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INTEGRAL long term monitoring of 4U 1722-30: spectral state variations

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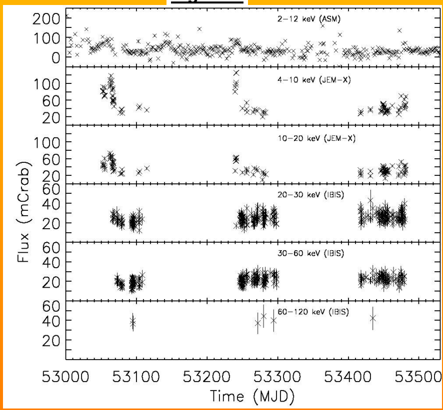
Abstract:

We report on the 2003-2005 INTEGRAL observations of the Neutron Star Low Mass X-ray Binary 4U 1722-30 (also known as GRS 1724-30) located in the Globular Cluster Terzan 2. The JEM-X and IBIS light curves show the source with a persistent yet variable flux. The Hardness-Intensity diagrams highlight the behaviour of a typical Atoll source: 4U 1722-30 repeatedly moves in the diagrams from the Banana (Soft state) to the Island (Hard state). We report on the detailed spectral analysis of Soft and Hard states and, for the first time, also in an Intermediate state. The Hard spectra reveal a Comptonised corona emission up to 200 keV with a high temperature of 40 keV and optical depth of 0.5. In the Soft state the main emission is from the accretion disk (with kTin~0.5 keV) whereas the Comptonised emission decreases showing an optically thick and cold corona (τ ~ 9, kTe ~ 2 keV). During the hardening there is an increase of the inner radius of the accretion disk suggesting a system expansion during the spectral transition. This behaviour draws 4U 1722-30 near to the Soft X-ray transient sources though 4U 1722-30 never reaches a real "quiescent" state.

Figure 1



Light curves:

We monitored the sources with INTEGRAL during the period October 2003 - April 2005, collecting a total of 883 pointing for IBIS and 256 pointings for JEM-X. The light curves with JEM-X and IBIS in different energy bands are shown in Figure 1. Each INTEGRAL point correspond to a signle pointing lasting about 2000 seconds. In the top panel are reported the ASM one-day monitoring during the same period. The source reveals a flux variation (similar to outbursts) in the soft band (<20 keV), while in the hard ones (>20 keV), when it is detected, the flux changes to a minor extent.

Hardness-Intensity diagrams:

We constructed two hardness-intensity diagrams, the first one with the IBIS and JEM-X contemporaneou data and the second one with JEM-X only. Both are shown in Figure 2.

The source moves through the diagram showing spectral changes. We indicated with different color the different spectral data sets:

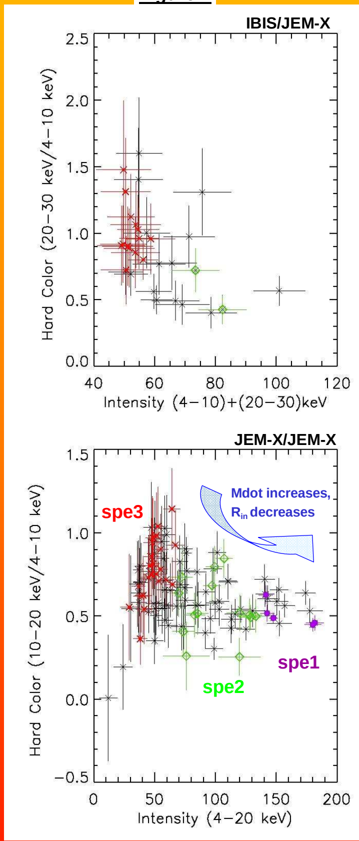
Spe1 (purple data) à Soft spectral state
Spe2 (green data) à Hard/Intermediate state
Spe3 (red data) à Hard spectral state

The spe1 data set refers only to the JEM-X/JEM-X hardness intensity diagram because of the lack of high energy detection with IBIS. This data set correspond, in fact, to a Soft (banana) spectral state.

