Swift uncovers that SAX J0840.7+2248 is not an X-ray Binary, but BeppoSAX X-ray Rich GRB 980429

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Abstract. During our Swift/XRT program to obtain X-ray positions at arcsecond level for a sample of Galactic X-ray binaries, we discovered that SAX J0840.7+2248 is not a binary, but rather BeppoSAX/WFC+GRBM X-ray Rich GRB 980429. Here we report on this discovery and on the properties of this long, X-ray rich gamma-ray burst, from prompt to (very) late followup.

Keywords: Gamma rays: bursts; X-rays: bursts; binaries; X-rays: X-rays: individuals (GRB 980429, SAX J0840.7+2248)
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INTRODUCTION

Several catalogued X–ray binaries still have sky positions measured with uncertainties at arcminute level. Such large error boxes prevent a fruitful multiwavelength study; in particular, they make it impossible to establish a firm association with optical/IR/radio counterparts. Therefore, we have a standing Swift fill-in target proposal to observe a sample of such objects drawn from the catalogues of [1, 2]. Among them is the Low Mass X–ray Binary SAX J0840.7+2248, which was at first classified as a so-called "burst-only" source [3, 4]. It was observed only once [5] through a bright (~ 1 Crab peak intensity in the 2–25 keV energy range), ~ 100 s long burst with the Wide Field Cameras [WFC, 6] on-board BeppoSAX [7], at the position RA(J2000) $= 08^{\rm h}\ 40^{\rm m}\ 40^{\rm s}$, Dec(J2000) $= +22^{\circ}\ 48'\ 18''$ (error radius $3'$). Here we describe the discovery, based on Swift data and reported in [8], that SAX J0840.7+2248 was actually a gamma ray burst, GRB 980429.

Throughout this paper the quoted uncertainties are given at 90% confidence level for one interesting parameter unless otherwise stated. We use Γ as the power-law photon index, $N(E) \propto E^{-\Gamma}$ (ph keV^{-1} cm^{-2} s^{-1}).

