A&A 410, 139–141 (2003)
DOI: 10.1051/0004-6361:20031329

Astronomy & Astrophysics

Research Note

Radio emission and the optical isophotal twist of radio-loud ellipticals

Gopal-Krishna[1], A. R. Dhakulkar[2], P. J. Wiita[3], and S. Dhurde[2]

[1] National Centre for Radio Astrophysics, TIFR, Pune University Campus, Pune 411007, India
[2] Department of Physics, University of Pune, Pune 411007, India
[3] Dept. of Physics and Astronomy, MSC 8R0314, Georgia State University, Atlanta, GA, 30303-3088, USA

Received 23 April 2003 / Accepted 22 August 2003

Abstract. Using the surface photometric analysis data for a well defined sample of 79 nearby radio galaxies ($z \leq 0.12$), it is shown that the level of radio emission associated with an elliptical galaxy during the radio-loud phase is related to the presence of large amounts of isophotal twist in its optical image. In particular, radio galaxies with $P_{408} > 3 \times 10^{25}$ W Hz^{-1} appear to show a preference to be associated with elliptical hosts exhibiting an isophotal twist in excess of $\sim 20^{\circ}$.

Key words. galaxies: active – galaxies: elliptical and lenticular – galaxies: formation – galaxies: interactions – galaxies: photometry – radio continuum: galaxies

1. Introduction

Whereas supermassive black holes are now known to reside in the nuclei of many elliptical galaxies (e.g. Magorrian et al. 1998; Gebhardt et al. 2000; Ferrarese & Merritt 2000), only a tiny fraction of them hosts powerful (twin-lobed) radio sources. What triggers the nuclear activity and how it is related to the actual formation and evolution of the host galaxy are widely debated issues. It is well established that powerful radio emission is almost exclusively associated with the spheroidal component of galaxies. However, at any given epoch, an overwhelming majority of luminous spheroidal galaxies sampled is found to be radio-quiet (e.g., Wisotzki et al. 2001). One oft discussed possibility, based on direct observations, is that galaxy mergers or interactions could be playing an important role in radio activity, as indicated by the frequent presence of optical isophotal distortions, shells and dust lanes seen in radio-loud ellipticals, particularly in the more powerful Fanaroff-Riley (1974) Class II (FR II) radio galaxies (RGs) (e.g., Heckman et al. 1986). It has also been proposed that the formation of the weaker FR I RGs may involve merging of early-type galaxies deficient in dense ISM, as the FR I RGs are often located in richer environments (Colina & Pérez-Fournon 1990; Colina & de Juan 1995).

Another set of potentially important clues reported on the basis of morphological analyses of the optical images are: (i) a marked tendency for the radio-loud ellipticals to be rounder than normal ellipticals (Disney et al. 1984; Calvani et al. 1989); (ii) a strong correlation between *boxiness* of the elliptical host and its radio emission (Bender et al. 1987, 1989). Both of these issues are addressed in a more recent study based on a surface photometric analysis of a well defined sample of 79 radio galaxies at $z \leq 0.12$ (Govoni et al. 2000, hereafter GFFS). Their analysis, however, did not confirm the suggestion that radio-loud ellipticals are rounder in shape, in agreement with the conclusions also reached by Smith & Heckman (1989) for powerful RGs, by Ledlow & Owen (1995) for (mostly) FR I RGs in Abell clusters, and by Falomo et al. (2000) for the hosts of BL Lacertae objects. Secondly, GFFS find no clear correlation between radio emission and the presence of *boxy* isophotes in the host, in agreement with Ledlow & Owen (1995) (see also, Jorgenson et al. 1995; González-Serrano et al. 1993). Another potentially interesting result emerging from their study concerns the presence of non-concentric disposition of the isophotes, which is believed to be a strong measure of galaxy interaction. In this respect, they find no significant difference between the FR I and FR II members of their sample of radio galaxies.

Larger isophotal twist is another potential indicator of strong galaxy interaction or merger events, although a small amount of isophotal twist could arise simply from the triaxiality of the galaxy (e.g., Kormendy 1982). The twist is quantified in terms of the total position angle variation, ΔPA, of the major axis of the stellar component over the entire range in surface

Send offprint requests to: Gopal-Krishna,
e-mail: krishna@ncra.tifr.res.in

brightness. However, isolated ellipticals are found to show a similar distribution of twist angle as a randomly selected sample of ellipticals, suggesting that by and large, twisting is probably an intrinsic property (Fasano & Bonoli 1989; also, Falomo 2003).

2. Is the radio output of radio-loud ellipticals related to isophotal twist?

Recently, Govoni et al. (2000) have reported a two-dimensional surface photometry analysis for 79 ellipticals with $z < 0.12$, extracted from two complete samples of radio galaxies. Among other parameters, they have published for each elliptical the value of its ellipticity, $\epsilon = 1 - b/a$, measured at its effective radius. Also, for 78 out of the 79 ellipticals, they have reported the isophotal twist angle, ΔPA. This is the maximum twist observed over the range of isophotes. (Note that they have excluded both the isophotes at radii <5″ as they are usually affected by seeing related smearing as well as the values of PAs having errors larger than 8°.) These superior data support the earlier claim that, statistically, rounder radio galaxies tend to have larger isophotal twists (Galletta 1980; Fasano & Bonoli 1989). As seen from the ϵ versus ΔPA diagram (Fig. 16 of GFFS), essentially all the elongated ellipticals ($\epsilon > 0.3$) have ΔPA < 10°. In contrast, for less elongated ellipticals ($\epsilon < 0.3$), the amount of isophotal twist appears to be independent of ellipticity (although few galaxies have ΔPA > 40°). The origin of this trend is unclear.