The green and red pointings correspond to an hardening of the sources that enters the Hard (island) spectral state. These pointings are reported in both the hardness-intensity diagrams.

The mass accretion rate increases during the softening. Moreover there is a corresponding decreasing of the inner accretion disk radius as shown by the arrow in Figure 2 (see discussion for details).

Figure 2



Spectral evolution:

We collected the data corresponding to the same spectral state as shown in the Hardness-Intensity diagram of Figure 2 and performed the spectral analysis. In Figure 3 is showed the spectral evolution.

Soft spectral state (spe1)

The bets fit model is rapresented by a black body model (or also simple black body model) (Mitsuda et al. 1984) plus a Comptonisation model (Titarchuk 1994) with parameters showed in Table 1. Changing the diskbb model with the simple black body model the fit doesn't change.

The source shows this spectral state during the soft "outbursts" clearly evident in the JEM-X light curve, when it isn't detected above 30 keV.

The spectrum, model and residuals are shown in Figure 3 (panel spe1). The unabsorbed bolometric luminosity during this spectral state corresponds to $1.8 \cdot 10^{38}$ ergs s^{-1}, i.e. L/L_{Edd}=0.9 (assuming a distance source of 9.5 kpc (Kuulkers et al. 2003).

Intermediate and Hard spectral state (spe2 and spe3)

The green and red spectral data sets corresponds to the hardening of the source. The Intermediate state is detected just after the soft "outburst" shown in the light curve, and the Hard state follows soon after this.

The Hard/Intermediate state is well represented by the diskbb model plus a Comptonisation model. For the Hard state, the best fit is a simple Comptonisation and the fit doesn't improve by adding a diskbb component. The plasma temperature rises with the hardening, while the optical depth decreases, as indicated in Table 1.

In the Hard state the plasma temperature is not contrained very well and there is the indication of a lack of cut-off, similarly to the Hard state of the atoll 4U 1608-522 (Tarana et al. ApJ submitted). Reflection component is not necessary.

The spectra, model and residuals are shown in Figure 3 (panel spe2, spe3). The bolometric luminosity of the Intermediate state corresponds to $1.2 \cdot 10^{38}$ ergs s^{-1}, that yields a 0.6 L_{Edd} . The bolometric luminosity of the Hard state corresponds to $1.4 \cdot 10^{37}$ ergs s^{-1}, i.e. a L_{Edd} ratio of 0.07.

Figure 3

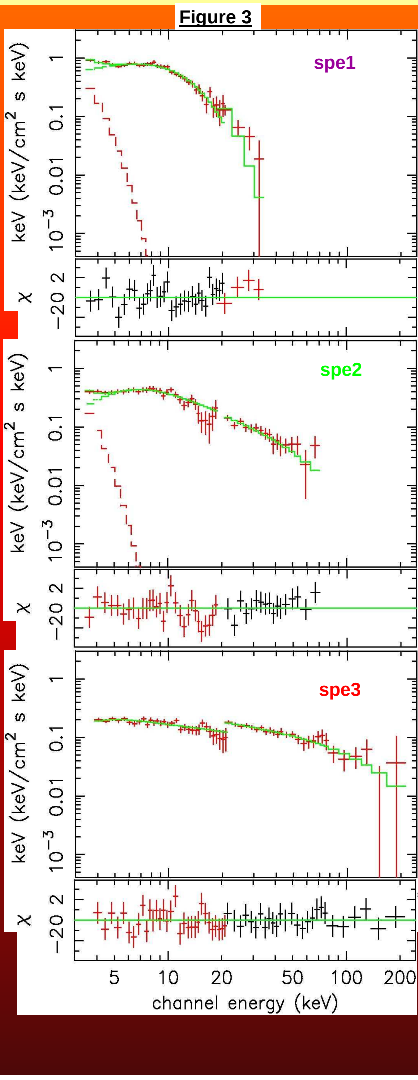


Table 1

Spectral fitting results for the JEM-X and IBIS spectra of 4U 1722-30. The model is CompTT for spe3 and CompTT+diskbb for spe1 and spe2.

