SPECTRAL PROPERTIES OF A SAMPLE OF LOW LUMINOSITY TYPE I X-RAY BURSTERS

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ABSTRACT

I report on a sample of new type I X-ray bursters, firstly detected with the Wide Field Cameras on board BeppoSAX and then studied with the Narrow Field Instruments on a broad spectral range (0.1-200 keV). Properties of the transient/persistent emission are summarized and the broad band X-ray spectra discussed in detail for a few sources.

INTRODUCTION

Short transient event phenomena like X-ray bursts are known since 1975 (Grindlay et al. 1976, Belian et al. 1976), with a total of ~ 20 burst sources revealed within about one year since the initial discovery. Accretion onto the surface of a weakly magnetized neutron star (NS) can give rise to X-ray bursts via unstable nuclear burning, if the system is filled through Roche-lobe overflow at transfer rates much lower than the Eddington limit of ~ 2 × 10^{-8} M_⊙/year (van Paradijs et al.,1988). Wind-fed systems cannot be X-ray burst sources whereas most persistent X-ray bursters are identified with low mass X-ray binaries (LMXB), being mostly Atoll sources. Relevant source properties can be derived from combined burst and persistent emission study (distance, radius, composition of nuclear fuel etc., see Lewin et al. 1995 for review). In this respect, very important are the so-called super-Eddington bursts, in which expansion of the blackbody (BB) emitting photosphere occurs up to radii of several tenths of kilometers (Lewin et al. 1993), due to the emission level reaching the Eddington luminosity. The profiles from these bursts tend to flatten at energies above ~ 5 keV and often show a double-peaked structure, each peak being associated with the expansion and contraction phases (see Figure 1). This allows to estimate distances via the determination of the burst peak fluxes, assumed to be at a level of ~ 2 × 10^{38} erg s^{-1} which is the Eddington luminosity of a standard 1.4 M_⊙ NS.

Recently, X-ray burst research went to a new exciting phase following the the discovery of high time resolution features like kHz nearly coherent oscillations in the burst time profiles (Strohmayer et al. 1996), present during both the rising and cooling phases and then probably associated to the NS spin period (Strohmayer & Markwardt, 1999). These studies can also give important insight in the understanding of the geometry, structure and composition of the burning layers (Muno et al., 2000).

Since 1992, the detection by GRANAT/SIGMA of hard X-ray emission from a few bursters, namely KS1731-260, GX354-0 and 1E1724-3045 (Barret & Vedrenne 1994) and subsequently other BATSE observations (Barret et al. 1996) have established X-ray bursters as a new important class of low luminosity hard X-ray emitters. A few years after these early '90 observations, the population of X-ray bursters had a substantial increase by means of the BeppoSAX observation campaigns performed since 1996 with the Wide Field Cameras (WFC). These allowed to discover 16 new bursters thus increasing the known population by about 30%. Among these objects, interesting is the discovery of burst emission from GS 1826-238 (Ubertini et al. 1999a) showing that this source, previously considered as a transient Black Hole Candidate (BHC) is instead a persistent, low luminosity source with nearly periodic, extremely regular bursting behaviour.

In this work I report about observations of a sample of these new bursters and discuss their broad band spectral properties, as obtained from Target-Of-Opportunity observations by the Narrow Field Instruments.
THE SOURCES

Burst detection is the objective tool to distinguish between BH and NS binaries. In case of NS LMXB transients with sporadic X-ray outbursts, type I bursts are often seen when the persistent emission level is above a few percent of the Eddington limit, whereas bursting activity is generally absent in quiescent state. Long term monitoring is then essential not also for discovering of new transients, but also for their characterization as NS or BH binaries.

