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A NEW EUVE-DETECTED FLARE STAR (EUVE J0613–23.9B)

CHRISTIAN, D. J.[1]; MATHIOUDAKIS, M.[1], JEVREMOVIĆ, D.[1,2]; DUPUIS, J.[3]; VENNES, S.[4]; KAWKA, A[4]

[1] Department of Pure and Applied Physics, Queens University Belfast, Belfast, BT7 1NN, UK

[2] Astronomical Observatory, Volgina 7, 11160 Belgrade, Serbia and Montenegro

[3] Department of Physics & Astronomy, Johns Hopkins University, Baltimore MD, 21218

[4] Astrophysical Theory Centre, Australian National University, Canberra, ACT 0200, Australia

Extreme Ultraviolet Explorer (EUVE) observations have provided detailed spectroscopic and timing studies of several flare stars, including AU Mic (Cully et al., 1993), AD Leo (Hawley et al., 1995), and EQ Peg (Monsignori-Fossi et al., 1995).

In this bulletin, we present the EUVE and optical follow-up observations of a newly detected flare star. This star was serendipitously discovered during an EUVE observation of the G star HD 43162 as part of the analysis for the 3rd EUVE Right Angle Program Catalog (Christian, 2002). Analysis of the EUVE spectra obtained during the largest flare (Fe XIX–XXIV emission and a strong 300–650 Å continuum) have been presented elsewhere (Christian et al., 2003). We present optical spectroscopy and results obtained at MT Stromlo Observatory to identify the optical counterpart in § 1, and the long-term EUVE Deep Survey light-curves in § 2.

There were 14 EUVE observations of EUVE J0613−23.9 between 20 Oct 2000 and 08 Dec 2000, and we obtained the EUVE data files from the Multimission archive at Space Telescope. We analysed all observations, but concentrated on the 9 observations that obtained data with the Deep Survey (DS; 60–200 Å) instrument. Two sources were clearly visible in the DS image of EUVE J0613−23.9, with a 2nd source 2.′5 SE of the guest observer target, HD 43162, which we call EUVE J0613−23.9B. We show the EUVE DS image from the 22 Oct 2000 observation in Figure 1a.

Searching of the SIMBAD database revealed no catalogued late-type stars near the EUVE-measured position of EUVE J0613−23.9B, and we obtained optical spectra of the source nearest this position. The optical finding chart for the field centered on HD 43162 is shown in Figure 1b. Surprisingly there is a source within 23″ of HD 43162 for which we also obtained an optical spectrum. This source coincides with 1RXS J061345.1−235205 (within 5″). The optical observations were conducted on 14 September 2002 using the Cassegrain spectrograph at the 74 inch telescope at Mount Stromlo Observatory. We used the 300 line/mm grating blazed at 5000 Å and the 2k×4k CCD camera binned 2×2. We obtained frequent comparison FeAr arc exposures of 120 sec and FeNe arc exposures of 5 sec. The spectra extend from 3900 to 7500 Å with a dispersion of 2.83 Å per pixel, and spectral resolution of ≈ 8 Å. The images were bias-subtracted and flat-fielded. The extracted spectra were flux-calibrated with the standard Feige 110, and wavelength-calibrated using NOAO's IRAF routines.

