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LETTER

Letter to the Editor

BeppoSAX observations of the EXS 1737.9−2952 region

I. Discovery of new X-ray sources

J. Huovelin[1], J. Schultz[1], O. Vilhu[1], D. Hannikainen[1], P. Muhli[1], and Ph. Durouchoux[2]

[1] Observatory, P.O. Box 14, FIN-00014 University of Helsinki, Finland
[2] C.E. Saclay, DSM, DAPNIA, Service d'Astrophysique, F-91191 Gif-Sur-Yvette Cedex, France

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Abstract. We have observed the region centered on the hard X-ray transient EXS 1727.9−2952 near the Galactic Centre using the Narrow Field Instruments (NFI) of the BeppoSAX X-ray satellite. The soft X-ray intensity distribution in the full field of the MECS instruments revealed the existence of 10 sources. Three of them are within the $10'$ error circle of the EXS 1737.9−2952 nominal position. With a $3'$ flux collection radius, the individual background-subtracted source count rates were 0.0069−0.0162 cts/s with the MECS 2 and 3 data combined, indicating source flux densities of the order 10^{-12} erg cm^{-2} s^{-1} (1.65−10.5 keV). The non-detections in LECS observations indicate that the sources are very weak in the 0.1−2 keV energy range. The locations of the new sources overlap partly with that of the CO molecular cloud observed by us with the SEST telescope at ESO. A few of the new sources are close to the VLA radio sources previously found inside the EXITE error circle of the EXS position, but none of them coincide.

Key words: Galaxy: center – X-rays: general – X-rays: stars

1. Introduction

Since the 1970's it has been known that the region near the Galactic Center (GC) contains a strong source of positron annihilation radiation at 511 keV, and in the beginning of 1980's the time variability became evident. Models included a broadly distributed diffuse component and variable point sources with broad and narrow components. The narrow component was assumed to arise via e^+e^--annihilation in a cold medium.

The discovery of the GC annihilator 1E1740.7−2942 was a highlight of this research (see Sunyaev et al. 1991). The annihilator has two radio jets and is close to a dense molecular cloud (Mirabel et al. 1992). In a preliminary model, a compact object (e.g. stellar mass black hole) is passing slowly through the cloud and has turned on as a hard X-ray and γ-ray source due to the accretion of matter from the cloud. The line emission and the hard spectrum are very variable, probably due to the instabilities of the accretion disc of the central black hole.

The observation of the GC by the imaging γ-ray balloon-born coded mask telescope EXITE showed a new transient gamma-ray source $\sim 40'$ from 1E1740.7−2942, with a $10'$ error radius. This new source, named **EXS1737.9−2952** (Grindlay et al. 1993) is particularly interesting since it showed a line at 102 keV which can be interpreted as a doubly backscattered annihilation line. During the discovery its brightness was comparable to that of 1E1740.7−2942 (100 mCrab, corresponding to a luminosity 4×10^{37} erg/sec between 20−200 keV at 8.5 kpc). Sigma and ART-P telescopes on board GRANAT have never detected it, so most of the time the brightness of the source has been below 10 mCrab. EXS 1737.9−2952 has also been searched by the CGRO/OSSE (Smith et al. 1995), but with no success.

With the SEST telescope, Vilhu et al. (1994) (see also Durouchoux et al. 1998) found a dense molecular cloud close to EXS1737.9−2952. This means that we may expect very strong extinction from optical region up to soft X-rays if the source is behind or inside the cloud. The region was also studied by the VLA in 1994 (see Durouchoux et al. 1998). These observations showed the existence of 6 sources within the EXS error circle, with radio continuum flux densities in the range 3−43 mJy (20 cm) and 0.8−17.8 mJy (6 cm). The morphology of these radio sources did not show similarity with that of e.g. 1E 1740.7−2942 (variable point source and lobes), which suggests that none of them are associated with the EXS source, if we expect that it is similar to 1E 1740.7−2942.

