INTEGRAL MONITORING OF THE BRIGHT NEUTRON STAR LOW MASS X-RAY BINARIES: PRELIMINARY RESULTS ON GX 17+2

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ABSTRACT

GX 17+2 is a bright Neutron Star Low Mass X-ray Binary. Albeit significant results were obtained from previous campaigns, many open points still remain in the understanding of such a source, in particular the origin (thermal or not) of the hard component and its behavior with the spectral state. *INTEGRAL* offers the opportunity to reduce these ambiguities. Combining data from JEM-X, IBIS and SPI to provide a complete soft to hard energy coverage, we report preliminary results based on the first year Core Program observations of GX 17+2 .

1. INTRODUCTION

Hasinger & van der Klis (1989) divided Low Mass X-ray Binaries in two groups, called Z sources and Atoll sources after the patterns these sources trace out in the X-ray Color-Color (CC) diagram. The Z sources show in the X-ray CC diagram three correlation *spectral branches* that correspond to three distinct X-ray power spectral states. All Z sources have a luminosity close to the Eddington limit (L_{Edd} $\sim 10^{38}$ erg s^{-1}), while the Atoll have a lower luminosity ($\sim$0.01–0.2 L_{Edd}). For the Z sources a larger accretion rate combined to a stronger neutron star magnetic field than atoll sources has been proposed to explain the differences in the observed variability behavior (Van der Klis 1995).

GX 17+2 is one of the best studied Z sources; its X-ray flux is $\sim$700 μJy, converting to a 1–10 keV luminosity of $\sim 10^{38}$ ergs s^{-1} for an assumed distance of 7.5 kpc (Penninx et al. 1988). A variable radio source (Hjellming & Wide 1971) and possibly an IR source (Deutsch et al. 1999) was also associated to the source. The source usually describes a complete Z pattern in the CC diagram in a relatively short time (3–4 days). The parameters of the noise components as well as the frequency of the quasi-periodic oscillations (QPOs) are well correlated with the position in the CC diagram (e.g., Langmeier et al. 1990; Kuulkers et al. 1997; Wijnands et al. 1997). Studies of the source X-ray spectrum were carried out by different authors (e.g. White, Stella & Parmar 1988) based on *EXOSAT* spectra, and Hoshi & Asaoka (1993) based on *Ginga* spectra. In all cases, the spectrum was found to steepen rapidly above energies of a few tens of keV, without any evidence of a distinct hard X-ray component.

Studies of the *BeppoSAX*(0.1–200 keV) energy spectra selected based on the source position in the X-ray Hard Color-Intensity (HCI) diagram are reported by Di Salvo et al. 2000. In particular the source was studied on the horizontal and normal branches. The continuum has been described by the sum of a $\sim$0.6 keV blackbody, contributing $\sim$10% of the observed 0.1–200 keV flux, and a Comptonized component, resulting from upscattering of $\sim$1 keV seed photons by an electron cloud with temperature of $\sim$3 keV and optical depth of $\sim$10. Iron K line and edge were also present at energies of $\sim$6.7 and $\sim$8.5 keV, respectively. In the spectra of the horizontal branch, a hard tail was clearly detected at energies above $\sim$30 keV. It could be fit by a power law of photon index $\sim$2.7, contributing 8% to the source flux detected by *BeppoSAX*. This component gradually faded as the source moved towards the normal branch, where it was no longer detectable. The same correlation with the accretion rate is also observed for the radio flux in Z sources (Penninx et al. 1988), which is probably due to jet emission. Therefore the hard tails of the Z sources can be interpreted as non-thermal Comptonization due to the mildly relativistic electrons of the jet.

In this paper, we report preliminary results on the timing behavior of the GX 17+2 (light curves and CC and HCI diagrams) and measurements of the the averaged X-ray spectrum obtained in the energy range 4–100 keV.

2. DATA REDUCTION AND ANALYSIS

We analyzed *INTEGRAL* Core Program data from Galactic Plan Scan (GPS) observations for a total of 114 Science Windows (SCWs) and $\sim 2\times 10^5$ s of on-source observing time.

