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Comptonization in 1E 1740.7−2942 spectra from 2 to 200 keV

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Studies of the long-term spectral variations have been used to constrain the emission processes of black hole candidates. However, a common scenario which is able to explain the emission from soft to hard X-rays has been proposed only recently. Here, we use XMM and INTEGRAL data on 1E 1740.7−2942 in order to demonstrate that Comptonization plays an important role in producing high energy photons, as predicted by the current modeling scenario.

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1. Introduction

1E 1740.7−2942 is a black hole candidate (BHC) discovered by the *Einstein* satellite [1], and it is one of the brightest hard X-ray sources close to the centre of our Galaxy [2]. The source has a very hard X-ray spectrum and is known to be associated with a doubled-sided radio-emitting jet [3]. For this reason, 1E 1740.7−2942 is classified as a *microquasar*. Due to the high Galactic extinction towards the Galactic Centre, so far it has not been possible to identify a stellar companion, but some observations suggest that the companion might be a low-mass star [4]. Many studies have been carried out to understand the nature of the source and the origin of its emission. In this work, we present a spectral analysis of 1E 1740.7−2942 using data from the XMM and INTEGRAL satellites in two epochs: 2003 and 2005. The data from XMM, to our knowledge, has never been reported in the literature.

2. Data selection, analysis and results

Data reported here are a first step of an ongoing project which aims to study long-term spectral variability of 1E 1740.7−2942 using INTEGRAL [5] and XMM [6]. Here we selected two simultaneous observations of 1E 1740.7−2942 with XMM and INTEGRAL, one in 2003 and another in 2005. Data were selected from the PN [7] camera of XMM and IBIS/ISGRI [8] telescope onboard INTEGRAL. INTEGRAL spectral extraction was done with the use of the OSA 9.0 [9] software. XMM spectral extraction was done with the SAS software version 1.52.9 [10]. Data from PN camera were then analyzed in the 2–10 keV band. Following the data analysis threads from SAS, we checked if the data were affected by pile-up, concluding that no corrections were necessary in the data. We want to mention that XMM data below 2 keV were not included in this preliminary work for two main reasons: the residuals of our fits (when the part below 2 keV is included) show a presence of a feature that can be modeled with a Gaussian line. It is still not clear to us if this is due to an instrumental effect or not. Including the data from below 2 keV would allow us to better constrain the `nH` parameter, but being not sure of the nature of the low-energy feature, and adopting an `nH` value from previous measurements, we proceeded with a lower energy threshold of 2 keV.

IBIS data lower threshold starts at 20 keV extending up to 200 keV. Data were analyzed with the use of XSPEC. Such coverage allowed us to test the framework currently used to model the spectra of black hole candidates [11]. It is noteworthy that in this first step we decided not to use JEM-X data to fill the gap between XMM and INTEGRAL data. Data were fitted, as suggested by Bouchet et al. [11], with a single (absorbed) Comptonization model. In XSPEC (language) we used the `comptt` model [12]. It is interesting to note that more specialized models such as `compps` [13] are also adequate to fit the spectra. A normalization factor between XMM and INTEGRAL was also included in the fit, and left free to vary in the 2003 data. The same normalization factor (equal to 0.9) was used (and frozen) in the 2005 data. As already mentioned, starting at ~ 2 keV, XMM data were not well suitable to estimate the hydrogen column (`nH` parameter in XSPEC). This value was frozen at $10^{23}\,\mathrm{cm}^{-2}$ [14]. Our spectral fits are shown in Fig. 1. We used the disk geometry and optical depth frozen at a value of 1 [11]. The values of the fluxes and fit parameters are shown in Tab. 1.

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Period	χ^2_{red}	kT$_0$	kT$_e$	Flux	Flux
	(keV)	(keV)	(2-10 keV)	(20-200 keV)	
2003	1.2	$1.02^{+0.03}_{-0.03}$	$63.2^{+2.9}_{-2.8}$	$2.86^{+0.08}_{-0.06}$	$1.65^{+0.05}_{-0.03}$
2005	1.7	$0.90^{+0.01}_{-0.01}$	$53.8^{+1.5}_{-1.5}$	$2.31^{+0.05}_{-0.05}$	$1.03^{+0.02}_{-0.02}$

Table 1: The fit parameters kT$_e$ (electron temperature), kT$_0$ (seed Wien photon temperature) and fluxes for the combined PN/XMM and ISGRI/INTEGRAL 1E 1740.7−2942 spectra with a (absorbed) Comptonization model (`const*phabs*compTT` in XSPEC). Fluxes are in units of 10^{-10} erg cm^{-2} s^{-1} (2-10 keV) and 10^{-9} erg cm^{-2} s^{-1} (20-200 keV).