Since LMXBs are highly concentrated towards the Galactic Bulge, a sensitive monitoring of this region can be obtained with pointed observations of wide field instruments. For this purpose, a monitoring program is being performed since August 1996 by the BeppoSAX/WFC (Jager et al 1997) by means of observations repeated periodically during the Spring and Fall of each year. The monitoring itself has a sensitivity of a few mCrab, that is an order of magnitude beyond the capabilities of current All-Sky monitors. At the distance of the Galactic Centre this sensitivity limit corresponds to a 2-10 keV source flux of less than $10^{36}$ erg s$^{-1}$. This has allowed the discovery of a new population of low luminosity NS transients in the Galactic Bulge, probably consisting of short period binaries with evolved mass companions (Heise et al. 1999). Binary systems harboring weakly magnetized NS are known to be preferentially persistent. This is possibly related to system thermal stability being induced by X-ray irradiation of the outer disk (e.g., King et al. 1997). This condition is more easily found in NS than in black hole binaries, but indeed it may be expected that NS systems with very low accretion rates can be transient (King 2000). Currently, 9 new faint transients have been discovered by the BeppoSAX/WFC. Most of them have been observed bursting, namely: the 2.5 ms accreting pulsar SAX J1808.4-3658 (in’t Zand et al. 1998a), SAX J1748.9-2021 in the globular cluster NGC 6440 (in’t Zand et al. 1999a), SAX J1750.8-2900 (Natalucci et al. 1999), SAX J1712.6-3739 (Cocchi et al. 1999a) and SAX J1810.8-2609 (Natalucci et al. 2000a). Burst events were also observed from three other sources, for which no persistent emission was detected: SAX J1753.5-2349, SAX J1806.5-2215 (in’t Zand et al. 1998b) and SAX J1752.3-3138 (Cocchi et al. 1999b). From another new faint transient, SAX J1819.2-2525 (in’t Zand et al. 2000) no bursts were detected so far.

The fact that the majority of these weak transients are NS is reminiscent of the observed behavior in persistent sources, where it is found that low state X-ray bursters are much less luminous than the corresponding low state BH sources (typically by a factor 10 to 100, see e.g. Barret et al. 2000).

For this work, I have selected a sample of X-ray bursters for which broad band spectra were obtained by means of a related BeppoSAX TOO program (see Table I) or by dedicated observations. This sample contains two weak transients, one recurrent transient (SAX J1747.0-2853) and two persistent sources (GS 1826-238 and SLX 1735-269). In remainder of the paper, I will outline the most relevant spectral properties of these sources.

| Source Name     | Obs. Date  | Duration (ksec) | $F_{2-10keV}$ ($10^{-10}$ erg s$^{-1}$ cm$^{-2}$) | References                      |
|-----------------|------------|-----------------|-----------------------------------|--------------------------------|
| SAX J1810.8-2609| 1998 Mar 12-13 | 85              | 4.3                               | Natalucci et al. (2000a)       |
| SAX J1712.6-3739| 1999 Aug 27    | 45              | 1.2                               | Cocchi et al. (1999a)          |
| SAX J1747.0-2853| 1998 Mar 23-24 | 72              | 3.0                               | Natalucci et al. (2000b)       |
| GS 1826-238     | 1999 Apr 6-7   | 41              | 5.4                               | in’t Zand et al. (1999b)       |
| SLX 1735-269    | 1997 Sep 18-19 | 61              | 5.0                               | Bazzano et al., in prep.       |

**SAX J1810.8-2609: a faint transient with a very hard spectrum**

This source was discovered by the BeppoSAX/WFC on 1998 March 10 (Ubertini et al., 1998a), with a persistent emission level of $3.1 \times 10^{-10}$ erg s$^{-1}$ cm$^{-2}$ ($\sim 15 \text{ mCrab}$) in the 2-10 keV band. The source...
Fig. 1. Time profiles of the March 11.06634 type I X-ray burst from the weak transient SAX J1810.8-2609. The ratio blackbody radius vs. distance is shown in units of km/10 kpc.