For data reduction we used version 3.0 of the standard software package Off-line Science Analysis (OSA) distributed by the *INTEGRAL* Science Data Centre (Courvoisier et al. 2003) and tools locally developed by authors.

For the spectral analysis, we used data from three *INTEGRAL* instruments: the X-ray monitor JEM-X (Lund et al. 2003) for 4–20 keV, the detector ISGRI (Lebrun et al. 2003) of the IBIS (Ubertini et al. 2003) telescope and the spectrometer SPI (Vedrenne et al. 2003) for 20–100 keV. The hard photons IBIS detector PICsIT (Di Cocco et al. 2003) was not used, since its peak sensitivity is above 200 keV, where GX 17+2 flux is below the PICsIT detectability.

The energy spectra have been averaged over the 114 SCWs. For the ISGRI spectrum extraction we used two different methods.

The first method consists of starting from event lists, produced with OSA 3 software, to extract the source spectrum selecting all the events falling in the detector pixels illuminated by the source with Pixel Illuminated Factor (PIF) ≥ 0.7 and to use the events falling in the pixels with PIF ≤ 0.3 as background.

The second method consists in combining data of different pointing in one single mosaic (weighted combination of the images) and extracting flux in several energy bands.

3. RESULTS

We extracted the IBIS/ISGRI mosaic image of the region of the sky containing GX 17+2 combining all the available SCWs. A part of this mosaic image in the range 20–40 keV is shown in Figure 1. In the same field of view 4U 1812–12, 4U 1811–171, GX 9+1, GS 1826–24 and GX 5–1, are visible.

In Figure 2 and Figure 3 we show the evolution of the JEM-X and ISGRI fluxes in four different energy band. A bin size equal to SCW exposition ($\sim$2000 s) was used. The points with larger error bars correspond to pointings where the source was more off-axis. The measured source variability is mainly intrinsic to the source although contaminations from

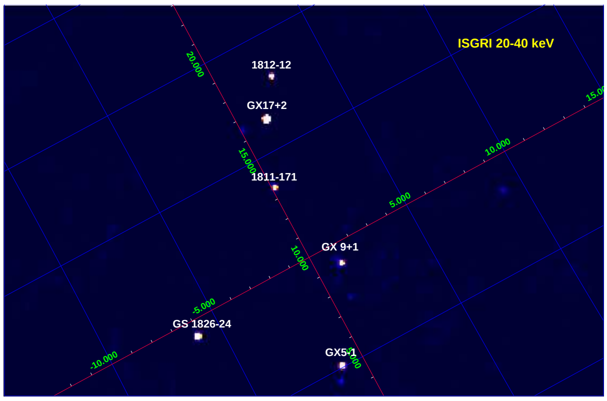

Figure 1. Part of the mosaic image of the field containing GX 17+2 as obtained by ISGRI in the energy range 20–40 keV.

a non optimal vignetting correction cannot be ruled out. The effect of the vignetting is difficult to quantify (it depends on the source position in the field of view) but seems to play a minor role since the dependency of the count rate on the off-axis angle has been studied and shows no evident trend.

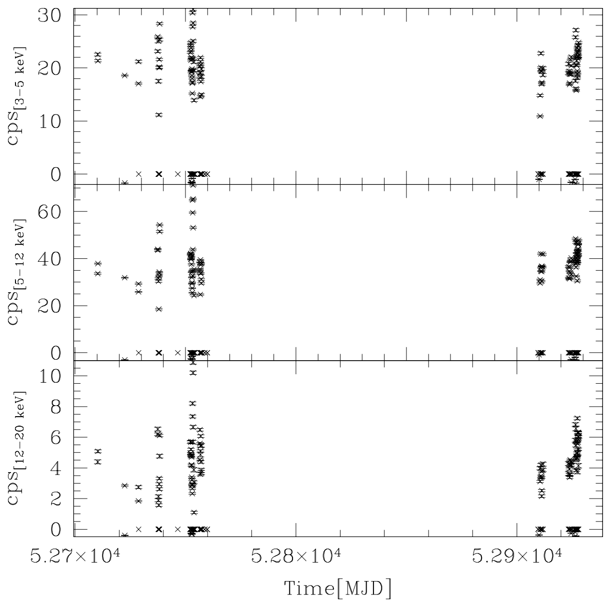

Figure 2. JEM-X count rates vs Time.

