

The *INTEGRAL*★ long monitoring of persistent ultra compact X-ray bursters (Research Note)

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ABSTRACT

Context. The combination of compact objects, short period variability and peculiar chemical composition of the ultra compact X-ray binaries make up a very interesting laboratory to study accretion processes and thermonuclear burning on the neutron star surface. Improved large optical telescopes and more sensitive X-ray satellites have increased the number of known ultra compact X-ray binaries allowing their study with unprecedented detail.

Aims. We analyze the average properties common to all ultra compact bursters observed by *INTEGRAL* from ~ 0.2 keV to ~ 150 keV.

Methods. We have performed a systematic analysis of the *INTEGRAL* public data and Key-Program proprietary observations of a sample of the ultra compact X-ray binaries. In order to study their average properties in a very broad energy band, we combined *INTEGRAL* with *BeppoSAX* and *SWIFT* data whenever possible. For sources not showing any significant flux variations along the *INTEGRAL* monitoring, we build the average spectrum by combining all available data; in the case of variable fluxes, we use simultaneous *INTEGRAL* and *SWIFT* observations when available. Otherwise we compared IBIS and PDS data to check the variability and combine *BeppoSAX* with *INTEGRAL*/IBIS data.

Results. All spectra are well represented by a two component model consisting of a disk-blackbody and Comptonised emission. The majority of these compact sources spend most of the time in a canonical low/hard state, with a dominating Comptonised component and accretion rate \dot{M} lower than $\sim 10^{-9} M_{\odot}/\text{yr}$, not depending on the model used to fit the data.

Conclusions.

Key words. gamma rays: observations – stars: neutron – X-rays: binaries

1. Introduction

Ultracompact X-ray binaries (UCXBs) are binaries with orbital periods (P_{orb}) shorter than ≈ 1 hr in which a neutron star or black hole accretes matter from a companion low mass star.

Their short periods rule out ordinary hydrogen-rich companion stars, since these stars are too large and do not fit in the Roche lobe (Nelson et al. 1986). UCXBs are rare objects and their identification is very difficult because it is hard to measure P_{orb} in Low Mass X-ray Binaries (LMXB). Eight out of 52 LMXBs with measured orbital period are in the ultracompact regime (in 't Zand et al. 2007; Nelemans & Jonker 2006). Another thirteen UCXBs have been identified by indirect methods depending on the notion that in an UCXB the accretion disk must be relatively small. The first indirect method concerns the ratio of optical to X-ray flux. Van Paradijs & McClintock (1994), assuming that most of the optical flux is generated by the X-ray irradiation of the accretion disc, showed that the absolute magnitudes of LMXBs correlate with the X-ray luminosities and the size of the disc. Seven UCXBs have been identified

following this method (e.g., Juett et al. 2001). The second indirect method concerns the critical accretion rate below which a system becomes transient (in 't Zand et al. 2007); it allowed the identification of six new UCXB candidates.

2. Sample

In order to obtain a broad band energy spectra, we carried out a systematic analysis of all burster UCXBs reported in the latest *INTEGRAL*/IBIS survey (Bird et al. 2007) with the following properties: a) they are persistent UCXB bursters; b) there are available data in the soft X-ray energy band (at least ~ 2 – 8 keV) from *SWIFT*/XRT or *BeppoSAX* archives; c) when a source does not vary during *INTEGRAL* monitoring, we use all available X-ray data, while when it varies we make use only of IBIS and XRT simultaneous spectra. If simultaneous data are not available, PDS and IBIS data are used to verify possible variability.

Following these criteria, we collected high quality IBIS average spectra with a long exposure time and built up a wide band spectrum from ~ 0.5 to ~ 150 keV. For the source SLX1735-269 there is evidence of variability in the IBIS data set and we have instead used the archival simultaneous broad band *BeppoSAX* data to derive spectral parameters. An overview of the observational properties of the known and candidate UCXBs is given in Table 1, which lists their name, ultracompact identification

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Table 1. Sample of UCXBs. The galactic N_{H} value was estimated from the 21 cm measurements of Dickey & Lockman (1990).

