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Recurrent activity in radio galaxies

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Abstract. One of the outstanding issues concerning extragalactic radio sources is the total duration of their active phase and the possible existence of duty cycles of their nuclear activity. A duty cycle can be recognized if there is a mechanism which preserves the information of past activity for a sufficiently long time after a new activity has started up. If a new cycle starts before the radio lobes created during a former activity period have faded, we can recognize this by the observations of a young radio source embedded in an old relic structure.

1. Introduction

Classical powerful radio galaxies (RGs) are characterized by extended radio lobes with compact and bright hot spots, and often a compact central radio core. The lobes are powered by two relativistic jets emerging from a supermassive black hole at the center of a galaxy. However, a small fraction of RGs show structures which can by explained as a product of repeated activity of the central AGN.

2. X-shaped Radio Galaxies

The idea of recurrent activity in RGs was first inherent in the models suggested for sources with 'X-shaped' radio morphologies (see Fig. 1). The 'X-shaped' RGs exhibit large, symmetric, and low-luminosity extrusions of radio plasma that extend at some angle from the nucleus to distances comparable to, or exceeding, the length of the active radio lobes. Several scenarios have been suggested for the formation of this kind of RGs, i.e. back-flow of radio plasma from the active lobes, conical precession of the jets, and reorientation of the jet axis. The present observations (e.g. Rottmann 2001) favor the third scenario.

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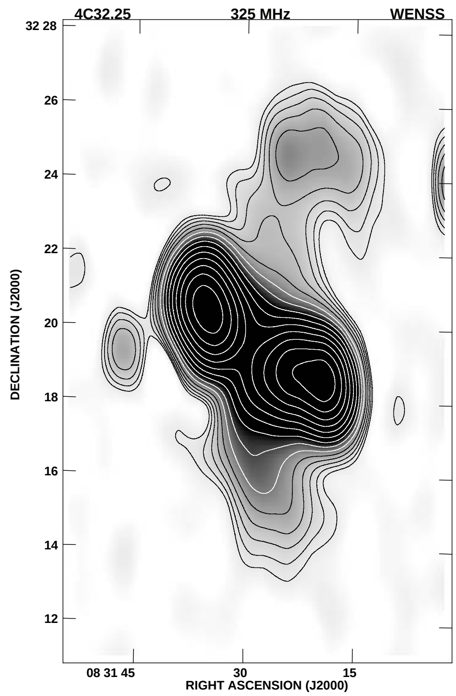

Figure 1. 325-MHz WENSS (Rengelink et al. 1997) map of a 'X-shape' radio source 4C 32.25. Contours are: 1, $\sqrt{2}$, 2, $\sqrt{2}^3$, ... $\times$ 9 mJy/beam area.

3. Double-double Radio Galaxies

A second class of restarted radio sources represent the so-called double-double radio galaxies (DDRGs; Schoenmakers et al. 2000). A DDRG is defined as consisting of two unequally sized, two-sided, double-lobed, edge-brightened radio sources. The two pairs of lobes are aligned and hosted by the same galaxy (for an example of a DDRG (see Fig. 2). We believe that DDRGs provide evidence for a few tens of Myr interruption of the jet activity in AGNs. The young beam of new activity propagates into the cocoon formed in the past activity phase. The ambient medium is, therefore, not intergalactic thermal plasma but synchrotron gas whose density is lower than that of the IGM. The advance speed of the inner lobes should be higher than the speed of the older lobes which expand in denser IGM. Approximately a dozen or so of such objects are known in the literature (Saikia et al. 2006). Synchrotron spectra of the outer and inner lobes of the best studied DDRG, J1453+3308, are shown in Fig. 3.

4. Nesting Radio Galaxies

The third group of sources with repeated activity contains objects with radio morphologies similar to that of Centaurus A or Virgo A. Jamrozy et al. (2007) have reported the discovery of a new galaxy of this class, 4C 29.30. This radio

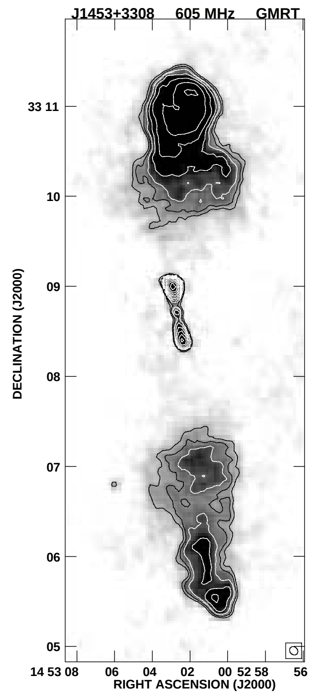

Figure 2. 605-MHz GMRT map of the best studied DDRG J1453+3308 (Konar et al. 2006). Contours are: 1, $\sqrt{2}$, 2, $\sqrt{2}^3$, ... $\times$ 1 mJy/beam area.

