THE CENTRAL ENGINE OF ACTIVE GALACTIC NUCLEI
*ASP Conference Series, Vol. **VOLUME**, 2007*
Luis C. Ho and Jian-Min Wang

SLAC-PUB-12866

Episodic activity in radio galaxies

D.J. Saikia[1], C. Konar[1], M. Jamrozy[2], J. Machalski[2], Neeraj Gupta[1], Ł. Stawarz[2,3], K.-H. Mack[4], and A. Siemiginowska[5]

[1] *National Centre for Radio Astrophysics, TIFR, Pune, India*
[2] *Uniwersytet Jagielloński, Kraków, Poland*
[3] *Stanford Linear Accelerator Center, USA*
[4] *INAF-Istituto di Radioastronomia, Bologna, Italy*
[5] *Harvard-Smithsonian Center for Astrophysics, Cambridge, USA*

Abstract. One of the interesting issues in our understanding of active galactic nuclei is the duration of their active phase and whether such activity is episodic. In this paper we summarise our recent results on episodic activity in radio galaxies obtained with the GMRT and the VLA.

1. Introduction

In radio galaxies and quasars the extended radio emission provides us with an opportunity to probe their history via the structural and spectral information of the lobes. A striking example of episodic nuclear activity is when a new pair of radio lobes is seen closer to the nucleus before the 'old' and more distant radio lobes have faded (e.g. Subrahmanyan, Saripalli & Hunstead 1996; Lara et al. 1999). Such sources have been christened as 'double-double' radio galaxies (DDRGs) by Schoenmakers et al. (2000). Approximately a dozen or so of such DDRGs are known in the literature (Saikia, Konar & Kulkarni 2006).

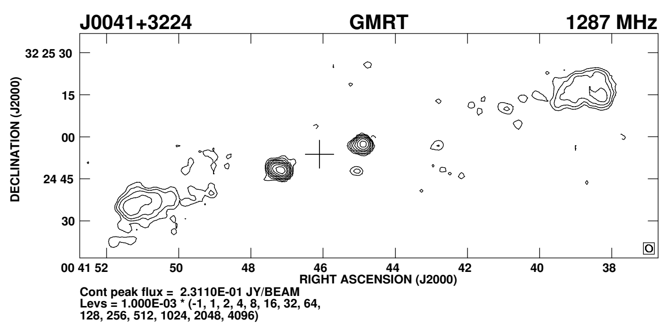

Figure 1. The GMRT image of J0041+3224 at 1287 MHz with an angular resolution of ∼2.7 arcsec (Saikia, Konar & Kulkarni 2006).

From observations made with the Giant Metrewave Radio Telescope (GMRT), Saikia et al. (2006) have reported the discovery of a new DDRG, J0041+3224. The inner and outer doubles are aligned within ∼4° and are reasonably collinear with the parent optical galaxy. The lobes of the outer double have steeper spec-

Contributed to The Central Engine Of Active Galactic Nuclei,
16-21 Oct 2006, Xi'an, China

