Radio morphology-accretion mode link in radio galaxies

Duccio Macconi[1 2], Eleonora Torresi[2], Paola Grandi[2], Cristian Vignali[1 4], Bia Boccardi[2 3]

1 Dipartimento di Fisica e Astronomia, Università degli Studi di Bologna, Via Gobetti 93/2, I-40129 Bologna, Italy
2 INAF – Osservatorio di Astrofisica e Scienza dello Spazio di Bologna, Via Gobetti 101, I-40129 Bologna, Italy
3 Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, D-53121 Bonn, Germany
4 INAF – Osservatorio di Astrofisica e Scienza dello Spazio di Bologna, Via Gobetti 93/3, I-40129 Bologna, Italy

Abstract: studies of radio galaxies (RG) FRI and FRII (Fanaroff & Riley 1974) are fundamental for the comprehension of the central engine role in powering RG jets and in shaping their extended radio morphology. In fact, different radio morphologies seem to reflect different nuclear properties: almost all FRIIs hide an efficient accretion, while the central engines of FRI sources are characterized by radiatively inefficient accretion (ADAF-like). However, there is a population which does not fit into this scheme, exhibiting powerful radio structure but inefficient accretion (FRII-ADAF). Given their properties, FRII-ADAF constitute the best candidates to test the role of accretion in shaping the radio morphology. In order to investigate their nature, an X-ray systematic analysis of all 19 FRII-ADAF belonging to the 3CR sample with z < 0.3 was performed, exploiting Chandra and XMM-Newton data. In addition, 31 FRII with an efficient accretion disk (FRII-DISK) were analyzed and used as a control sample.

The sample: The 3CR catalog limited at z<0.3 has a uniform classification both in terms of extended radio morphology and AGN optical spectra.

The X-ray study concerns **50** FRIIs in the 0.3-7 keV band, analyzed with Chandra and/or XMM-Newton telescopes: **19 FRII-ADAF** + 31 FRII-DISK .

FRI-ADAF data available from literature were added to ensure a complete comparison of the sample

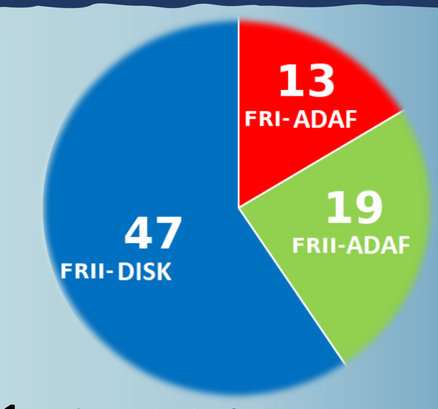

Fig. 1: About 60% of 3CR sources at z<0.3 with both radio and optical classification are FRII-DISK, 24% are FRII-ADAF and 16% are FRI-ADAF.

X-ray analysis:

The main results of the X-ray study are:

1) **FRII-ADAF** have intermediate values of gas column densities (cm^{-2}) between more obscured FRII-DISK and less obscured FRI-ADAF (Fig. 2). The intrinsic column density measures the quantity of gas on pc/sub-pc scales;

2) **FRII-ADAF** have also intermediate values in terms of X-ray luminosity, used in this work as a proxy of the accretion rate (Fig. 3)

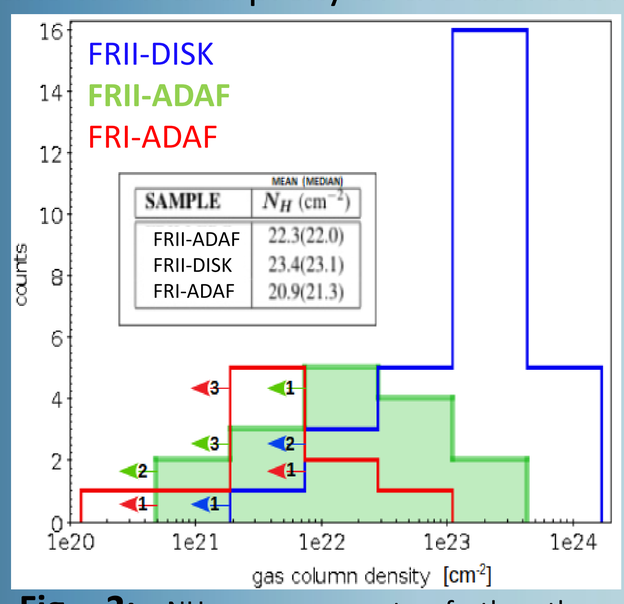

Fig. 2: NH measurement of the three populations. The table indicates respectively the mean (and median) value for each population.

