The EUV Excess in Magnetic Cataclysmic Variables

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We present preliminary analysis of *EUVE* pointed data of 8 magnetic cataclysmic variables. Blackbody temperatures, luminosities, and interstellar columns have been better constrained. Using these luminosities we look for correlations between the EUV excess (over optical and hard X-rays) and various system parameters. While it appears there is no correlation between the EUV excess and the system inclination and orbital period, correlations are suggested between the EUV excess and the longitude of the accretion spot, the colatitude of the accretion spot, the white dwarf magnetic field, and the magnetic capture radius.

1. Introduction

Magnetic cataclysmic variables, or polars, are cataclysmic variables (CVs) with a white dwarf magnetic field of $\sim$ 10–60 MG. They have no accretion disk and the accretion column lands directly on the white dwarf in a small region(s) near one or both of its magnetic poles. See Cropper (1990) for a review. In the standard (outdated) model the accreting material passes through a standoff shock just above the white dwarf, cooling via optically thin thermal bremsstrahlung hard X-rays (HXR) and optical gyrocyclotron radiation. Half of this radiation is reradiated by the white dwarf in the extreme ultraviolet (EUV) and soft X-rays (SXR). This model of magnetic CV accretion predicts that the ratio R of observed EUV luminosity to the sum of the observed HXR and optical luminosities is obeys the simple relation $R \sim 0.5$, where

$$R = \frac{L_{euv}}{L_{hxr} + L_{opt}} = \frac{L_{hxr,0}\,(1 - a_x)}{L_{hxr,0}\,(1 + a_x) + L_{opt}} \sim \frac{1 - a_x}{1 + a_x} \tag{1.1}$$

L_{euv}, L_{hxr}, and L_{opt} are the EUV, HXR and optical luminosities, respectively, $L_{hxr,0}$ is the HXR luminosity directed toward the white dwarf, and $a_x \sim .3$ is the X-ray albedo of the white dwarf. The above approximation, in which the optical luminosity is small enough to be neglected, applies in many systems.

Since the days of *HEAO-1* it has been known that R far exceeds the expected value of 0.5 in many systems. This has been known historically as the SXR excess, but which we call here the EUV excess. Several theories have been proposed to explain the EUV excess, the most promising of which is direct mechanical heating of the white dwarf atmosphere by dense filaments in the accretion stream (Kuijpers & Pringle (1982), Frank, King, & Lasota (1988)). Some as yet unknown mechanism is necessary to separate the flow (at the threading region or perhaps the L1 point) into segments which will then be turned into dense filaments by being pinched by the converging magnetic field lines and stretched by white dwarf tidal forces. No extra pressure or heat is needed to create these segments.

The EUV characteristics of CVs have been difficult to determine, because of their distances ($\geq$ 65 pc) and the high attenuation (a factor of 0.16 at 100 pc and a column of $5 \times 10^{19}\mathrm{cm}^{-2}$) suffered by the EUV photons traversing these distances. In polars, these characteristics include the size, shape, and temperature of the accretion region(s), the number of such regions, and the intervening column. New data from *EUVE* allow tighter

S. Bowyer and R. F. Malina (eds.), Astrophysics in the Extreme Ultraviolet, 325–329.

https://doi.org/10.1017/S0252921100036174 Published online by Cambridge University Press

TABLE 1. Log of Observations

Star Name	Start Date	End Date	Eff. Exp. (ks)
V834 CEN	1993 May 28.1	May 29.6	42.7
EF ERI	1993 Sep. 5.6	Sep. 9.7	120.7
UZ For	1995 Jan. 15.9	Jan. 19.7	120.8
AM HER	1993 Sep. 23.7	Sep. 28.5	143.8
VV PUP	1993 Feb. 7.9	Feb. 9.3	46.0
RE J1149+284	1993 Feb. 22.8	Feb. 25.3	81.0
RE J1844-741	1994 Aug. 17.6	Aug. 24.0	150.0
RX J1938-461	1992 July 8.2	July 9.7	37.3
RX J1938-461	1993 Aug. 16.1	Aug. 17.1	29.1
RX J1938-461	1993 Oct. 6.3	Oct. 10.7	143.2
MR SER	1993 June 1.2	June 2.8	48.7
AN UMA	1993 Feb. 27.9	Feb. 1.2	40.1
EK UMA	1994 Dec. 14.3	Dec. 16.0	50.0

constraints on these characteristics and enable tighter constraints on the EUV excess. In this work we search for correlations between the EUV excess as observed by *EUVE* (Bowyer & Malina (1991)) and other missions, and system parameters. *EUVE* derived parameters are in boldface in the figures.

