

The HST view of the FR I / FR II dichotomy^{*}

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Abstract. In order to explore how the FR I / FR II dichotomy is related to the nuclear properties of radio galaxies, we studied a complete sample of 26 nearby FR II radio galaxies using Hubble Space Telescope (HST) images and compared them with a sample of FR I previously analyzed. FR I nuclei lie in the radio-optical luminosity plane along a tight linear correlation, which argues for a common synchrotron origin. FR II show a more complex behavior, which is however clearly related to their optical spectral classification.

Broad line FR II radio galaxies (BLRG) are located overall well above the FR I correlation, suggesting that a contribution from thermal (disc) emission is present. Three narrow line (NLRG) and one weak line radio galaxy (WLRG), in which no nuclear source is seen, can be interpreted as the obscured counter-parts of BLRG, in agreement with the current unification schemes.

Conversely, in 5 sources of the sample, all of them NLRG or WLRG, optical cores are located on the same correlation defined by FR I and with similar radio and optical luminosities. This suggests that, in analogy to FR I, the emission is dominated by synchrotron radiation and represents the optical counter-part of the non-thermal radio cores. Interestingly, all these galaxies are located in clusters, an environment typical of FR I.

These results imply that, at least at low redshifts, the FR II population is not homogeneous. Furthermore, the traditional dichotomy between edge darkened and brightened radio morphology is not unequivocally connected with the innermost nuclear structure, as we find FR II with FR I-like nuclei and this has interesting bearings from the point of view of the AGN unified models.

Key words: galaxies: active – galaxies: elliptical and lenticular, cD – galaxies: jets – galaxies: nuclei

1. Introduction

The original classification of extended radio galaxies by Fanaroff & Riley (1974) is based on a morphological criterion, i.e.

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edge darkened (FR I) vs edge brightened (FR II) radio structure. It was later discovered that this dichotomy corresponds to a (continuous) transition in total radio luminosity (at 178 MHz) which formally occurs at $L_{178} = 2 \times 10^{33} \text{ erg s}^{-1} \text{ Hz}^{-1}$. The presence of radio sources with intermediate morphology, in which typical FR I structures (such as extended plumes and tails) are seen together with features characteristics of FR II sources (narrow jets and hot spots) (see e.g. Parma et al. 1987; Capetti et al. 1995) argues in favour of a continuity between the two classes.

From the optical point of view both FR I and FR II are associated with various sub-classes of elliptical-like galaxies, but statistically their populations are different (Zirbel 1995). Owen (1993) found that the FR I/FR II division is also linked to the optical magnitude of the host galaxy, possibly suggesting that the environment plays an important role in producing different extended radio morphologies. Moreover, FR II are generally found in regions of lower galaxy density and are more often associated with galaxy interactions with respect to FR I (Prestage & Peacock 1988; Zirbel 1997). Differences are also observed in the optical spectra: while FR I are generally classified as weak-lined radio galaxies, strong (narrow and broad) emission lines are often found in FR II (Morganti et al. 1992; Tadhunter et al. 1993), although a sub-class of weak-lined FR II is also present (Hine & Longair 1979).

Within the unification scheme for radio-loud AGN (for a review, see Urry & Padovani 1995), FR I and FR II radio galaxies are thought to represent the parent population of BL Lac objects and radio-loud quasars, respectively (Barthel 1989). In order to explain the lack of broad lines in the “mis-oriented” (narrow-lined) FR II-type objects, obscuration by a thick torus is invoked. A combination of obscuration and beaming is therefore necessary at least for the FR II-quasars unification (e.g. Antonucci & Barvainis 1985). However, there is evidence that this simple picture is probably inadequate: some radio-selected BL Lacs - among the most powerful sources in the class - display an extended radio structure and luminosity typical of FR II (Kollgaard et al. 1992; Murphy et al. 1993) and broad - although weak - lines have been observed in some BL Lacs. Moreover, Owen et al. (1996) noted that the lack of BL Lacs in a sample of radio galaxies located in Abell clusters can be an effect of their selection criteria if the parent population of BL Lacs includes both FR I and FR II. This idea is also consistent with a recently proposed modification of the unification scheme, which

claim that the weak-lined FR II are indeed associated with BL Lac objects (Jackson & Wall 1999). These observations can be however reconciled with the unification scenario once continuity between the weak and powerful radio-loud sources is allowed and thus transition objects are expected.