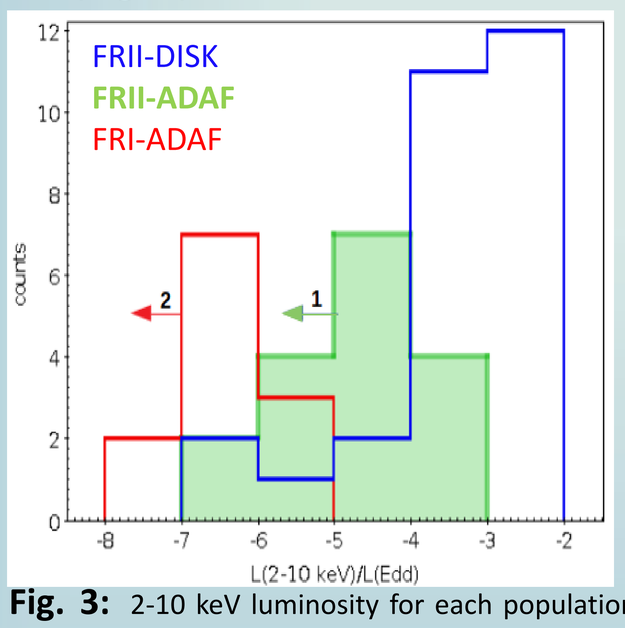

Fig. 3: 2-10 keV luminosity for each population normalized by the Eddington luminosity. L(Edd) was calculated from the H-band magnitude in the near-IR spectrum (literature data).

Gas and dust comparison:

in order to estimate the dust content in the three classes of sources, we calculated the dust extinction E(B-V) from the Balmer decrement, using literature data. Then, it was compared with the neutral gas distribution on pc-scales from X-ray analysis. **FRIIs have a similar dust distribution but different gas content.**

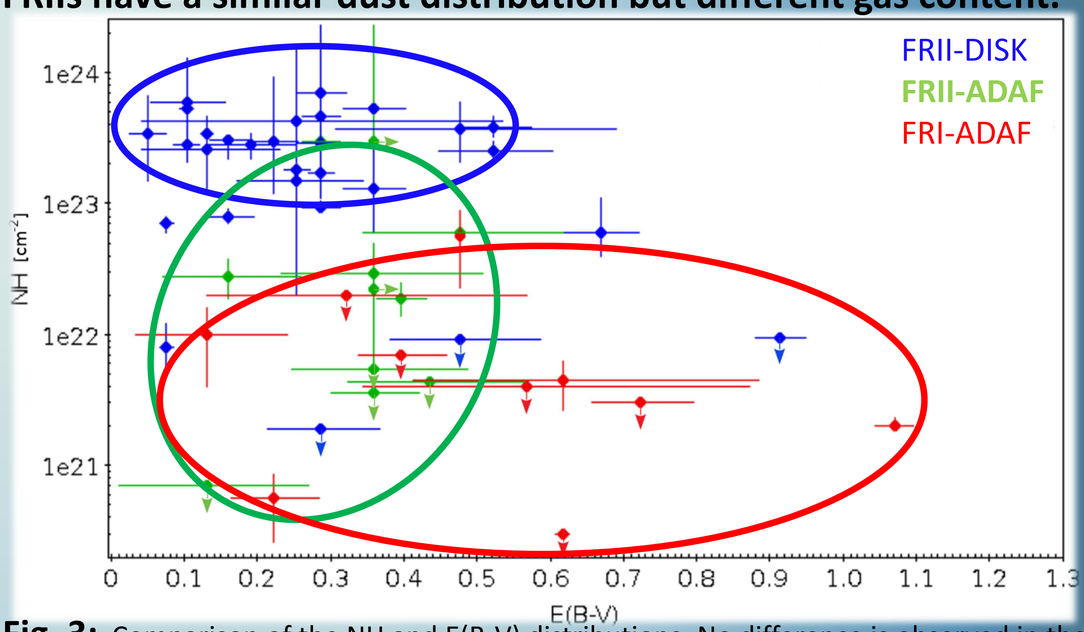

Fig. 3: Comparison of the NH and E(B-V) distributions. No difference is observed in the E(B-V) of FRII sources, on scales of the NLR and beyond. On the contrary, FRIs appear to be reddened. This comparison definitively excludes that the different optical classification of FRIIs depends on the presence of dust.

Conclusions:

- we can definitely rule out the hypothesis that FRII-ADAF are NOT heavily-obscured FRII-DISK: they have similar dust distribution but lower neutral gas column density;
- an evolutionary explanation is favoured. The nuclear power seems to suffer of a depletion of the cold gas reservoir. The depletion information have not yet reached the large-scales radio structures at kpc distances from the central engine.

Future studies:

In order to complement this study and solidly attest our conclusions, the following steps are necessary:

1. to better constrain the N_H value of FRII-ADAF, e.g. with NuSTAR;
2. to study the jet power on pc-scales (VLBI) and combine with MW data to pursue SED studies;
3. to extend this study to higher z in order to verify the evolutionary nature of this phenomenon (e.g. with 3CRR catalog, Ibba et al. in prep.);
4. to perform a molecular study on galaxy-scales with IRAM/ALMA: CO is a fundamental AGN feed tracer.

References: Fanaroff & Riley (1974); Willott et al. (1999); Buttiglione et al. (2009,2010,2011); Momcheva et al. (2013); Ghisellini et al. (2014)

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