

A NEW XMM-NEWTON OBSERVATION OF PICTOR A RADIO LOBES CONFIRMS THE NON-THERMAL ORIGIN OF THE X-RAY EMISSION

G. Migliori^{1,2}, P. Grandi¹, G. G. C. Palumbo², G. Brunetti³, G. Malaguti¹, M. Guainazzi⁴

¹INAF/IASF Bologna, Italy ²Bologna University, Italy ³INAF/IRA Bologna, Italy ⁴XMM-Newton SOC Vilspa, Spain

ABSTRACT

X-ray emission from the eastern radio lobe of the FR II Radio Galaxy Pictor A was serendipitously discovered by a short observation of XMM-Newton in 2001. The X-ray spectrum, accumulated on a region covering about half of the entire radio lobe, was well described by both a thermal model and a power law, making non-univocal the physical interpretation. A new XMM-Newton observation performed in 2005 has allowed the detection of the X-ray emission from both radio lobes and unambiguously revealed its non-thermal origin. The X-ray emission is due to Inverse Compton (IC) of the cosmic microwave background photons by relativistic electrons in the lobe. We confirm the discrepancy between the magnetic field, as deduced from the comparison of the IC X-ray and radio fluxes, and the equipartition value.

Key words: Radio-galaxies - radio lobes - radiation mechanism.

1. INTRODUCTION

Pictor A is a nearby ($z=0.035$) double lobe radio source with a Fanaroff Riley II (FR II) morphology. VLA observations (Perley et al. 1997) show two nearly circular radio lobes with hot spots and a faint radio jet connecting the nucleus to the west hot spot. The spectral indices are fairly uniform throughout each lobe $\langle \alpha_R \rangle = 0.8$. XMM-Newton discovered X-ray radiation associated to the extended radio lobes (Grandi et al. 2003). In spite of the relatively short exposure time (~ 15 ks), and the very high background, a quite good spectrum was obtained from a circular region centered on the east lobe. However, the data interpretation was not univocal, as the X-ray spectrum could be described by both a power law ($\alpha_X = 0.6 \pm 0.2$) and a thermal model ($kT \sim 5$ keV). The presence of an extended emission, most likely to be ascribed to non-thermal processes, has been recently confirmed (Hardcastle & Croston 2005). To definitely solve the ambiguity on the nature of the radio-lobes X-ray emission, a new XMM-Newton 50 ks observation was

performed on 14 January 2005. Here we present the preliminary results.

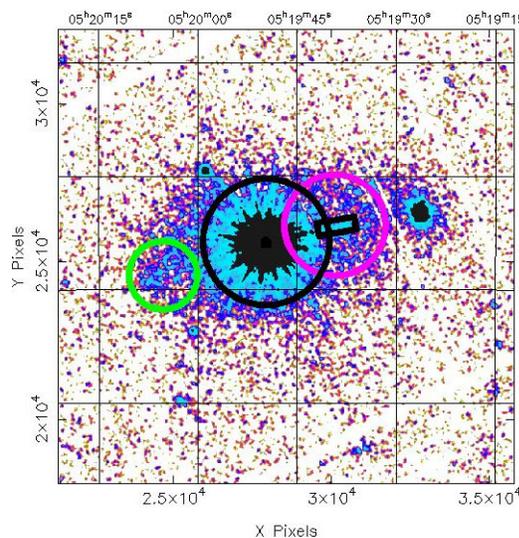


Figure 1. XMM/MOS1 image (0.2-10 keV) of Pictor A observed on 14 January 2005. Several components are visible: the bright nucleus, the west hot spot, the jet, and the two lobes. The green and the pink circles (excluding the nuclear and the jet contributions), represent the extraction regions of the east and west lobe spectra, respectively.

2. SPECTRAL ANALYSIS

Figure 1 shows the observed MOS1 image (0.2-10 keV) of Pictor A. The X-ray counterparts of radio lobes are clearly visible as asymmetric diffuse emission around the bright nucleus. Unlike the previous XMM-Newton observation, performed in 2001, spectra of good quality can be extracted from both lobes. This has allowed a spatially resolved X-ray spectral analysis. The green circle

Table 1. East lobe spectral fit results

Power Law		Thermal Emission	
Γ	$1.80^{+0.17}_{-0.14}$	$kT(\text{keV})$	$4.94^{+3.01}_{-1.47}$
$F^{(a)}$	$1.09^{+0.21}_{-0.12}$	$F^{(a)}$	$1.00^{+0.01}_{-0.01}$
χ^2/dof	19/23	χ^2/dof	28/23