Fig. 2. The broadband spectrum of SAX J1810.8-2609 measured by the NFI on 1998 March 12-13. The model fit is as explained in text.

position is consistent with that of a soft X-ray source, RX J1810.7-2609, revealed by ROSAT during a follow-up observation performed 15 days later (Greiner et al., 1998). On March 11, i.e. one day after its discovery a strong, super-Eddington type I burst was detected. This allowed an estimate of the source distance of $\sim 5$ kpc. The burst has the characteristic radius expansion profile (Figure 1) and a very fast ($\sim 1$ sec) rise time, typical of a helium burning flash (Lewin et al. 1993).

SAX J1810.8-2609 was observed again by BeppoSAX about two days after its discovery, using the NFI. The X-ray spectrum from the source is exceptionally hard for a NS system, as the slope of the high energy power law is 1.96 and there is no visible high energy cutoff (Figure 2). The best fit spectrum, yielding $\chi^2 = 0.99$ (161 dof) is obtained as a sum of two components: a blackbody spectrum with a $\sim 0.4$ keV temperature, and a hard tail which results from Compton up-scattering of soft seed photons, represented by a thermal distribution at $\sim 0.6$ keV (see the referenced paper for details). The presence of the soft blackbody component, with a total flux of $\sim 3 \times 10^{-11}$ erg s$^{-1}$ cm$^{-2}$ is highly significant, as the estimated chance probability evaluated via F-test is $\sim 7 \times 10^{-9}$ for the model given above. For this source, a two-component blackbody plus power law gives also a good fit ($\chi^2 = 0.97$ for 163 dof) but only the former model, which involves thermal comptonization is capable of matching the estimated value of Galactic column absorption of $3.7 \times 10^{21}$ cm$^{-2}$.

SAX J1712.6-3739

This new, faint transient object was detected for the first time on 1999, August 25 by the WFC (in 't Zand et al., 1999c), at a position $\sim 0.6$ arcmin from a ROSAT all-sky-survey source, 1RXS J171237.1-373834. The source was designated as a candidate NS LMXB, following the WFC detection of a long (lasting $\sim 20$ s) type I X-ray burst on September 2 (Cocchi et al. 1999a) having a peak intensity of 1.7 Crab. On August 27 the NFI were pointed on SAX J1712.6-3739 for a TOO observation, when the source intensity was $\sim 6$ mCrab in the 2-10 keV band. The measured spectrum is quite hard and is well fitted by unsaturated thermal comptonization with seed photons temperature of 0.47 $\pm$ 0.03 keV, and the resulting $\chi^2$ is 1.00 for
117 dof. The overall flux, however, was too weak to determine the cutoff energy of the comptonized tail.

This weak outburst and the related type I X-ray burst emission were the only observed events from SAX J1712.6-3739 throughout about five years of monitoring.

The recurrent transient SAX J1747.0-2853 very close to the Galactic Centre

SAX J1747.0-2853 is a rather intriguing source. Until last year it was known to have recurrent weak outbursts, i.e. at a level less than \( \sim 20 \) mCrab. Since its discovery in 1998 by in’t Zand et al. (1998c), two faint outburst events were observed by the WFC in spring of 1998 and spring of 1999. In March 2000 the source re-appeared with an average intensity of \( \sim 42 \) mCrab in the 2-10 keV band, increasing up to 140 mCrab on March 7.9 as observed by the RXTE PCA (Markwardt et al. 2000) and BeppoSAX (Campana et al. 2000).