The median value ΔPA for the GFFS sample is found to be ∼10°, similar to ΔPA ∼ 16° found for a sample of isolated ellipticals using an identical method (Fasano & Bonoli 1989). Also, at least for $z < 0.2$, there is no significant statistical difference between the isophotal twist for radio galaxies and radio-quiet ellipticals (Falomo et al. 2000). Thus, it would appear that radio emission has no obvious dependence on isophotal twisting. In contrast, Colina & de Juan (1995) found a significantly larger twisting for FR I radio galaxies, with a median twist angle of ∼14°, compared to a sample of isolated normal ellipticals studied by Sparks et al. (1991) for which the median twist angle is only ∼4°.

To follow up these rather conflicting claims, we have examined the distribution of ΔPA against P_{408} for the GFFS sample (Fig. 1). The values of these two parameters are directly taken from GFFS, so we follow them in taking H_0 = 50 km s^{-1} Mpc^{-1} and $q_0 = 0$. For two of the 78 radio galaxies, the values of P_{408} are not tabulated by GFFS and we have determined these by extrapolating from the values of P_{2700} given in GFFS and P_{843} reported by Jones & McAdam (1992).

From Fig. 1, one notices an upper envelope of the data points, which rises with the radio luminosity until $P_{408} \sim 10^{26}$ W Hz^{-1}. In particular, larger twist angles (ΔPA > 20°) are found almost exclusively above $P_{408} \simeq 3 \times 10^{25}$, which is close to the well known average transition luminosity between the low and high power radio sources (Fanaroff & Riley 1974). We note, however, that there is a considerable overlap between the morphologically determined FR I and FR II sources in the luminosity range considered here (e.g. Ledlow & Owen 1995). In fact, as can be seen from Fig. 1, there is no obvious relation

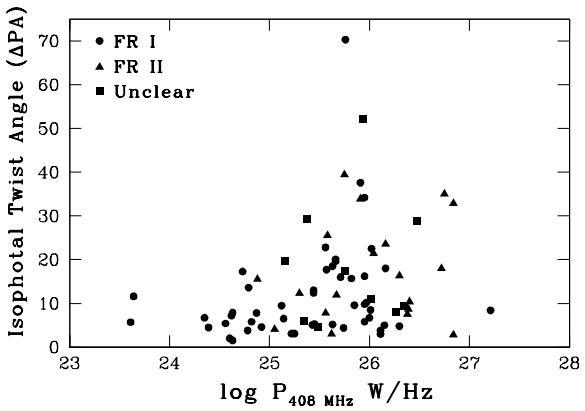

Fig. 1. Isophotal twist angles against radio power for this sample. FR I sources are denoted by circles, FR II's by triangles, and intermediate or unclear sources by squares.

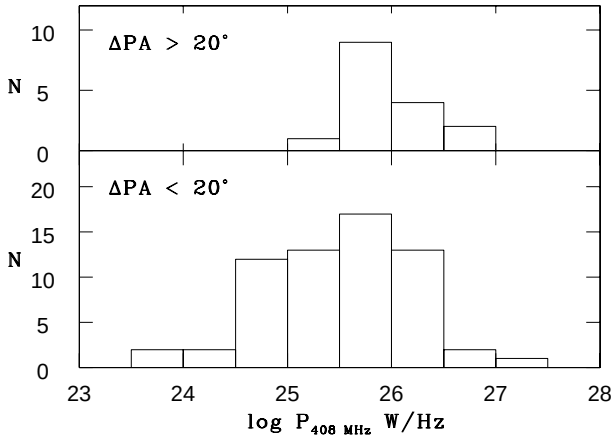

Fig. 2. Distributions of large (ΔPA > 20°) and small (ΔPA < 20°) isophotal twists against radio power.

between twist angle and FR classification; in order to avoid introducing possible bias into the present analysis, we have simply adopted the FR classification given by GFFS. Govoni et al. (2000) themselves note that the mean twist for FR I's is 13° ± 12° while for FR II's it is nearly identical: 15° ± 12°.

Another version of Fig. 1 is displayed in Fig. 2 where the histograms of P_{408} are presented for two ranges of the twist angle separated at ΔPA = 20°. A Kolmogorov-Smirnov test shows that the two distributions are statistically different at the 97% confidence level. Thus, there seems to be a relation between isophotal twist and radio luminosity for massive ellipticals in their active phase, and the two may share a common origin.