In Chiaberge et al. (1999, hereafter Paper I) we studied HST images of all FR I radio galaxies belonging to the 3CR catalogue, finding that unresolved nuclear sources are commonly present in these objects. A strong linear correlation is found between this optical and the radio core emission, extending over four orders of magnitude in luminosity. This, together with spectral information, strongly argues for a common non-thermal origin, and suggests that the optical cores can be identified with synchrotron radiation produced in a relativistic jet, qualitatively supporting the unifying model for FR I and BL Lacs. Furthermore, the high rate detection ($\gtrsim 85\%$) of optical cores in the complete sample indicates that a standard pc-scale geometrically thick torus is not present in these low-luminosity radio galaxies. Any absorption structure, if present, must be geometrically thin, and thus the lack of broad lines in FR I cannot be attributed to obscuration. Alternatively, thick tori are present only in a minority of FR I. Given the dominance of non-thermal emission, the optical core luminosity also represents a firm upper limit to any thermal component, suggesting that accretion might take place in a low efficiency radiative regime.

The picture which emerges from this analysis is that FR I lack substantial thermal (disk) emission, Broad Line Regions and obscuring tori, which are usually associated with radio-quiet and powerful radio-loud AGN.

As a natural extension of Paper I, here we study the HST images of a sample of low redshift FR II radio galaxies, in order to explore how the differences in radio morphology are related to the optical nuclear properties. In particular, one of the most important questions is whether the FR I/FR II dichotomy is generated by two different manifestations of the same astrophysical phenomenon, and the transition between the two classes is indeed continuous, or instead it reflects fundamental differences in the innermost structure of the central engine.

The selection of the sample is presented and discussed in Sect. 2, while in Sect. 3 we describe the HST observations. In Sect. 4 we focus on the detection and photometry of the optical cores. Finally, in Sect. 5 we discuss our findings.

2. The sample

The sample considered here comprises all radio galaxies belonging to the 3CR catalogue (Spinrad et al. 1985) with redshift $z < 0.1$, morphologically classified as FR II. We directly checked their classification for erroneous or doubtful identifications by searching the literature for the most recent radio maps. The final list (see Table 1) constitutes a complete, flux and redshift limited sample of 26 FR II radio galaxies.

We searched for optical spectral classification and/or optical spectra, in order to differentiate our sources on the basis of the presence of broad or narrow emission lines. For only one source (namely 3C 136.1) we could not find spectral informa-

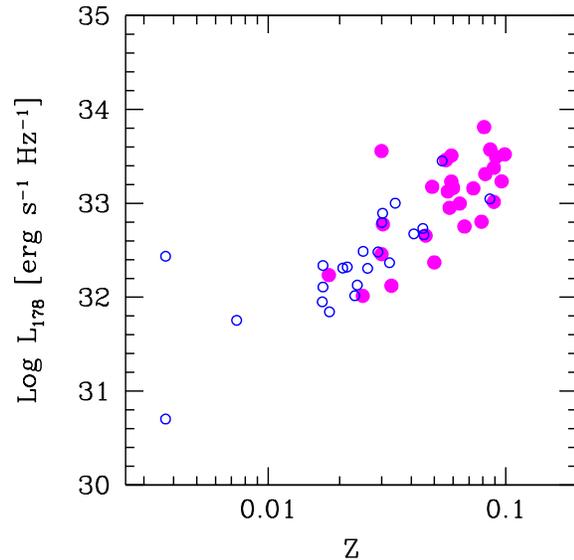


Fig. 1. Total radio luminosity (at 178 MHz) vs redshift diagram for the FR I (empty circles) and FR II (filled circles) samples.

tion in the literature. All spectral types usually associated with FR II galaxies are represented in the sample: five objects are BLRG, fifteen are classified as NLRG, while four show only weak lines in their optical spectrum (WLRG). The remaining source, namely 3C 371, has been classified as a BL Lac object. In Table 1 redshifts and radio data are reported, as taken from the literature, together with the optical spectral classifications.