A total of 14 X-ray bursts were detected during the 1998 Spring campaign. One of the strongest events clearly showed radius expansion and allowed to estimate a distance of \( \sim 9 \) kpc (Natalucci et al., 2000b). The outburst X-ray light curve has a slowly rising edge, with intensity increasing at a rate of \( \sim 1.1 \times 10^{35} \) erg s\(^{-1}\) day\(^{-1}\) (see Figure 3). The peak luminosity for this outburst is \( \sim 3 \times 10^{36} \) erg s\(^{-1}\) in the 2-10 keV band. The source was pointed with the NFI in March 23-24. Figure 4 shows the MECS image, obtained in the 0.5-10.5 keV band, of the \( \sim 1 \) square degree region centered on the object. Two other objects are present in the field, one is identified with the Sgr A complex and the other is a soft spectrum source, 1E 1743.1-2843. Up to 10.5 keV, the presence of additional sources is not a problem when careful background subtraction is performed. At higher energies, however, the lack of spatial resolution of the BeppoSAX collimated instruments leads to source confusion.

Under reasonable assumptions and excluding the spectral channels between 10.5 and 32 keV (see Natalucci et al., 2000b for all details on data selection), a broadband spectrum could be obtained as shown in Figure 4. The primary emission from SAX J1747.0-2853 can be described by a combination of thermal comptonization plus a soft blackbody component at \( \sim 0.55 \pm 0.10 \) keV. A sharp iron absorption edge is detected at an energy of \( \sim 7.4 \pm 0.2 \) keV (see Figure 6), together with a narrow K\( \alpha \) line at 6.9 ± 0.1 keV, with an equivalent width of \( \sim 55 \) eV. The significance of the line is high (the F-test gives a 1.4 \times 10^{-5} \) chance probability). However, as a thermal plasma with line emission is present in the Galactic Centre region (Koyama et al., 1996), systematics could be induced in the background subtraction process by the non-uniform spatial distribution of this diffuse emission. For this reason this detection should be not considered a straight evidence.
GS 1826-238

GS 1826-238 flux measurements throughout several years established this X-ray binary to be a faint, persistent source. The WFC discovery of extremely regular bursting intervals, with a slowly evolving quasi-periodicity (Ubertini et al. 1999a,1999b) has recently raised great interest around this source, formerly believed to be a BHC. An up-to-date description of the long term bursting behaviour can be found in Cocchi et al (2001).

The source was observed several times by the BeppoSAX/NFI. Del Sordo et al. (1999) fitted a broad band spectrum with a blackbody component and high energy tail represented by a cutoff power law. A two component model was also suggested by int’Zand et al. (1999b), in which the hard X-ray emission is accounted by unsaturated thermal comptonization (Titarchuk, 1994; Hua & Titarchuk, 1995). Using the same model, good quality fits ($\chi^2 \sim 1.1$) have been obtained for an observation performed during the Fall of 1999. In this case the spectrum is compatible with the sum of a comptonized emission with seed photon temperature $\sim 1.3$ keV and a soft blackbody component at $\sim 0.6$ keV (Cocchi et al., in preparation). For the latter, the ratio BB radius/distance is $\sim 100$ km/kpc, hence compatible with a typical NS radius.

SLX1735-269

This persistent source, recently discovered as a new burster (Bazzano et al., 1997) was observed by the NFI on Fall 1999, showing a persistent flux of $\sim 5 \times 10^{-10}$ erg s$^{-1}$ cm$^{-2}$ in the 0.5-150 keV band. From a preliminary analysis, the spectrum is fitted by a single component model consisting of unsaturated thermal comptonization with seed photon temperature $0.48 \pm 0.02$ keV. There is weak indication of a high energy cutoff, corresponding to $kT_e=26 \pm 11$ keV. This fit yields $\chi^2=1.15$ for 101 dof, and an absorption coefficient $N_H=0.74 \pm 0.08$ cm$^{-2}$. No additional blackbody component is detected.

DISCUSSION

The sample of X-ray bursters considered has remarkable common properties. The luminosities found are generally low, below $\sim 10^{-37}$ erg s$^{-1}$ cm$^{-2}$, with detection of hard tails in all the sources. The analysis of broadband spectra reveals unsaturated thermal comptonization as the primary mechanism for the hard X-ray source in these X-ray bursters. This is also confirmed by other observations of similar NS (Guainazzi et al., 1999). An additional soft component is observed in SAX J1810.8-2609, SAX J1747.0-2853 and GS 1826-238,
well described by blackbody emission at a temperature of $\sim 0.5$ keV. In SLX1735-238 and SAX J1712.6-3739 this soft component is not necessary to obtain a good fit, possibly due to the lower statistics.