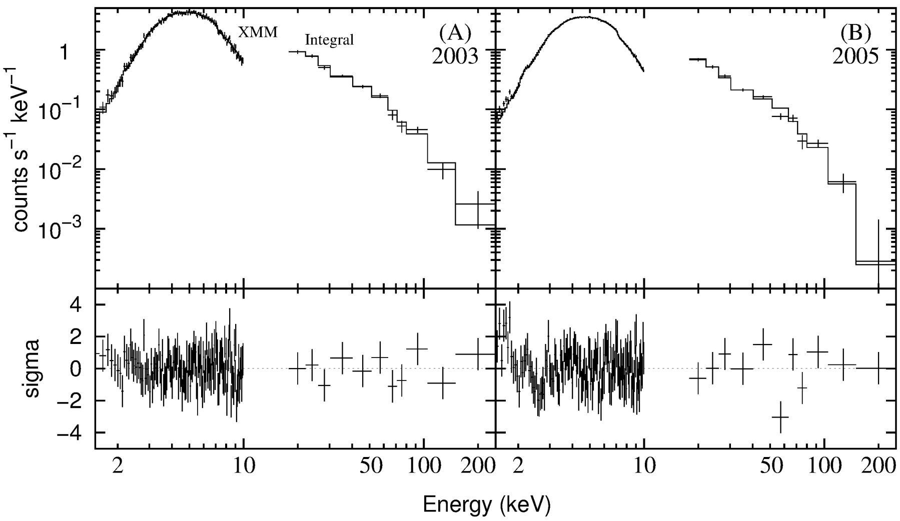

Figure 1: (A) Data for 2003 and (B) 2005 for 1E 1740.7−2942 .

3. Discussion

It should be stressed that other model combinations can be used in order to achieve an adequate fit to the data presented here. As can be seen from Fig. 1 the residuals in the IBIS part can be interpreted as noisy. Indeed, this is much more clear in the 2005 data, where the residuals of the fit shows that additional components can be included in the fit. Notwithstanding, the simple picture shown here with only one component, based on the Comptonization of lower energy (Wien) photons by a hot plasma (the scenario of `comptt`) can provide an adequate fit to the data and is within the framework of modeling the spectra of black hole candidates [11]. We emphasize that we are claiming that the fit with only `comptt`, adequate for 2003 data and marginally also for 2005 data, allowed us to proceed with (one of) the simplest data modeling, within the reaches and goals of this study. It is tempting to correlate the observed fluxes decrease in both bands (2-10 and 20-200 keV) with the variation of kT$_e$. Taking into account a distance of 7.7$\pm$ 0.4 kpc to the Galactic Centre [13], the observed 2-200 keV luminosities are, respectively, 1.4×10^{37} and 9.1×10^{36} erg/s for 2003 and 2005. It is not a surprising fact that spectral variations were detected, since this is a common feature in the spectra of black hole candidates.

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According to a recent definition of the emission states in black holes [15], fits using two components, a powerlaw plus a thermal (blackbody), are suitable in characterizing such states. Accordingly, we also performed fits to our data following this recipe, i.e., using cutoff powerlaw plus a multicolor disk blackbody model applied to both spectra (2003 and 2005: see Tab. 2). For 2003, a single powerlaw model (absorbed) was enough to achieve an adequate fit whereas in 2005 it was necessary to add to the powerlaw a thermal component (`diskbb`), contributing with less than 0.2% to the total 2–10 keV flux. Such a thermal component is interpreted as originating from the disk and it was already reported in the spectra of other black hole candidates, such as GRS 1758 − 258 [16], as well as in 1E 1740.7−2942 [17] [18]. We were able to determine that in both epochs 1E 1740.7−2942 was in the canonical low/hard state.

	2003	2005
T_{in} (keV)	-	$0.245^{+0.040}_{-0.009}$
A_{disk}	-	48820^{+50000}_{-39316}
Γ	$1.38^{+0.06}_{-0.06}$	$1.61^{+0.03}_{-0.02}$
E_{cutoff} (keV)	70^{+18}_{-13}	76^{+9}_{-15}
A_{cut}	$8^{+1}_{-1}\times10^{-2}$	$105^{+6}_{-6}\times10^{-3}$
χ^2_{red}	0.9	1.2

Table 2: Fit using a power law cutoff model for both epochs. For 2005 the fit also includes a `diskbb` component.

4. Conclusions

We present here the first results of an ongoing investigation to study the long-term variations of 1E 1740.7−2942 . Data shown here were collected during two observations of 1E 1740.7−2942, one carried out in 2003 and the other in 2005, simultaneously by the XMM and INTEGRAL satellites. This has provided us a chance to fit the spectrum from 2 to 200 keV. To our knowledge these XMM observations are being reported here for the first time. We fit the spectra with a simple Comptonization. We observed a flux variation which correlates with the behavior of kT_e . Our results are compatible with the current framework of modeling spectra of black holes candidates with Comptonization from a $\tau \sim 1$ and $kT_e \sim 60$ keV plasma, which can explain the origin of the observed high energy flux (E>20 keV) as originating from Comptonization of the lower energy photons.

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