In Fig. 1 we show the redshift vs total radio luminosity diagram for the sample of FR II galaxies, together with the sample of FR I discussed in Paper I, but limited to sources with $z < 0.1$ for coherence with the FR II sample. FR II have a median redshift $z = 0.06$, and total radio luminosities at 178 MHz are between 10^{32} and 10^{34} erg s $^{-1}$ Hz $^{-1}$ ($H_0 = 75$ km s $^{-1}$ Mpc $^{-1}$ and $q_0 = 0.5$ are adopted hereafter). Notice that whereas the two samples are selected at the same limits of redshift and flux, FR II are, on average, more luminous and distant than FR I.

3. HST observations

HST observations of the FR II sources are available in the public archive (up to April 1999) for 25 out of the 26 sources (only 3C 33 and 3C 105 have not been observed). The HST images were taken using the Wide Field and Planetary Camera 2 (WFPC2). The whole sample was observed using the F702W filter as part of the HST snapshot survey of 3C radio galaxies (Martel et al. 1999; De Koff et al. 1996). For 3C 192 we used a F555W image, as this source was not observed with the F702W filter. Exposure times are in the range 140–300 s. The data have been processed through the standard PODPS (Post Observation Data Processing System) pipeline for bias removal and flat fielding (Biretta et al. 1996). Individual exposures in each filter were combined to remove cosmic rays events.

Table 1. Summary of FR II radio and optical data.

Name	Redshift z	Spectral class.	Log L_{178} erg s ⁻¹ Hz ⁻¹	Log L_r (5GHz) erg s ⁻¹ Hz ⁻¹	F_o (7000 Å) erg s ⁻¹ cm ⁻² Hz ⁻¹	Log L_o (7000 Å) erg s ⁻¹ Hz ⁻¹
3C15	0.073	NLRG	33.16	31.54	<-28.12	<26.85
3C33	0.059	NLRG	33.51	30.27	no HST observations	
3C35	0.067	NLRG	32.75	30.27	<-28.47	<26.42
3C40	0.018	WLRG	32.24	30.60	-	-
3C88	0.030	WLRG	32.46	30.50	-27.64	26.57
3C98	0.030	NLRG	32.78	29.25	<-28.58	<25.64
3C105	0.089	NLRG	33.38	30.36	no HST observations	
3C111	0.049	BLRG	33.18	31.69	-26.51	28.12
3C136.1	0.064	-	33.00	-	-	-
3C192	0.060	NLRG	33.16	29.73	<-27.86	<26.94
3C198	0.082	NLRG	33.31	-	-27.10	27.96
3C227	0.086	BLRG	33.57	30.48	-26.27	28.83
3C236	0.099	WLRG	33.52	31.51	<-28.26	<26.95
3C285	0.079	NLRG	32.80	29.93	-29.44	25.58
3C318.1	0.046	NLRG	32.66	-	-28.94	25.63
3C321	0.096	NLRG	33.23	30.78	-	-
3C326	0.089	NLRG	33.02	30.34	<-28.11	<27.02
3C353	0.030	NLRG	33.56	30.54	<-28.71	<25.51
3C371	0.050	BL Lac	32.37	31.89	-25.56	29.09
3C382*	0.058	BLRG	32.95	31.13	-25.11*	29.66*
3C388	0.091	WLRG	33.49	31.04	-27.96	27.18
3C390.3*	0.056	BLRG	33.46	31.38	-25.75*	28.99*
3C402	0.025	NLRG	32.01	29.73	-27.49	26.57
3C403	0.059	NLRG	33.23	29.87	-28.19	26.60
3C445*	0.057	BLRG	33.13	31.34	-25.56*	29.20*
3C452	0.081	NLRG	33.81	31.24	<-28.22	<26.83