Work supported in part by US Department of Energy contract DE-AC02-76SF00515

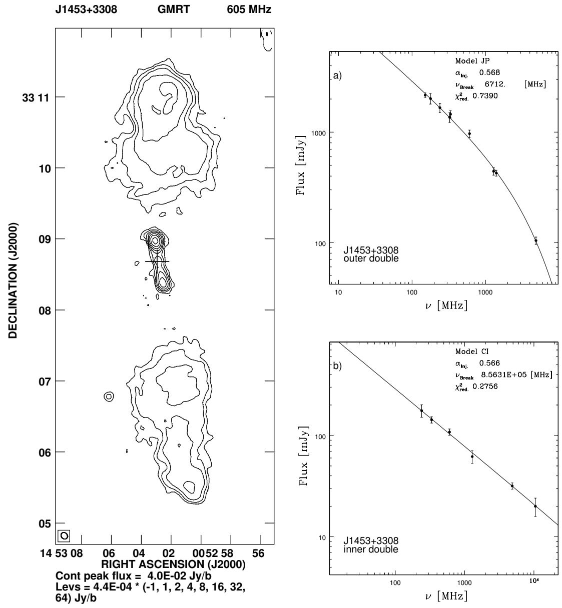

Figure 2. The GMRT image of the DDRG J1453+3308 at 605 MHz with an angular resolution of ∼5.4 arcsec. Spectra of the outer and inner doubles fitted with the models of radiative losses. Upper panel: the outer double fitted with the Jaffe-Perola model; lower panel: the inner double fitted with the continuous-injection model (Konar, Saikia, Jamrozy & Machalski 2006).

tral indices compared with those of the inner double. The time scale of interruption of jet activity has been estimated to be ∼20 Myr similar to other known DDRGs. For an estimated redshift of ∼0.45, the linear size of the outer double is 969 kpc, while that of the inner double is 171 kpc ($H_\circ$=71 km s^{-1} Mpc^{-1}, Ω_m=0.27, Ω_Λ=0.73). The luminosity of the outer and inner double at 1400 MHz is $\sim 3.3\times10^{26}$ and 3.6×10^{26} W Hz^{-1} respectively.

Unlike most DDRGs with l_{in} less than about 50 kpc, the inner double of J0041+3224 is marginally more luminous than the outer one. Schoenmakers et al. (2000) reported an inverse correlation between the ratio of the luminosities of the outer and inner doubles, $P_{o:in}$, and l_{in}. For their sample of DDRGs the luminosity ratio, $P_{o:in}$, is as high as ∼100 for $l_{in}\sim$50 kpc and approaches unity when l_{in} approaches values close to a Mpc, the ratio being always >1. Considering the more compact inner doubles with l_{in} less than a few kpc, namely J1006+3454 (3C236) and J1247+6723, the inner doubles are significantly more luminous than the outer ones. This suggests that in the early phase of the evolution of the inner double, where it is ploughing its way through the dense interstellar medium, conversion of beam energy into radio emission may be more efficient. In this case, the ratio of the luminosity of the outer to the inner double could increase with size before decreasing and approaching a value of about unity when l_{in} approaches ∼1 Mpc. We also note that the inner doubles appear to be more asymmetric in both its armlength and flux density ratios compared with the outer doubles, although they appear marginally more collinear with the radio core than the outer doubles.

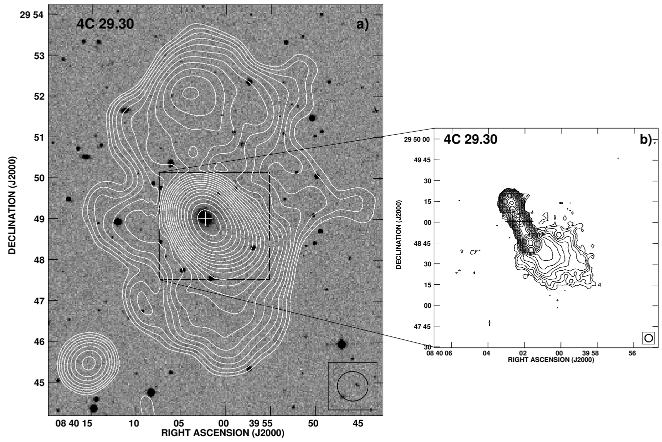

Figure 3. 1400-MHz VLA images of 4C 29.30. **a)** D-array contour map of the entire source overlayed on the optical field from the Digital Sky Survey. **b)** B-array contour map of the central part of the source from FIRST (Jamrozy, Konar, Saikia, Stawarz, Mack & Siemiginowska 2006).

