On the behavior of the black hole candidate 1E 1740.7−2942's corona based on long-term INTEGRAL data base

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Abstract

One of the most straightforward ways to explain the hard X-ray spectra of X-ray binaries is to assume that compontonization of soft photons, originated in the disk, is occurring. The region in which such comptonization takes place, called the corona, is commonly characterized by only two parameters: its thermal energy kT and its optical depth τ. In this study we analyzed a large number (>300) of hard spectra (20–200 keV) of the black hole candidate 1E 1740.7-2942 from the INTEGRAL satellite public database. By applying simple and widely used models to fit the data, we were able to verify that thermal comptonization describes the spectra of 1E 1740.7-2942 in these energies very well, regardless of the source's luminosity. The Compton parameter y values, computed from kT and τ, show that the source remains in the unsaturated comptonization regime for almost our entire sample. Moreover, the predicted power-law indices calculated from y are in great agreement with the indices found when a phenomenological power-law is fitted to the spectra.

Introduction

The object 1E 1740.7-2942 (1E, henceforth) is one amongst many strong hard X-ray emitting sources in the Galactic Center (GC) region (Figure 1). It is known to spend most of its time in the so-called low/hard state of emission, a state in which the hard spectra are well described by comptonization models. With the aim of better understanding the behavior of 1E in this state, we performed an homogeneous analysis for a large data set from the ISGRI telescope[3] onboard the INTEGRAL satellite. We present here the preliminary results.

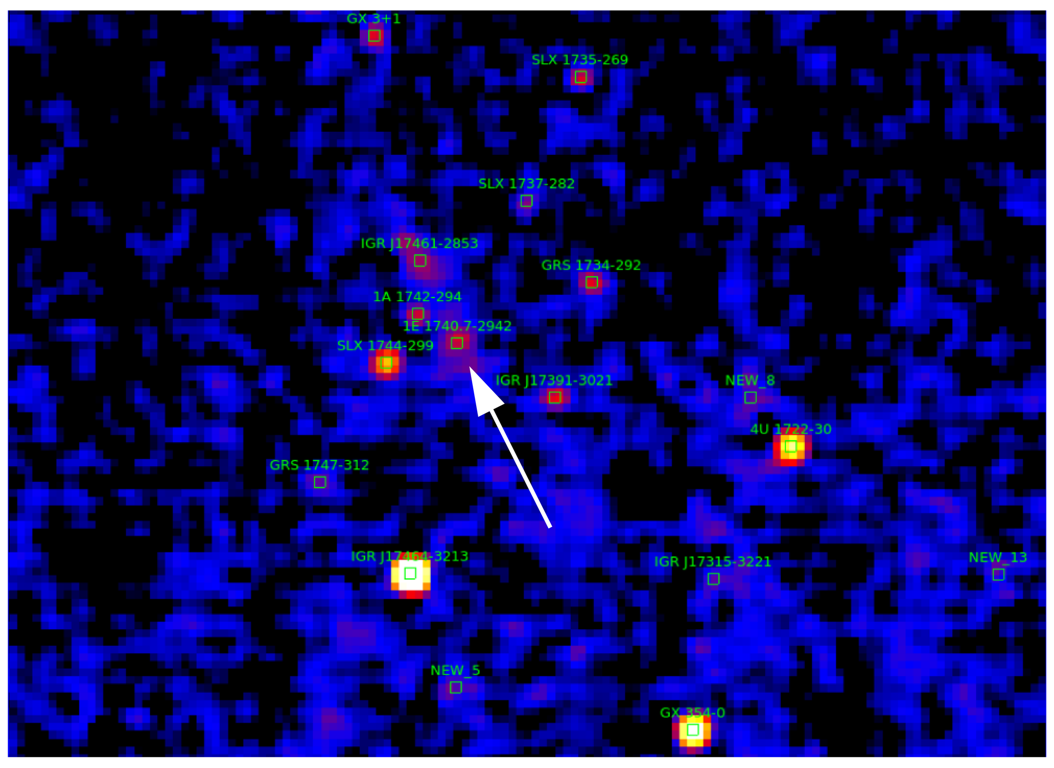

Figure 1: Zoom of the Galactic Center region observed by ISGRI (40–80 keV). 1E 1740.7-2942 is indicated.