L_{178} and L_r are the total (at 178 MHz) and core radio luminosities, taken from the literature. F_o is the flux of the optical core. Total radio luminosities are calculated from Kühr et al. (1981) or Gower et al. (1967). Radio core luminosities are taken from Zirbel & Baum (1995). “<” indicate upper limits, i.e. not detected optical cores, “*” indicate objects in which the optical core saturates, “-” in the F_o and L_o columns mark objects with complex nuclear morphologies for which we do not estimate the core flux and “-” in the L_r column indicate unavailable radio core data in the literature.

4. Optical cores in FR II

In Paper I we have adopted a simple operative approach, based on the analysis of the nuclear brightness profile, in order to establish when an optical core is present in a radio galaxy. As in the case of FR I sources, the FWHM fall into two very distinct regimes: in 11 cases we measured a FWHM = 0.05'' – 0.08'', i.e. indicative of the presence of an unresolved source at the HST resolution, while in 8 cases we found widths larger than 0.2''. We therefore believe that no ambiguity exists on whether or not a central unresolved source is present.

In three sources (3C 382, 3C 390.3 and 3C 445) the central regions are saturated. While, on the one hand, this prevents us from deriving their brightness profile, on the other is by itself a clear indication of a point-like source. In fact diffuse emission would produce saturation with our instrument configuration and exposure times only for surface brightness < 13 mag arcsec⁻² in the R band, much larger than typically observed in the central regions of radio-galaxies at this redshift. Furthermore in all these sources we observe diffraction rings and spikes, the characteristic hallmarks of the HST Point Spread Function.

We performed aperture photometry of these components. The background level is evaluated, as in Paper I, by measuring the intensity at a distance of ~ 5 pixels ($\sim 0.23''$) from the center. The dominant photometric error is thus the determination of the background in regions of steep brightness gradients, especially for the faintest cores, resulting in a typical error of $\sim 10\%$. For the saturated cores we evaluated their fluxes by comparing the PSF wings with those of several bright stars seen in archival HST images taken with the same filter. This method leads to a somewhat larger uncertainties, 25% as estimated from the scatter of measures obtained with different reference stars, which arise from the time dependent structure of the HST PSF. In Table 1 we report fluxes and luminosities of the optical cores.

All of the images were taken using broad band filters, which include emission lines. In particular, the F702W transmission curve covers the wavelength range 5900 – 8200 Å and thus within our redshift range includes the H α and [N II] emission lines. Unfortunately, no HST narrow band images are available for the NLRG and WLRG, however, we expect the line contamination to be small, due to the wide spectral region covered by the filters used (~ 2000 Å) with respect to typical lines equiv-

