FRII radio galaxies - the SDSS view

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Motivation

FRII radio galaxies (Fanarof & Riley, 1974) constitute a well defined class of objects in terms of radio morphology. But in terms of optical properties this class is not homogeneous. **The diversity of the spectral features of FRIIs makes these objects a prime target for understanding the relation between optical and radio activity.**

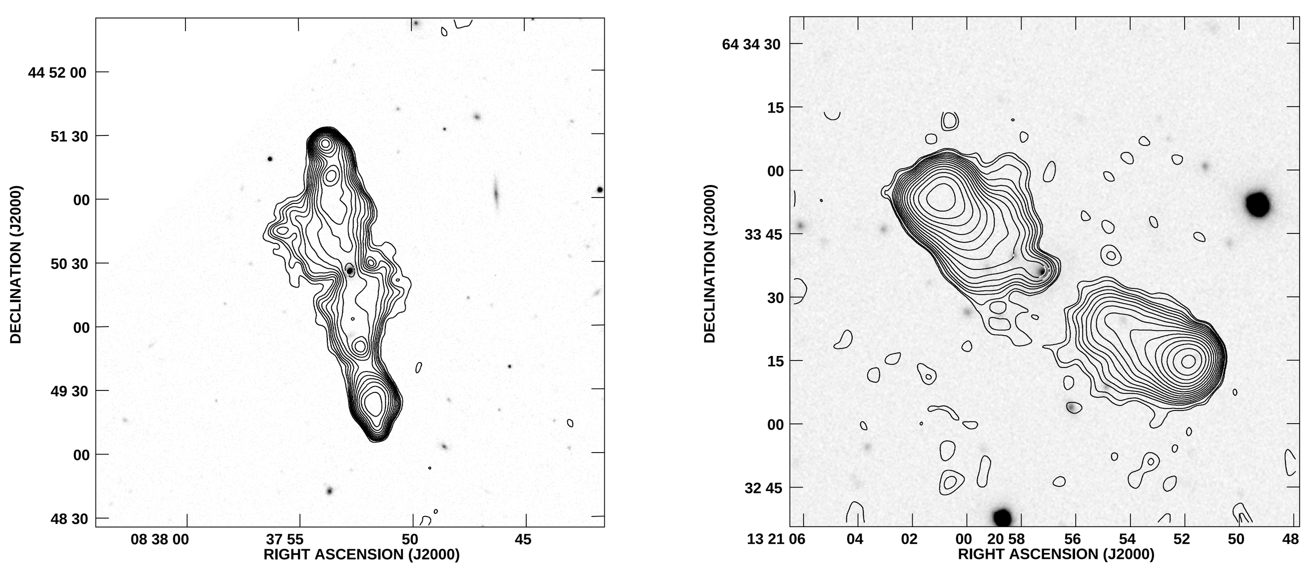

Figure 1: *Two examples of the FRII radio galaxy from our sample: J083752+445025 (left) and J132057+643335 (right)*

Method

Starting from the Cambridge Radio Catalogues, we have created a complete sample of 401 FRII radio sources that have counterparts in the SDSS DR7 main galaxy sample (Abazajian 2009) and analyse their radio and optical properties. We excluded all objects classified in the SDSS as quasars, but we included all known giant radio sources (even if not present in the Cambridge Radio Catalogues) with available SDSS optical spectra. The stellar masses, velocity dispersions, emission line equivalent widths and fluxes were taken from the STARLIGHT database (Cid Fernandes et al. 2009) while the 1.4 GHz radio luminosities, $P_{1.4\mathrm{GHz}}$, were calculated from the total flux density obtained from the NVSS catalogue. Black hole masses were calculated using velocity dispersions and the relation of Tremaine at al. (2002). Using these data we looked for the presence of correlations that might improve our understanding of radio loud AGN.

Results

Optical luminosity - radio luminosity correlation

Rawlings et al. (1989) were the first to note the existence of an intrinsic correlation between the radio power and $L_{[\mathrm{O\,III}]}$ in a sample of 39 FRII galaxies. They take it as evidence for a physical coupling of the processes that supply energy to the emission line region and to the extended radio source. Our sample confirms this trend. Both the Hα and [O III] luminosities show a very strong correlation with $P_{1.4\mathrm{GHz}}$, as seen in Fig.2.