2. Observations

To date, 11 polars have been observed by *EUVE* in pointed observations: V834 Cen, EF Eri, UZ For, AM Her, VV Pup, RE J1149+284, RE J1844-741, RX J1938-461, MR Ser, AN UMa, and EK UMa. A summary of these observations is provided in Table 1. The data of RE J1844-741 are not publicly available, and two of the other 10—MR Ser and EK UMa—were undetected. The 8 remaining spectra were detected, as expected, only in the short wavelength channel (70–190 Å); no flux was detected in the medium wavelength (140–380 Å) or long wavelength (280–760 Å) channels. Blackbody fits were performed on these spectra, yielding T_{euv}, N_H, & L_{euv}, i.e., the blackbody temperature, the interstellar column, and the bolometrically corrected blackbody luminosity, respectively. These, along with values from other missions (see Ramsay et al. (1994)), are plotted in Figure 1.

3. Results and Discussion

In addition to the *EUVE* observations, we made use of the values compiled by Ramsay et al. (1994) of the HXR and optical luminosities of these 8 systems, as well as the blackbody parameters and HXR and optical luminosities of several other magnetic CVs. Ratios R of observed EUV luminosity to the sum of the (non-simultaneously) observed HXR and optical luminosities were computed, according to Equation 1.1. We then plotted these values of R against various system parameters: orbital inclination i, period P, longitude ψ of the accretion region, colatitude β of the accretion region, white dwarf

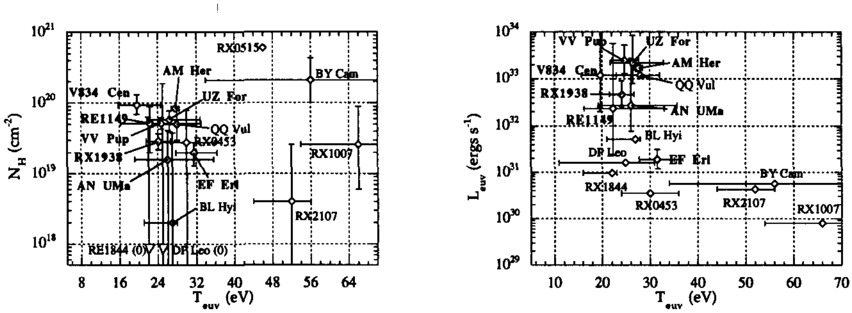

FIGURE 1. Plots of EUV blackbody parameters T_{euv}, N_H, and L_{euv}. EUV Results are in boldface.

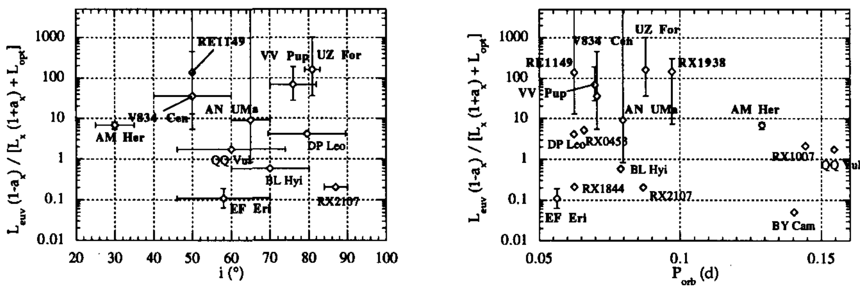

FIGURE 2. EUV excess vs. inclination i and orbital period P.

magnetic field B, and magnetic capture radius R_c. R_c is given by the equation of the ram pressure of the stream with the magnetic pressure (Mukai (1988)):

$$R_c = 1.48 \times 10^{10} B_7^{\frac{4}{11}} R_9^{\frac{12}{11}} D_9^{\frac{4}{11}} \dot{M}_{16}^{\frac{-2}{11}} M_1^{\frac{-1}{11}} \,\text{cm}, \tag{3.2}$$

where B_7 is the magnetic field in units of 10^7 gauss, R_9 is the white dwarf radius in units of 10^9 cm, D_9 is the stream diameter in units of 10^9 cm, $\dot{M}_{16}$ is the mass transfer rate in units of 10^{16} gm cm^{-1}, and M_1 is the mass of the white dwarf in units of $M_\odot$.

We did not see a correlation between the EUV excess R and the inclination i, indicating the absence of beaming effects. No correlation is observed between R and the orbital period P, which is related to the secondary mass (Figure 2). However, there seems to exist a correlation between R and the longitude ψ of the accretion region, and between R and the colatitude β of the accretion region (Figure 3).