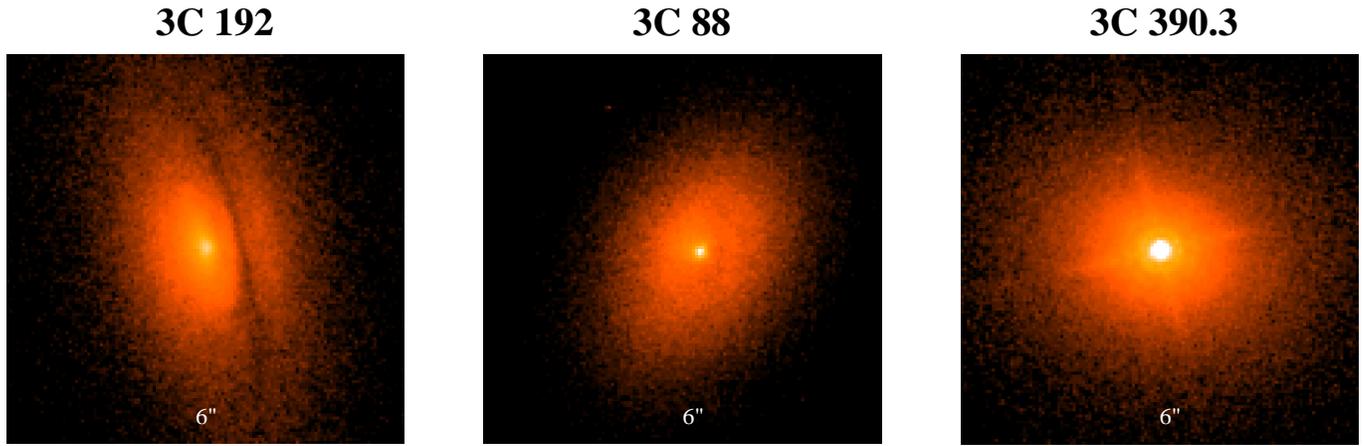


Fig. 2. HST/WFPC2 broad band images of three FR II: 3C 192 is a NLRG showing a diffuse nucleus; 3C 388 is a NLRG with an optical core; 3C 390.3 is a BLRG.

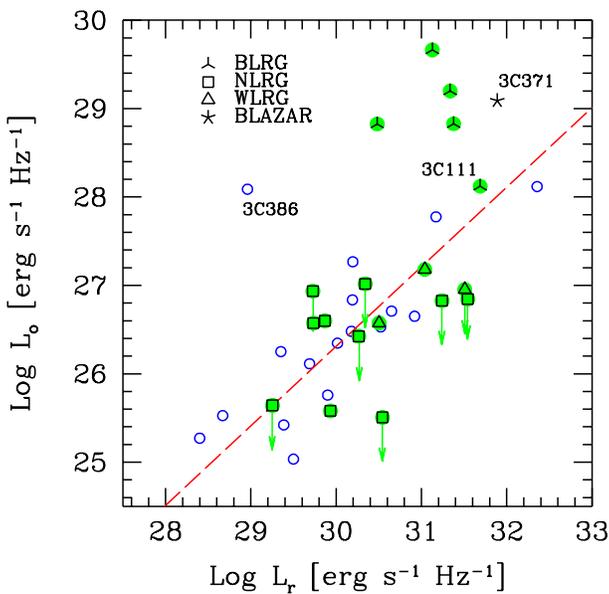


Fig. 3. Optical nuclear luminosity versus radio (5 GHz) core luminosity for both the FR I (open circles) and FR II (filled circles) samples. Different symbols are used to identify different spectral classifications. The dashed line is the correlation found in the case of FR I galaxies (see Paper I).

alent width. We correct the broad band fluxes only in the case of BLRG, where the emission of broad lines is probably co-spatial to the optical core, using ground-based data taken from the literature (Tadhunter et al. 1993). The resulting emission line contribution is typically 25 – 30% of the total flux measured in the F702W filter.

In 8 cases the nuclear regions only show diffuse emission: for such galaxies we estimate upper limits to a possible central component evaluating the light excess of the central 3x3 pixels with respect to the surrounding galaxy background. The remaining 3 sources show complex morphologies, e.g. with dust lanes obscuring the central regions, and no photometry was performed.

FR II cores span a wide range of optical luminosities L_o (from $10^{25.5}$ up to 10^{30} $\text{erg s}^{-1} \text{Hz}^{-1}$). In Fig. 3 we report the optical core versus radio (5 GHz) core luminosity for the FR II sample, superimposed to the data (as from Paper I) for FR I galaxies limiting ourselves, for consistency, to those with redshift $z < 0.1$. FR II show a complex behavior, which however seems to be related to their optical spectral classification.

