A radio study of misaligned double-double radio galaxies

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Out line of talk

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- A misaligned DDRG 3C293
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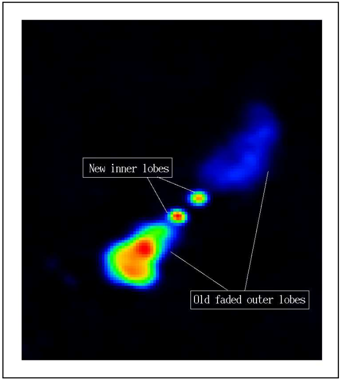
- Conclusion

Introduction

‘Double-double radio galaxies’ (DDRGs) provide an unique opportunity to study the episodic nature of jet in AGN.

Examples of DDRGs with radio morphological evidence for changed axes between activity epochs are rare.

These objects form a valuable resource for understanding the occurrence rate of perturbations to the black hole axes and for examining time-scales and conditions under which the axes change.



A double-double candidate, J0746+4526 (Nandi et al. 2014).

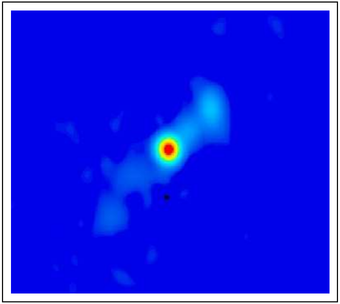
A study of the misaligned DDRG 3C293

Objectives:

To present the results of low-frequency observations.
Estimation of ages of the inner and the outer lobes to give information about the active phase of AGN and phase of interruption of jet flow.

A study of the misaligned DDRG 3C293

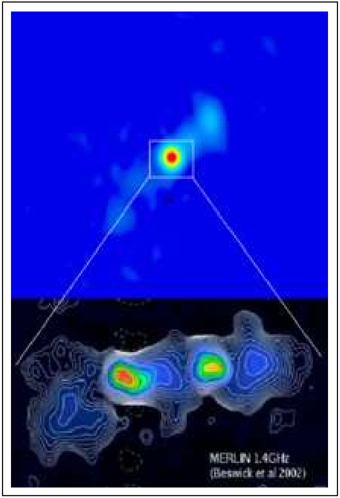
- 3C293 is a striking example of a DDRG. It is a highly misaligned DDRG.
- Redshift of 0.045, with a projected linear size 190 kpc. The optical host galaxy is peculiar with compact knots and multiple dust lanes (de Koff et al. 2000) and appears to be a merger remnant. It has a small companion galaxy towards the southwest (Beswick et al. 2004)



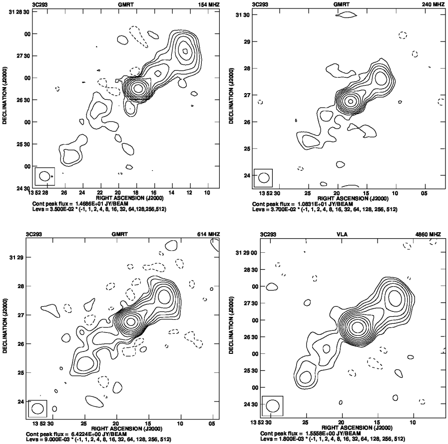
GMRT image at 614 MHz

A study of the misaligned DDRG 3C293

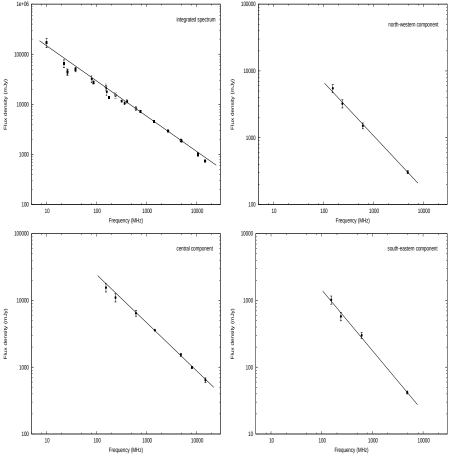
- The prominent central core contains a compact double-lobed source with multiple components (Akujor et al. 1996; Beswick et al. 2004).
- The projected linear separation of the two prominent peaks on opposite sides of the nucleus is $\sim$1.7 kpc. The total extent of the inner source including the extended emission is $\sim$4.2 kpc.