Our searches for a source in the optical and ultraviolet data of the EXS 1737.9−2952 region, as well as studies of the IRAS maps, have also been fruitless. Thus, it would seem that the only wavelength band left with hope for finding a persistent source is the soft X-ray region. Indeed, there actually was a marginal enhancement in the Einstein IPC map within the error circle (0.086 cps, 2.4 σ above noise. Note the corrected S/N ratio, c.f. Durouchoux et al. 1998). The possibly high interstellar extinction complicates the situation by depressing the spectral

Send offprint requests to: J. Huovelin

intensity of the source up to a few keV, and therefore the range up to 10 keV (or higher) would be desirable for the target search. We were allocated observing time with the BeppoSAX satellite for this search, and we report the first part of this research in the present paper, including the target identifications and overall brightness information. The latter part of our study, including the analysis of the spectra and the target physics, will be included in a second publication to be submitted in the near future.

2. Observations and reductions

The observations were made on 1998 April 12−13, using the co-aligned narrow field instruments, LECS (Parmar et al. 1997), MECS (Boella et al. 1997), PDS (Frontera et al. 1997), and HPGSPC (Manzo et al. 1997) of the BeppoSAX satellite. The time interval of the observing programme was from 12/04/98 14:00 to 13/04/98 07:30 (UTC), including 13200, 30500, 14300, and 51700 seconds of effective target observing time (i.e., sum of good time intervals, GTI's) with LECS, MECS, PDS and HPGSPC, respectively. Final, separately reduced data from MECS2 and MECS3 are summed. The MECS1 detector failed in May 1997, and was not used in these observations.

The circular fields of view of LECS and MECS are $37'$ and $56'$ in diameter, respectively, while those of the HPGSPC and PDS are hexagonal with FWHM of $78'$ and $66'$, respectively. The LECS and MECS detectors are position sensitive counters with imaging capability, working in the energy range 0.1−10 keV. The LECS detector system is more sensitive at soft energies (0.1−2 keV), with angular resolution of $9.7'$ FWHM at 0.28 keV and $2.1'$ FWHM at 6 keV. The position resolution of the MECS detectors is $\sim 1'$ at 6 keV, and the detector system is more sensitive at higher energies (1.3−10 keV). The practical position reconstruction uncertainty for MECS is $0.5'$ in the central area of $9'$ radius, and $\sim 1.5'$ in the outer region of the FOV. Both LECS and MECS have spectral sensitivity, with moderate energy resolution close to 8% at 6 keV, typical of Xenon filled GSPC's.

The HPGSPC and PDS detector systems have spectral sensitivity over the ranges 3−120 keV and 15−300 keV, respectively, but they are not position sensitive. Their data is therefore difficult to interpret and analyse for individual sources, when the field includes more than one major source. However, also the total flux of the EXS1737 field is of great interest, especially in comparison with the previous EXITE detection and the nondetections with SIGMA and CGRO.

The data were reduced using the standard procedures for SAX included in the SAXDAS package for FTOOLS. The MECS 2+3 data contained the total of 28036 events after standard reductions and GTI filtering. The total count rate was 0.92 cps, including the estimated background level of 0.28 cps, as derived from the standard background event list for observations made after May 7, 1997, available at the SAX ftp site.

Due to the shorter effective observing time and the weakness of the soft spectra of the sources, the data of the LECS detector contained too few photons above the background for reliable source detection and further spectral analysis. The total number of events in the LECS observation during GTI's was 3939, and the count rate in the 0.1−2 keV interval was 0.0696 cps, including the estimate of 0.054 cps from the background, which indicates only about 200 events over background (0.1−2 keV) in the whole detector area. The background estimate was extracted from the background observation (LECS_bkg.evt) available at the SAX ftp site.