Let us firstly consider the blazar, 3C 371. As one might expect, since its emission is dominated by beamed synchrotron radiation, it is among the brightest source both in the radio and in the optical band (see Fig. 3). In the L_r vs L_o plane it falls in the low luminosity end of the region defined by radio selected blazars (Chiaberge et al., in preparation).

The second group of sources is represented by the BLRG (3C 111, 3C 227, 3C 382, 3C 390.3 and 3C 445): all of them have very luminous optical cores ($L_o > 10^{28}$ $\text{erg s}^{-1} \text{Hz}^{-1}$) being – together with 3C 371 – the most powerful objects of the sample and clearly separating from the other FR II in the diagram. Notice that they have an optical excess (or radio deficiency) of up to 2 orders of magnitude with respect to the radio-optical core luminosity correlation found for FR I.

In 5 WLRG and NLRG, namely 3C 88, 3C 285, 3C 388, 3C 402 and 3C 403, we detected optical cores which share the same region in the luminosity plane as FR I sources with luminosities between $L_o = 10^{25.5}$ up to more than $10^{27.5}$ $\text{erg s}^{-1} \text{Hz}^{-1}$.

The 8 upper limits, all associated with WLRG or NLRG, are also plotted. Four objects (3C 35, 3C 98, 3C 192 and 3C 326) lie close to the correlation defined by FR I. Conversely, 3C 15, 3C 353, 3C 452 and 3C 236 present an optical luminosity deficit of one to two orders of magnitude given their radio core emission with respect to FR I.

No radio core data have been found in the literature for 3C 136.1, 3C 198 and 3C 318.1.

5. Discussion

In the 24 nearby FR II radio galaxies (out of a complete sample of 26) studied in this paper, 13 show an unresolved optical core,

in 8 cases we can only set an upper limit to their luminosity, while 3 sources present a complex nuclear morphology. The location in the optical-radio core luminosity plane is clearly connected to the optical spectral classification.

Conversely, cores in FR I radio galaxies show a linear correlation between their radio and optical luminosity, which strongly argues for a common non-thermal origin. The presence of such correlation provides a useful benchmark to investigate the origin of optical cores in FR II.

In the following we consider each FR II group separately.

5.1. Broad line radio galaxies

Let us first focus on BLRG. These sources present, overall, a strong optical excess (or radio deficit), of up to two orders of magnitude, with respect to the correlation defined by the FR I cores (see Fig. 3). Note that in the sample of nearby FR I, the only source lying well above the radio-optical correlation is 3C 386, which also shows a broad $H\alpha$ line.

BLRG are objects in which the innermost nuclear regions are thought to be unobscured along our line of sight (Barthel 1989). We therefore expect the presence of a thermal/disc component: indeed this might dominate over any synchrotron jet radiation and thus be responsible for the observed emission. The idea that we see directly an accretion disc is supported by several observations: in the case of 3C 390.3, a bump in the spectral energy distribution has been interpreted as radiation emitted by a disc component with intermediate inclination (Edelson & Malkan 1986). Furthermore, the broad and double peaked $H\beta$ line observed in this source as well as in other BLRG (see e.g. Eracleous & Halpern 1994), can be accounted for within a relativistic accretion disc model (Perez et al. 1988).

The location of 3C 111 is puzzling, as it lies along the correlation. However, several pieces of evidence point to the idea that beamed radiation from the relativistic jet significantly contributes in this source: it has the largest core dominance among the BLRG of our sample; superluminal motions with apparent speed $v \sim 3.4c$ have been revealed in the inner jet (Vermeulen & Cohen 1994), implying that the angle between the line of sight and the jet axis is smaller than $\sim 30^\circ$; the radio core is strongly variable and polarized (Leahy et al. 1997). Furthermore a broad $K\alpha$ iron line is detected in the X-ray band, but with a relatively small equivalent width which can be explained if the continuum emission is diluted by a beamed component (Reynolds et al. 1998). However, its total radio extent of ~ 250 kpc argues against a viewing angle typical of blazars. Thus 3C 111 appears to be a transition source between radio-galaxies and blazars, seen at an angle sufficiently small that the jet beaming already affects its nuclear properties.