misaligned DDRG 3C293



Two lobes are highly asymmetric in intensity. The north-western component has a hotspot which is brighter than the peak of emission at the outer extremeties of the southern lobe by a factor of ∼10. The ratio of the total flux densities lies between a factor of ∼5 and 7, depending on the frequency of observations



The flux densities of all the three components are consistent with straight spectra, the spectral indices being 0.72$\pm$0.02 for the central component, and 0.80$\pm$0.02 and 0.91$\pm$0.03 for the north-western and south-eastern components.

Spectral ages

The spectral age, $\tau_{\rm spec}$, is given by

$$\tau_{\rm spec} = 50.3 \frac{B^{1/2}}{B^2 + B_{\rm iC}^2} \left\{\nu_{\rm br}(1+z)\right\}^{-1/2} [\rm Myr], \qquad (1)$$

Magnetic field strength for each strip calculated using equipartition formula. On the other hand $B_{\rm iC}$=$0.318(1+z)^2$ is the magnetic field strength equivalent to the CMBR.

The equipartition magnetic field estimate for the inner double is 16.92$\pm$1.67 nT, indicating that for a conservative break frequency $\gtrsim$16 GHz, the inferred spectral age is $\lesssim$0.18 Myr.

For the extended lobes, where reliable measurements of the total flux density are available up to $\sim$5 GHz, the magnetic field strengths are 1.12$\pm$0.11 and 0.88$\pm$0.09 nT for the north-western and south-eastern lobes respectively, while the corresponding spectral ages are $\lesssim$16.9 and 23.0 Myr respectively for a break frequency $\gtrsim$5 GHz.

The hot-spot in the north-western lobe implies that it still receives jet material.To be able to see the hot-spot as well as the inner structure, the interruption of jet activity must be less than 0.1 Myr, within which period of time the inner double must also form.

Till date a few dozen good examples of recurrent activities of AGNs have been identified. Restarting of AGN activity in radio galaxy is still not clear. To understand the nature of these sources and possible reasons for their episodic activity, we need to enlarge the sample of objects.

Based on only radio structural information Proctor (2011) classified 242 sources as candidate DDRGs. Further detailed investigation of these sources along with optical data from SDSS[a] and DSS[b] catalogues showed only 23 of these sources to be promising examples of DDRGs (Nandi & Saikia 2012).

[a] http://www.sdss3.org/dr9/
[b] http://archive.eso.org/dss/dss

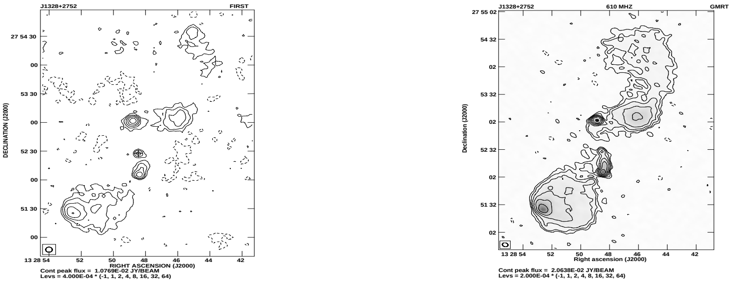
Table 1: Some of the observed properties of the sample of DDRGs

