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

P. Romano*,†, C. Guidorzi*,†, L. Sidoli**, E. Montanari†,§, F. Capitanio§, L. Amati∥, A. Cucchiara††, F. Frontera‡,∥, N. Masetti∥, S. Mereghetti** and F. Rossi‡

*INAF–Osservatorio Astronomico di Brera, Via E. Bianchi 46, I-23807 Merate (LC), Italy
†Università degli Studi di Milano, Bicocca, Piazza delle Scienze 3, I-20126 Milano, Italy
**INAF–Istituto di Astrofisica Spaziale e Fisica Cosmica, Via E. Bassini 15, I-20133 Milano, Italy
††Dipartimento di Fisica, Universita’ di Ferrara, via Saragat 1, I-44100 Ferrara
‡I.S. "Calvi", Finale Emilia, Modena
§INAF–Istituto di Astrofisica Spaziale e Fisica Cosmica, Via del Fosso del Cavaliere 100, I-00133 Roma, Italy
∥INAF–Istituto di Astrofisica Spaziale e Fisica Cosmica, Via Gobetti, 101 I-40129 Bologna, Italy
††Dept. of Astronomy & Astrophysics, Pennsylvania State University, University Park, PA 16802

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 [6 on-board BeppoSAX [7], at the position RA(J2000) = 08h 40m 40s, Dec(J2000) = +22° 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 $\Gamma$ 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 \(\sim 10.6 \text{ ks} \) PC mode data. The large circle is the BeppoSAX/WFC error circle (3' radius). The small squares mark X-ray sources detected at > 3-\(\sigma\) 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) = 08h 40m 40s, Dec(J2000) = +22° 48' 18'' [5]. A 3-\(\sigma\) upper limit on a source within the BeppoSAX error box can be placed at \(4.5 \times 10^{-14} \text{ erg cm}^{-2} \text{ s}^{-1}\) (assuming a spectrum of \(\Gamma = 2\), no intrinsic absorption, and a Galactic Hydrogen column of \(N_{\text{H}} = 3.45 \times 10^{20} \text{ cm}^{-2}\)). Assuming a distance of 8 kpc (or 1 kpc), we obtain a 3-\(\sigma\) upper limit on the luminosity of \(3 \times 10^{32} (5 \times 10^{30}) \text{ erg s}^{-1}\). 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 $\sigma$ significant in the lower and higher energy channels, respectively.

GRB 980429 is a $\sim200$ 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 $1.7^{+0.5}_{-0.4} \times 10^{-6} \text{ erg cm}^{-2}$ and a photon index of $3.4^{+0.7}_{-0.6}$. The peak flux evaluated over 16 s (40–700 keV) is $(2.7 \pm 0.9) \times 10^{-8} \text{ erg cm}^{-2} \text{ s}^{-1}$ with a photon index of $2.5 \pm 0.8$. 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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