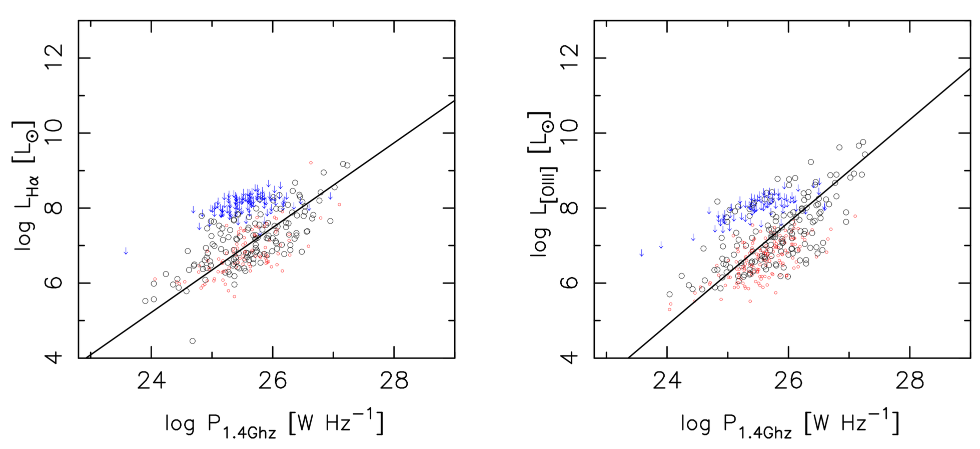

Figure 2: *$L_{\mathrm{H}\alpha}$ (left) and $L_{[\mathrm{O\,III}]}$ (right) versus $P_{1.4\mathrm{GHz}}$ for FRII galaxies of our sample. Black circles correspond to objects having $S/N > 3$ in the Hα ([O III]) line, small red circles to objects where the Hα ([O III]) line is detected with a lower S/N and blue arrows represent the lower limit in Hα ([O III]) flux.*

But is the $L_{\mathrm{H}\alpha}$ and $P_{1.4\mathrm{GHz}}$ correlation universal or do the line-less FRII radio galaxies form a separate class?

Using the S/N ratio in the continuum and assuming a typical emission-line width of 10Å, we have estimated the minimum detectable flux in emission lines for each line-less object. These numbers, converted into luminosities, are plotted as blue arrows in Fig. 2. We find that the objects with undetected Hα or [O III] lines could well follow exactly the same trend as the ones with detected lines. **Thus, we find no evidence for the existence of a class of truly line-less FRII radio galaxies.**

Emission lines diagnostic diagrams

The classical Baldwin, Phillips & Terlevich (1981, BPT) diagram is used to characterize the ionizing source of the gas in galaxies. Figure 3 shows BPT diagrams for our FRII radio galaxies (left) and a random comparison sample of 1000 SDSS galaxies hosting an active galactic nucleus (AGN) (right). Most of the objects in the comparison sample gather close to the blue curve, which is a separation between star-forming and AGN galaxies proposed by Stasińska et al. (2006, S06). Close to the blue curve, young stars contribute significantly to the energy emitted in the emission lines. **Most of the FRII galaxies lie well away from it, indicating that the line emission in them is entirely due to their AGN.** Also our **FRII sample is characterized by a larger proportion of AGNs with the hard ionizing radiation field and high ionization parameters than in the comparison sample** (black points).

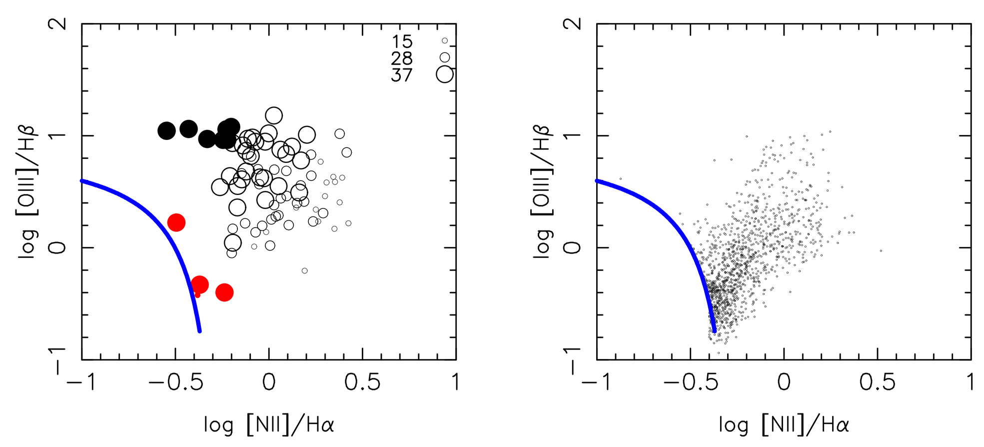

Figure 3: *(left) FRII radio galaxies in the BPT diagram for objects having $S/N > 3$ in all the relevant lines. The thick blue curve represents the line above which all the galaxies are believed to host an AGN, according to S06. (right) The BPT diagram for a comparison sample of 1000 AGN galaxies.*

There are, however a few objects (represented in red) that lie close to the divisory line between pure star-forming galaxies and AGN hosts. This is a priori surprising, as there is no indication of present-day star formation in those objects and they fit well into the $L_{\mathrm{H}\alpha}$ versus $P_{1.4\mathrm{GHz}}$ correlation. Thus, we suggest that **those objects are ionized by a softer radiation field**, as compared with the rest of the FRIIs.

