The Compton-thick AGN in the GPS radio source OQ+208

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Abstract. We report in this paper the ASCA discovery of the first (to our knowledge) radio-loud Active Galactic Nucleus (AGN) covered by a Compton-thick X-ray absorber, in the GigaHertz Peaked Spectrum radio source OQ+208. It represents one of the few available direct measurements of dense matter in the nuclear environment of this class of sources, which may provide the confining medium to the radio-emitting region if GPS sources are indeed ”frustrated” classical radio doubles. The perspective of future studies with XEUS are discussed.

1. Introduction

GigaHertz Peaked Spectrum radio sources are a class of powerful \((L_{\text{radio}} \sim 10^{45} \text{ erg s}^{-1})\) radio sources, defined by a simple convex spectrum peaking near 1 GHz. They represent \(\approx 10\%\) of the 5 GHz selected sources, \(i.e.\) a significant fraction of the powerful radio sources in the universe. They are characterized by compact radio cores, most likely not extending beyond the narrow-line regions (NLRs; \(\leq 1 \text{ kpc}\)). Some of them exhibit very faint extended radio emission on scales larger than the host galaxy (Baum et al. 1990; Stanghellini et al. 1990; Fanti et al. 2001), but rarely on Mpc scales (Schoenmakers et al. 1999). Their radio morphologies and host galaxies are generally consistent with classical 3CR doubles. Emission-lines optical spectra suggest interaction between the radio source and emission-line gas, as well as dust obscuration. Mid-IR measurements suggest the existence of a powerful hidden active nucleus (Heckman et al. 1994: see, however, de Vries et al. 1998 and Fanti et al. 2000 for a different point of view).

Two scenarios are currently proposed to explain the nature of GPS sources:

1. the \textit{young scenario}: GPS could be young versions of large scale radio galaxies at an earlier stage of their formation (Carvalho 1985: Mutel & Philips 1988; Fanti et al. 1995; Readhead et al. 1996: O’Dea & Baum 1997). In this scenario, objects which are \(\approx 100 \text{ pc}\) in size are about \(10^4\) years old, which is consistent with proper motion measurements on about 10 of them (Fanti 2000)

2. the \textit{frustrated scenario}: GPS may represent ”aborted” classical doubles, which will never reach their full maturity because they are embedded in a dense and turbulent medium, able to confine and trap the radio-emitting region on the scale-length of the NLRs (van Breugel et al. 1984; O’Dea et al. 1991)

X-ray observations can provide an important contribution to elucidate the nature of this class of objects. In facts:

- measurements of hot gas, through its optically thin emission peaking in the soft X-rays, may provide indication for the presence of hot confining medium (O’Dea et al. 1996). Constraints on the presence of such a gas phase from other wavelengths is not conclusive (Kameno et al. 2000; Marr et al. 2001)
- measurements of heavy X-ray absorption (in the most extreme case Compton-thick, \(N_H > \sigma_T^{-1} \approx 10^{24} \text{ cm}^{-2}\)) may indicate the presence of cold confining matter, to be compared with hydrodynamical models (De Young 1993; Carvalho 1994, 1998) to identify possible mechanisms responsible for the confinement of the jet
- the detection of large-scale X-ray jets may challenge one or more of our current assumptions on the nature of GPS sources (Siemiginowska et al. 2002)

The properties of the cold and hot phases, that one can derive from the X-ray spectral fitting may therefore provide a test for the ”frustration” scenario.

Unfortunately, GPS sources are X-ray weak: only 3 out of 9 GPS sources observed in the soft X-rays have been detected. Hints that this low rate may be due to absorption were put forward by Elvis et al. (1994) and Zhang &
Fig. 1. **Left panel:** 1404+286 ASCA spectra (upper panel) and residuals in units of data/ratio models (lower panel) when a simple power-law model is applied. Photoelectric absorption column density due to our Galaxy ($N_H = 1.4 \times 10^{20}$ cm$^{-2}$) is assumed. **Right panel:** Unfolded best-fit model superimposed to the ASCA spectra of the same objects in the Compton-reflection plus thermal plasma scenario. The individual components are labeled.