Name	(1)	Distance kpc	Persistent Bursters			Donor	Long burst	Ref.
			P_{orb} min	N_{H} 10^{21} cm^{-2}	M_V			
<i>UCXBs with orbital periods</i>								
4U 1820-303 (in NGC 6624)	pX	5.8–6.4–7.6	11	1.5	3.7	He dwarf 0.06–0.08 M_{\odot}	yes	<i>a, q, c, j</i>
4U 1850-087 (in NGC 6712)	pO	6.8–8.0	21 or 13	2.8	5.1	dwarf 0.04 M_{\odot}	...	<i>b, r, f, k</i>
<i>UCXBs with tentative orbital periods</i>								
4U 0614+091	pO, r	1.5–3.0	50	5.5	3.7	C/O dwarf	yes	<i>d, t, m, f, w</i>
XB 1832-330 (in NGC 6652)	pO	9.2–14.3	55	1.2	>3.5	blue star $M_V = 3.7$ or dwarf	...	<i>e, u, p</i>
<i>candidate UCXBs with low optical to X-ray flux</i>								
1A 1246-588	r	5	...	4.0	>3.5	blue star $M_V > 3.5$	yes	<i>g, r</i>
4U 1812-12	r	4.1	...	7.3	...	weak blue star	...	<i>m, h, g, x</i>
<i>candidate UCXBs based on method from in 't Zand et al. (2007)</i>								
SAX J1712.6-3739	z	5.9–7.9	...	13.4	...	...	...	<i>i, y</i>
4U 1705-32	z	11–15	...	2.9	...	...	yes	<i>l</i>
1RXS J172525.5-325717	z	<14.5	...	8.7	...	...	yes	<i>n, s</i>
SLX 1735-269	z	6–8.5	...	4.8	...	...	yes	<i>o, z</i>
SLX 1737-282	z	6.5	...	7.4	...	...	yes	<i>o, v, aa</i>

(1) Ultracompact identification based on: r = L_x/L_{opt} , p = period measurement (pX using X-ray data, pO using optical modulation), z = in 't Zand method.

^a Kuulkers et al. (2003), Shaposhnikov & Titarchuk (2004), Vacca et al. (1986); ^b Harris et al. (1996), Paltinieri (2001); ^c Strohmayer & Brown (2002); ^d Brandt et al. (1992); ^e in 't Zand et al. (1998), Chaboyer et al. (2000); ^f Homer et al. (1996); ^g Bassa et al. (2006); ^h Cocchi et al. (2000); ⁱ Cocchi et al. (2001), Jonker et al. (2004); ^j Blosler et al. (2000); ^k Sidoli et al. (2006); ^l in 't Zand et al. (2005); ^m Nelemans, Jonker et al. (2004); ⁿ Cornelisse et al. (2002); ^o Molkov et al. (2005); ^p Parmar et al. (2001); ^q Stella et al. (1987); ^r Levine et al. (2006), Piro et al. (1997), Boller et al. (1997); ^s Chenevez et al. (2007); ^t O'Brien et al. (2005); ^u Heinke et al. (2001); ^v Falanga et al. (2008); ^w Piraino et al. (1999); ^x Barret et al. (2003); ^y Fionchi et al. (2008); ^z Gladstone et al. (2007); ^{aa} in 't Zand et al. (2002).

Table 2. Observation details.

Name	Expos.	START	Expos.	START	Expos.	Expos.	Expos.	Energy range
	INTEGRAL/IBISSWIFT/XRTSWIFT/XRT	BeppoSAX	BeppoSAX/LECS	BeppoSAX/MECS	BeppoSAX/PDS			
	ks		ks		ks	ks	ks	keV
4U 1820-303	8	2007-03-16	4	...	...	...	...	2.5–60
	...	...	...	1999-08-31	22	46	20	0.5–50
4U 1850-087	2060	...	...	1997-04-24	18	42	18	0.5–150
4U 0614+091	23	...	...	1996-10-13	12	45	21	0.5–150
XB 1832-330	3067	...	...	2001-03-17	29	54	29	0.2–150
1A 1246-588	1606	2006-08-11	12	...	...	...	...	0.3–150
4U 1812-12	2054	...	...	2000-04-20	15	33	14	0.3–200
SAX J1712.6-3739	685	...	...	1999-09-01	11	21	10	0.5–150
4U 1705-32	4832	2007-02-28	7	...	...	...	...	0.3–100
1RXS J172525.5-32	5309	2007-03-17	2.5	...	...	...	...	0.6–100
SLX 1735-269	...	...	...	1997-09-18	9	29	14	0.5–80
	...	...	...	1999-08-29	15	37	17	0.3–80
SLX 1737-282	6206	...	...	2000-10-14	14	48	...	0.5–70

method, distance, orbital period, galactic column density, absolute V-band magnitude, available information on the donor and the eventual detection of a long intermediate burst or superburst. This sample represents ~60% of all known persistent burster ultra compact sources and candidates.

3. Observations and data analysis

The *INTEGRAL* (Winkler et al. 2003) data set consist of the IBIS/ISGRI (Ubertini et al. 2003) observations from revolution 37 to 488. Images for each available pointing were generated using the scientific analysis software (OSA v6.0) released by the *INTEGRAL* Scientific Data Center. Count rates at the position of the sources were extracted from individual images in order to provide light curves; average fluxes were then extracted from such light curves and combined to produce source spectra (see Bird et al. 2007, for details).