5.2. WLRG and NLRG with optical cores

Let us now concentrate on the NLRG and WLRG in which we detected optical cores. These objects (2 WLRG and 3 NLRG), all with FR II radio morphology, have cores with radio and optical emission properties that are *completely consistent with those*

found in FR I. This suggests that in these sources the nuclear emission is similarly dominated by synchrotron radiation from the inner jet.

In the case of FR I, based on the high fraction of detected nuclei, we suggested that any obscuring material must be geometrically thin and thus the absence of broad lines and the relative weakness of any thermal (disc) component with respect to the synchrotron emission cannot be ascribed to extinction.

For FR II with FR I-like nuclei – of which we do not have enough statistics – there is an alternative possibility, namely that the optical core (jet) emission is produced outside the obscuring torus (and thus outside the BLR). In this sense they would represent transition objects seen at an intermediate angle between the completely obscured and unobscured ones. However, VLBI observations show that radio cores are unresolved on scale of ~ 0.1 pc in nearby radio galaxies and this suggests that their optical counter-parts have a similar extent, as already discussed in Paper I. Furthermore, a symmetric jet-counter jet structure has been observed in several radio sources, implying that they lie essentially in the plane of the sky (Giovannini et al. 1998). If the core emission is indeed produced outside the torus, at a distance of, say, ~ 1 pc from the central black hole, a clear separation between the two sides of the jet (and no stationary core) should be observed in these highly misoriented objects (although, at present, symmetric jets have been found only in FR I). This ad hoc geometrical model does not seem to be viable, but a conclusive test requires spectropolarimetry looking for polarized scattered broad lines. A further indication could be obtained from the comparison of the nuclear infrared (reprocessed?) luminosity of FR Is and FR IIs with FR I-like nuclei of similar optical luminosity.

We conclude that these FR II are intrinsically narrow-lined objects which are in every aspect, except their extended radio-morphology, similar to FR I. Note that the presence of an FR I-like nucleus in a FR II does not seem to be connected with the total (radio) luminosity or redshift of the galaxy. In fact, the total power of such sources spans the range $L_{178} = 10^{32} - 10^{33.5}$ erg s^{-1} Hz $^{-1}$ and the redshifts are between $z = 0.025 - 0.091$, completely overlapping with the entire sample and not limited, as one might expect, to the low luminosity end.

Conversely, it appears that a possible relationship exists between the occurrence of FR I-like nuclei in FR II and the environment, as all these 5 galaxies reside in clusters. This result can be particularly important, as it is known that FR I and FR II inhabit different environments, with FR II generally avoiding rich groups, especially at low redshifts (Zirbel 1997), while FR I are usually located in rich clusters. However, before any firm conclusion can be drawn about this issue, a larger sample of objects has to be considered.

5.3. WLRG and NLRG without optical cores

In 8 galaxies, all WLRG or NLRG, we do not detect the presence of an unresolved nuclear component. Four sources are located above or very close to the FR I correlation. They are consistent with being objects in which an optical counter-part to the radio

core is present, but it is too faint to be seen against the bright background of the host galaxy.

The remaining 4 objects (3 NLRG and 1 WLRG) are certainly more interesting, since they lie 1 - 2 orders of magnitude below the correlation. Therefore they lack not only of a BLR, but also of the expected optical counterpart of the radio core. However, note that these sources have radio core luminosities which cover the same range of BLRG. According to the prescriptions of the unification schemes, they can well be the obscured counter-parts of BLRG. Noticeably, excluding the blazar 3C 371, BLRG and these obscured sources clearly distinguish themselves for having the brightest radio cores among FR II.