There may be a marginal correlation between R and the magnetic field B of the white dwarf. Associated with this there may also be a correlation between R and the magnetic capture radius R_c (Figure 4), indicating that in stars where the material is captured farther out the EUV excess is higher. The asynchronous system BY Cam is an exception in both plots. In any case, an *anti*-correlation between R and R_c is expected from the

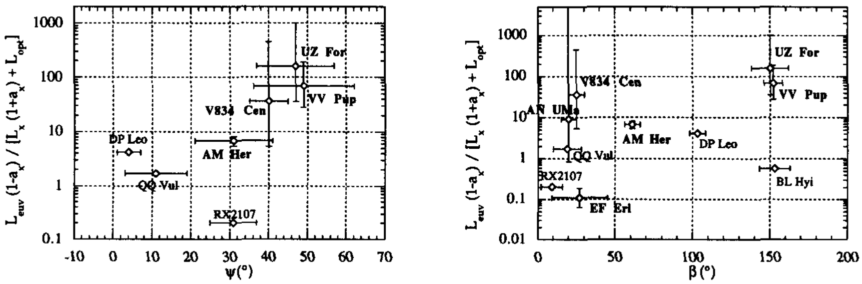

FIGURE 3. EUV excess vs. longitude ψ and colatitude β of accretion spot.

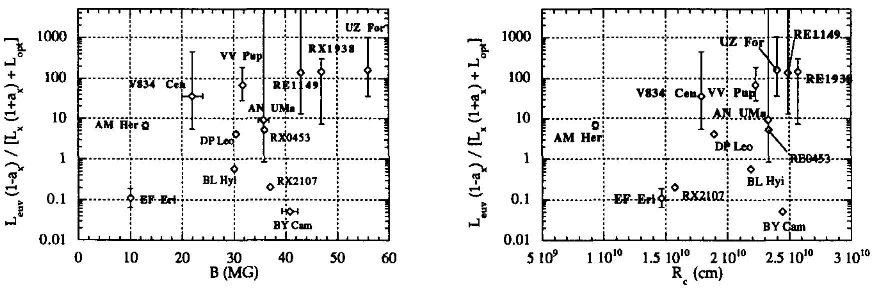

FIGURE 4. EUV Excess vs. white dwarf magnetic field B and magnetic capture radius R_c.

theory that the Kelvin-Helmolz instability has more time to shred the filaments into fine droplets in streams that are captured farther out (Cropper (1990)). However, this anti-correlation is not observed (see also Ramsay et al. (1994)).

Further analysis is in progress, including the exploration of deviations from blackbody spectral shape in the brighter systems, the results of which will be the subject of a forthcoming paper.

This work was supported by NASA grant NAG 5-2641, and by NASA contract NAS-5-32490.

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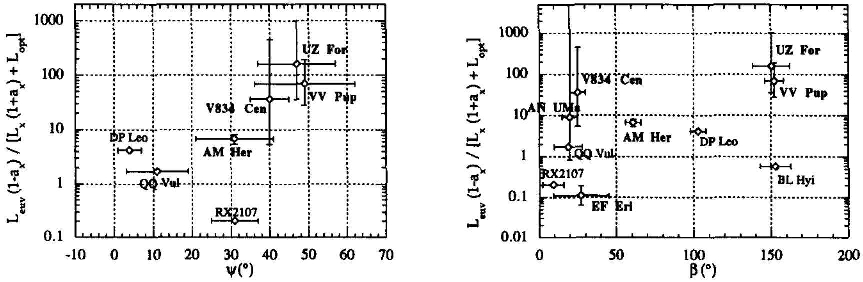
https://doi.org/10.1017/S0252921100036174 Published online by Cambridge University Press



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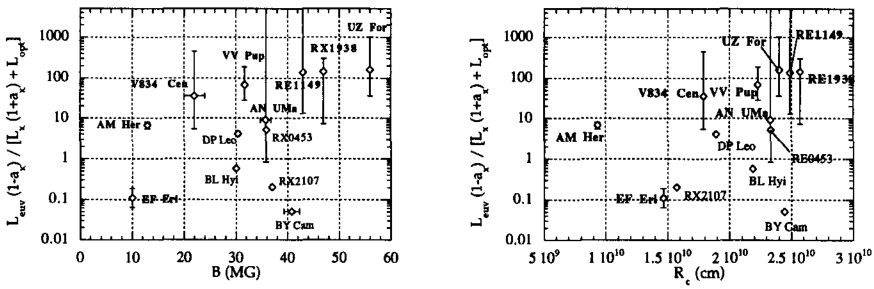

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