ARE CLASSICAL Be STARS SOURCES OF HARD X-RAYS?

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ABSTRACT

A point summation technique was used to search the UHURU data base for X-ray emission from classical Be stars. Of the thirty-two stars considered, only three (γ Cas, HR 4009, and HD 187399) were detected at the 3.3σ level or higher. For reasons discussed in this paper, HD 45314, π Aqr, κ Dra, and 48 Per are considered to be possible detections. The X-ray emission from γ Cas from late 1970 through early 1973 is discussed.

1. INTRODUCTION

The optical counterparts of intrinsically strong galactic X-ray sources are usually early type emission line stars. But, in general, these objects are not the so-called "classical" Be stars (B stars of luminosity classes III - V whose spectra appear more or less normal except for the presence of Balmer and, perhaps, Fe II emission and/or shell features). The classical Be stars γ Cas and X Per are known to be the optical counterparts of hard X-ray sources but these sources are intrinsically weak ($<5\times10^{33}$ erg s^{-1}).

In order to determine whether weak X-ray emission is commonplace among classical Be stars a point summation technique (Ulmer and Murray 1976) was used to search the UHURU data base for evidence of 2-6 keV X-rays from these objects. The input data were the UHURU superposition data sets and, unless otherwise indicated, all data were from the narrow ($\frac{1}{2}^{o}\times5^{o}$) collimator. The individual superposition plots were visually inspected and data sets were eliminated if there was excessively high noise, an irregular or undulating background, or a source nearby which contaminated either the candidate object or the background. Thirty-two objects were considered which include Be stars which have recently been active in the visible spectral region, Be mass transfer binary systems including the peculiar binaries β Lyr and HD 187399, Be stars classified as B0ne (like γ Cas and X Per), and all Be stars within 100 pc of the sun.

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2. GENERAL RESULTS

If the point summation produced a signal of 3σ or higher and only data from the high resolution collimator were included, the object is considered to be a detected source. If $2.5 < \sigma < 3.0$, or if $\sigma > 3.0$ but data from the wide collimator were used, the star is considered to be a possible source. The results appear in Table 1. Intrinsic fluxes in the interval 2-6 keV are listed for all detected and possible sources; otherwise, 3σ upper limits are quoted. Most distances used for the computations are from Schmidt-Kaler (1964).

Only seven of the program stars are considered to be detected/possible X-ray sources. In general, the upper limits for the nearest objects are less than 10^{32} erg s^{-1}. Upper limits for the BOne stars are comparable with the X-ray flux observed from X Per. Classical Be stars do not appear to be sources of hard X-rays.

3. INDIVIDUAL RESULTS

a. Detected Sources

γ Cas (MX0053+60) was discovered to be a hard X-ray source (in SAS-3 data) by Jernigan (1976). The fact that γ Cas was not included in the third UHURU Catalog of X-ray Sources has led to the popular belief that the X-ray source was off during the early 1970's. Careful examination of the UHURU data base has shown that the source, although variable, persisted throughout the lifetime of the satellite. On the average, the source was 4.1 ± 0.3 cts s^{-1} (from the point summation). It was observed on the first useful UHURU superposition plot as well as on one of the last. The flux results from 36 good data sets are presented in Figure 1. The source was detected in 20 of the observation sets; 3σ upper limits were computed for the others. χ^2 tests performed on the data (both summed data for each superposition set and the pass by pass counting rates) show that the source is quite variable. In fact, it was not uncommon to observe variations of a factor of three between successive passes. Although the daily average UHURU flux was always below the 15 cts s^{-1} first recorded by SAS-3, individual obser-

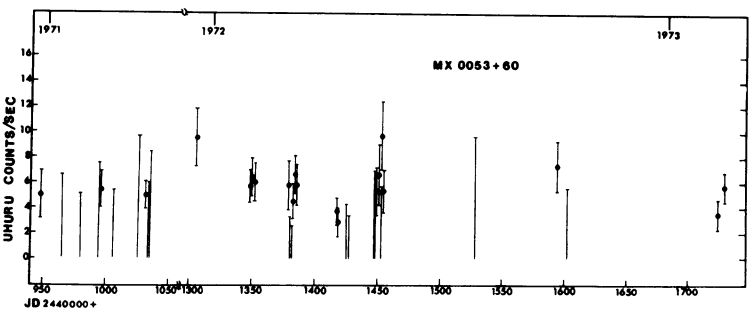

Fig. 1 - UHURU observations of MX0053±60 (γ Cas) from 1970 December 28 to 1973 February 16. 3σ upper limits are also indicated.

