Bright Radio Galaxies with BeppoSAX

P. Grandi 1, L. Maraschi2, M. Guainazzi3, F. Haardt4, G. Matt5, E. Massaro6, C. M. Urry7, L. Bassani8, P. Giommi9

1) IAS/CNR, Area di Ricerca di Tor Vergata, Roma I-00133, Italy
2) Osservatorio Astronomico di Brera, Milano, Italy
3) SSD/ESA, ESTEC, Postbus 299, 2200 AG Noordwijk, The Netherlands
4) Universita’ dell’Insubria/Polo di Como, Como, Italy
5) Universita’ degli Studi “Roma 3”, Roma, Italy
6) Istituto Astronomico, Universita’ di Roma, Via Lancisi 29 Roma, Italy
7) Stsci, Baltimore, MD, USA
8) ITESRE/CNR, Bologna, Italy
9) BeppoSAX SDC, c/o Nuova Telespazio, Roma, Italy

ABSTRACT Although a strong similarity between radio galaxies and Seyferts has been pointed out with ASCA, some radio galaxies do not seem to fit very well the cold thin accretion disk model proposed for radio quiet AGN. The BeppoSAX observations of 3C390.3 and Centaurus A show that cold material responsible for the photon reprocessing is present in these sources but not necessarily near to the primary X-ray source. The featureless spectrum of the broad line radio galaxy 3C111 indicates the absence of cold material near the X-ray source or, alternatively, the presence of a strong jet X-ray component.

KEYWORDS: X-ray: observations; Radio Galaxies

1. INTRODUCTION

Radio Galaxies have been poorly investigated in the past, as shown by scarce and sometime contradictory results from previous satellites. The bright radio galaxies, in particular the Fanaroff-Riley (FR) II, have been often treated as Seyfert galaxies and included in sample of radio quiet AGN without taking into account their radio loudness. It was implicitly assumed that they share the same nuclear properties of the Seyfert galaxies, in agreement with the unified scheme for AGN that considers the Broad Line Radio Galaxies (BLRG) and the Narrow Line Radio galaxies (NLRG) the radio loud counterparts of the Seyfert 1 and Seyfert 2, respectively. The detection of broad iron lines in several BLRG with ASCA seemed to confirm this picture; the large intrinsic width (σ > 0.6 keV) observed in 3C120, 3C382, 3C109 (Allen et al. 1997, Grandi et al. 1997, Reynolds 1997) suggested that the line is produced in the inner regions of the accretion disk as it is thought to be the case in Seyferts. The detection of a strong UV bump (Maraschi et al. 1991) and the indication of a possible soft excess (Grandi et al. 1997) in 3C120 further strengthened this hypothesis.

The BeppoSAX observations of bright radio galaxies reported here show that
the similarity between radio quiet and radio loud AGN is not a foregone conclusion. At least two questions needed to be addressed: 1) are the accretion processes the same in radio galaxies and Seyferts? 2) Is really the X-ray jet component negligible in the radio galaxies?

2. BeppoSAX OBSERVATIONS

3C390.3 is a BLRG \( \left( L_{2-10\text{keV}} \sim 3 \times 10^{44} \text{ erg sec}^{-1} \right) \) characterized by a FRII morphology with a core showing superluminal motion. It is characterized by a weak blue bump and double peaked emission lines in the optical and UV bands. The BeppoSAX spectrum is well fitted by a power law \( \Gamma = 1.80^{+0.05}_{-0.04} \) reflected at high energies by material with a fairly large covering factor \( \left( \Omega/2\pi = 0.9^{+0.3}_{-0.3} \right) \). The column density \( (N_H \sim 10^{23} \text{ cm}^{-2}) \) is larger than the Galactic one and probably variable on time scale of years. No soft X-ray excess was detected. The iron line at 6.4 keV is intrinsically narrow \( (\sigma = 73^{+270}_{-73} \text{ eV}) \) and has an equivalent width of \( \sim 140 \text{ eV} \) (see Grandi et al. 1998a for more details).

Although these features are typical of Seyfert galaxies the absence of a X-ray soft excess, the presence of a weak blue bump and of a narrow iron line are difficult to reconcile with a Seyfert like model that assumes a geometrically thin accretion disk and an active corona above it (Haardt & Maraschi 1991,1993). A completely hot inner flow (Shapiro, Lightman Eardley 1976, Narayan Mahadevan and Quataert 1998), surrounded by cold material in shape of a warped disk or a thick dusty torus at parsec distances is a more plausible description. A hot inner region can explain the lack of the soft excess and the cold external material the weak blue bump, the narrow iron line and the reflection.

