RADIO-OPTICAL CORRELATIONS IN DISTANT RADIO GALAXIES

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ABSTRACT

Optical identifications and redshifts are now available for nearly all 3CR radio galaxies (Spinrad *et al.* 1985; Djorgovski *et al.* 1988). Using new radio and optical observations, supplemented with data from the literature, we are conducting a systematic comparison of their radio and optical (emission-line and galaxy) properties, and their dependence on redshift. Here we present new results on the alignments of galaxies and their associated radio sources, and radio source asymmetries.

1. RADIO SOURCE AND GALAXY ALIGNMENTS

The number of (elongated) galaxies and extended emission-line regions which are aligned with their associated radio sources increases rapidly with redshift (see Table). The emission-line regions in some distant radio galaxies appear to be better aligned with the *inner* radio axes (3C 294, Spinrad *et al.* 1988). In several sources the optical line emission extends *beyond* their radio hotspots (3C 435A, van Breugel and McCarthy 1987).

Because of the strong correlation between radio power and redshift in the (flux limited) 3CR sample it is not possible to determine which of these parameters is more fundamental for the observed alignments. Current evidence suggests that the radio/optical *galaxy* alignments may be due to star bursts which have been triggered by the bowshocks and backflows associated with the radio hotspots as they propagate through their (young, proto ?) galactic media (McCarthy *et al.* 1987; Chambers *et al.* 1987).

The emission-line morphologies suggest that the radio galaxies may have an anisotropic source of (photo-) ionization which is associated with their radio jets or AGN's, strong evidence for which has also been found from spectroscopic measurements (McCarthy *et al.* 1987; Baum and Heckman 1988). The slightly S-shaped radio morphology of 3C 294 and alignment of the emission-line gas with the inner radio axis would be a natural consequence from a change in direction (for example because of precession) of such a collimated source of ionization.

2. RADIO SOURCE ASYMMETRIES

The fraction of 3CR, FRII–type radio galaxies with asymmetric lobes, both in terms of their relative lobe distances ($D_r = D_{max}/D_{min}$) and integrated flux densities (F_r at 5 GHz, ($F_r = F_{max}/F_{min}$) increases rapidly with redshift. In virtually all sources with D_r–asymmetries the brightest emission-line gas is on the side of the lobe closer to the radio galaxy nucleus, even if D_r is relatively small. Longslit–spectroscopic observations show that there is no correlation between blue- or redshifted gas velocities relative to the radio AGN's and radio morphology asymmetries. Using radio data of 3CR (and other) quasars by Barthel and Miley (1988), and by Neff *et al.* (1988) we find that radio galaxies and

D. E. Osterbrock and J. S. Miller (eds.), Active Galactic Nuclei, 546–547.

https://doi.org/10.1017/S0074180900141968 Published online by Cambridge University Press

quasars seem to have similar $D_r(z)$ distributions, except that for z $\lesssim$ 1.0 the fraction of radio galaxies with large F_r asymmetries ($\sim$ 22%) is smaller than for quasars ($\sim$ 50%). D_r and F_r do not appear to be correlated (for radio galaxies nor quasars).

The kinematic data of the emission-line gas suggests that the D_r and F_r asymmetries for radio galaxies are *not* dominated by projection effects of approaching vs. receding lobes i.e. differences in light travel time (= evolution), or relativistic Doppler effects enhancing the brightness in approaching lobes. Two possible explanations are: (1) non-uniform ambient media or (2) non-synchronous ejection of jets from their AGN's. In either case a redshift dependence of the asymmetries would occur since the environments at early epochs were more dense and inhomogeneous (mergers ?), and early nuclear activity might be more erratic. The similar asymmetry–distributions of radio galaxies and quasars at high redshifts, is somewhat unexpected if these two classes of objects would be related in a simple evolutionary scheme such as proposed by Hutchings *et al.* 1988.

ASYMMETRIES AND ALIGNMENTS IN POWERFUL RADIO SOURCES

Z	$D_r \gtrsim 2$		$F_r \gtrsim 2$		$\mid PA_{radio} - PA_{opt} \mid$
	RG	QSR	RG	QSR	(Major Axes)
0.0 – 0.2	0/24 (0%)	0/2 (-%)	2/8 (25%)	2/2 (-%)	$\gtrsim$ 75° 8/26 (31%)
0.2 – 0.6	3/28 (11%)	0/12 (0%)	8/34 (24%)	6/12 (50%)	Transition
0.6 – 1.0	2/25 (8%)	1/14 (7%)	7/33 (21%)	6/14 (43%)	$\lesssim$ 15° 9/15 (60%)
1.0 – 2.0	6/26* (23%)	8/32$^\heartsuit$(26%)	17/32 (53%)	40/47$^\heartsuit$(85%)	$\lesssim$ 15° 14/16 (88%)

$F_r = F_{max}/F_{min}$, at 5 GHz (observed). Differential K-corrections for lobe pairs with different spectral indices may change these values somewhat as function of z.

$D_r = D_{max}/D_{min}$. Sources $\lesssim$ 4″ with no radio cores were excluded since optical positions typically have $\sim$ 1″ uncertainties.

* = excludes one source $\lesssim$ 4″ with no radio core (3C 454.1), and one $\gtrsim$ 4″ with no core and no galaxy (3C 326.1). $^\heartsuit$ = Neff *et al.* (1988) 1 $\lesssim$ z $\lesssim$ 2 sample.

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