

to that suggested by Baity *et al.*². The extension of the emission spectrum of NGC 4151 up to 20 MeV would correspond to a luminosity of $(8 \pm 2) \times 10^{45}$ erg s⁻¹ for a distance of 20 Mpc.

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Optical candidates for two X-ray bursters and an X-ray pulsar

WE suggest faint ($B \sim 18$), blue stars as the optical counterparts of two X-ray bursters, 4U1636-53 (MXB1636-53)¹⁻⁴ and 4U1735-44 (MXB1735-44; KGX345-6?)^{1,4-6}, and for the 7-s X-ray pulsar, 4U1626-67^{1,7,8}. The candidate stars have large ultraviolet excesses and were discovered well within the 20" and 30" X-ray error radii determined using the rotating modulation collimator experiment aboard the SAS-3 X-ray Observatory^{9,10}. Photographic observations of several X-ray error boxes were performed (by C.R.C. and W.A.H.) in April 1976 (before final SAS-3 X-ray positions were known) with the 4-m telescope at the Cerro Tololo Interamerican Observatory (CTIO). R , B and U plates were obtained for the regions including 4U1636-53 and 4U1735-44. The R plates (RG610 filter with 127-04 emulsion) are shown as

finding charts in ref. 9. Preliminary iris photometry of some of the plates was performed to identify the bluest stars in each error box for further study.

The photoelectric photometry was performed (by J.E.M.) using the 1.5-m telescope at CTIO during 8-13 June, 1977. A 10" aperture, a standard UBV filter set and an RCA 4516 photomultiplier tube were used during the entire run. For each colour typical integration times were 10 s for standard stars and 50 s for the programme stars and sky background. All objects were observed in the colour sequence $BVUB$ as a check on sky conditions, telescope tracking and the stability of the instrumentation. The observations were made between the fourth quarter and new moon. The sky conditions were of photometric quality throughout each night with the exception of 9 June, which had some cirrus. Five or six UBV standard stars¹¹ were observed several times each night. A television guider, mounted at the customary position of the offset-guider eyepiece, was used on four nights (8, 9, 12 and 13 June), and provided the crucial capability to centre stars as faint as $B \sim 20$ in the photometer aperture.

About 100 faint ($B \sim 15-20$) stars in the fields of 16 X-ray sources were examined during the six nights. Most of the observations were made within the 20-30" radius error circles determined using SAS-3 data. Stars with large ultraviolet excesses were discovered in the fields of three X-ray sources: 4U1626-67, 4U1636-53 and 4U1735-44.

A summary of the photometry data, coordinates of the stars and references to literature containing finding charts are given in Table 1. A measurement of the candidate for 4U1626-67 made while setting up on 12 June (0553 UT) and not included in Table 1 indicates that the star may be variable on timescales of minutes, but further observations are necessary to establish this. The three measurements of the candidate for 4U1735-44 show no evidence of variability during the course of four nights. Iris photometry of two R plates taken four days apart in April 1976 also shows no variability. A spectrogram of this candidate obtained by Bond¹² shows a generally featureless blue continuum with weak $H\beta$ emission. HeII λ 4,686 and HeI λ 5,875 may also be present weakly in emission.

Figure 1 is a colour-colour diagram showing the measured locations of the candidate stars and several established optical counterparts (see refs 13-17), and the calculated location of a model accretion disk around a massive black hole¹⁸. The candidates for 4U1626-67 and 4U1636-53 lie further from the reddened supergiant or main sequence than any known counterparts and have colours inconsistent with those of a reddened, normal star. The candidate for 4U1735-44 has the colours of Sco X-1 as well as the colours of a late O or B0 star suffering ~ 1 mag of extinction.

Table 1 Description of optical candidates

X-ray source	Star no.*	Star position (+3")		UT (June 1977)	V^\dagger	$B-V^\dagger$	$U-B^\dagger$
		RA (1950) (l^{II} , b^{II})	Dec. (1950)				
4U1626-67 (2S1627-673)	4	16h27m14.2s (321.8-13.1)	-67°21'16"	12d06h05m	18.67	+0.00	-1.18
				12 06 34	18.42	+0.26	-1.23
4U1636-53 (2S1636-536)	3	16 36 56.2 (332.9-4.8)	-53°39'15"	12 03 21	17.52	+0.69	-0.70
4U1735-44 (2S1735-444)	5	17 35 19.0 (346.1-7.0)	-44°25'19"	09 06 39	17.43	+0.24	-0.78
				11 05 10	17.40	+0.22	-0.86
				13 06 54	17.52	+0.21	-0.81

*Finding charts showing the SAS-3 (2S) positions and labelled with these star numbers are given for 4U1626-67 (in ref. 10) and for 4U1636-53 and 4U1735-44 (in ref. 9).

† Uncertainties ($\sim 90\%$ confidence) in V , $B-V$ and $U-B$ are + 0.15 mag. for 4U1626-67 and + 0.10 mag. for 4U1636-53 and 4U1735-44. Uncertainties due to counting statistics are $\lesssim + 0.05$ mag.

