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Dr. Hab. Krzysztof Nalewajko
Nicolaus Copernicus Astronomical Center
Polish Academy of Sciences
Bartycka 18, 00-716 Warsaw

Review of the doctoral dissertation of Mr. Rameshan Thimmappa
"A Comprehensive and Novel Analysis of the Chandra X-ray Observatory Data for the Pictor A Radio Galaxy"

Mr. Rameshan Thimmappa presented a doctoral dissertation consisting of three main chapters, all of which concern analysis of archival observational data from the Chandra X-ray Observatory (CXO) of a nearby bright Fanaroff-Riley type II radio galaxy Pictor A. Chapter 2 is focused on the active nucleus of Pictor A, these results have been presented as proceedings of an International Astronomical Union symposium. Chapter 3 is focused on the western hotspot of Pictor A, these results have been published in the Astrophysical Journal. Chapter 4 is focused on the eastern radio/X-ray lobe of Pictor A, these results have been submitted to the Astrophysical Journal. These three chapters have been obtained in local and international collaboration. Declarations of the co-authors indicate that the contribution of Mr. Thimmappa to Chapters 3 and 4 is at the level of ~50%, and a similar contribution is assumed for Chapter 2. The dissertation is supplemented with a decent introduction in Chapter 1.

Pictor A has been studied extensively as an extended X-ray source, and hence a large number of observations with the CXO, with its unique capability for sub-arcsecond angular resolution, have been obtained during the period of 2000 – 2015. It appears that the direct motivation for this dissertation has been the publication of Hardcastle et al. (2016, MNRAS, 455, 3526), which involved Dr. Hab. Stawarz, and was based on the same dataset. That previous work included a basic analysis of multiple regions of Pictor A – the nucleus, the western hotspot, the eastern hotspot/lobe, and in addition the jet. It also compared the morphology of the X-ray image of Pictor A with the archival radio image from the Very Large Array (VLA). The greatest novelty of Mr. Thimmappa's dissertation is that it addresses two specific difficulties involved in the analysis of CXO data for Pictor A. The high X-ray brightness of the nucleus creates a problem of photon pileup, and a major part of Chapter 2 is devoted to address this problem. The exact X-ray morphology of the western hotspot is affected by variations in the point spread function (PSF) resulting from different pointing geometries (off-axis angles) for individual CXO observations, Chapter 3 presents PSF simulations and deconvolution analysis to obtain a sharper image of the hotspot.

The dissertation of Mr. Thimmappa addresses a few interesting questions concerning X-ray emission of Pictor A. Is there an iron emission line in the X-ray spectra of the Pictor A nucleus? Is

the X-ray brightness of the western hotspot varying over 15 years? Is there a thermal component in the X-ray emission from the eastern lobe? However, the answers to those questions are rather ambiguous, either because the data appear to be insufficient (the eastern lobe) or because the problems involved in the analysis are not resolved entirely (the nucleus).

Major comments:

1. The problem of photon pileup should be presented in more detail, a proper introduction should be included in Chapter 1. Chapter 2.2.2 describes two alternative approaches ('takes') to pileup correction when evaluating the X-ray surface brightness profiles of the nucleus, but in the end which one is more appropriate? Comparing these two takes is complicated by different assumptions, in particular an additional Gaussian component is considered only in 'Take #2'. It could be argued that 'Take #1' yields a better result without invoking a Gaussian component.

2. In the spectral analysis of the nucleus (Chapter 2.2.1), it is suggested that the high-energy (4.5-7 keV) excess could be an artifact of inadequate correction of the photon pileup. However, in case of a soft X-ray spectrum the pileup is expected to affect mainly the low-energy photons. How could the pileup result in an artificial excess of high-energy photons? Is there any information returned by the 'jdpileup' model on the energies of piled photons?

3. The new high-resolution X-ray structure of the western hotspot (Chapter 3) includes a component oriented parallel to the jet direction and located upstream from the perpendicular termination shock. This component is described as belonging to the jet flow. However, upstream from the termination shock the jet should be supersonic, and in such case no information about the shock would propagate upstream to trigger dissipation there. Indeed, what could be the dissipation mechanism powering this component?

4. Figure 3.9 defines the western hotspot of Pictor A as a rather large region “HS” consisting of two subregions “hotspot North” (N) and “hotspot South” (S). It can be argued, based in addition on Figure 3.7, that region S does not belong to the hotspot, because its X-ray, optical and radio emissions are much weaker than those from region N.

5. When comparing the X-ray and radio structures of the eastern lobe (Chapter 4), the term 'correlation' should be avoided. Figure 11 of Hardcastle et al. (2016) shows that when considering the entire radio galaxy of Pictor A, there is no correlation between X-ray and radio surface brightness. What is shown in Chapter 4 is that region A of enhanced X-ray brightness separates regions of strong polarized radio emission. The formal analysis of integrating surface brightness along 'Profile1' does not appear to be essential, as this result can be seen in more detail in the bottom panel of Figure 4.3 (a similar figure for the total radio intensity would be helpful). One can see there that the region of polarized radio emission located SW from region A, and partially overlapping with it, is significantly

stronger than regions of polarized emission located NE from region A. This raises a question whether the middle panel of Figure 4.7 correctly shows the maximum polarized radio intensity along Profile1 is located to the East (left) of the X-ray intensity peak?

Overall, the dissertation of Mr. Thimmappa presents a fairly comprehensive (except for the jet) X-ray picture of the Pictor A radio galaxy. It utilizes advanced methods for X-ray data analysis and presents the results in a systematic fashion, well written and accessible to non-experts in X-ray analysis. I am convinced that the presented dissertation satisfies all requirements for doctoral dissertations in Poland, and I recommend proceeding towards its public defense.

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Digitally signed by Krzysztof Nalewajko
Date: 2021.04.12 12:18:49 CEST

Krzysztof Nalewajko