Marscher (1994). O’Dea et al. (1996) report the detection of a luminous ($L_X \sim 2 \times 10^{43}$ erg s$^{-1}$) and highly absorbed ($N_H \approx 4 \times 10^{22}$ cm$^{-2}$) hard X-ray source in 1314+125 ($z = 0.122$). Siemiginowska et al. (2002) recently discovered with Chandra a prominent X-ray jet on scales $\sim 300 h_{50}^{-1}$ in PKS 1127-145 ($z = 1.187$).

2. OQ+208: discovery of the first radio-loud Compton-thick AGN

We present in this paper results of the January 1999 ASCA observation of the GPS radio galaxy OQ+208 (1404+286; $z = 0.077$). The inverted X-ray spectrum (see Fig. 1; energy index $\alpha = -0.17^{+0.16}_{-0.17}$) and the remarkably strong (Equivalent Width, $\text{EW} = 900^{\pm 400}$ eV) K$_\alpha$ fluorescent neutral iron line ($E_{\text{centroid}} = 6.49^{\pm 0.09}$ keV) are best explained if the X-ray emission is dominated by the Compton-reflection of an otherwise invisible continuum. The column density covering the AGN is likely to be as large as $10^{24}$ cm$^{-2}$. If this explanation is correct, 1404+286 would be the first radio-loud Compton-thick AGN ever observed. The alternative possibility of a Compton-thin absorber (still with $N_H \approx 1.2 \times 10^{23}$ cm$^{-2}$) is equally viable from the statistical point of view, although in this scenario there is no clear explanation for the extreme intensity of the iron line (Leighly & Creighton 1993). In both cases, a soft excess below 3 keV is present, which can be explained as thermal emission from an optically thin hot gas, whose temperature is, however, loosely constrained ($T > 3.8 \times 10^7$ K; cf. the right panel of Fig. 1). Again, the quality of the ASCA data is not good enough to rule out alternative explanations for the soft X-ray emission, as electron scattering of the primary nuclear emission. The observed fluxes are $0.7$ and $5.5 \times 10^{-13}$ erg cm$^{-2}$ s$^{-1}$ in the 0.5–2 keV and 2–10 keV bands, respectively. They correspond to rest-frame unabsorbed luminosities of $1.7 \times 10^{42}$ and $1.4 \times 10^{43}$ erg s$^{-1}$ in the same energy bands. However, if the bulk of the hard X-ray emission is indeed due to Compton-reflection, the true intrinsic 2–10 keV luminosity of 1404+286 is likely to be at least one order of magnitude higher (Guainazzi et al. 1999; Awaki et al. 2000).

Although the measurement of the iron line is robust, and points unambiguously to a reflection-dominated spectrum, the overall spectral deconvolution is still ambiguous. Time has been allocated for the XMM-Newton 2$^\circ$ observational cycle (January-September 2003) to reobserve this target. The unprecedented collecting power of XMM-Newton in the hard X-rays (Jansen et al. 2001) will allow us to unambiguously characterize all the spectral components in this intriguing source.

3. The XEUS perspective

Only with XEUS one can get spectroscopic information on GPS sources at cosmological redshifts, where most of them are located (cf. Fig. 2). Simulations have been done, placing at redshift of $z = 1$ (Fig. 3; upper and central panels) and $z = 3$ (lower panels) the two GPS sources for which hard X-ray measurements are available (see above). An exposure time of 50 ks has been assumed throughout, and the CIS Superconducting Tunnelling Junctions detectors response...
**Fig. 2.** Redshift distribution of the known GPS sources after O’Dea 1998.

matrices employed. In each spectral plot, the lower curve corresponds to the initial configuration, the upper curve corresponds to the final configuration one. The iso-$\chi^2$ contours plots refer to the latter case.

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Fig. 3. XEUS simulation of GPS sources at cosmological redshifts. Details in text.