3. Results

The supervised standard analysis made by the SAX team (presently public information at the SAX WWW site), using the XIMAGE package under the XANADU software, identified 10 new sources with greater than 4 σ significance for the observed field with MECS 2+3. Our own analysis with the XIMAGE yielded approximately the same results with appropriate settings for background and source finding boxes (background box of 32 pixels and source box of approximately $3'$ radius, and special tuning for crowded regions). We were, however, not able to detect source number 8 in Table 1. Source 8 is somewhat weaker than the other sources and very close to the edge of the FOV, but is still above the 4 σ detection limit. All following results are from our own analysis, except for the position of source 8. Using the event list derived with SAXDAS and XSELECT, we made a data projection to a final map of the observed region. The map is shown in Fig. 1. As seen in the map, the emission does not show a clear point source in all indicated maxima. The identification of the close source pairs as separate point sources instead of smaller number of more extended diffuse objects is slightly uncertain, and is based on believing in the reliability of the detection algorithm. We have applied for observing time with XMM to confirm the identifications with better spatial resolution and sensitivity.

We extracted the events from circular areas of $3'$ radius centered at the 10 source positions. The extraction circles overlap slightly for several sources (see Fig. 1, where the extraction circles are shown). Due to the smallness of overlapping, the effect of duplicating a fraction of the source fluxes is, however, insignificant. The count rate data for MECS(2+3), with the proposed source names, are compiled in Table 1, where uncertainties due to count statistics is given with the count rate. The background was subtracted from the source count rates, where the background estimate for each source is taken inside the source extraction radius of the appropriate MECS background observation provided by the SAX ftp site in the WWW. To reduce underestimation of the uncertainty in the count rates, the error estimates are derived from the count statistics before background subtraction, with quadratically added errors due to the uncertainty in the subtracted background level. Systematic errors due to other effects are not included. A separate source finding significance (σ), as provided by the XIMAGE "detect" procedure (including systematic errors), is given in a separate column.

Preliminary powerlaw spectral modelling to the 1.65−10.5 keV MECS observations yield fluxes of the order 10^{-12} erg cm^{-2} s^{-1} with the XSPEC/XANADU spectral

Table 1. Data of new X-ray sources in the EXS 1737.9−2952 region. Count rates (cps) are background-subtracted MECS(2+3) count rates in units 10^{-2} counts/s for the given source, (3′) indicates the count extraction radius, and σ is the significance (S/N) of the detection derived with XIMAGE. Vignetting corrections have not been applied to the count rates. The last column is distance from the EXS1737.9−2952 error circle centre.

Source	Name	α(2000.0)	δ(2000.0)	cps(3')	σ	Distance from EXS (′)
1	SAXJ1740.8−2950	17 40 46.4	−29 50 20.1	1.45 ± 0.08	5.4	4.9
2	SAXJ1741.3−2948	17 41 19.4	−29 47 55.7	1.33 ± 0.07	7.6	6.5
3	SAXJ1741.6−2952	17 41 38.3	−29 51 59.9	1.62 ± 0.08	8.5	8.7
4	SAXJ1741.6−2940	17 41 38.3	−29 40 59.9	1.19 ± 0.07	5.3	14.6
5	SAXJ1742.0−2941	17 42 00.3	−29 40 54.9	1.11 ± 0.07	8.3	17.6
6	SAXJ1742.2−2958	17 42 10.2	−29 58 02.0	1.60 ± 0.08	10.3	15.1
7	SAXJ1742.3−3003	17 42 18.0	−30 02 44.0	1.11 ± 0.07	4.3	18.5
8	SAXJ1740.5−3013	17 40 28.6	−30 13 18.4	0.69 ± 0.06	4.6	21.2
9	SAXJ1742.6−2956	17 42 33.9	−29 56 09.0	1.13 ± 0.07	5.5	19.7
10	SAXJ1743.0−2956	17 42 57.7	−29 55 45.2	1.13 ± 0.07	7.8	24.8