Cen A is a well-known NLRG \( \left( L_{2-10\text{keV}} \sim 10^{43} \text{ erg sec}^{-1} \right) \) which has been extensively studied over the whole X-ray and \( \gamma \)-ray range (Turner et al. 1997 and refs therein). It was observed by BeppoSAX twice on 1997 February 20-12 and 1998 January 6-7 for 35 and 75 ksec, respectively. The average source flux increased between the two observations, being brighter by about a factor 1.3 in 1998. Given the complexity of this source we initially focused on the nuclear point-like emission. We studied the 1.5-150 keV spectrum (MECS and PDS data), fixing the contributions of the extended components (see Grandi et al. 1998b). At both epochs, the nuclear point-like emission is well fitted with a similar strongly absorbed \( (N_H \sim 10^{23} \text{ cm}^{-2}) \) power law \( (\Gamma \sim 1.7) \) with an exponential cutoff at high energies \( (E_{\text{cut}} > 200 \text{ keV}) \). The 1997 data need the contribution of a weak reflection component \( (\Omega/2\pi \sim 0.2) \), which should be considered with caution because of intercalibration uncertainties (10%) still present between MECS and PDS. A significant flux variation of the iron line was observed between the two observations. The flux of the line and of the continuum changes in the opposite sense. The line is more intense at the first epoch, when the nuclear source is at the lower intensity level (see figure 2 in Grandi et al. 1998b). The implied delay between the continuum and line variations strongly suggests that the cold material responsible for the iron line production can not be located (as in the case of 3C390.3) very near to the primary X-ray source.

3C111 is a BLRG \( \left( L_{2-10\text{keV}} \sim 3 \times 10^{44} \text{ erg sec}^{-1} \right) \) with radio properties similar
to 3C390.3. It is a strongly absorbed source, being located behind the galactic dark cloud, Taurus B.

BeppoSAX observed this source for about 100 ksec. The spectrum is well fitted by a simple power law with a quite hard spectral index ($\Gamma \sim 1.7$). Neither reflection component nor iron line are required by the data. We could only estimate an upper limit for the 6.4 keV fluorescence feature (EW $< 66 \text{ eV}$) and for the amount of reflection ($R < 0.13$) (Grandi et al. in preparation). In agreement with the ASCA results (Reynolds et al. 1998), the low energy absorption requires a column density ($N_H = 10^{(\pm 0.1) \times 10^{21} \text{ cm}^{-2}}$) which is larger than that estimated in the direction of Taurus B ($N_H \sim 3 \times 10^{21} \text{ cm}^{-2}$; Ungerer et al. 1985, Elvis Lockman and Wilkes 1989). The interpretation of the data is not immediate. At least two possible scenarios can be prospected. 1) The absorption due to the Taurus B cloud is underestimated because the current measures of $N_H$ do not take into account sub-parsec molecular inhomogeneities (see Reynolds et al. 1998) for an accurate discussion). In this case, the X-ray photons are absorbed in our Galaxy, there is not intrinsic absorption in 3C111 and the spectrum is blazar-like. 2) Intrinsic photons absorption occurs in the source and, as suggested by the superluminal motion observed at radio frequencies, we are directly seeing the nuclear region. The lack of signatures of cold material, like the iron line and the reflection component, might indicate the presence of an accretion flow (or a considerable part of it) too hot to produce typical Seyfert 1 features. Note that another BLRG, Pictor A, is characterized by a similar X-ray spectrum (Padovani et al. 1998, Eracleous and Halpern 1998).

3. CONCLUSIONS

The similarity between radio-quiet and radio loud AGN has still to be confirmed. Recent observations of radio galaxies have shown that there is not a unique type of X-ray spectrum (see Figure 1)

Some sources (3C120, 3C109, 3C382) fit very well the Seyfert-like model. The broad iron line observed by ASCA can be easily explained assuming cold material (a geometrically thin disk) rapidly rotating very near the black hole. In this case the X-ray primary photons are assumed to be produced by an active corona embedding the inner region of the accretion disk.

In other cases (3C390.3 and Cen A), a geometry which assumes cold material far away from the X-ray primary source seems to provide a better explanation of the observations. In particular for 3C390.3, it is possible that the X-ray continuum is produced by a hot inner flow while the reprocessed radiation come from an outer region shaped as a warped disk and/or a torus.

Some objects (3C111, Pictor A) do not show the iron line and, in the case of 3C111, the Compton hump is also absent. The beamed jet component could be important in these sources and obscure the Seyfert-like emission. Alternatively, the accretion flow could be hot, maybe in a two temperature configuration (as that suggested for the inner region of 3C390.3).
FIGURE 1. Spectral energy distributions of three types of BLRG. 3C120 shows a Seyfert-like spectrum with strong blue bump, broad iron line and probably reflection. 3C390.3 is characterized by a weak blue bump and a narrow iron line. 3C111 shows neither the iron line nor the Compton hump (BeppoSAX data). The UV points and the extrapolated X-ray power laws (dotted blue lines) refer to simultaneously IUE-EXOSAT (3C120: Maraschi et al. 1991) and IUE-ROSAT/PSPC (3C390.3: Walter et al. 1991, A&A, 285, 119) observations. The ASCA and OSSE data of 3C120 are from Grandi et al. 1997, the BeppoSAX data of 3C390.3 from Grandi et al. 1998a.

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