BeppoSAX LECS, MECS and PDS event files and spectra were generated by the Supervised Standard Science Analysis (Fiore et al. 1999). Both LECS and MECS spectra were accumulated in circular regions of 8' radius. The PDS spectra were obtained with the background rejection method based on fixed rise time thresholds.

XRT/*SWIFT* data reduction was performed using Swift software version 2.7.1 released as part of the HEASOFT software. Data were collected in the Photon Counting mode (PC) or in the Windowed Timing (WT) mode with the grade filtering 0–12 or 0–2, respectively. For the PC mode, events are extracted within a circular region of radius 20 pixels, centered on the source position. For WT mode, events for spectral analysis were extracted within a box region centered on the source position and with a width of 40 pixels and an height large enough to include all the photons in the Y dimension. The background was selected using a region on either side of the source.

Table 3. BeppoSAX spectral results using the cutoff powerlaw and disk-blackbody model. L is the 0.1–100 keV (assumed isotropic, in units of 10^{36} erg s^{-1}) source unabsorbed luminosity using the average values of distances given in Table 1. The units of N_{H} are 10^{22} atom cm^{-2} . θ is the inclination angle of the disk. All uncertainties are quoted at the 90% confidence level.

Source	Continuum parameters						
	L 10^{36} erg s^{-1}	N_{H}	Γ	kT_{cut} (keV)	kT_{eff} (keV)	$r_{\text{eff}}(\cos \theta)^{0.5}$ (km)	$\chi^2/\text{d.o.f.}$
1) 4U 1820-303 ^a	68^{+47}_{-26}	<0.58	$1.1^{+1.0}_{-0.8}$	6^{+5}_{-2}	$1.6^{+0.5}_{-0.2}$	6 ± 1	598/556
2) 4U 1820-303 ^a	29^{+4}_{-3}	0.16 ± 0.05	0.3 ± 0.1	$4.4^{+0.2}_{-0.4}$	0.4 ± 0.2	12.0 ± 0.6	179/120
4U 1850-087	2.2 ± 0.3	0.47 ± 0.03	2.03 ± 0.08	120^{+80}_{-92}	0.37 ± 0.02	3.5 ± 0.4	133/121
4U 0614+091 ^b	5 ± 1	0.40 ± 0.05	2.36 ± 0.06	100^{+19}_{-6}	0.15 ± 0.02	16^{+6}_{-3}	260/155
XB 1832-330	8 ± 1	0.26 ± 0.02	$1.54^{+0.04}_{-0.05}$	62 ± 8	0.68 ± 0.04	1.0 ± 0.2	209/137
1A 1246-588	4^{+1}_{-3}	0.5 ± 0.1	2.08 ± 0.01	61 ± 14	0.10 ± 0.02	$<352^{+356}_{-123}$	940/650
4U 1812-12	3.2 ± 0.6	1.78 ± 0.08	1.89 ± 0.05	136 ± 28	0.38 ± 0.05	$2.4^{+1.3}_{-0.5}$	633/890
SAX J1712.6-3739 ^c	1.3 ± 0.3	1.4 ± 0.1	1.4 ± 0.1	30 ± 6	0.40 ± 0.04	2.8 ± 0.3	138/133
4U 1705-32	4 ± 2	0.37 ± 0.05	1.8 ± 0.3	>50	0.7 ± 0.3	1.0 ± 0.4	148/148
1RXS J172525.5-32	<4.7	$2.1^{+0.4}_{-0.3}$	1.7 ± 0.3	119^{+465}_{-59}	0.5 ± 0.2	<9	48/32
1) SLX 1735-269	4 ± 2	1.2 ± 0.1	1.3 ± 0.3	28^{+18}_{-10}	0.60 ± 0.05	$1.8^{+0.3}_{-0.2}$	135/102
2) SLX 1735-269	4^{+2}_{-1}	1.2 ± 0.1	1.5 ± 0.2	42^{+22}_{-10}	0.58 ± 0.03	1.7 ± 0.2	119/124
SLX 1737-282	$1.0^{+0.4}_{-0.8}$	1.8 ± 0.3	1.6 ± 0.2	61^{+54}_{-20}	0.47 ± 0.06	$1.2^{+0.6}_{-0.2}$	119/94

Name	Emission Lines parameters		
	E_{line} keV	σ keV	flux 10^{-3} ph cm^{-2} s^{-1}
1) 4U1820-303	6.1 ± 0.2	0.5 ± 0.3	6 ± 4
2) 4U1820-303	6.6 ± 0.3	1.0 ± 0.2	2^{+4}_{-1}
4U0614+091	0.71 ± 0.03	<0.7	232^{+68}_{-48}
4U0614+091	6.0 ± 0.1	1.4 ± 0.3	6 ± 2
SLX1737-282 ^a	6.6 ± 0.3	$0.4^{+0.4}_{-0.3}$	$0.08^{+0.08}_{-0.04}$

^a A Gaussian component is required by the data; ^b two Gaussian components are required by the data; ^c fit results from Fiocchi et al. (2008).