The analysis of the spectra reveal a preference for two different sources of thermal photons, corresponding to the blackbody (apparently unscattered) and to the comptonized seed photons. A systematic study is on going to determine the relevant properties of these two components, in particular to constrain the origin of the emission. For the sources observed, the blackbody component is generally compatible with a photosphere radius of the order of (or slightly greater than) 10 km, so indicative of a NS origin. If the soft component is fitted with a multicolor disk model, the values of the inner radii are those expected from an inner disk quite close to the NS ($\sim 10$ km to several tenths of km). Detections of blackbody temperatures around $\sim 2$ keV are sometimes reported for low/hard states (e.g., Balucinska-Church et al. 1999, Barret et al. 2000), but in this case the normalization often yields blackbody radii much smaller than the NS radius (typically less than $\sim 1$ km). Incidentally, this happens mostly when a cutoff power law is used to model the primary hard component instead of thermal comptonization with a Wien-like input spectrum.

The situation is more complex for what concerns the comptonized component. For SAX J1748.9-2021 in’t Zand et al. (1999a) report a seed temperature of 0.57 keV which is compatible with a radius very close to the NS, $\sim 13$ km. Values close to $\sim 0.5$ keV are also obtained from SLX 1735-269 and SAX J1810.8-2609. For the former source, this is consistent with RXTE data, with the report of a $0.53 \pm 0.07$ keV temperature (Barret et al., 2000). In other sources (GS 1826-238, SAX J1747.0-2843) temperatures in the range 1-1.2 keV are reported. For the electron plasma, there is a “clustering” of $kT_e$ values around $\sim 20$ keV, apart from SAX J1810.8-2609 which shows a rather peculiar and very hard tail (no cutoff is observed). Its spectrum is reminiscent of that of a low state BHC where the high energy cutoff is located above $\sim 100$ keV.

ACKNOWLEDGEMENTS

The author would like to thank the WFC Galactic Bulge Collaboration, and in particular J.Heise, P.Ubertini, A.Bazzano, M.Cocchi, J.J.M in’t Zand and E.Kuulkers for providing many results outlined in this paper. I am also grateful to Team Members of the BeppoSax Science Operation Centre and Science Data Centre for the continuos support. The BeppoSAX satellite is a joint Italian and Dutch programme.