6. Conclusions

In Chiaberge et al. (1999) we discovered that FR I nuclei lie in the radio-optical luminosity plane along a tight linear correlation. We argued that this is due to a common synchrotron origin for both the radio and optical emission. FR I nuclei must also be unobscured and intrinsically lacking of BLR and of significant thermal emission from any powerful accretion disc.

In order to explore how the differences in radio morphology are related to the optical nuclear properties, we analyzed HST images of 24 extended radio-galaxies morphologically classified as FR II, belonging to the 3C catalog and with $z < 0.1$. We detected optical cores in 13 sources, which implies that the covering fraction of any obscuring material is less than ~ 0.54 , or equivalently, the torus has an opening angle of $\sim 63^\circ$. This can be even larger if at least some of the upper limits are actually just below the detection threshold. Notice that our determination of this critical angle is inconsistent with the division between higher redshift ($0.5 < z < 1$) 3CR quasars and radio galaxies, which has been found to be $\theta \sim 45^\circ$ (Barthel 1989). This might be a problem, however the low redshift selection of our sources does not allow to derive any firm conclusion. We are currently studying a larger and higher redshift sample in order to further investigate this issue (Chiaberge et al. in preparation).

Our results suggest that the radio morphology is not unequivocally connected with the optical properties of the innermost structure of radio galaxies. In fact, at least at low redshifts, there is not a single homogeneous population of FR II: unlike FR I, they show a complex behavior, which is however clearly related to their optical spectral classification.

In BLRG optical nuclei are likely to be dominated by thermal (disc) emission. As discussed above, line emission contamination cannot account for this excess. In agreement with the current unification scheme of radio loud AGNs, we also identify their possible obscured counter-parts. It seems that broad lines and obscuring tori are closely linked and both are present only associated to radiatively efficient accretion.

We also find five FR II sources, spectrally identified as narrow lined objects, which harbor nuclei essentially indistinguishable from those seen in FR I. By analogy with FR I, we argue that their optical nuclear emission is produced primarily by synchrotron radiation, they are not obscured to our line of sight and therefore intrinsically lack a BLR.

Clearly, a classification based on the optical nuclear properties, as seen in these HST images, is more likely to reflect true similarities (or differences) on the nature of the central engine (such as, e.g., the rate of radiative dissipation in the accretion disc) than the traditional dichotomy of radio morphology.

From our data and within the limits of the available statistics, we find no evidence of a continuous transition between the two classes (FR I and FR II), as they are well separated in the L_r vs L_o plane. At this stage we only point out that sources with cores below $L_o < 10^{27.5} \text{ erg s}^{-1} \text{ Hz}^{-1}$ (or equivalently $L_r < 10^{31} \text{ erg s}^{-1} \text{ Hz}^{-1}$) have FR I like nuclei, while FR II start above this threshold.

It is of particular interest that a significant fraction of FR II (at least 30%, but can be as large as 50% depending on the nature of the sources without detected optical nuclei) have FR I-like nuclei. The fact that all of these are located in clusters, an environment typical of FR I, might represent an important hint on the origin of the different flavours of radio galaxies, worth exploring through the study of a larger sample of objects.

These results have also interesting bearings from the point of view of the unified models. In fact, this picture argues against the idea that all FR II radio galaxies constitute the parent population of radio-loud quasars. We propose instead that galaxies with FR II morphology and an FR I-like core are possibly misaligned counter-parts of BL Lac objects. This can account for the observation that some radio-selected-type BL Lacs show radio morphologies more consistent with FR II than with FR I (e.g. Kollgaard et al. 1992).

To conclude, we note that all of the galaxies included in our sample are low redshift objects with total radio powers not exceeding $L_{178} \sim 10^{27} \text{ erg s}^{-1} \text{ Hz}^{-1}$: thus a crucial observational issue is to understand whether these results hold to higher power/redshift samples or they are limited to low luminosities FR II. This will be explored in a forthcoming paper.

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