Table 2 gives the log of the observations.

The whole data set was fitted with this physical model, using XSPEC v. 11.3.1. Errors are quoted at a 90% confidence level for one parameter of interest. In the fitting procedure, a multiplicative constant has been introduced to take into account the cross calibration mismatches between the soft X-ray and the *INTEGRAL* data; this constant has been found to be ~ 1 for all sources, except for 1A1246-588 (see below).

4. Spectral analysis

To analyze all data in a homogeneous way, we searched for a model for the whole sample. Firstly, average spectra were fitted with a simple power law model, resulting in a poor fit to the data with reduced chi squares >10 for all spectra. Generally, the strongest obtained residuals were at energies below few keV, indicating that a more complex model with a soft component was needed to fit these data.

For the soft component we used a multicolor disk blackbody in the formulation of Makishima et al. (1986). The two parameters of this model are free: 1) $r_{\text{in}}(\cos i)^{0.5}$ where r_{in} is the innermost radius of the disk, i is the inclination angle of the disk and 2) kT_{in} the blackbody effective temperature at r_{in} . It is expected, however, that the true spectrum emitted by the accretion disk will be that of a modified blackbody as a result of the effects of electron scattering, and the multi color disk parameters must then be modified by a spectral hardening factor

f (Ebisawa et al. 1994). The effective temperature and inner radius are $kT_{\text{eff}} = kT_{\text{in}}/f$ and $R_{\text{eff}} = f^2 R_{\text{in}}$. Shimura & Takahara (1995) have found that $f = 1.7$ is a good approximation for accretion parameters appropriate for an X-ray binary.

Nevertheless, adding a soft X-ray component (DISKBB in XSPEC) to the power law only in four cases did the reduced chi squares decrease below two, with strong residuals at energies >40 keV, indicating that a high energy tail is also needed to fit these data. X-ray spectra clearly show the necessity of a soft X-ray component that is well described by a multicolor disk blackbody and of a high-energy curvature that is well reproduced by a cutoff power law. These fit results of the broad band spectrum using the models with two emission components are reported in Table 3, available at the CDS. We also tried to fit this data set with a model consisting of a only one Comptonization component. For this hard component we used the model COMPTT in XSPEC (Titarchuk 1994), assuming a spherical geometry for the Comptonizing region and leaving free the following parameters: the temperature of the Comptonizing electrons kT_e , the plasma optical depth τ_p and the input temperature of the soft photon Wien distribution kT_0 . Using this model we can estimate the sizes of the emitting seed photon region, assuming their emission as a blackbody with temperature T_0 and radius R_{seed} (in 't Zand et al. 1999). We obtain $R_{\text{seed}} \approx 8.3 \text{ km} (L_C/10^{37} \text{ erg s}^{-1})^{1/2} (1+y)^{-1/2} (kT_0/1 \text{ keV})^{-2}$, where L_C is the luminosity of the Comptonization component.

Table 4. BeppoSAX spectral results using the standard COMPTT and disk-blackbody model. L is the 0.1–100 keV (assumed isotropic, in units of 10^{36} erg s^{-1}) source unabsorbed luminosity using the average values of distances given in Table 1. The units of N_H and \dot{M} are 10^{22} atom cm^{-2} and $10^{-10} M_{\text{sun}}/\text{yr}$, respectively. θ is the inclination angle of the disk. All uncertainties are quoted at the 90% confidence level.