Source	Opt. Id.	Red-shift	l_{in} kpc	l_o kpc	Cmp.	$R_{\theta(in)}$	$R_{\theta(o)}$	$R_{s(in)}$	$R_{s(o)}$	P_{in} W/Hz	P_o W/Hz
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
J0746+4526		(0.517)	95	630	N/S	1.86	1.35	0.79	0.19	25.41	26.17
J0804+5809					W/E	2.00	0.99	1.43	0.81		
J0855+4204	G	(0.279)	40	516	N/S	1.17	0.86	1.34	0.87	24.64	25.30
J0910+0345	G	(0.588)	34	225	E/W	2.17	0.73	0.84	0.99	25.85	25.66
J1039+0536	G	0.0908	29	163	W/E	1.25	0.74	1.03	1.29	24.05	24.97
J1103+0636	G	(0.449)	71	652	E/W	1.28	0.93	1.51	0.72	24.99	25.56
J1158+2621	G	0.1120	143	503	N/S	1.70	1.01	1.81	1.31	24.33	24.80
J1208+0821	G	(0.600)	121	687	W/E	1.07	1.04	0.93	0.96	24.49	25.76
J1238+1602	S				S/N	1.23	0.91	1.12	0.79		
J1240+2122	G	(0.357)	68	584	S/N	2.00	1.07	4.40	0.72	25.10	25.42
J1326+1924	G	0.1762	27	149	E/W	1.20	1.25	1.06	0.65	23.68	24.56
J1328+2752	G	0.0911	95	355	N/S	1.53	1.61	1.85	0.63	23.76	24.39
J1344−0030	G	(0.579)	86	643	N/S	1.25	1.06	1.30	0.35	25.46	25.60
J1407+5132	G	(0.324)	87	613	W/E	1.40	0.84	1.51	0.62	24.43	26.15
J1500+1542	G	(0.456)	128	485	S/N	1.54	0.76	1.68	1.27	24.93	24.92
J1521+5214	G	(0.537)	64	391	S/N	1.50	0.74	2.09	0.81	24.99	25.28
J1538−0242	G	(0.575)	59	534	N/S	1.16	0.93	0.73	1.24	25.05	26.30
J1545+5047	G	0.4309	66	483	E/W	1.12	0.84	0.67	1.23	24.95	25.69
J1605+0711	G	(0.268)	311	576	S/N	1.30	1.06	0.54	0.69	25.05	25.38
J1627+2906	G	(0.722)	74	702	N/S	2.20	0.98	0.80	1.46	25.40	26.30
J1649+4133	S				E/W	1.25	0.94	1.38	1.66		
J1705+3940	G	(0.701)	130	528	S/N	1.70	0.96	2.52	1.27	25.84	26.07
J1706+4340	S				S/N	1.24	0.98	8.67	0.59		

One more misaligned DDRG

From our study we identified a new misaligned candidate J1328+2752. To confirm its renewed jet activity we observed this source with the Giant Metrewave Radio Telescope (GMRT) at 607 MHz.

The projected linear size of the inner and outer double 95 kpc and 355 kpc respectively. The lobes of the outer double are asymmetric in nature.



Left panel: The FIRST image at 1400 MHz. Right panel: The GMRT image at 607 MHz.

- The two-point spectral indices for the NW_{out} and SE_{out} lobes are 1.46 and 1.21 respectively. The spectral indices for the NW_{inn} and SE_{inn} components are 0.68 and 1.18 respectively.
- The steeper spectral indices of the outer lobes, suggest that these are formed due to much older emission.
- A more detailed multi-frequency study would be required to estimate its ages.

Conclusion

- Such objects indicates that an AGN not only gives a irregular jet outflow but also there is irregularity in direction of its ejection axis.
- For 3C293 we have determined the spectra of the outer and inner lobes over a large frequency range. Our estimation shows that the interruption of jet activity of 3C293 to be $<$0.1 Myr, much smaller than the other known DDRGs.
- The overall linear size of these sources is much smaller than most DDRGs. Such objects help us explore the intermediate range of time scales of episodic nuclear activity.

Thanks