parameters	spe1	spe2	spe3
kT_0 (keV)[a]	0.40	1.33	0.81
kT_e (keV)	$2.21^{+0.20}_{-0.09}$	$11.37^{+1.31}_{-0.56}$	$40.36^{+47.03}_{-15.06}$
τ	$9.06^{+9.65}_{-3.40}$	$1.33^{+0.19}_{-0.09}$	$0.48^{+0.42}_{-0.35}$
$norm_{CompTT}$	$0.46^{+0.09}_{-0.18}$	$1.19^{+0.27}_{-0.42} \times 10^{-2}$	$3.79^{+2.78}_{-3.79} \times 10^{-3}$
kT_{in}	$0.46^{+0.10}_{-0.15}$	$0.54^{+0.02}_{-0.02}$	–
$norm_{diskbb}$	$2.13^{+4.93}_{-0.42} \times 10^4$	$1.42^{+0.40}_{-0.32} \times 10^3$	–
χ^2_r(d.o.f)	1.27(30)	1.03(41)	0.70(55)
$F_{4-20keV}$[b]	2.8×10^{-9}	8.1×10^{-10}	6.4×10^{-10}
$F_{20-200keV}$	3.7×10^{-11}	1.5×10^{-10}	3.3×10^{-10}

[a] Fixed parameters
[b] The Fluxes are in units of erg s^{-1} cm^{-2}

Discussion and conclusions:

4U 1722-30, also known as GRS 1724-30, is a bright LMXB located in the Globular Cluster Terzan 2. The observed Type 1 X-ray bursts indicate that the compact object is a weakly magnetized neutron star (NS) (Grindlay et al. 1980). 4U 1722--30 is classified as Atoll type based on its track described in a color-color diagram and its timing properties (Olive et al. 1998). It is a persistent though variable source, and it is one of the first NS systems from which hard X-ray emission (E >35 keV) was detected by SIGMA with a power law spectrum extending above 100 keV, with photon index Γ~1.65 (Barret et al. 1991), while previous EXOSAT observation didn't reveal flux above 10 keV (Parmar et al. 1989). BeppoSAX and RXTE allowed a broad band observations, detecting the source with a Comptonized spectrum extending up to 200 keV (with kTe of about 30 keV), plus an additional soft componenet (below 3 keV), described by a blackbody emission (Guainazzi et la. 1998).

The INTEGRAL observations of 4U 1722-30 allow us to follow the X-ray behaviour of this source that is very similar to a X-ray transient, though a real "quiescent" state is never reached. The outbursts are clearly visible in the INTEGRAL light curves, with spectral changes typical of transient sources as also confirmed by the color-intensity diagrams, such as the ones for the transient source 4U 1608-522 (Tarana et al. ApJ submitted).

At high soft flux level the source was in Soft state, followed by hardening. During the Soft state the source doesn't show emission above 30 keV, and the spectrum is well described by a cold and optically thick Comptonized corona (τ ~9 and kTe~ 2 keV) plus a soft black body emission (kTin~0.46 keV) coming from either the accretion disk or the neutron star.

During the hardening (at low accretion rate) the contribution of the soft component decreases, with a corresponding increase of the hard X-ray emission (up to 200 keV) described by a hot and optically thin Comptonizing corona (τ ~0.5 and kTe~ 40 keV) , without evidence of an energy cut-off.

We estimated the inner radius of the accretion disk in the soft and hard/intermediate state and derived a increasing in its value (from 5 to 20 km), suggesting an extension of the inner radius during the hardening, as also shown by the transient source 4U 1608-522 (Tarana et al. ApJ submitted).

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