Black hole mass versus stellar mass

In Fig. 4 we show our FRII sample (top), SDSS line-less galaxies (midle) and SDSS AGNs (bottom) in the "M_{BH}" vs M_* plot. **The black hole masses and stellar masses in the FRII galaxies and line-less SDSS galaxies are closely related and follow the same relationship, but in the case of the latter the masses are smaller.**

In the case of the comparison sample of SDSS AGN galaxies (Fig.4, bottom) the bulk of objects deviate from the "M_{BH}" – M_* relation obtained for FRII or line-less galaxies. Also, galaxies that have smaller $D_{\mathrm{n}}(4000)$ (i.e. younger galaxies) tend to have smaller "M_{BH}"/$M_*^{1.13}$, and this ratio increases with $D_{\mathrm{n}}(4000)$. This suggests that **optical AGNs, mostly spirals which are still forming stars, are still building their central massive black holes.**

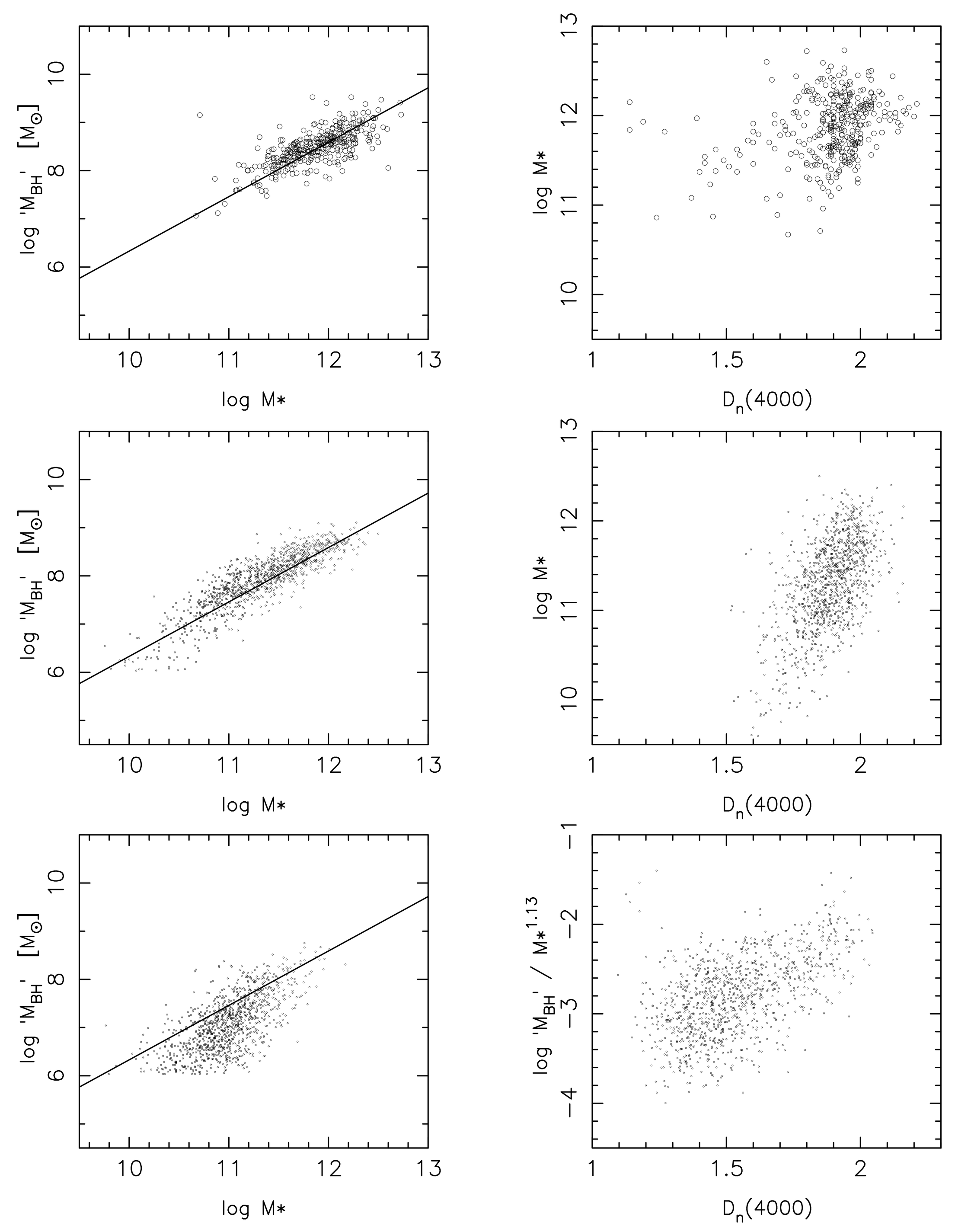

Figure 4: *(top) "M_{BH}" vs M_* (left) and M_* vs $D_{\mathrm{n}}(4000)$ (right) for our sample of FRII galaxies. (midle) The same but for a sample of SDSS line-less galaxies. (bottom) "M_{BH}" vs M_* (left) and "M_{BH}"/$M_*^{1.13}$ vs $D_{\mathrm{n}}(4000)$ (right) for a random sample of 1000 AGN hosts.*

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