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Table 1 - X-ray flux from Be stars

Star	Sp Type	d (pc)	F_{2-6} erg s^{-1}
γ Cas	B0IVne	220	4.0×10^{32}
HD 45314	B0IVne	550	6.5×10^{32}
HD 53367	B0IVne	670	$<8.1 \times 10^{32}$
HD 153261	B0IVne	800	$<2.2 \times 10^{33}$
HD 161306	B0IVne	910	$<2.4 \times 10^{33}$
HD 203374	B0IVne	700	$<1.2 \times 10^{33}$
HD 204116	B0IVne	950	$<1.6 \times 10^{33}$
HD 206773	B0IVne	900	$<1.8 \times 10^{33}$
HR 2855	B0IVpne	760	$<1.2 \times 10^{33}$
AX Mon	B0pe	560	$<5.7 \times 10^{32}$
φ Per	B0.5IV-Vnne	200	$<1.2 \times 10^{32}$
π Aqr	B0.5Vne	325	5.0×10^{32}
HR 2142	B1IV-Vnne	400	$<4.5 \times 10^{32}$
HD 173219	B1pe	900	$<3.1 \times 10^{33}$
υ Cyg	B1.5IV-Ve	290	$<1.5 \times 10^{32}$
HR 4009	B1.5IVe	715	9.8×10^{32}
HD 7636	B2Ve	305	$<1.8 \times 10^{32}$
μ Cen	B2IVe	180	$<6.9 \times 10^{31}$
η Cen	B2IVe	100	$<3.4 \times 10^{31}$
66 Oph	B2Ve	280	$<4.2 \times 10^{32}$
48 Per	B3IVe	175	2.2×10^{32}
HD 218393	B3IVne	550	$<6.8 \times 10^{32}$
HD 51480	B3pe	500	$<4.6 \times 10^{32}$
α Eri	B5IV(e)	39	$<3.0 \times 10^{30}$
ψ Per	B5pne	160	$<5.7 \times 10^{31}$
ο And	B6pn(e)	100	$<1.8 \times 10^{31}$
κ Dra	B7IVe	100	1.5×10^{31}
28 Tau	B8pne	130	$<7.4 \times 10^{31}$
β Lyr	B8IIe	200	$<1.4 \times 10^{32}$
HD 187399	B8IIIe	450	3.7×10^{32}
17 Lep	B9pe	100	$<2.5 \times 10^{31}$
3 Pup	A2Ibpe	600	$<6.1 \times 10^{32}$

vations often exceeded the latter value. The longest segment of semi-continuous data (1972 May 8-16) were analyzed for X-ray pulsations but no period was found. Further details of the UHURU observations of γ Cas will be published separately.

According to Polidan (Polidan, Locke, and Parmar 1981), ten Copernicus X-ray observations of γ Cas from 1973 November 4 to 1979 September 25 have revealed a behavior similar to that seen during the lifetime of UHURU. On two occasions, the source was definitely off. Quite noteworthy is an X-ray flare event which coincided with the UV event reported by Slettebak and Snow (1978). Apparently, during the course of the observation, the flux discontinuously increased from zero to about 10 UHURU cts s^{-1}.

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HR 4009 (HD 88661) was detected at the 3.8σ level and, thus, is a good candidate for a hard X-ray source. Thirty-four data sets were included in the superposition yielding a flux of 0.9±0.2 cts s^{-1}. HR 4009 is in a crowded portion of the sky, however. An error box of 0.3 deg^2 generated from four lines of position in the UHURU files contains nine other SAO stars (all much fainter), one of which is close enough to have contributed to the summed intensity. Recent IUE observations of HR 4009 reveal the presence of highly violet shifted (≃600 km s^{-1}) C IV and, perhaps, Si IV lines.

HD 187399 is a spectroscopic binary with a large mass function and, according to a suggestion by Hutchings and Redman (1973), may harbor a black hole secondary. Although this star is in Cygnus, 28 data sets were found suitable to be included in the point summation. If one adopts a distance of 450 pc (Hutchings and Laskarides 1972), the summed UHURU flux of 0.9 ± 0.3 cts s^{-1} suggests an intrinsic flux of 4×10^{32} erg s^{-1}, 10^4 times lower than one would expect if the secondary is a collapsed object. Hutchings (1981) failed to find soft X-ray emission from HD 187399 in a single IPC observation with the Einstein satellite. It is, of course, reasonable to assume that the source is highly variable.

b. Possible Sources

HD 45314 displays a slightly variable, low contrast ground-based spectrum. 16 good UHURU data sets suggested a flux of 1.1±0.4 cts s^{-1} (2.6σ). The intrinsic flux is comparable with the one obtained for γ Cas.

π Aqr and κ Dra are also being considered as possible X-ray sources. Since both are in regions of the sky relatively free from UHURU sources, data from both narrow and wide collimators were used. When all data were included, both showed 3σ results.

48 Per (MX Per) was suggested as a possible optical identification for 4U0404+47. It is the only SAO or known variable star in the error box. The point summation, including 44 data sets, gave only a 2.1σ result (0.5±0.2 cts s^{-1}). Considering all data, a χ^2 test failed to suggest variability. However, four daily averages gave fluxes of 3-8 cts s^{-1}. If 48 Per is indeed associated with 4U0404+47, the X-rays are transient.

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DISCUSSION

Endal: Can we assume that the Be stars in x-ray binaries are normal (typical) Be stars?

Peters: Not "classical" Be stars. With the exception of HD187399, all objects which showed up at the 3 σ level or higher are "normal" Be stars.

Henrichs:(additional answer): It is likely that in the case of (wide) x-ray binaries with Be companions, the Be star does not "know" that there is an orbiting compact object around. In other words: in these binaries the Be phenomenon is not caused by the presence of a companion now. It is, however, conceivable that in this case the Be phenomenon is caused by the nearby presence of the companion in the past, when the system was not yet evolved. This might be true for other Be binaries as well.

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