Source	Continuum parameters									
	L 10^{36} erg s^{-1}	N_H	kT_0 (keV)	kT_e (keV)	τ_p	kT_{eff} (keV)	$r_{\text{eff}}(\cos \theta)^{0.5}$ (km)	R_{comptt} km	\dot{M}	$\chi^2/\text{d.o.f.}$
1) 4U 1820-303 ^a	59^{+40}_{-15}	0.11 ± 0.08	0.2 ± 0.1	3.3 ± 0.3	15 ± 3	1.2 ± 0.2	6.7 ± 2.3	140	104	599.3/555
2) 4U 1820-303 ^a	33 ± 3	$0.14^{+0.07}_{-0.02}$	$0.23^{+0.03}_{-0.22}$	3.17 ± 0.09	16.6 ± 0.7	$0.56^{+0.01}_{-0.05}$	$19.1^{+0.9}_{-1.1}$	102	58	167.3/119
4U 1850-087	$2.0^{+3.5}_{-0.4}$	$0.33^{+0.06}_{-0.09}$	<0.3	38^{+54}_{-11}	$2.1^{+1.9}_{-1.5}$	0.39 ± 0.03	$9.5^{+2.0}_{-1.5}$	25	3.5	133.0/120
4U 0614+091 ^b	3 ± 1	0.24 ± 0.01	$0.78^{+0.03}_{-0.02}$	141^{+39}_{-71}	$0.17^{+0.05}_{-0.07}$	0.28 ± 0.01	35 ± 3	7	5.3	216.3/154
XB 1832-330	7 ± 1	$0.03^{+0.02}_{-0.01}$	$0.44^{+0.03}_{-0.01}$	23^{+3}_{-1}	$4.1^{+0.2}_{-0.3}$	$0.12^{+0.05}_{-0.03}$	23^{+54}_{-9}	18	12	165.7/136
1A 1246-588	3 ± 1	0.49 ± 0.03	0.25 ± 0.02	19^{+6}_{-4}	$3.5^{+0.6}_{-1.3}$	0.10 ± 0.01	479^{+349}_{-133}	43	5.3	888.8/649
4U 1812-12	$2.6^{+2.2}_{-0.4}$	1.4 ± 0.1	$0.38^{+0.08}_{-0.06}$	60^{+12}_{-13}	1.5 ± 0.3	$0.29^{+0.06}_{-0.06}$	<29	21	4.6	630/889
SAX J1712.6-3739 ^c	$1.6^{+0.5}_{-1.2}$	1.4 ± 0.3	0.5 ± 0.2	24^{+22}_{-9}	3 ± 2	0.4 ± 0.1	<32	10	3.5	110/132
4U 1705-32	3^{+7}_{-2}	0.3 ± 0.1	$0.6^{+0.3}_{-0.2}$	25^{+63}_{-3}	$3.5^{+1.5}_{-0.2}$	0.3 ± 0.1	17^{+26}_{-3}	7	5.3	152/147
1RXS J172525.5-32	<4.7	$2.0^{+0.3}_{-0.6}$	$0.2^{+0.8}_{-0.1}$	67^{+45}_{-40}	1.5 ± 0.6	$0.6^{+0.1}_{-0.4}$	<9	<75	8.3	43.9/31
1) SLX 1735-269	3 ± 2	$0.9^{+0.3}_{-0.2}$	$0.52^{+0.09}_{-0.03}$	15^{+32}_{-5}	5^{+1}_{-3}	$0.4^{+0.4}_{-0.3}$	<12	10	5.3	133/101
2) SLX 1735-269	3 ± 2	1.0 ± 0.2	$0.5^{+0.2}_{-0.1}$	21^{+19}_{-6}	4^{+1}_{-2}	$0.4^{+0.3}_{-0.1}$	<12	9	5.3	97/123
SLX 1737-282 ^a	$1.0^{+0.2}_{-0.5}$	1.4 ± 0.2	0.5 ± 0.1	30^{+40}_{-12}	$2.9^{+1.6}_{-0.8}$	0.4 ± 0.1	5^{+17}_{-1}	7	1.8	117.6/93

Emission Lines parameters			
Name	E_{line} keV	σ keV	flux 10^{-3} ph cm^{-2} s^{-1}
1) 4U1820-303	6.0 ± 0.2	0.6 ± 0.3	7^{+5}_{-3}
2) 4U1820-303	6.0 ± 0.1	1.6 ± 0.2	18^{+5}_{-3}
4U0614+091	0.72 ± 0.03	<0.7	113^{+78}_{-28}
4U0614+091	6.4 ± 0.1	1.4 ± 0.2	6^{+2}_{-1}
SLX1737-282	6.6 ± 0.3	$0.4^{+0.5}_{-0.3}$	$0.09^{+0.08}_{-0.04}$

^a A Gaussian component is required by the data; ^b two Gaussian components are required by the data; ^c Fit results from Fionchi et al. (2008).

We have estimated the amplification factor of the seed luminosity by Comptonization as $(1 + y)$, where y is the Comptonization parameter, $y = 4kT_e \max(\tau, \tau^2)/m_e c^2$. However, this model alone is not representative of the entire sample, indeed 8 fits out 13 require a soft component, assuming a significant improvement of the fit for F-test chance probabilities $<5 \times 10^{-3}$. Fit results of the broad band spectrum using the models with both DISKBB and COMPTT components are reported in Table 4, available at the CDS, while spectra and residuals with respect to the corresponding overplotted best fits are shown in Fig. 1, available at the CDS. We have not found differences in the spectral results using the simple black body model instead of the multi color disk black body. Unfortunately the available data do not allow us to discriminate the emission from the neutron star and the accretion disk. When statistically required, a Gaussian component was added to the model to reproduce the K_{α} iron line. We found that only three sources display meaningful emission lines.

