GRS 1758−258 WITH *INTEGRAL* AND *RXTE*: ANOTHER DIM SOFT STATE

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ABSTRACT

The Galactic Center black hole candidate (BHC) GRS 1758−258 has been observed extensively within *INTEGRAL*'s Galactic Center Deep Exposure program in 2003 and 2004, while also being monitored with *RXTE*. We present quasi-simultaneous PCA, ISGRI, and SPI spectra from four GCDE observation epochs. During the first epoch GRS 1758−258 displayed another of its rare dim soft states like the one observed in 2001. In the recently emerging picture of the hardness-intensity evolution of black hole transient outbursts in which hard and soft states are observed to occur in a large overlapping range of luminosities (hysteresis), the dim soft state is not peculiar.

Key words: black hole physics; stars: individual: GRS 1758−258; gamma rays: observations; X-rays: binaries; X-rays: general.

1. INTRODUCTION

Most of the time GRS 1758−258 displays X-ray properties typical for the canonical hard state of black hole binaries, i.e., a power law spectrum with indices of Γ=1.4–1.9 and an exponential cutoff above 100 keV. A weak soft excess is also sometimes seen. However, a sudden drop of the power law component within a few days occurred in 2001 February, leading to a much softer and dimmer source state (Smith et al., 2001a, and Fig 1). As predicted by Smith et al. (2001b) based on the two-flow accretion model (Chakrabarti & Titarchuk, 1995), the soft spectral component decayed more slowly than the hard one, on a timescale of ~28 days. Here, we report results of monitoring observations of GRS 1758−258 with *INTEGRAL* and *RXTE* in 2003 and 2004. While the source was in its usual variable hard state during most of the time, the data obtained in spring 2003 clearly correspond to another dim soft state.

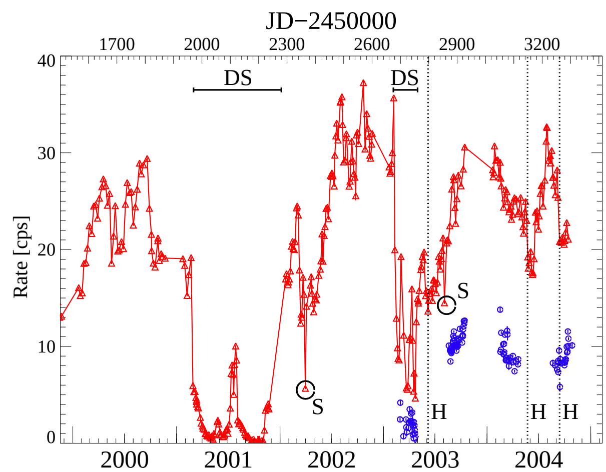

Figure 1. 2.5–25 keV RXTE/PCA (red triangles) and 20–60 keV INTEGRAL/ISGRI (blue circles) monitoring lightcurves of GRS 1758−258. The dim soft states ("DS") as well as times of softening ("S") and hardening ("H") are indicated , see text for details.

2. LIGHTCURVES & SPECTRA IN 2003/2004

Version 4.2 of the Offline Scientific Analysis package was used to extract *INTEGRAL* spectra and lightcurves (Fig 1, blue circles) obtained during four Galactic Center viewing epochs (JEM-X did not yield any useful epoch-summed data; single-pointing ISGRI spectra were extracted from energy resolved images and then epoch-summed). HEASOFT v5.3.1 was used for the extraction of long term PCA lightcurves (Fig 1, red triangles) as well as spectra summed over those monitoring observations coinciding with the *INTEGRAL* epochs. Our basic phenomenological model for the simultaneous fits to the summed *INTEGRAL*/*RXTE* spectra of each epoch consists of an absorbed cutoff power law (no cutoff is required for epoch 1) plus a Gaussian Fe Kα line and a multicolor disk blackbody component, if required. We