(a): 2–10 keV flux in 10^{-13} erg cm^{-2} s^{-1}

Table 2. West lobe spectral fit results

Power Law		Thermal Emission	
Γ	$1.75^{+0.17}_{-0.17}$	$kT(\text{keV})$	$5.59^{+3.18}_{-1.62}$
$F^{(a)}$	$1.58^{+0.16}_{-0.16}$	$F^{(a)}$	$1.48^{+0.12}_{-0.12}$
χ^2/dof	34/30	χ^2/dof	42/30

(a): 2–10 keV flux in 10^{-13} erg cm^{-2} s^{-1}

indicated in Figure 1 represents the selected accumulation region for the east lobe spectrum. The spectrum of the west lobe was instead extracted from the pink circle, after subtraction of the nuclear and the jet contributions (black circle and rectangle, respectively).

Following the previous work (Grandi et al. 2003) we tested both a power law and a thermal model to fit the data. For both lobes, a non-thermal emission is preferred to a thermal process, as shown in Tables 1 and 2. This appears also evident in Figure 2 where the two spectral models to the east lobe data are compared. The residuals result clearly larger for the thermal model fit. The comparison between Table 1 and 2 indicates that the X-ray photon index value is $\Gamma \sim 1.8$ ($\alpha_X = 0.8$) independently of the position of the extraction region. The X-ray spectral index, α_X is thus in very good agreement with the radio slope ($\alpha_R \sim 0.8$). Moreover, the non-thermal X-ray flux of the east lobe is in agreement with the previous value reported in Grandi et al. (2003).

3. DISCUSSION

This new observation solves the ambiguity on the nature of the extended X-ray emission. Radio emitting electrons in the lobes upscatter local cosmic microwave background, producing the observed X-ray emission. We assume $k = 1$, where k is the ratio between electron and proton energy density in the lobes, and an electron spectrum $N(\gamma) \propto \gamma^{-(2\alpha_R+1)}$, with a low energy cut-off

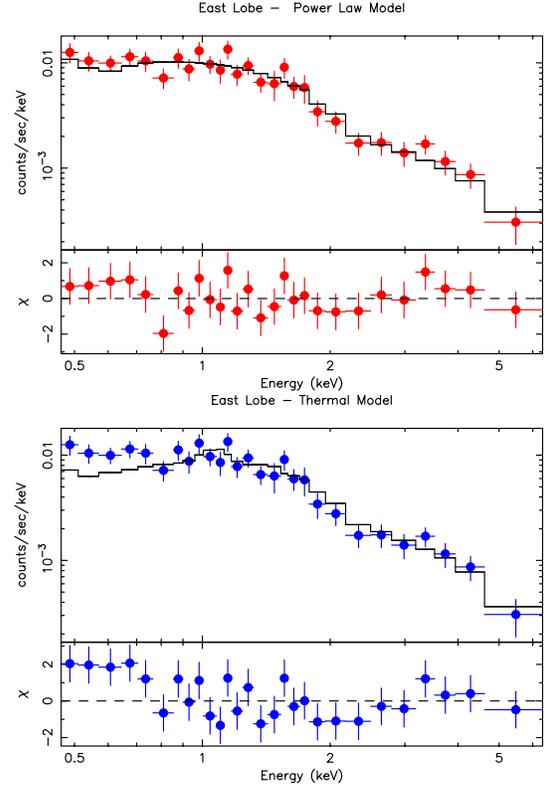


Figure 2. XMM/MOS1 spectrum of the east lobe: a power law (upper panel) is clearly preferred to a thermal model (bottom panel).

$\gamma_{\min} = 50$. Following Brunetti et al. (1997) and Blumenthal & Gould (1970), we find $B_{\text{EQ}}/B_{\text{IC}} \simeq 2.7$, which implies a ratio between the particle and magnetic field energy density equal to (Brunetti 2004): $(\omega_{(e+p)}/\omega_B) \sim [2/(\alpha_R + 1)](B_{\text{EQ}}/B_{\text{IC}})^{(3+\alpha_R)} \sim 50$, thus showing a strong particle dominance in the radio lobes.

REFERENCES

- Blumenthal., G. R. & Gould, R.J. 1970, Rev. Mod. Phys., 42, 237
- Brunetti G., Setti, G. & Comastri, A., 1997, A&A, 325, 898
- Brunetti G. 2004, in The Role of VLBI in Astrophysics, Astrometry and Geodesy, Mantovani & kus eds, p. 29.
- Grandi, P. et al. 2003, ApJ, 586, 123
- Hardcastle. M., J. & Croston, J. H. 2005, MNRAS, 363, 649
- Miley, G., 1980 ARA&A, 18, 165
- Perley R.A., Roser H.J. & Meisenheimer K. 1997 A&A, 328, 12