Finally, we also tried to fit data adding to the model a partial covering fraction absorption. Only in the case of the burster XB 1832-330 is this component statistically required by the fit as previously reported by Parmar et al. (2001, for details see notes on the individual sources below).

Hereafter, we add these peculiarities on the spectral fitting of individual sources:

- *1A1246-588*: this X-ray burster was detected with Swift on 2006 August 11 during an outburst. The authors suggested that it is a long type-I X-ray burst with duration of at least

10 min (Kong 2006). Such as outburst was excluded during the extraction of the spectrum from the persistent emission; nevertheless the XRT/IBIS intercalibration constant is ~ 4 .

- *4U1735-269*: the light curve reported in this paper and a previous analysis performed by Molkov et al. (2005) show spectral variations during *INTEGRAL* observations in 2003; for this reason here we report only *BeppoSAX* data.
- *SLX 1737-282*: we exclude PDS data because they are contaminated by the new near *INTEGRAL* source IGR J17407-2808 (see Bird et al. 2007).
- *XB 1832-330*: Fig. 1, available at the CDS, shows that there are structured residuals remaining in the low energy part of the spectrum (LECS and MECS data). Following indications in Parmar et al. (2001), we fitted data using a partial covering model. This component is statistically highly significant, reducing $\chi^2/\text{d.o.f.}$ from 209/137 to 154/135 for the model consisting of a disk black body plus a cutoff power law and from 166/136 to 142/134 for the model consisting of a disk black body plus a COMPTT, with the corresponding F-test chance probabilities of 3×10^{-5} and 1×10^{-9} , respectively. Spectral parameters obtained using a partially covered disk-black body and COMPTT model are the following: the fraction of the flux that undergoes extra absorption $f_{\text{PCF}} = 0.2 \pm 0.1$, $N_{\text{PCF}} = 5.9 \pm 0.8 \times 10^{22}$ atoms cm^{-2} , $N_H = 4.5^{+2.6}_{-1.6} \times 10^{20}$ atoms cm^{-2} , $kT_{\text{in}} = 0.64 \pm 0.09$ keV, $kT_0 = 0.45^{+0.06}_{-0.02}$ keV, $kT_e = 25 \pm 2$ keV and $\tau = 3.8 \pm 0.3$.