The candidates for 4U1735-44 and 4U1636-53 bring the number of possible stellar counterparts to X-ray burst sources to three (the third is Davidsen's candidate for Ser X-1^{9,20}). The colours of the two presented here are far from those estimated by Katz¹⁸ for an accretion disk surrounding a massive black hole. Evidence of the binary nature of any or all these candidates could resolve the uncertainty over the nature of the bursters (see refs 21, 22). The extreme colours of the candidate for 4U1626-67 are remarkable since this source is a rapid X-ray pulsar⁸. The optical emission of all other X-ray pulsars, with the exception of HZ Her, is dominated by that of the OB companion.

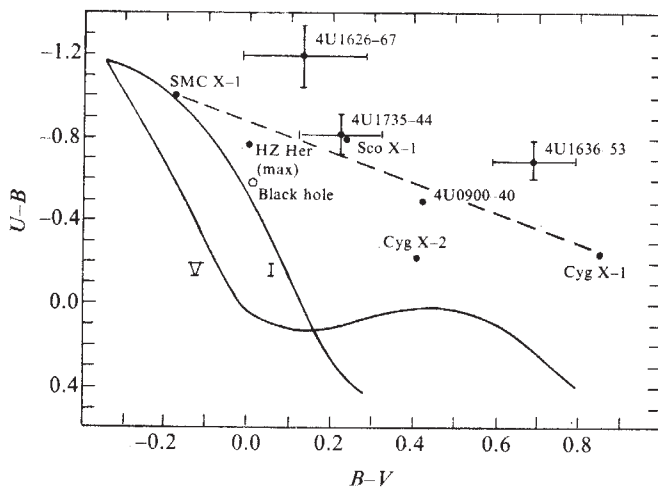


Fig. 1 A colour-colour diagram in the *UBV* system showing the three candidates presented in this paper, several well-established optical counterparts¹³⁻¹⁷ and a model accretion disk surrounding a massive black hole¹⁸. The solid curves give the locus of colours for unreddened, main-sequence stars (V) and supergiants (I) following Davis.²⁴ The dashed curve is the reddening line for a B0 supergiant.

Possibly 4U1626-67 is an even more extreme example of the HZ Her phenomenon, in which the optical luminosity at maximum light is a direct result of the X-ray emission (see ref. 23).

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Positions of three X-ray burst sources

PRECISE (20-30') positions of three steady X-ray sources which have been identified recently as X-ray burst sources 4U1636-53 = MXB1636-53 (refs 1, 2), 4U1728-33 = MXB1728-34 (refs 3, 4), and 4U1735-44 = MXB1735-44 (refs 5, 6, 7) are reported here. These positions, hereafter designated with a 2S prefix, have been derived from data obtained with the SAS-3 rotating modulation collimators during a survey of the galactic plane⁸⁻¹⁰. The small solid angles of the error regions make possible a thorough survey of all potential optical, infrared, and radio counterparts of these burst sources. Two of these positions, 2S1636-536 and 2S1735-444, have led to the probable identifications of optical counterparts¹¹.

The burst sources MXB1636-53 and MXB1728-34 were discovered respectively with the OSO-8 (ref. 1) and SAS-3 (refs 3, 12) satellites. The source MXB1735-44, located precisely⁵ with SAS-3, is probably the burst source KGX345-6 that was discovered earlier^{6,7} with the COSMOS 428 satellite. All three sources emit X-ray bursts with peak flux densities (2-15 keV) comparable to, or greater than, that of the Crab nebula and with rise times of 1-2 s.

The association of the X-ray burst sources with the previously known Uhuru sources is now well established (Fig. 1). These identifications have been made possible through the determination^{2,3,5} of the burst source positions to an accuracy of 6-10' with the SAS-3 slit collimators¹³. Positions of the steady components of these sources have been measured with the Uhuru¹⁴, Copernicus¹⁵, and Ariel V¹⁶ satellites. The present SAS-3 positions are shown in Figs 1 and 2 and Table 1. Astrometric positions and stellar magnitudes are given in Table 2.

An optical study based upon the Copernicus position for MXB1636-53 led to the suggested optical identification¹⁷ of a flare star (star M in Fig. 2) that lies outside but near the 2S error region. A recent study of the 2S1636-536 and 2S1735-444 positions led to the discovery¹¹ of two faint *V* ~ 17.5, ultraviolet excess stars that lie well within the 2S regions (stars 3 and 5 respectively in Fig. 2). A search¹⁸ for an optical counterpart for MXB1728-34 has yielded no likely candidates. Several bright (*K* < 10 mag) infrared sources have been detected, however, within ~ 1' of 2S1728-337 by I. Glass and by S. Kleinmann (personal communications).

Altogether, we have measured with SAS-3 precise (20-35') positions of six steady X-ray sources (other than known globular clusters) which have been identified^{1-7,13,19-22} as