REFERENCES

Balucinska-Church, M., M.J. Church, T. Oosterbroek, A. Segreto; R. Morley et al., An X-ray study of the dipping low mass X-ray binary XV 1323-619, 1999, A&A 349, 495-504, 1999.
Barret, D. and G. Vedrenne, Hard X-ray emission from weakly magnetized neutron stars, ApJ Suppl. 92, 505-510, 1994.
Barret, D., J.E. Grindlay; P.F. Bloser, S.N. Zhang, G.J. Fishman et al., BATSE observations of hard X-ray emission from X-ray bursters. Presentation of a CGRO/BATSE investigation and first results, A&A Suppl. 120, 121-127, 1996.
Barret, D., J.F. Olive, L. Boirin, C. Done, G.K. Skinner et al., Hard X-Ray Emission from Low-Mass X-Ray Binaries, ApJ 533, 329-351, 2000.
Bazzano, A., M. Cocchi, P. Ubertini, J. Heise, J.J.M in ’t Zand et al., SLX 1735-269, IAU Circ. 6668,2, 1997.
Belian, R.D., J.P. Conner and W.D. Evans, The discovery of X-ray bursts from a region in the constellation Norma, ApJ Lett. 206, L135-L138, 1976.
Boella, G., R.C. Butler, G.C. Perola, L. Piro, L. Scarsi et al., BeppoSAX the wide band mission for X-ray astronomy, A&A Suppl. 122, 299-307, 1997.
Campana, S., G.L. Israel and L. Stella, SAX J1747.0-2853, IAU Circ. 7401,1, 2000.
Cocchi, M., L. Natalucci, J.J.M. in ’t Zand, J. Heise, J.M. Muller et al., SAX J1712.6-3739, IAU Circ. 7247,3, 1999a.
Cocchi, M.A. Bazzano, L. Natalucci, P. Ubertini, R. Cornelisse et al., SAX J1752.3-3138, IAU Circ. 7307,2, 1999b.
Cocchi, M., A. Bazzano, L. Natalucci, P. Ubertini, J. Heise et al., Wide band observation of the burster GS 1826-238, these proceedings, 2001.
Del Sordo, S., F. Frontera, E. Pian, S. Piraino, T. Oosterbroeck et al., BeppoSAX observation of the galactic source GS 1826-238 in a hard X-ray high state, Astrophys. Letters & Communications 38, 125-128, 1999.
Greiner, J., A.J. Castro-Tirado, T. Boller, H.W. Duerbeck, S. Covino et al., X-ray and optical-to-infrared follow-up observations of the transient X-ray burster SAX J1810.8-2609, *MNRAS* 308, L17-L21, 1999.

Grindlay, J.E., H. Gursky, H. Schopper, D.R. Parsignault, J. Heise et al., Discovery of intense X-ray bursts from the globular cluster NGC 6624, *ApJ Lett.* 205, L127-L130, 1976.

Guainazzi, M., A. Comastri, G.M. Stirpe, W.N. Brandt, F. Fiore et al., The comptonized X-ray source X 1724-308 in the globular cluster Terzan 2, *A&A* 339, 802-810, 1998.

Heise, J., J.J.M. in't Zand, M. Smith, J.M. Muller, P. Ubertini et al., Dim transient X-ray binaries in the Galactic Bulge, *Astrophys. Letters & Communications* 38, 297-300, 1999.

Hua, X. and L. Titarchuk, Comptonization models and spectroscopy of X-Ray and Gamma-Ray sources: a combined study by Monte Carlo and analytical methods, *ApJ* 449, 188-203, 1995.

in 't Zand, J.J.M., J. Heise, J.M. Muller, A. Bazzano, M. Cocchi et al., Discovery of the X-ray transient SAX J1808.4-3658, a likely low-mass X-ray binary, *A&A Lett.* 331, L25-L28, 1998a.

in 't Zand, J.J.M., J. Heise, J.M. Muller, A. Bazzano, M. Cocchi et al., Discovery of SAX J1753.5-2349 and SAX J1806.5-2215: two X-ray bursters without detectable steady emission, *Nuclear Physics B* 69, 228-231, 1998b.

in 't Zand, J.J.M., A. Bazzano, M. Cocchi, P. Ubertini, J.M. Muller et al., SAX J1747.0-2853 and GX +0.2-0.2, *IAU Circ.* 6846, 2, 1998c.

in 't Zand, J.J.M., F. Verbunt, T.E. Strohmayer, A. Bazzano, M. Cocchi et al., A new X-ray outburst in the globular cluster NGC 6440: SAX J1748.9-2021, *A&A* 345, 100-108, 1999a.

in 't Zand, J.J.M., J. Heise, E. Kuulkers, A. Bazzano, M. Cocchi et al., Broad-band X-ray measurements of GS 1826-238, *A&A* 347, 891-896, 1999b.

in 't Zand, J.J.M., J. Heise, A. Bazzano, M. Cocchi and M.J.S. Smith, SAX J1712.6-3739, *IAU Circ.* 7243, 2, 1999c.

in 't Zand, J.J.M., E. Kuulkers, A. Bazzano, R. Cornelisse, M. Cocchi et al., BeppoSAX observations of the nearby low-mass X-ray binary and fast transient SAX J1819.3-2525 *A&A* 357, 520-526, 2000.