Data Selection and Method

The standard INTEGRAL OSA software was used to retrieve and reduce a total of 479 revolutions containing 1E in the field-of-view. This spans approximately 15 years (2003–2017) of data. From these, 392 remained after we excluded those whose counts' signal-to-noise ratio was below 5. We used the X-ray analysis package XSPEC to fit each of the 392 spectra with two models: a phenomenological power-law (`powerlaw`) and a thermal comptonization model (`comptt`). The former is dependent only on the index Γ of the power-law; the latter depends on the thermal energy (kT) and optical depth (τ) of the corona – as well as the inner disk temperature (t_{in}). As the spectral coverage does not allow one to constrain t_{in}, we have restrained this parameter to values previously reported for 1E, i.e. 0.2–0.4 keV[1][5]. Parameters kT and τ were let free.

Analysis and Results

For 284 and 283 spectra, `powerlaw` and `comptt` provided an acceptable fit ($\chi^2_{\text{red}} < 2$), respectively. From the `powerlaw` fit, we have gauged the 20–200 keV fluxes in order to take a look at the source's L/L_{Edd} evolution throughout the sample. The approximate distance to the GC and a recently reported mass for the black hole in 1E[5] were used for the calculations. The values are shown in Figure 2 (blue points). For a matter of continuity, we have also included luminosities from not well-fitted spectra (green points); for these, the fluxes were calculated based in polynomial fits to the data. Figure 3 presents the frequency histogram of the kT values provided from the 283 fitted spectra by `comptt`.

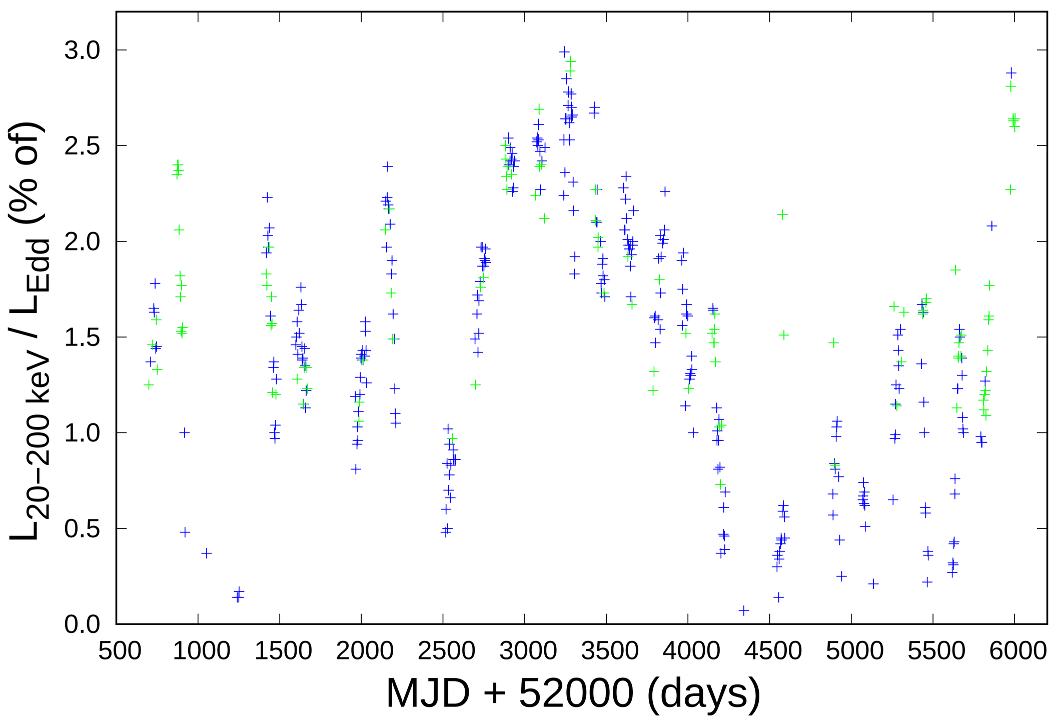

Figure 2: L/L_{Edd} evolution in time for 1E 1740.7-2942. Blue points: flux calculated from a power-law fit. Green points: from a polynomial fit.