Here it may be recalled that in any flux limited sample, such as the present one (GFFS), luminosity is strongly correlated with redshift. It is therefore conceivable that the primary correlation is between the parameters ΔPA and z. However, this is highly unlikely, since that would imply an unphysically steep cosmological evolution of ΔPA, given that the entire sample is defined over a very narrow range in redshift ($z \leq 0.12$). Explicitly, a plot of twist angle against redshift shows that sources with ΔPA > 20° are essentially uniformly distributed in z. Alternatively, the radio power could be correlated

primarily with the rounder shape of the host (Sect. 1), given the $\Delta PA - \epsilon$ dependence mentioned above. However, as also concluded by Govoni et al. (2000), we find no significant correlation of radio power with ellipticity of the host to be evident in the GFFS sample. Thus, it appears more likely that, during the radio-loud phase, powerful radio sources are preferentially associated with ellipticals exhibiting relatively large isophotal twist. At the same time, a large twist cannot be a sufficient condition for generating and sustaining strong nuclear activity, since similarly large twists are also seen in radio-quiet ellipticals (Falomo et al. 2000; Fasano & Bonoli 1989).

In summary, the relation between radio power and the isophotal twist reported here suggests that during the radio-loud phase of an elliptical galaxy the conditions giving rise to a more powerful radio source are reflected in the occurrence of larger isophotal twist of the stellar component. At present, no satisfactory theoretical explanation is available for this trend. It is certainly conceivable that a recent merger or strong tidal interaction could both twist the isophotes and drive more gas into the central engine, thereby triggering the radio activity, but no convincing results on the mechanisms and relative timescales of these phenomena are yet available. We also note that there is some support for the scenario in which radio loudness is linked to the spin of the nuclear black hole (Wilson & Colbert 1995; also, Small & Blandford 1992; Rees 1978). Thus it is of considerable interest to investigate any possible link between the isophotal twist of the stellar body and the process of spinning up the supermassive black hole at the nucleus. It is clearly also important at this stage to verify the empirical trend emerging in the present analysis, using an independent sample of radio galaxies.

Acknowledgements. We thank Prof. V. Kulkarni for helpful comments and the anonymous referee for suggestions that improved the clarity of the manuscript. P.J.W. is grateful for hospitality at Princeton University Observatory and for support from RPE funds at GSU.

References

Bender, R., Döbereiner, S., & Möllenhoff, C. 1987, A&A, 177, L53
Bender, R., Surma, P., Döbereiner, S., Möllenhoff, C., & Madejsky, R. 1989, A&A, 271, 35
Calvani, M., Fasano, G., & Franceschini, A. 1989, AJ, 97, 1319
Colina, L., & de Juan, L. 1995, ApJ, 448, 548
Colina, L., & Pérez-Fournon, I. 1990, ApJ, 349, 77
Disney, M. J., Sparks, W. B., & Wall, J. V. 1984, MNRAS, 206, 899
Falomo, R. 2003, in High Energy Blazar Astronomy, ed. A. Sillanpaa, L. Takalo, & E. Valtaoja, ASP Conf. Ser. (San Francisco: ASP), in press [astro-ph/0212164]
Falomo, R., Scarpa, R., Treves, A., & Urry, C. M. 2000, ApJ, 542, 731
Fanaroff, B. L., & Riley, J. M. 1974, MNRAS, 167, 31
Fasano, G., & Bonoli, C. 1989, A&AS, 79, 291
Ferrarese, L., & Merritt, D. 2000, ApJ, 539, L9
Galletta, G. 1980, A&A, 81, 179
Gebhardt, K., Bender, R., Bower, G., et al. 2000, ApJ, 539, L13
González-Serrano, J. I., Carballo, R., & Pérez-Fournon, I. 1993, AJ, 105, 1710
Govoni, F., Falomo, R., Fasano, G., & Scarpa, R. 2000, A&A, 353, 507 (GFFS)
Heckman, T., Smith, E. P., Baum, S. A., et al. 1986, ApJ, 311, 526
Jones, P. A., & McAdam, W. B. 1992, ApJS, 80, 137
Jorgenson, I., Franx, M., & Kjaergaard, P. 1995, MNRAS, 273, 1097
Kormendy, J. 1982, in Morphology and Dynamics of Galaxies, ed. L. Martinet, & M. Mayor, 12th Advanced Course of the Swiss Society of Astronomy and Astrophysics, 113
Ledlow, M. J., & Owen, F. N. 1995, AJ, 110, 1959
Magorrian, J., Tremaine, S., Richstone, D., et al. 1998, AJ, 115, 2285
Rees, M. J. 1978, Nature, 275, 516
Small, T. A., & Blandford, R. D. 1992, MNRAS, 259, 725
Smith, E. P., & Heckman, T. M. 1989, ApJ, 341, 658
Sparks, W. B., Wall, J. V., Jorden, P. R., Thorne, D. J., & van Breda, I. 1991, ApJS, 76, 471
Wilson, A. S., & Colbert, E. J. M. 1995, ApJ, 438, 62
Wisotzki, L., Kuhlbrodt, B., & Jahnke, K. 2001, in QSO Hosts and their Environments, ed. I. Marquez, J. Masegosa, A., Del Olmo et al. (Dordrecht: Kluwer), 83