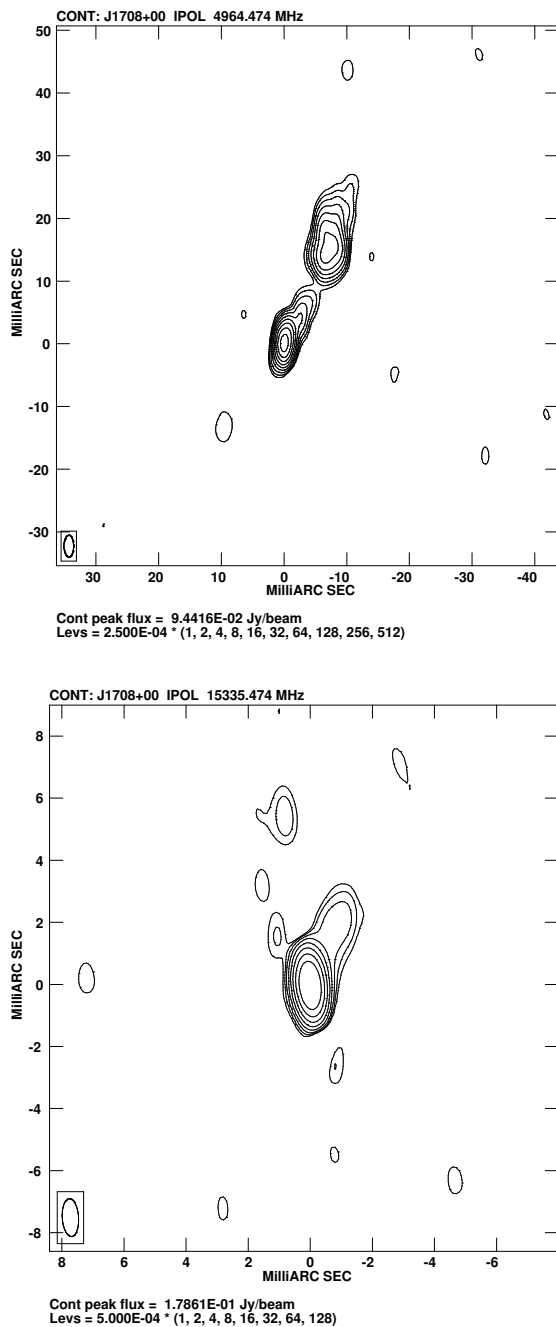


Fig. 2. VLBA maps of J1708+0035 at 5 GHz (top) and 15 GHz (bottom). Note the different scales on both maps. The north-western feature seen in the 5 GHz image does *not* show up on the 15 GHz image at all so its absence in the map shown does not result from the enlargement of the central core-jet feature.

jets in BL Lac objects do not lend firm support to the explanation of misalignments by means of helical jets.

Thus, although an interpretation of misaligned sources based on a twisted jets concept can be argued, adopting a scenario of re-ignition with a simple change of jet axis leads to a straightforward and natural explanation without complex

modelling. Re-ignition becomes even more plausible when the overall linear size of the source in question is small. In the case of TXS 1055+018, which has a size of $150 \text{ kpc } h^{-1}$, a helical model might be viable. However, in the case of J1708+0035 which is 15 times more compact there is simply not enough space for the helix to be squeezed into it.

Finally, we would like to suggest that misaligned sources could actually be compact X-shaped sources in which one ‘arm’ of the cross lies almost in the sky plane and the other ‘arm’, namely the one pertinent to the reborn radio source, is highly beamed toward the observer. But do compact X-shaped sources exist? In fact, such a class has not been recognised so far. Nevertheless, we *have* serendipitously found a map of a compact X-shaped source (TXS 0229+132) in the literature (Murphy et al., 1993). According to Browne (priv. comm.) it is very unlikely that the strange structure of this source could result from gravitational lensing. It is, however, easily imaginable that if one arm of its cross-like structure was pointed towards the observer, the image “distorted” by Doppler boosting would show the pattern we have here: a core-dominated triple. We claim that, taking into account the difficulties of the helical jet model when trying to explain large misalignments (Appl et al., 1996; Cassaro et al., 2002, and references therein), the restarted activity concept is a very competitive alternative because of its simplicity and plausibility.

Acknowledgements. I thank Ian Browne for sharing the JVAS data for J1708+0035 from which we produced the image shown in Fig. 1, and Peter Thomasson for careful reading of the manuscript.

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