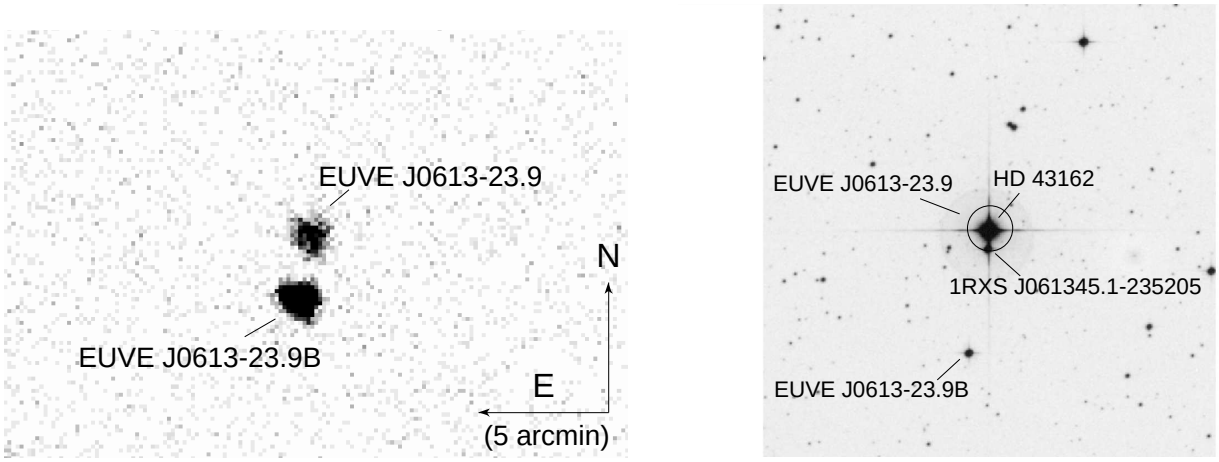

Figure 1. (*left*) EUVE Deep Survey image of EUVE J0613−23.9 from the 22 Oct 2000 observation. The new source, labelled EUVE J0613−23.9B can clearly be seen 2.5′ south of EUVE J0613−23.9. Each arrow is 5′ in length. (*right*) The DSS I-band (10′ × 10′) optical finding chart of the EUVE J0613−23.9 field centered on position of HD 43162. The EUVE positional uncertainty (60″) is indicated with a circle, and the candidates for EUVE J0613−23.9B and 1RXS J061345.1−235205 are indicated. In the EUVE image, HD 43162 and 1RXS J061345.1−235205 are not resolved.

The optical spectra of EUVE J0613-23.9B and 1RXS J061345.1−235205 show the molecular bands typical of late M-type stars. These spectra also show the Balmer series in emission as seen for active late-type stars selected from EUVE and ROSAT surveys. We present the measured strength and equivalent widths of the Balmer lines along with the depth of the TiO molecular band in Table 3. We used the strength of the TiO band at 7050 Å to determine the spectral types and absolute magnitudes using the relations given by Reid et al. 1995. The 7050 Å band is denoted as "TiO5" in the Reid et al. paper, and has upper and lower wavelength ranges of 7042−7046 Å and 7126−7135 Å, respectively. We derived a spectral type of dM3.5e ($M_V = 11\overset{m}{.}9$) for EUVE J0613−23.9B and dM4e ($M_V = 12\overset{m}{.}2$) for 1RXS J061345.1−235205.

Apparent visual magnitudes were calculated from the spectra using the IRAF SBANDS routine, giving visual magnitudes (m_v) of 12.7 and 12.5 for EUVE J0613−23.9B and 1RXS J061345.1−235205, respectively. Using these visual magnitudes and the absolute magnitudes from the Ti05 bands we calculated distances to EUVE J0613−23.9B and 1RXS J061345.1−235205 of 15^{+5}_{-4} and 12^{+4}_{-3} pc, respectively. The 0.5 mag uncertainty in the absolute magnitude derived from the TiO band (Reid et al., 1995) dominates the uncertainty in m_v, which we conservatively estimate at 0.2 magnitudes. The parallax for HD 43162 gives a distance of 16.7 pc (Perryman et al., 1997) and further observations are needed to determine if it and 1RXS J061345.1−235205 form a physical pair.

We present the DS Lexan (60–200 Å) light curves for EUVE J0613−23.9B and EUVE J0613−23.9 in Figure 3. The light curve of EUVE J0613−23.9 may be dominated by EUV emission from 1RXS J061345.1−235205, but it and HD 43162 are not resolved by EUVE. The EUVE J0613−23.9B Lexan light curve clearly shows a strong flare rising above quiescent near MJD 51839.9. We then examined the flare light curve on a smaller time-scale and present the DS Lexan light curve in Figure 4 using 200 sec bins. The flare had a peak count rate of 3.24±0.13 counts sec^{-1}, over 200-times that of the pre-flare quiescent count rate. The rise time of the flare is less than 1 ksec and the decay time is ≈28 ksec. The flare decay e-folding time-scale is short, at ≈3 ksec. We also present the