Figure 4 shows the CC diagram (upper panel) and the HCI diagram (bottom panel) obtained with the JEM-X fluxes in 3–5 keV, 5–12 keV, 12–20 keV and 3–20 keV energy ranges. Horizontal and flaring branches are not easily distinguished with respect to normal branch.

In Figure 5 we compare the ISGRI spectrum extracted with the two methods: in black we show spectrum obtained from the event lists, in red the spectrum obtained from the mosaic.

To fit the X-ray continuum of GX 17+2 we tried to use a two component model, blackbody for the soft component and thermal Comptonization for the

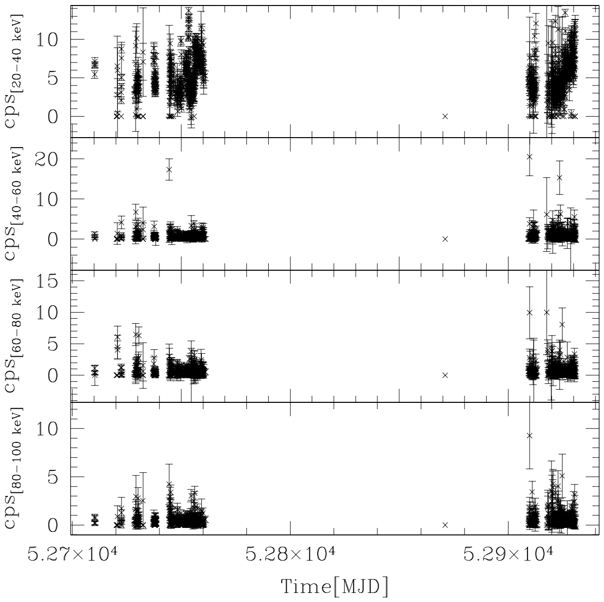

Figure 3. ISGRI count rates vs Time. In the 20–40 keV energy band 1 Crab corresponds to ∼100 counts/s.

harder component. However, using JEM-X and ISGRI data, we found a more stable fit using only the thermal Comptonization. As the blackbody temperature for this source was found to be about 0.7 keV (Di Salvo et al. 2000), our coverage of the lower part of the spectrum is not enough to constrain this soft component (JEM-X data start at 4–5 keV). The addition of an Fe K_α at ∼6.7 keV proved necessary. The best fit to the total spectrum (averaged over all observations) was obtained using CompTT Comptonization model plus iron line. In the upper panel of Figure 6 we show the total spectrum, the best-fit model and the residuals in units of σ obtained using JEM-X and ISGRI data; the addition of the SPI data (bottom panel of the same figure) did not change the fit result. The fit parameters are reported in the column I of Table 1. The values are consistent with previous results.

We tried to use the same model to fit the spectrum obtained with ISGRI data extracted from the mosaic. As a little excess of counts above 40 keV seems apparent in this spectrum, we added an extra power law component to the model. The best-fit parameters are reported in column II in Table 1. The status of the calibrations together with the data statistics make the observation of this component still to be explored.

The CC diagram resolved spectroscopy analysis in ongoing.

