BeppoSAX observations of low power radio galaxies: possible detection of obscured nuclei

E. Trussoni$^a$, F. Vagnetti$^b$, S. Massaglia$^c$, L. Feretti$^d$, P. Parma$^d$, R. Morganti$^d$, R. Fanti$^e$, P. Padovani$^{b,*}$, G. Bodo$^a$

$^a$Osservatorio Astronomico di Torino, Pino Torinese, Italy
$^b$Dipartimento di Fisica, Università di Roma “Tor Vergata”, Roma, Italy
$^c$Dipartimento di Fisica Generale, Università di Torino, Torino, Italy
$^d$Istituto di Radioastronomia del CNR, Bologna, Italy
$^e$Dipartimento di Fisica, Università di Bologna, Bologna, Italy

We present the first results of BeppoSAX observations of a small sample of low brightness FRI radio galaxies. The flux of all the targets is consistent with a thermal spectrum, as due to the presence of hot intracluster gas or galactic corona. Moreover in three sources a non thermal absorbed spectrum can be present in the MECS spectrum at energies $\sim 7$ keV, while for a fourth object a high energy flux has been detected in the PDS instrument at energies $\sim 15$ keV. This component could be related to the inner AGN surrounded by an obscuring torus.

1. INTRODUCTION

In the unified model for AGN, radio galaxies are usually assumed as parent objects for radio loud quasars and BL Lac objects. This theory predicts that the Doppler effect in relativistic jets and the presence of an obscuring torus around the AGN, with different position angles with respect to the line of sight, can explain the various properties of powerful radio galaxies (FR II) and radio loud quasars [1,2]. The unification of low luminosity radio galaxies (mostly FR I) with BL Lac objects in principle does not require a thick absorbing torus [3], however its presence is not ruled out [1]. This possibility could be supported by the detection in FR I radio sources of an increasing X-ray flux at energies above $\approx 5 – 10$ keV, where the contribution from the thermal component is very low and the photoelectric absorption of the torus becomes negligible. For the evaluation of the orientation of the AGN - torus system, a useful parameter is $R$, the ratio between the core and the lobe radio fluxes at a given frequency. In sources with low values of $R$ we expect the absorbing torus to be almost edge-on.

In the framework of this problem, we have observed with BeppoSAX a sample of 5 low power radio galaxies extracted from the 2 Jy sample of Morganti et al. [4]. The targets (see Table 1), selected with $R \lesssim 1$, are all but one members of clusters. Their morphology is mostly typical for FR I radio sources, however a member of the sample (0625-53) belongs to the class of low-excitation FR II radio galaxies [5].

2. THE OBSERVATIONS

The details of the MECS and LECS observations are reported in Table 2. The data have been handled with the SAXDAS pipeline, and the source counts have been extracted by assuming the standard background evaluated by merging different exposures of blank fields. The PDS data have been reduced with the XAS software, and a significative flux has been detected only from the source 0625-53, with a count rate $0.4 \pm 0.1$ s$^{-1}$. The spectral analysis has been performed with the Xanadu package, rebinning the events in order to have at least 20 counts per energy channel.

*Present address: ESA, STScI, Baltimora, USA
Table 1
The Sample

| Object          | Alt. name          | z     | m_Y  | R^a   | Envir. |
|-----------------|--------------------|-------|------|-------|--------|
| PKS 0305+03     | 3C78, NGC1218      | 0.029 | 13.84| 0.12  | Isolat.|
| PKS 0620-52     |                    | 0.051 | 15.50| 0.06  | Cluster|
| PKS 0625-53     |                    | 0.054 | 15.54| 0.008 | A 3391 |
| PKS 0625-35     | OH 342             | 0.055 | 16.50| 0.23  | A 3392 |
| PKS 1648+05     | 3C38, Her A        | 0.154 | 18.50| 0.0004| Cluster|

^a At 2.3 GHz

Table 2
The Observations

| Object          | Date     | Exp.(s) / Rad. | S. counts | Exp.(s) / Rad. | S. counts |
|-----------------|----------|---------------|-----------|---------------|-----------|
| 3C78            | 7/1/97   | 20594 / 4"    | 494 ± 21  | 8890 / 8"     | 142 ± 27  |
| 0620-52         | 2/12/96  | 13680 / 10'   | 698 ± 41  | 4458 / 8'     | 134 ± 27  |
| 0625-53         | 2/12/96  | 13482 / 10'   | 4988 ± 81 | 3588 / 8'     | 378 ± 26  |
| OH 342          | 5/10/96  | 17528 / 10'   | 1928 ± 53 | 8211 / 8'     | 575 ± 33  |
| Her A           | 28/3/97  | 18836 / 10'   | 1620 ± 57 | 9875 / 8'     | 504 ± 30  |

^a Merging the data of the three instruments
^b Radius of the region from where the photons were extracted

in the MECS, and 10 counts in the PDS. Concerning the LECS data, the flux for 3C 78 and 0620-52 is too weak for a useful analysis. In addition in the other sources some further calibration analysis is still required.

3. RESULTS

We discuss separately the spectral properties deduced from the MECS and PDS observations.