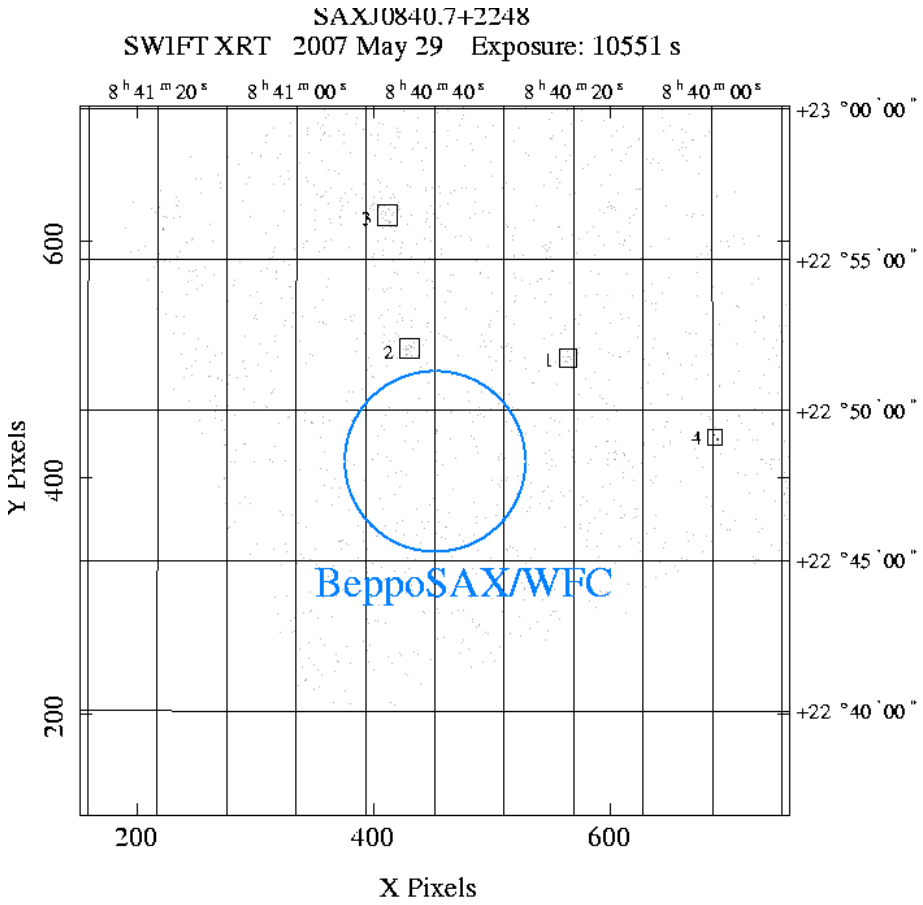

FIGURE 1. Swift/XRT image of the field of SAX J0840.7+2248, obtained from the total ~ 10.6 ks PC mode data. The large circle is the BeppoSAX/WFC error circle ($3'$ radius). The small squares mark X-ray sources detected at > 3-σ level.

THE SWIFT DATA

The Swift [9] data on SAX J0840.7+2248 were collected as a fill in target observation. The source was observed for a total of 10.6 ks on 2007 May 29 00:35:49 to 23:21:57 UT. The XRT data were processed with standard procedures (`xrtpipeline` v0.10.6), filtering and screening criteria by using `FTOOLS` in the `Heasoft` package (v.6.1.2). The UVOT data were reduced with the standard tools within the same `Heasoft` package.

Figure 1 shows the field of SAX J0840.7+2248 as imaged by Swift/XRT in photon counting (PC) mode. The data show no X-ray counterpart within the BeppoSAX/WFC position error circle ($3'$ radius) centered on RA(J2000) $= 08^{\rm h}\ 40^{\rm m}\ 40^{\rm s}$, Dec(J2000) $= +22^\circ\ 48'\ 18''$ [5]. A 3-σ upper limit on a source within the BeppoSAX error box can be placed at 4.5×10^{-14} erg cm^{-2} s^{-1} (assuming a spectrum of $\Gamma = 2$, no intrinsic absorption, and a Galactic Hydrogen column of $N_{\rm H} = 3.45 \times 10^{20}$ cm^{-2}). Assuming a distance of 8 kpc (or 1 kpc), we obtain a 3-σ upper limit on the luminosity of 3×10^{32} (5×10^{30}) erg s^{-1}. These values are quite low for a Galactic X-ray binary hosting a neutron star, while black-hole X–ray novae in quiescence can reach luminosities below