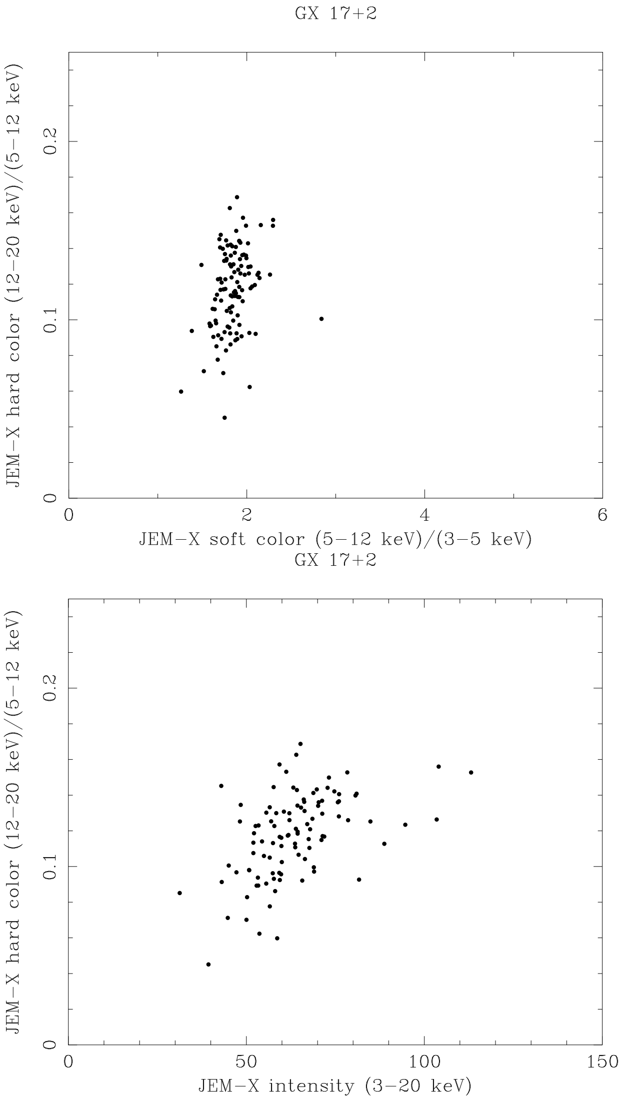

Figure 4. JEM-X CC diagram (upper panel) and HCI diagram (bottom panel)

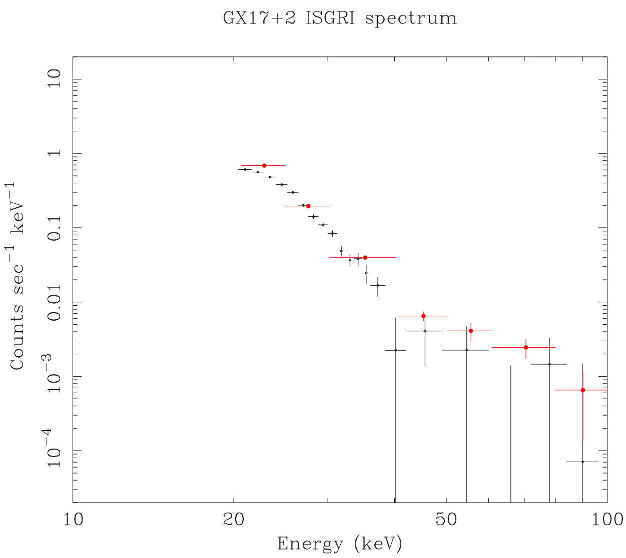

Figure 5. ISGRI averaged spectrum: extraction from the event lists (black data), extraction from mosaic (red data)