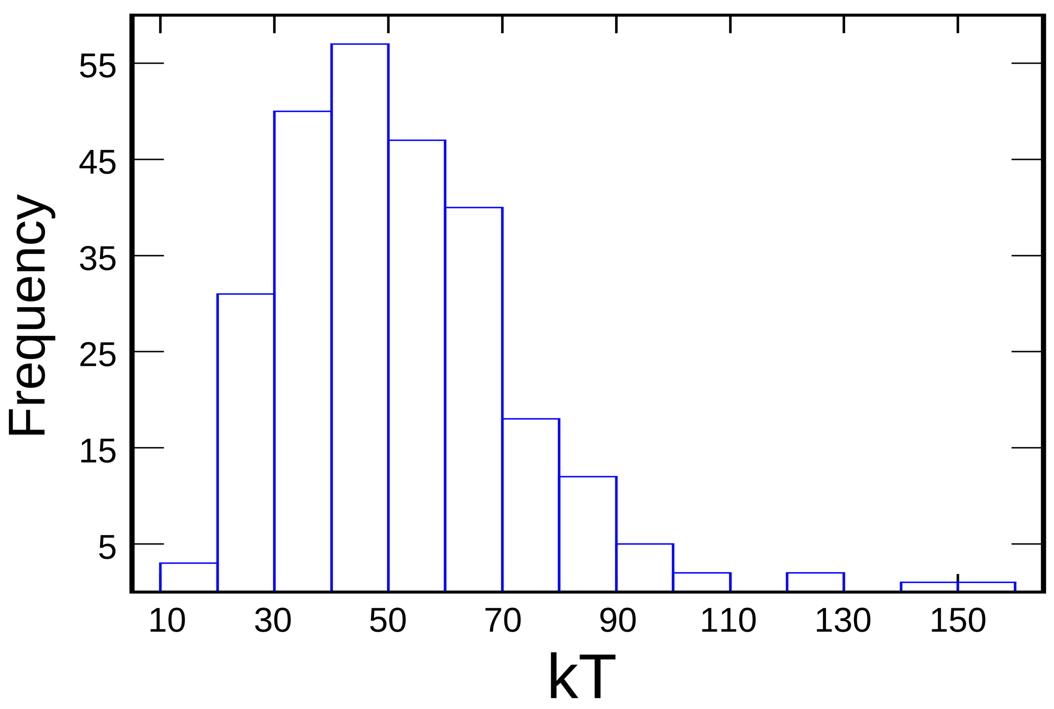

Figure 3: Frequency histogram of the corona's thermal energy kT, in keV, for 283 spectra.

A total of 250 spectra could be well adjusted by both models concurrently. We proceeded the analysis with them. To explore the nature of the comptonization spectra, we have computed the Compton parameter y, whose value may be used as a measure of the compontonization component's importance for the system. A general expression for y, valid for any kT or τ, is[2]

$$y = 4\left(\frac{kT}{m_e c^2}\right)\left[1 + 4\left(\frac{kT}{m_e c^2}\right)\right]\tau(1+\tau). \quad (1)$$

If the comptonization is unsaturated ($y \approx 1$) the index of the power-law shaped spectrum may be calculated by[4]

$$\Gamma = -\frac{1}{2} + \sqrt{\frac{9}{4} + \frac{4}{y}}. \quad (2)$$

We find a y median value of 1.53 and standard deviation of 0.65, which is compatible with an unsaturated comptonization regime. At last, the Γ values, calculated from y, are in great agreement with the power-law indices provided from the phenomenological fits, as may be seen in Figures 4 and 5.