2. Spectral ages of DDRGs

Low-frequency GMRT observations along with high-frequency Very Large Array (VLA) observations can play an important role in determining spectral ages of radio sources. New radio observations at frequencies ranging from 240 to 4860 MHz of the well-known, DDRG, J1453+3308, have helped determine the spectra of the inner and outer lobes over a large frequency range and demonstrate that while the spectrum of the outer lobes exhibits significant curvature, that of the inner lobes appears practically straight. The break frequency, and hence the inferred synchrotron age of the outer structure, increases with distance from the heads of the lobes. The maximum spectral ages for the northern and southern lobes are ∼47 and 58 Myr respectively. Because of the difference in the lengths of the lobes these ages imply a mean separation velocity of the heads of the lobes from the emitting plasma of 0.036c for both the northern and southern lobes. The synchrotron age of the inner double is about 2 Myr which implies an advance velocity of ∼0.1c, but these values have large uncertainties because the spectrum is practically straight (Konar et al. 2006).

3. 4C29.30

Besides the DDRGs, diffuse relic radio emission due to an earlier cycle of activity may also be visible around the radio lobes which are currently being fed by the jets. This relic radio emission is expected to remain visible for $\sim 10^8$ yr or so. In the radio galaxy 4C29.30 (J0840+2949) Jamrozy et al. (2006) have reported the existence of weak extended emission with an angular size of ∼520 arcsec (639 kpc) within which a compact edge-brightened double-lobed source with a size of 29 arcsec (36 kpc) is embedded. From multifrequency observations at frequencies ranging from 240 to 8460 MHz, Jamrozy et al. show that the inner

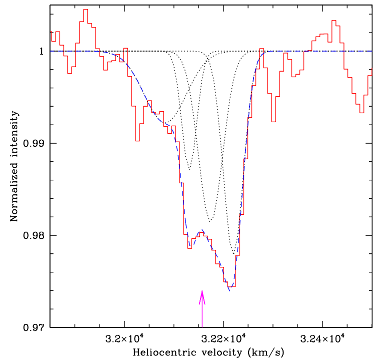

Figure 4. The HI absorption spectrum (histogram) towards the compact inner double of the radio galaxy J1247+6723. The Gaussian components fitted to the absorption profile and the sum of these components are also shown. The systemic velocity (32157 km s^{-1}) has been marked by an arrow (Saikia, Gupta & Konar 2006).

double is younger than the outer diffuse emission, suggesting that the extended diffuse emission is possibly due to an earlier cycle of activity.

4. HI gas in the nuclear regions of DDRGs

If renewed activity is due to a fresh supply of gas, one might find a higher incidence of HI or CO gas towards the central regions of these systems. We have found HI absorption towards the inner double of the DDRG J1247+6723 with the GMRT. The inner double is a giga-Hertz peaked spectrum source with a linear size of 14 pc while the overall size defined by the outer double is 1195 kpc, making it a giant radio source. The absorption profile is well resolved and consists of a number of components on either side of the optical systemic velocity. The neutral hydrogen column density is estimated to be $N(\mathrm{HI})=6.73\times10^{20}(T_s/100)(f_c/1.0)$ cm^{-2}, where T_s and f_c are the spin temperature and covering factor of the background source respectively. We suggest that there could be a strong relationship between the occurrence of HI absorption and rejuvenation of radio activity, the other examples in this category being 3C236, 3C258 and 3C293.

References

Jamrozy, M., Konar, C., Saikia, D.J., Stawarz, Ł., Mack, K.-H., & Siemiginowska, A. 2006, MNRAS, submitted
Konar, C., Saikia, D.J., Jamrozy, M., & Machalski, J. 2006, MNRAS, 372, 693
Lara, L., Márquez, I., Cotton, W.D., Feretti, L., Giovannini, G., Marcaide, J.M., & Venturi, T. 1999, A&A, 348, 699
Saikia, D.J., Konar, C., & Kulkarni, V.K. 2006, MNRAS, 366, 1391
Saikia, D.J., Gupta, N., & Konar, C. 2006, MNRAS, in press (astro-ph/0611837)
Schoenmakers, A.P., de Bruyn, A.G., Röttgering, H.J.A., van der Laan, H., & Kaiser, C.R. 2000, MNRAS, 315, 371
Subrahmanyan, R., Saripalli, L., & Hunstead, R.W. 1996, MNRAS, 279, 257