3.1. Spectral analysis: MECS

In the MECS all the sources appear extended, with radii ∼ 150 kpc for 3C 78, ∼ 700 – 800 kpc for 0625-53, OH 342 and 0620-52, and ∼ 1.5 Mpc for Her A. This is expected taking into account that four targets belong to clusters, while 3C 78 is an isolated galaxy but embedded in a hot galactic corona. Consistently, from the spectral analysis we see that all the sources can be satisfactorily fitted with a thermal spectrum (Raymond-Smith), where the iron line appears quite evident. The spectral parameters, with the hydrogen column density kept fixed to its galactic value N_{H, gal}, are reported in Table 3. We have also tested that fits with power law spectra are much worse.

However, even though the thermal spectrum is consistent with the data, the following points must be remarked:

1) In three sources (3C78, OH 342 and Her A) a count excess is evident at high energies (> 7 keV).
2) The temperature obtained for the halo of 3C 78 is higher than expected for hot galactic coronae (≈ 0.5 – 1.5 keV [6,7,8]).
3) The temperature of the intracluster gas of Her A is higher than obtained from a Rosat observation in the soft X-ray energy band [9].

These issues suggest that a second component can be present in the spectrum of the sources. In the framework of our initial discussion, we have assumed that this second component may be related to the non-thermal emission from the central nucleus, surrounded by an obscuring torus seen edge-on.

Due to the low photon flux, the fit with a double spectrum does not provide useful results unless some parameters are fixed. We have seen that the best fits are obtained only whether a high absorption is assumed for the non-thermal component. Therefore, besides the galactic hydrogen...
Table 3
Thermal fits from the MECS (1.5 - 10 keV)

| Object | N_{H, gal}^a | kT (keV) | µ^b | χ^2_red |
|--------|-------------|---------|-----|---------|
| 3C78   | 7.3         | 2.7 ± 0.4 | 0.5 ± 0.4 | 1.09    |
| 0620-52 | 5.2         | 2.0 ± 0.3  | 0.1 ± 0.1 | 1.08    |
| 0625-53 | 5.4         | 5.4 ± 0.4  | 0.3 ± 0.1 | 1.02    |
| OH 342 | 7.1         | 2.7 ± 0.2  | 0.3 ± 0.2 | 1.13    |
| Her A  | 6.3         | 4.8 ± 0.7  | 0.3 ± 0.1 | 1.01    |

^a × 10^{20} cm^{-2} (fixed)

^b Metallicity in units of the standard cosmic values

Table 4
Thermal + absorbed power law fits\textsuperscript{a} from the MECS (1.5 - 10 keV)

| Object | kT (keV) | χ^2 (red.) | L_X^\text{ther.} (erg s^{-1}) | L_X^\text{power l.} (erg s^{-1}) |
|--------|---------|------------|-----------------------------|---------------------------------|
| 3C78   | 1.4 ± 0.3 | 0.82 | 3.1 × 10^{42} | 4.2 × 10^{42} |
| OH 342 | 1.7 ± 0.2 | 1.03 | 5.3 × 10^{43} | 4.1 × 10^{43} |
| Her A  | 2.0 ± 0.4 | 0.97 | 2.8 × 10^{44} | 3.8 × 10^{44} |

\textsuperscript{a} Fixed parameters: N_{H, gal} as in Tab. 3, N_{H, abs} = 10^{23} \text{ cm}^{-2}, µ = 0.3, α = 2

\textsuperscript{b} erg s^{-1} (H_0 = 50 \text{ km s}^{-1} \text{ Mpc}^{-1})

In the MECS, the data of 0625-53 (associated with the cluster Abell 3391) are fully dominated by the emission of the intracluster gas. This thermal spectrum cannot be related to the high energy flux detected in the PDS, as we can see in Fig. 3. Assuming that this emission originates from nucleus of the radio galaxy, and is nonthermal with a photon index α = 2, we deduce a luminosity 4.1 × 10^{44} erg s^{-1}, in the energy range 15 – 150 keV. This also implies that this spectral component must have a cut-off at energies ∼ 10 keV, consistent with a hydrogen column density N_{H, abs} > 10^{24} cm^{-2}. We must remark however that we cannot exclude at the moment that the detected flux originates from a foreground hard

Figure 1. The MECS unfolded, two-component spectrum (thermal + absorbed power law) of 3C 78. The spectral parameters of the fit are reported in Table 4.

3.2. Spectral analysis: PDS

In the MECS, the data of 0625-53 (associated with the cluster Abell 3391) are fully dominated by the emission of the intracluster gas. This thermal spectrum cannot be related to the high energy flux detected in the PDS, as we can see in Fig. 3. Assuming that this emission originates from nucleus of the radio galaxy, and is non-thermal with a photon index α = 2, we deduce a luminosity 4.1 × 10^{44} erg s^{-1}, in the energy range 15 – 150 keV. This also implies that this spectral component must have a cut-off at energies ∼ 10 keV, consistent with a hydrogen column density N_{H, abs} > 10^{24} cm^{-2}. We must remark however that we cannot exclude at the moment that the detected flux originates from a foreground hard
4. SUMMARY

From the MECS observations of the five radio galaxies of our sample, an absorbed non-thermal emission seems to be present in 3C78, OH 342 and Her A, that can be associated with the active nucleus surrounded by a thick obscuring torus. A similar interpretation can also hold for the radio galaxy 0625-53, but at much higher energies. Should this scenario be confirmed by detailed observations of a larger sample of low power radio galaxies, then the unified scheme proposed for FR II - radio loud quasars (Doppler beaming plus absorbing torus) could be also valid for FR I - Bl Lac objects.

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