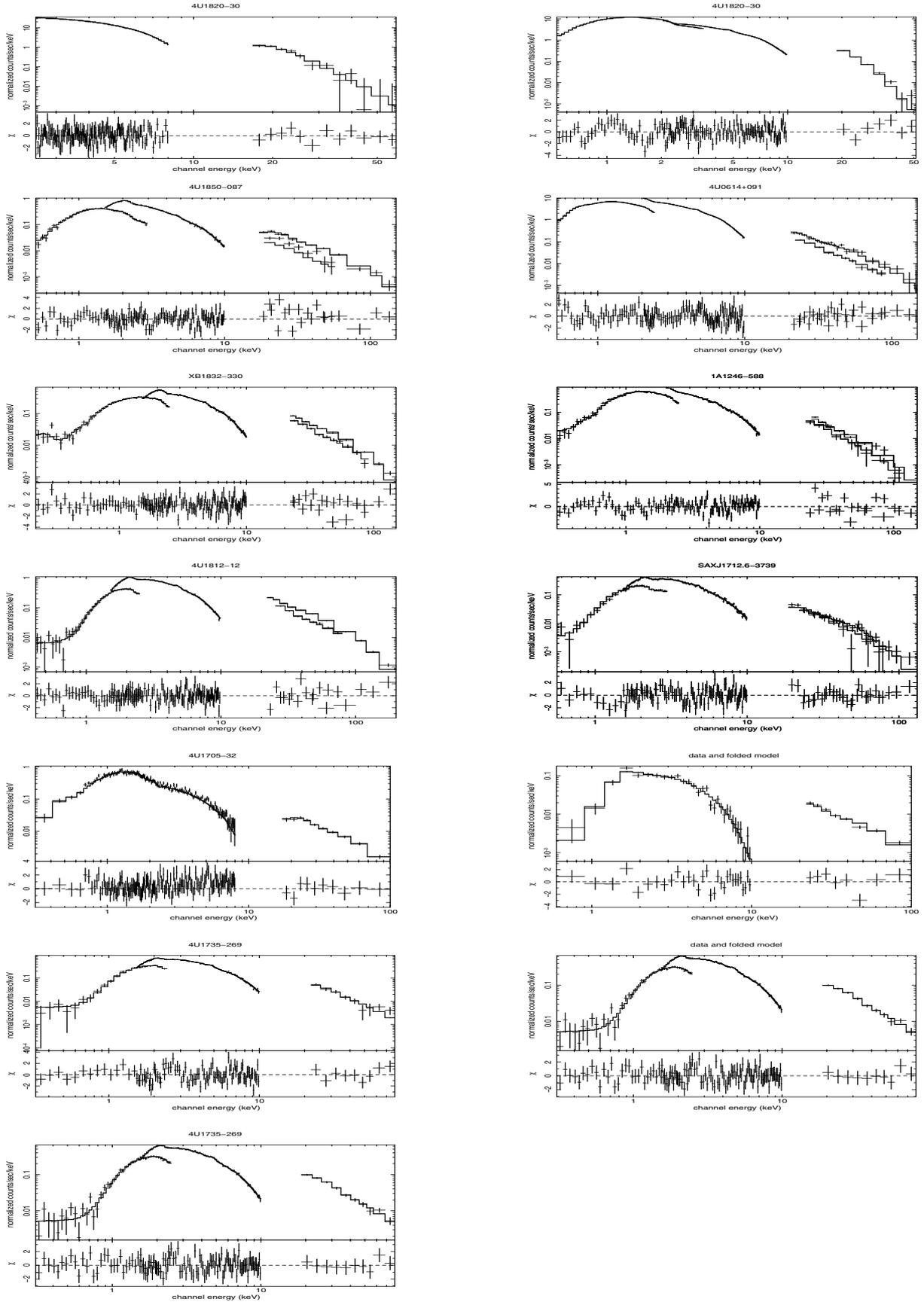


Fig. 1. Spectra of burster UCXB sample and the residuals with respect to the corresponding overplotted best fits, using a model consisting of DISKBB and COMPTT components.

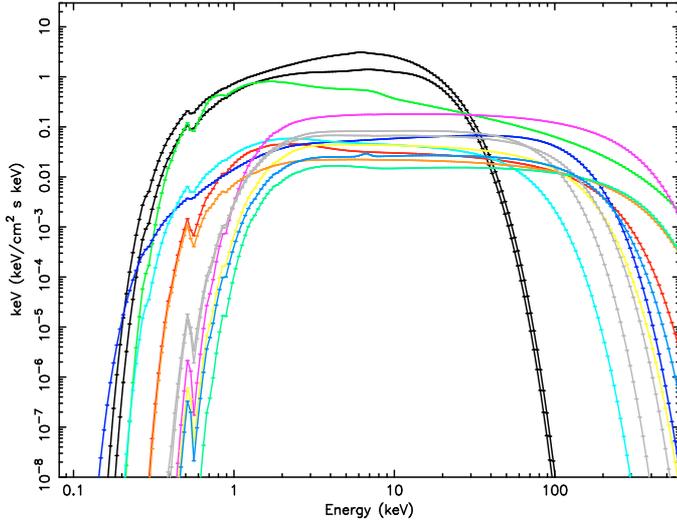


Fig. 2. Comparison of the extrapolated models for the burster UCXB observations, using the Comptonization models.

- *4U 0614+091*: in the *BeppoSAX* data a feature at 0.7 keV, well reproduced by a Gaussian component, has been reported by Piraino et al. (1999). Juett et al. (2001) attributed this feature in the *ASCA* spectra to an excess photoelectric absorption due to a non solar abundance of Ne. Grating spectra with *Chandra* and *XMM-Newton* confirm the unusual Ne/O ratio (Paerels et al. 2001). Motivated by the above, we again fitted data with a new absorbed black body and Comptonization model, allowing the relative abundances of O and Ne to vary (using the *vphabs* model in *XSPEC*). We obtained for this fit a $\chi^2/\text{d.o.f.}$ of 221/155, statistically similar to one with a Gaussian component ($\chi^2/\text{d.o.f.} = 216/154$). The Ne and O abundance ratios relative to solar are ~ 2.6 and ~ 0.3 , respectively, in agreement with previously reported values by Juett et al. (2001).