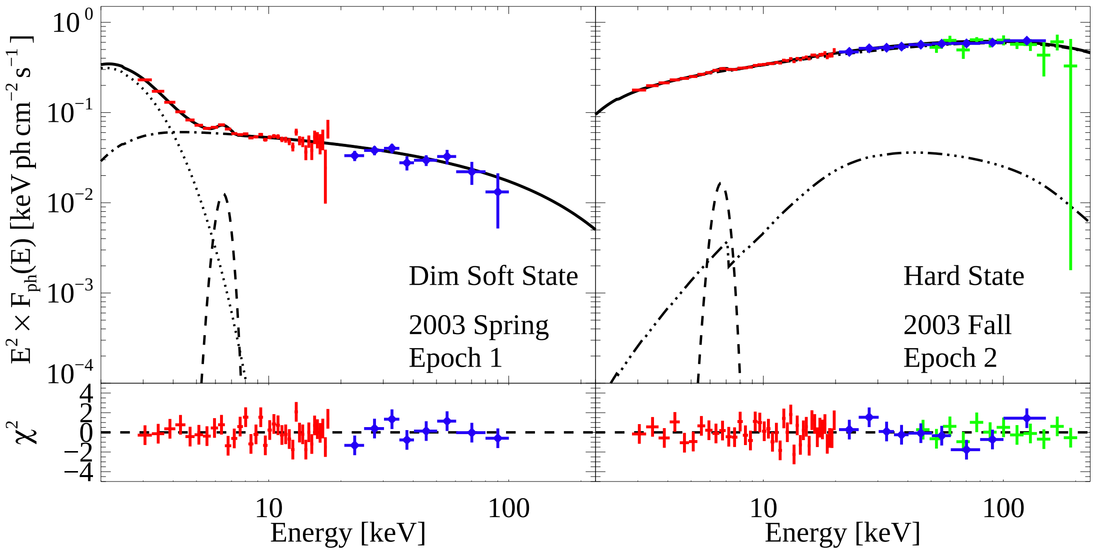

Figure 2. Unfolded spectra and residuals for the `compTT` *fits to epochs 1 and 2 (red: PCA, blue: ISGRI, green: SPI).*

Table 1. Best fit parameters for the `compTT` *fits to the summed INTEGRAL/RXTE spectra of the four epochs.*

	Epoch 1	Epoch 2	Epoch 3	Epoch 4
$N_{\rm H}/10^{22}$ [cm^{-2}]	$1.50^{+0.21}_{-0.26}$	$1.37^{+0.20}_{-0.15}$	1.50	1.50
$kT_{\rm in}$ [eV]	482^{+14}_{-16}	379^{+116}_{-378}	441^{+86}_{-55}	501^{+71}_{-90}
$A_{\rm disk}/10^3$	$2.5^{+0.4}_{-0.3}$	–	$0.38^{+0.54}_{-0.04}$	$0.28^{+0.72}_{-0.07}$
τ	$0.29^{+0.43}_{-0.13}$	$0.71^{+0.16}_{-0.07}$	$1.00^{+0.21}_{-0.21}$	$0.37^{+0.24}_{-0.12}$
$kT_{\rm e}$ [keV]	64^{+4}_{-15}	78^{+34}_{-15}	49^{+29}_{-9}	114^{+32}_{-35}
$E_{\rm Fe}$ [keV]	$6.41^{+0.13}_{-0.24}$	$6.62^{+0.21}_{-0.30}$	$6.74^{+0.15}_{-0.26}$	$6.47^{+0.32}_{-0.25}$
$EW_{\rm Fe}$ [eV]	208.0	61.0	42.6	64.3
$c_{\rm ISGRI}$	$0.76^{+0.08}_{-0.08}$	$0.83^{+0.03}_{-0.02}$	$0.82^{+0.01}_{-0.02}$	$0.87^{+0.02}_{-0.02}$
$c_{\rm SPI}$	–	$0.96^{+0.05}_{-0.04}$	$0.97^{+0.10}_{-0.09}$	$0.97^{+0.12}_{-0.11}$
$10^2\ \Omega/2\pi$	–	$10.0^{+5.6}_{-5.6}$	$13.8^{+5.0}_{-5.5}$	–
χ^2/dof	37.2/34	52.5/63	57.3/51	49.8/52
$\chi^2_{\rm red}$	1.09	0.83	1.12	0.96

also applied a thermal Comptonization model (`compTT`; Titarchuk, 1994) to all four epochs, allowing for reflection. Both modeling approaches resulted in equally good descriptions of the data. Systematic errors of 0.5% and 2% were added to the PCA and ISGRI spectra, respectively. Fig. 2 shows the `compTT` fits for epochs 1 and 2. In epoch 1 the source was too soft for SPI.

3. THE DIM SOFT STATE IN CONTEXT

The 2003 dim soft state is 0–20% less luminous than the hard state, depending on the epoch and spectral model. While this is different from the soft state in persistent HMXBs, like Cyg X-1, where softening is associated with higher bolometric luminosities, it is well within the range of hysteretic behavior displayed by LMXB transients, like GX 339−4, where a large range of soft state intensities is observed (Zdziarski et al., 2004). The dim soft state would thus correspond to the outburst decay of a transient. This can be understood since GRS 1758−258 most likely has a low mass companion and is accreting via Roche lobe overflow (Rothstein et al., 2002). In addition to the clear dim soft states (indicated by "DS" in Fig. 1), the PCA lightcurve shows short soft episodes as well as instances of sudden hardening ("S" and "H", respectively, see also Pottschmidt et al., 2005). These are additional examples of quasi-independent changes of the hard and soft components, further supporting the interpretation in terms of two independent accretion flows.

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