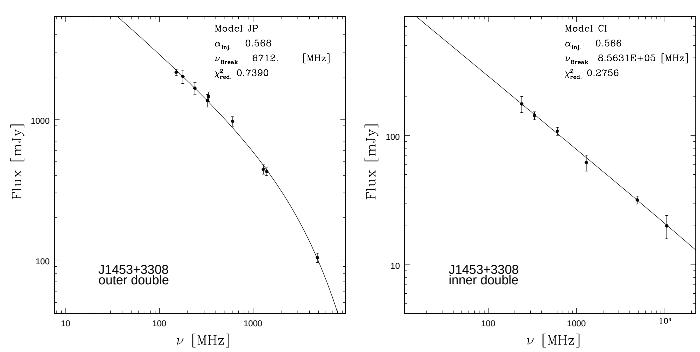

Figure 3. Synchrotron spectra of the outer and inner lobes of J1453+3308. *Right:* The 50 Myr old outer lobes fitted with the Jaffe-Perola model. *Left:* The about 2 Myr old inner lobes fitted with the continuous-injection model.

galaxy (see Fig. 4) is associated with a bright elliptical galaxy at z=0.065. Low-resolution radio maps show evidence of large-scale weak emission with an angular extent of about 520 arcsec (640 kpc). Within the extended structure a small-scale (40 kpc) edge-brightened double-lobed source is embedded. Spectral ageing analysis based on multi-frequency observations between 200 and 8500 MHz show that the outer double is more than 200 Myr old while the compact inner structure is much younger.

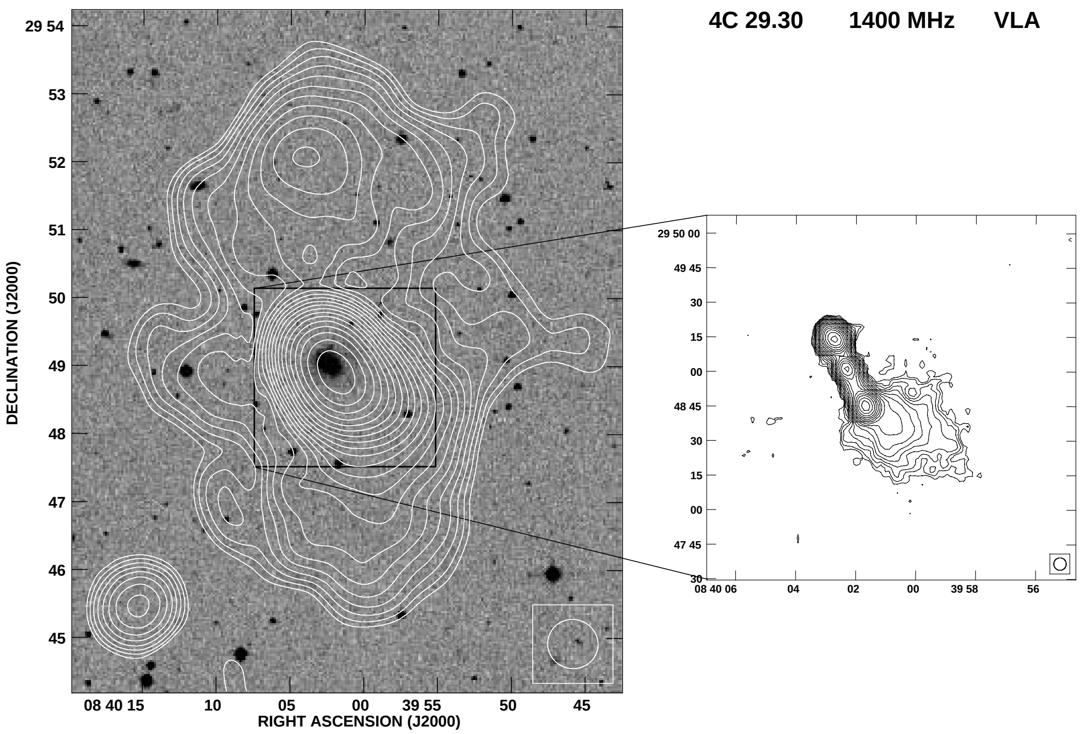

Figure 4. 1400-MHz VLA maps of the galaxy 4C 29.30. *Left:* D-array contour map of the entire source. Contours are: 1, $\sqrt{2}$, 2, $\sqrt{2}^3$, ... $\times$ 0.3 mJy/beam area. *Right:* B-array contour map of the central part of the source from the FIRST survey (Becker et al. 1995). Contours are: 1, $\sqrt{2}$, 2, $\sqrt{2}^3$, ... $\times$ 0.45 mJy/beam area.

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References

Becker, R.H., White, R.L., & Helfand, D.J. 1995, ApJ, 450, 559
Jamrozy, M., Konar, C., Saikia, D.J., et al. 2007, MNRAS, 378, 581
Konar, C., Saikia, D.J., Jamrozy, M., et al. 2006, MNRAS, 372, 693
Rengelink, R.B., Tang, Y., de Bruyn, A.G., et al. 1997, A&AS, 124, 259
Rottmann, H. 2001, Ph.D. Thesis, University of Bonn
Saikia, D.J., Konar, C., & Kulkarni, V.K. 2006, MNRAS, 366, 1391
Schoenmakers, A.P., de Bruyn, A.G., Röttgering, H.J.A., et al. 2000, MNRAS, 315, 371