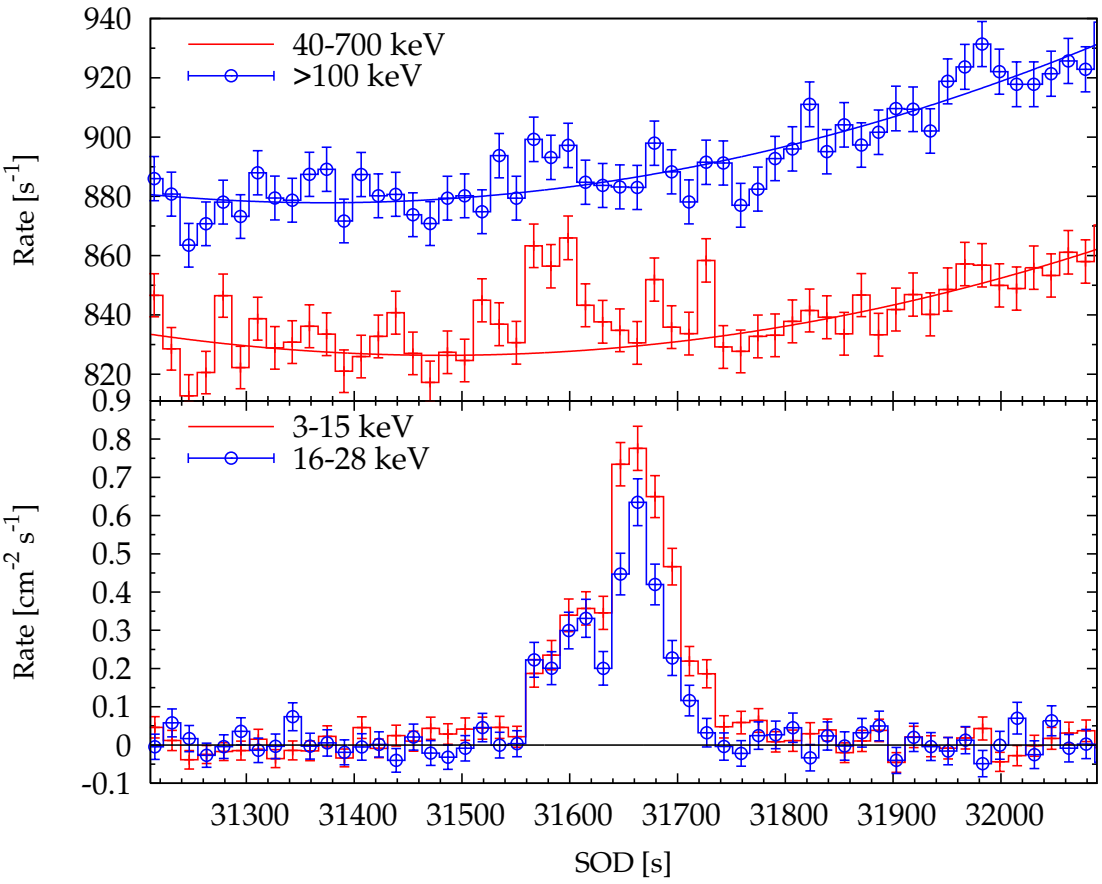

FIGURE 2. **Top**: BeppoSAX/GRBM light curves of GRB 980429 in two energy channels: 40–700 keV (red crosses) and $>$ 100 keV (blue circles). The binning time is 16 s. Time is expressed in seconds of day (SOD). The solid lines show the background level, resulted from parabolic interpolation. **Bottom**: BeppoSAX/WFC light curves in the 3–15 (red crosses) and 16–28 keV (blue circles) energy bands.

10^{32} erg s^{-1} (e.g. Kong et al. 10). Since the putative source should be an X–ray burster, and since the UVOT images revealed no new sources in the BeppoSAX/WFC error circle, we considered that this event might not be associated with an X-ray binary at all.

THE BEPPOSAX DATA

Prompted by this finding, we performed a reanalysis of the BeppoSAX/GRBM data on this transient. We discovered that the X-ray Fast Transient in [5] is an X-ray rich gamma-ray burst, instead. The data were reduced and analyzed following the procedures described in [11]. Fig. 2 (top) shows the light curves in the two energy channels 40–700 keV and $>$ 100 keV. The detection is 7.4 and 3.3 σ significant in the lower and higher energy channels, respectively.

GRB 980429 is a $\sim$ 200 s long GRB, with an onset time of 1998-04-29 08:46 UT. The GRBM spectrum was fit with a simple power law. We find a total 40–700 keV fluence

of $1.7^{+0.5}_{-0.4} \times 10^{-6}$ erg cm^{-2} and a photon index of $3.4^{+0.7}_{-0.6}$. The peak flux evaluated over 16 s (40–700 keV) is $(2.7 \pm 0.9) \times 10^{-8}$ erg cm^{-2} s^{-1} with a photon index of 2.5 ± 0.8. We also re-analysed the data collected by the WFCs. The analysis was performed with the BeppoSAX WFC Data Analysis System (version 204). Fig. 2 (bottom) shows the 3–15 and 16–28 keV light curves.

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