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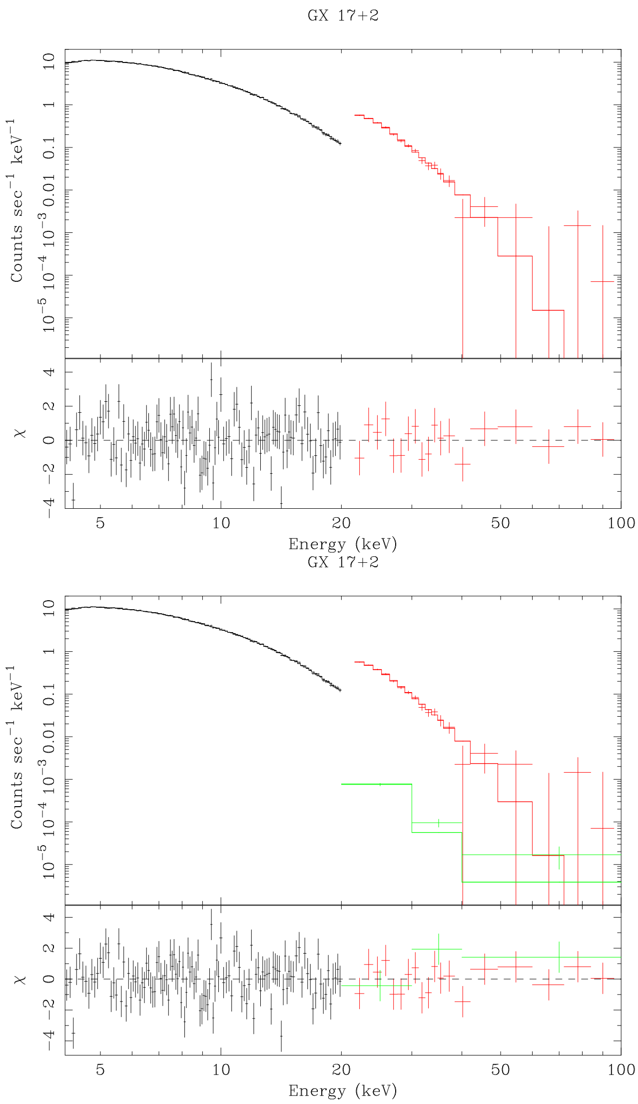

Figure 6. Upper panel: JEM-X and ISGRI spectrum, best-fit model and the residuals in units of σ. SPI data are added in the bottom panel.

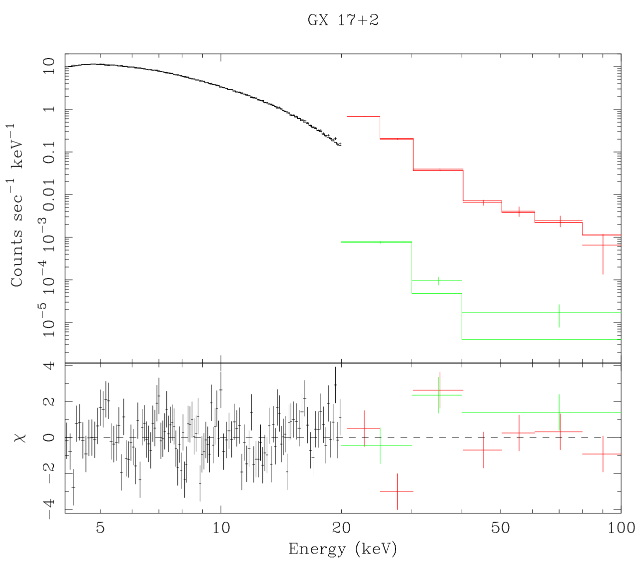

Figure 7. Spectral fit and residuals in units of σ using ISGRI spectrum obtained from mosaic

Table 1. Best fit parameters for JEM-X, ISGRI and SPI averaged spectrum. Parameters in column I are obtained using as ISGRI spectrum the one extracted from the event lists. In column II the ISGRI spectrum is extracted from the mosaic.

	I	II
$kT_{\rm W}$ (keV)	2.85 ± 0.05	2.35 ± 0.1
$kT_{\rm e}$ (keV)	6.8 ± 0.4	5.5 ± 0.2
τ	5.1 ± 0.4	8.5 ± 0.5
N_c	0.67 ± 0.04	0.88 ± 0.05
$E_{\rm Fe}$ (keV)	6.8 ± 0.4	$6.48(fixed)$
$\sigma_{\rm Fe}$(keV)	0.6 ± 0.2	1.2 ± 0.2
$I_{\rm Fe}$ *	(0.013 ± 0.004)	(0.037 ± 0.015)
Γ		2.5 ± 0.4
N_p		0.1 ± 0.1
$F_{2-20\ \rm keV}$ **	1.21	1.28
$F_{2-100\ \rm keV}$ **	1.24	1.31
$\chi^2_{\rm red}$ (d.o.f.)	1.58(133)	1.58 (120)

NOTE —All quoted errors represent 90% confidence level for a single parameter

(*) *ph* cm^{-2} s^{-1}

(**) 10^{-8} *erg* cm^{-2} s^{-1}

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