Final Remarks

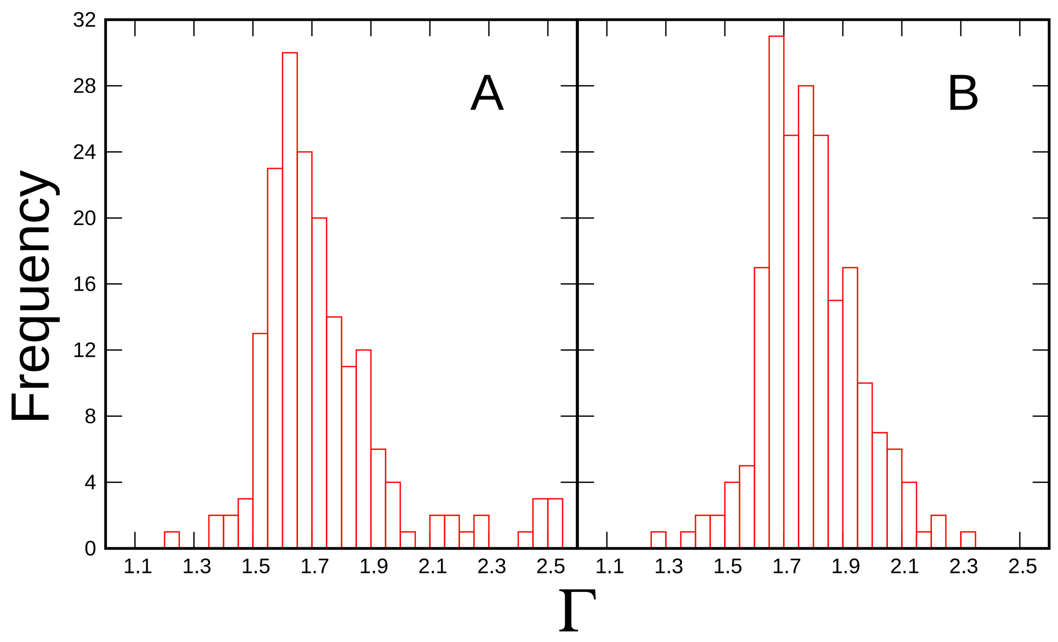

Figure 4: Frequency histograms of Γ. A: Computed from the Compton parameter y, function of kT and τ. B: indices from a `powerlaw` model fit to the data.

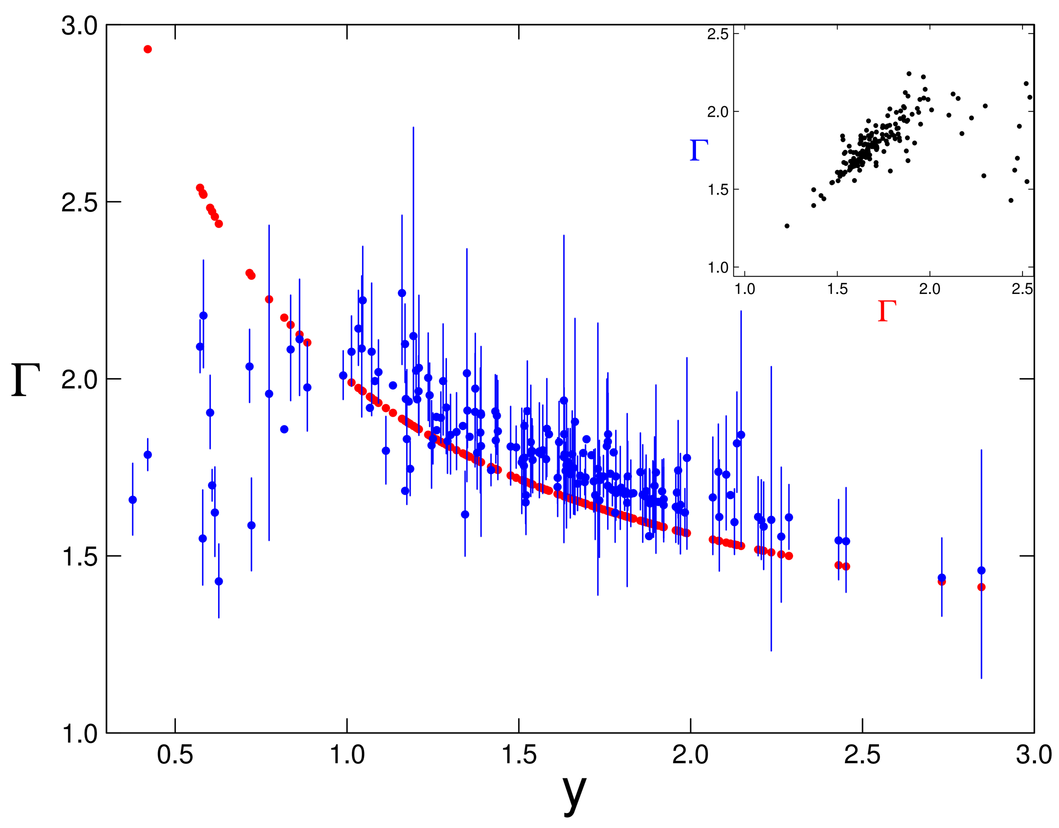

Figure 5: Calculated Γ (red) against Compton parameter y. Over plotted are the indices from the `powerlaw` fit (blue), including 90% errors, also against y. The inset plot shows Γ versus Γ for a better visualization of their correlation.

This preliminary analysis demonstrates that a simple thermal comptonization model reproduces the spectra of 1E 1740.7-2942 very well. In other words, that the luminosity and shape (as in the power-law index) variability observed may be completely explained by means of the variation of the corona parameters kT and τ for most of our sample. Nonetheless, a closer look at the not-fitted spectra from the sample is required for further conclusions.

References

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Acknowledgements

P.E. Stecchini acknowledges FAPESP under grant #2017/13551-6 and J.L. Santos acknowledges IFSP - Car.