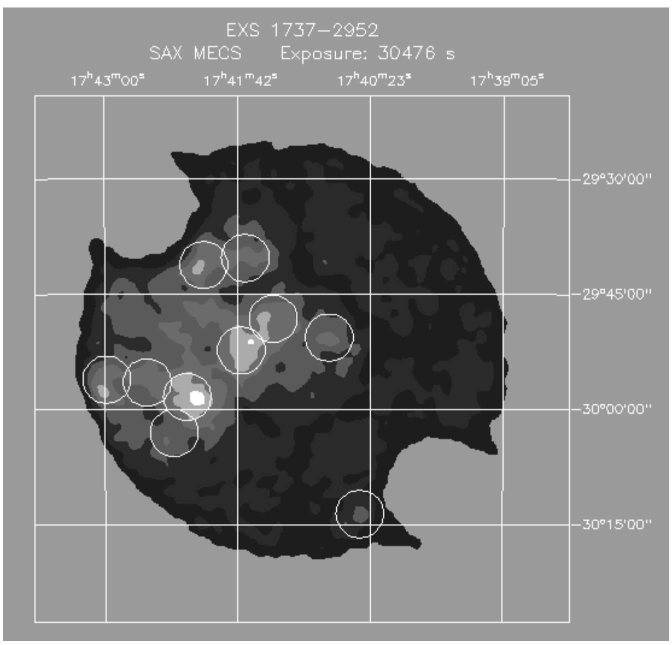

Fig. 1. MECS (2+3) image of the region centered at the EXS 1737.9-2952 nominal position, α(2000.0) = 17h 41m 3.8s, and $\delta(2000.0) = -29^o\ 53'\ 31''$. The circles are of $3'$ radius.

fitting package. The results indicate that the sources differ significantly from each other. The photon indices from the XSPEC fits range from 0.8 to 1.9, and the N_H values from 1.1 to 6.2 $\times 10^{22}$ cm^{-2}. For several sources, a Raymond-Smith thin plasma model corresponds better with the observation, since there is clear iron line emission near 7 keV. With the RS models the temperature (kT) ranges from 4 to 10 keV and the interstellar absorption is similar to that obtained with the powerlaw models. Comparison with the LECS observations indicate that the N_H values from the MECS models may be underestimates for several sources.

Preliminary results from the PDS spectral analysis yields a flux density $\sim 10^{-9}$ erg cm^{-2} s^{-1} (10−200 keV) with a powerlaw photon index ∼1.9. This corresponds to 2−3 mCrab at the same energy range. It is only a few percent of that during the transient observed by Grindlay et al. (1993), and thus consistent with the nondetections of SIGMA and CGRO, assuming that the brightness of the field in our observations represents a persistent low level. On the other hand, an extrapolation of the PDS powerlaw spectrum to the MECS energies indicates a spectral intensity which is an order of magnitude higher than the total of the observed MECS field. This may be partly due to the bigger FOV of PDS, which may include X-ray flux from also other sources than those seen by MECS. The N_H values for the PDS spectral fits are $10^{23} - -10^{24}$ cm^{-2}, supporting the indications given by the LECS observations. The PDS absorption estimates are also only suggestive, since the effect is very weak at high energies (above 5 keV).

4. Conclusions

We have found 10 new X-ray sources in the EXS1737.9-2952 region with the BeppoSAX MECS detectors. Three of the sources are within the 10' error circle of EXS1737.9−2952 position. We cannot identify unambiguously any individual source with the hard X-ray transient found by Grindlay et al. (1993). The sources are not detected in the SAX LECS image, which most probably indicates high absorption in the soft X-rays. Since the LECS count rates predicted by the MECS powerlaw models are for several sources higher than the upper limits from the LECS observations, the true N_H may be significantly higher than the value from the MECS results (i.e., $10^{23} - -10^{24}$ cm^{-2}). Previous non-detections with soft X-ray instruments like ROSAT support this impression. This would be expected if the sources are near the Galactic Centre, and behind of, or embedded in, high density molecular clouds such as the one reported by Vilhu et al. (1994).

At present we do not know the nature of these sources. Since the distances are unknown, we cannot exclude the possibility that some (or all) of the new sources are front field X-ray objects, not lying physically close to the Galactic Centre. More clues will be found with the detailed spectral analysis of our data, which will be undertaken in our second paper on this subject. It will account for the constraint on the interstellar absorption set by the weakness of the LECS signal at low energies, and combine our CO map information with current X-ray data. Also the summary of the PDS and HPGSPC data will be presented.

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