Chandra Observations of the Diffuse X-ray Emission in Pictor A Radio Galaxy

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Abstract
Here we present some preliminary results of our analysis of the Chandra observations of the diffuse X-ray emission from the extended lobes in Pictor A radio galaxy. All the available Chandra data for the target, consisting of multiple pointings spanning over 15 years and amounting to the total exposure time of 464 ks, have been included in the analysis. All the point and compact sources in the field – both unrelated background/foreground objects, as well as the unresolved core, the jet, and the hotspot regions of Pictor A – were removed, and the radio contours were superimposed on the Chandra image to define the edges of the lobes. This will allow us to calculate the ratio of the X-ray to radio (both total and polarised) fluxes of the non-thermal emission, as a function of the position within the lobes. Our main goal is a in-depth statistical analysis of the resulting distribution, offering a unique insight into the lobes magnetic field structure.

Chandra data and analysis
Radio lobes of Pictor A, one of the most prominent radio galaxy in the sky, are characterized by the total angular extension of ~8 arcmin (Perley et al. 1997). The non-thermal X-ray emission of the lobes has been also been detected with the Chandra X-ray Observatory (e.g., Hardcastle et al. 2016). As such, the source is the best target for a detailed investigation of the X-ray and radio flux distribution within the lobes, utilizing the matching arcsec resolution of Chandra and VLA. This analysis may, in principle, unveil the underlying distribution of relativistic electrons and magnetic field. Note that the observed synchrotron radio flux scales with the product of the magnetic field energy density, \( u_B \), and the electron energy density, \( u_e \), namely \( S_{\nu} \propto u_B \times u_e \), while the non-thermal X-ray flux, believed to be dominated by the inverse-Comptonization of the CMB radiation, scales as \( S_{\nu} \propto u_e \times u_{cmb} \), where \( u_{cmb} \) is the energy density of the CMB photons. Hence, only the combined VLA and Chandra data analysis for Pictor A, may allow us to map independently the spatial distribution of \( u_B \) and \( u_e \) within the lobes. However, the Chandra data analysis for the diffuse lobes in Pictor A is complicated by the fact that multiple Chandra pointings carried out over the last 15 years have been performed with different ACIS configurations, often not covering the entire source (see the Table below). As a result, the exposure across the lobes, as well as the Chandra point spread function (PSF), are highly non-uniform. In addition, due to the large angular extension of the target, there are numerous unrelated foreground and background X-ray sources. Finally, the bright core, the jet, and the hotspots regions, all contribute significantly to the total X-ray output of the source, contaminating the diffuse emission of the lobes.

Conclusions & Future work
• The next step of the analysis will include a detailed point-to-point correlation analysis between the X-ray fluxes and radio (total and polarized) fluxes of the extended lobes in Pictor A.

References
Acknowledgement
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Figure 1: Merged exposure-corrected smoothed X-ray image of the extended lobes in Pictor A in the energy range 0.5–7.0 keV, with the resolution radio contours superimposed.

Figure 2: Point and compact sources (detected by green regions) detected with the wavdetect tool using the “minimum PSF” method on the merged and exposure-corrected Chandra image of Pictor A. Different regions sizes across the field reflect varying PSF and/or sources’ extension.

Figure 3: Merged and exposure-corrected Chandra image of Pictor A field, in the energy range 0.5–7.0 keV. (The image shows the bright core of the radio galaxy in the center, the jet extending to the northeast from the core, the western hotspot, the eastern hotspot region, and the surrounding diffuse lobes.)

Figure 4: Merged and exposure-corrected smoothed Chandra image of the extended lobes in Pictor A in the energy range 0.5–7.0 keV, with the 30 arcsec resolution radio contours superimposed. The radio contours with the intensity ratio \( \nu^2 \) and \( \nu^3 \) resolution are between 0.6% and 20% of the peak intensity of 21 Jy/beam (Perley et al. 1997).

Figure 5: Merged and exposure-corrected smoothed Chandra image of the extended lobes in Pictor A in the energy range 0.5–7.0 keV, with the 30 arcsec resolution radio contours superimposed.

Figure 6: The degree of \( \lambda^{3/2} \) polarization of Pictor A at 30\′ resolution, with the Chandra intensity contour superposed (corresponding to the merged and exposure-corrected image of the extended lobes in the energy range 0.5–7.0 keV).

Figure 7: The spectral index (\( \alpha_u \) vs. \( \nu^{-2} \)) map between \( \lambda^{3/2} \) cm and \( \lambda^{4/3} \) cm at 30\′ resolution, with the Chandra intensity contour superimposed (corresponding to the merged and exposure-corrected image of the extended lobes in the energy range 0.5–7.0 keV).