5. Discussion

We have performed a systematic study of the average properties of the persistent burster UCXBs. The *IBIS* long monitoring results indicate that UCXB sources spend most of the time in the canonical low/hard state, with unabsorbed luminosities lower than $\lesssim 8 \times 10^{36} \text{ erg s}^{-1}$ except for the source *4U 1820-30* which was always detected in a soft/high state (see discussion below). Figure 2 clearly shows that the majority of the sources are in the hard state with constant emission between 10 and 70 keV. Generally, the hard component, due to the Comptonization of soft photons coming from the accretion disk and/or the neutron star surface, dominates the emission. The two sources *4U 1820-30* and *4U0614+091* have shown a different energy spectrum shape. The first burster is observed only in a typical high/soft state with an accretion rate of $(0.6-1.0) \times 10^{-8} M_{\odot}/\text{yr}$, a low electron temperature ($\sim 3 \text{ keV}$) and a very high optical depth ($\sim 15-16$). This behavior differs from other UCXB burster. We note that this source could be a triple system consisting of a white dwarf accreting onto a neutron star and a third body with its mass weakly constrained ($0.004 M_{\odot} < M < 0.5 M_{\odot}$), with two timing modulations, a orbital period of 685s and super orbital variability of $\sim 170 \text{ d}$ (Zdziarski et al. 2007a,b). The second burster *4U 0614+091* shows a stronger disk emission

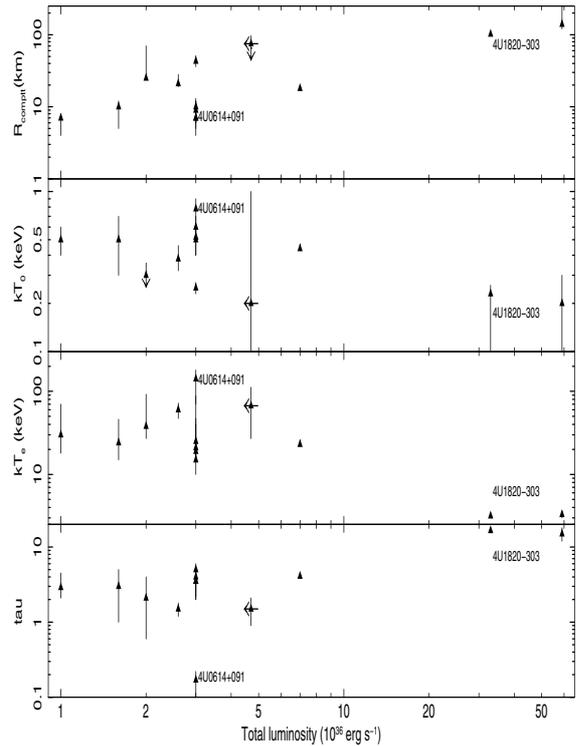


Fig. 3. The radius of the emission area of the seed photons, the seed photon temperatures, the electron temperature and the optical depth of the Comptonizing plasma versus the total luminosity in the 0.1–100 keV energy range, in units of $10^{36} \text{ erg s}^{-1}$.

than other UCXB bursters and a very high electron temperature ($\sim 140 \text{ keV}$). This very high electron temperature could be due to inverse Comptonisation of seed photons with a non Maxwellian electron distribution, which generate a power law spectrum without a high energy cutoff, as previously reported by Piraino et al. (1999).

The soft component of our sample is successfully fitted with a multi disk black body model, providing reasonable physical parameters of the disk. The temperature at the inner disk radius is 0.1–0.6 keV (in one case only is ~ 1.2), lower than 1 keV as previously reported by Sidoli et al. (2001) for a sample of 3 UCXBs. Moreover, these authors show that three ultra compact binaries display seed photon temperatures kT_0 consistent with the temperature of the inner regions of the accretion disk. Although a clear correlation between the temperature of the seed photons and the inner disk temperature is not observed for our sample, we note that values of both temperatures are in the range 0.1–0.8 keV, except for the candidate triple system *4U 1820-303*. This behavior indicates that the inner disk could be the location of the seed photons of the Comptonization emission.

The thermal Comptonization component well fits the UCXB sample spectra in the high energy region. The electron temperatures kT_e are typically $\gtrsim 20 \text{ keV}$, the optical depth $\tau \lesssim 4-5$ and the seed photons temperatures $kT_0 \lesssim 0.8 \text{ keV}$ (except for *4U 1820-303* which is in a high/soft state). The relation between the *COMPTT* parameters obtained from the spectral analysis and the total luminosities is shown in Fig. 3. As previously reported by Sidoli et al. (2001), the radius of the emission area of the seed photons seems to correlate with the total luminosity, suggesting that the seed photons originate from the boundary layer rather than from the accretion disk (Popham & Sunyaev 2001).

Finally we note that the intermediate long burst (decay times ranging between ten and a few tens of minutes) or superbursts (decay time more than an hour) are very rare events. Indeed the estimated fraction of intermediate long burst or superbursts among the whole type I burst population is only 0.3–0.4%. In our studied sample 64% of the UCXBs show superbursts or intermediate long burst (as reported in Table 1). This suggests that such timing behavior could be a common feature of the UCXBs. On the other hand, there are only 13 objects showing long or intermediate bursts (Lewin & van der Klis, 2006) and they are UCXBs or binary systems with unknown orbital period.

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