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*Beppo*SAX OBSERVATIONS OF THE BLACK HOLE CANDIDATES LMC X–1 AND LMC X–3

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ABSTRACT

We describe *Beppo*SAX observations of the black hole candidates LMC X–1 and LMC X–3 performed in Oct. 1997. Both sources can be modelled by a multicolor accretion disk spectrum, with temperature ~ 1 keV. However, there is some evidence that a thin emitting component coexists with the thick disk at these temperatures. In the direction of LMC X–1, we detected a significant emission above 10 keV, which we suspect originates from the nearby source PSR 0540-69. For LMC X–1, we estimate an absorbing column density of $\simeq 6 \times 10^{21}$ cm^{-2}, which is almost ten times larger than that found for LMC X–3. In both sources, we find no indication of emission or absorption features whatsoever.

1 INTRODUCTION

LMC X–3 and LMC X–1 are two luminous persistent X–ray binaries. LMC X–3 has an orbital period of 1.7 days and is one of the most secure black hole candidates ($M_X \simeq 10M_\odot$). For LMC X–1 there is still some uncertainty regarding the optical counterpart. The most probable optical candidate has a period of 4.23 d, which implies a companion (hole) mass of $\simeq 5M_\odot$ (Cowley et al. 1995).

The two objects have soft X–ray spectra reminiscent of Cyg X–1 in the high/soft state. A high energy tail extending above 10 keV is detected in both systems (Ebisawa, Mitsuda & Inoue 1989; Treves et al. 1990).

We observed the two sources with *Beppo*SAX in Oct. 1997, which allowed us to construct simultaneous spectra in a broad energy band (0.1–100 keV). All the four narrow field instruments (LECS 0.1–4 keV, MECS 1.8–10 keV, HPGSPC 7–70 keV, PDS 12–150 keV) performed nominally; the MECS functioning with two units. Here we are presenting some preliminary results on the X–ray spectral distribution. HPGSPC data analysis is not discussed in this paper.

Our observations correspond to a low intensity state of LMC X–3, while LMC X–1 appears stable on month/year time scale, as apparent from the the XTE–ASM light curves.

TABLE 1: Observation Log

Source Name	Exposure Time (ks)			Count rate (cts/s)		
	LECS	MECS	PDS	LECS	MECS	PDS
LMC X–1	14.4	38.2	43.3	3.26±0.02	2.67±0.01	0.21±0.05
LMC X–3	17.4	39.5	38.0	3.37±0.01	2.19±0.01	0.03±0.05

Note: MECS counts are for one unit. PDS counts are for four units.

TABLE 2: Spectral Fits: Disk Spectrum[a] + Free–Free

Source Name	N_H (10^{22} cm^{-2})	kT_{in} (keV)	N^b_{diskbb}	kT_{brems} (keV)	N^c_{bremss}	$F^d_{[2-10]keV}$	χ^2/dof
LMC X-1	$0.61^{+0.03}_{-0.03}$	$0.85^{+0.01}_{-0.02}$	$45.1^{+7.0}_{-8.5}$	$2.39^{+0.25}_{-0.19}$	$0.15^{+0.04}_{-0.04}$	3.25	190/214
LMC X-3	$0.056^{+0.005}_{-0.004}$	$1.05^{+0.01}_{-0.02}$	$19.4^{+1.7}_{-1.2}$	$2.01^{+0.42}_{-0.90}$	$0.036^{+0.008}_{-0.009}$	2.71	217/214

Note: errors are 90% confidence level for one parameter.

[a] $\frac{dN}{dE} = \frac{8\pi}{3}\frac{R_{in}}{D^2}\cos\theta \int_{T_{out}}^{T_{in}} (T/T_{in})^{-11/3} B(E,T) dT/T_{in}$

[b] $[(R_{in}/\mathrm{km})/(D/10\mathrm{kpc})]^2 \cos\theta$

[c] $\frac{3.02\times10^{-15}}{4\pi D^2} \int n_e n_I \, dV$

[d] Flux unit: (10^{-10} erg/cm^2/s)

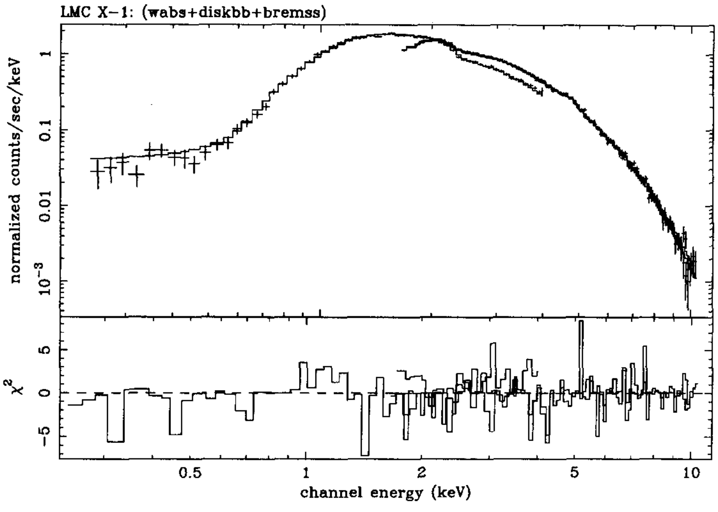

Figure 1: LMC X-1: count spectrum and contribution to χ^2 when data are fitted with a `wabs[diskbb+bremss]` model.