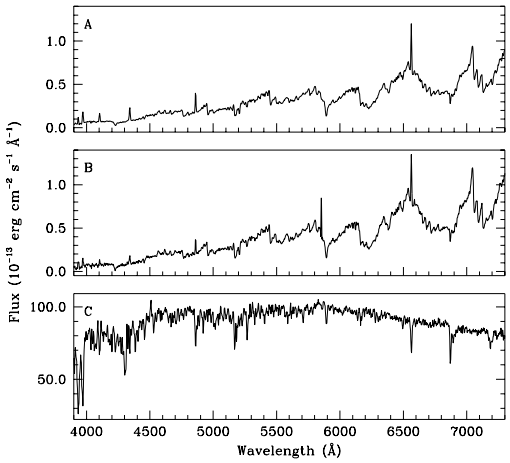

Figure 2. The optical spectra in the 3900−7300 Å range taken with the MSO 74 inch, for a. (*top*) EUVE J0613−23.9B, b. (*middle*) 1RXS J061345.1−235205, and c. (*bottom*) HD 43162.

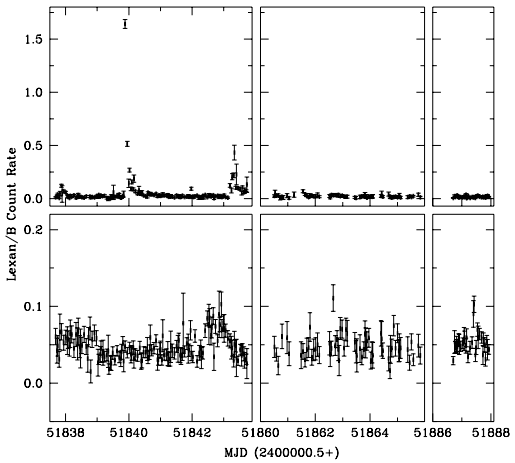

Figure 3. EUVE Deep Survey Lexan(60–200 Å) light curves of the entire observation for: (*top*) EUVE J0613−23.9B and (*bottom*) EUVE J0613−23.9. Bin sizes are 2000 seconds (the nighttime portion of an EUVE orbit).

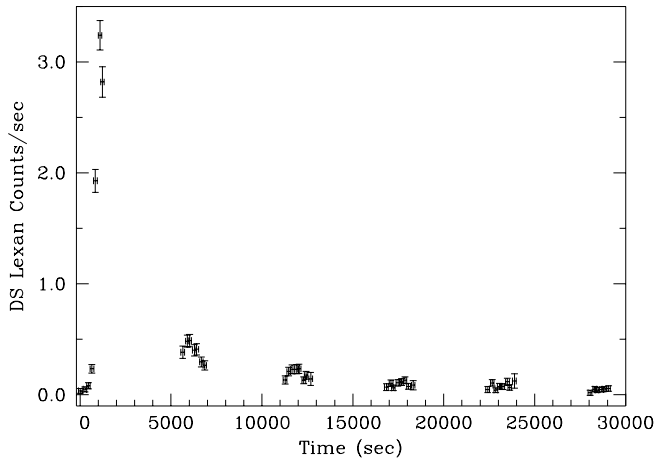

Figure 4. The EUVE DS light curve of EUVE J0613−23.9B with a bin size of 200 seconds.

Observed Optical Line Fluxes and Equivalent Widths

	EUVE J0613−23.9B	1RXS J061345.1−235205
RA_J2000:	06 13 47.2	06 13 45.4
DEC_J2000:	−23 54 26	−23 52 09
Line fluxes (10^{-14} erg cm^{-2} s^{-1}):		
Ca K	5.3	7.8
Ca H (+Hϵ)	11.0	7.7
Hα	40.0	42.0
Hβ	17.0	12.4
Hγ	12.4	10.0
Hδ	8.6	4.8
Equivalent widths (Å):		
Ca K	12.3	19.5
Ca H (+Hϵ)	18.7	14.8
Hα	6.0	5.3
Hβ	9.4	6.3
Hγ	13.8	12.3
Hδ	12.4	7.3
TiO (7050 Å)	0.44	0.42
Sp. Type	dM3.5e	dM4e
m_v	12.7	12.5
M_v	11.9	12.2
d (pc)	15^{+5}_{-4}	12^{+4}_{-3}

DS Lexan count rates using a 200 second time bin in a table which is available at the IBVS-website as `5447-t2.txt`. There was a second smaller flare on Oct 26 (MJD 51843.3) with peak count rate of 0.25±0.09 counts sec^{-1}, ≈13 times less than the larger flare. This smaller flare was only a factor of ≈3 over the quiescent emission and had a rise time of ≈1 ksec and a decay time of only 5 ksec.

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