Jager, R., W.A. Mels, A.C. Brinkman, M.Y. Galama, H. Gouloose et al., The Wide Field Cameras onboard the BeppoSAX X-ray Astronomy Satellite, *IAU Suppl.* 125, 557-572, 1997.

King, A.R., U. Kolb and E. Szuszkiwicz, Why low-mass Black Hole Binaries are transient *ApJ*, 488, 89-93, 1997.

King, A.R., The population of faint transients in the Galactic Centre, *MNRAS* 315, L33-L36, 2000.

Koyama, K., Y. Maeda, T. Sonobe, T. Takeshima, Y. Tanaka et al., ASCA View of Our Galactic Center: Remains of Past Activities in X-Rays?, *PASJ* 48, 249-255, 1996.

Lewin, W.H.G., J. van Paradijs and R.E. Taam, X-Ray Bursts, *Space Sci Rev.* 62, 223-389, 1993.

Lewin, W.H.G., J. van Paradijs and R.E. Taam, X-ray bursts, in X-ray binaries, W.H.G. Lewin, J. van Paradijs, E.P.J. van den Heuvel (eds.), Cambridge Univ. Press, Cambridge, pp.175-232, 1995.

Markwardt, C.B., F.E. Marshall and J.H. Swank, SAX J1747.0-2853 and GX +0.2-0.2, *IAU Circ.* 542, 1016-1033, 2000.

Muno, M.P., D.W. Fox, E.H. Morgan and L. Bildsten, Nearly coherent oscillations in type I X-ray bursts from KS 1731-260, *ApJ* 542, 1016-1033, 2000.

Natalucci, L., R. Cornelisse, A. Bazzano, M. Cocchi, P. Ubertini et al., A New bursting X-Ray transient: SAX J1750.8-2900, *ApJ Lett.* 523, L45-L49, 1999.

Natalucci, L., A. Bazzano, M. Cocchi, P. Ubertini, J. Heise et al., SAX J1810.8-2609: A new hard X-Ray bursting transient, *ApJ* 536, 891-895, 2000a.

Natalucci, L., A. Bazzano, M. Cocchi, P. Ubertini, J. Heise et al., Broadband observations of the new X-Ray burster SAX J1747.0-2853 during the 1998 March Outburst, *ApJ Lett.* 543, L73-L76, 2000b.

Strohmayer, T.E., W. Zhang, J.H. Swank, A. Smale, L. Titarchuk et al., Millisecond X-Ray variability from an accreting Neutron Star system, *ApJ Lett.* 469, L9-L12, 1996.

Strohmayer, T.E. and C.B. Markwardt, On the frequency evolution of X-Ray brightness oscillations during thermonuclear X-Ray bursts: evidence of coherent oscillations, *ApJ Lett.* 516, L81-L85, 1999.

Titarchuk, L., Generalized Comptonization models and application to the recent high-energy observations, *ApJ* 434, 570-586, 1994.

Ubertini, P., J.J.M. in't Zand, A. Tesseri, D. Ricci and L. Piro, SAX J1810.8-2609, *IAU Circ.* 6838,1, 1998a.
Ubertini, P., A. Bazzano, M. Cocchi, L. Natalucci, J. Heise et al., Bursts from GS 1826-238: a clocked thermonuclear flashes generator, *ApJ Lett.* **514**, L27-L30, 1999a.

Ubertini, P., A. Bazzano, M. Cocchi, J. Heise, J.J.M. in’t Zand et al., Long term behaviour of the hard tailed X-ray burster GS 1826-238, *Astrophys. Letters & Communications* **38**, 129-132, 1999b.

van Paradijs, J., W. Penninx and W.H.G. Lewin, On the relation between X-ray burst properties and the persistent X-ray luminosity, *MNRAS* **233**, 437-450, 1988.