2 *Beppo*SAX SPECTRA

Data reduction followed the standard procedure. Total exposure times and count rates are reported in Table 1. Results of the spectral analysis described below are reported in Table 2.

LMC X-1: In the field of view of the MECS and PDS there is the source PSR 0540-69. In the $[2 - 10]$ keV band, the pulsar is fainter than LMC X-1 by a factor ~ 10. The pulsar spectrum is rather hard, and a power-law fit of the MECS data yields an energy index $\Gamma = 2.01 \pm 0.07$. In principle, the pulsar emission could account of (part of) the signal detected in the PDS. To test this hypothesis, we first fitted separately the LECS+MECS data of LMC X-1 with an absorbed disk blackbody, obtaining a totally unacceptable fit ($\chi^2/dof > 3$). The inclusion of an optically thin free-free component greatly improves the fit ($\chi^2/dof = 0.89$; see Table 2 and Fig. 1). We did not find any narrow emission or absorption feature. The column density is quite large, $N_{\rm H} \simeq 6.5 \times 10^{21}$ cm^{-2}. Then, we fitted the PDS data alone. They are well represented by a hard power-law, which is completely consistent, in terms of flux and spectral index, with the extrapolation in the PDS energy range of the MECS spectrum of the pulsar. We therefore suspect that the pulsar is responsible of the high energy emission detected in the PDS.

LMC X-3: In this source, we did not find any positive detection in the PDS. A variable hard X-ray tail was observed in the PDS in only one of the two one-month spaced *Beppo*SAX science verification phase observations performed in 1996, while in the other it had an upper limit comparable to ours (Siddiqui et al. 1998). As in the case of LMC X-1, a fit with an absorbed multicolor disk spectrum showed evidence of features in the 0.8-2 keV range (χ^2 null probability $\lesssim 0.1\%$). The inclusion of a free-free component reduced the χ^2 to an acceptable value (see Table 2 and Fig. 2). Again, we did not find any narrow emission or absorption feature above 2 keV. The absorbing column lies in the range reported by previous X-ray observations ($N_{\rm H} \simeq 5.7 \times 10^{20}$ cm^{-2}, Treves et al. 1988).

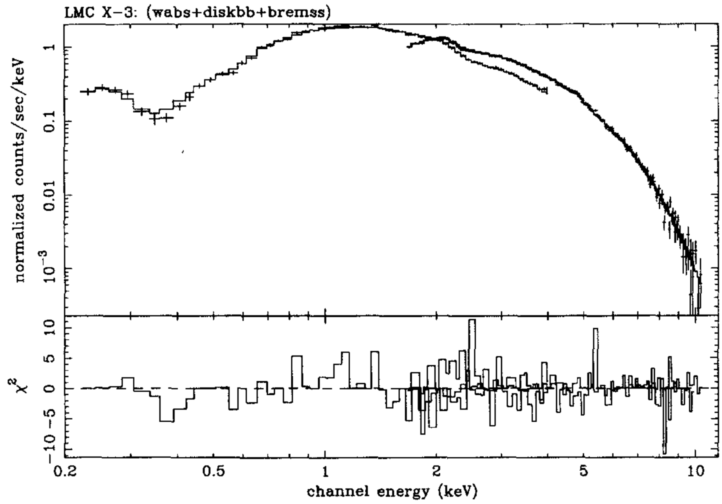

Figure 2: LMC X–3: count spectrum and contribution to χ^2 when data are fitted with a `wabs[diskbb+bremss]` model.

3 CONCLUSIONS

Our analysis shows that in LMC X–1 and LMC X–3 an optically thick accretion disk coexists with an optically thin, X–ray emitting gas, with comparable temperatures. This may indicate that the thermal emission from the innermost region of the accretion disk is modified by electron scattering. In LMC X–1 direction there is also indication of a component at much higher energy, responsible for the power–law emission in the PDS, which however we suspect arises from a nearby pulsar. Previous claims of the presence of a hard tail in LMC X–1 were based on non imaging instruments, where confusion with the nearby pulsar can not be excluded. LMC X–1 is found to be severely absorbed at low energies. Theoretical interpretations of the results are in progress and will be presented in a forthcoming paper.

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