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CATACLYSMIC VARIABLES IN OPEN CLUSTERS: EU Cnc

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Magnetic CVs (MCVs) or polars are semi-detached binary systems, in which a lower main sequence Roche-lobe filling star loses mass to its highly magnetic ($B \geq 10^7$G) white dwarf companion. H-rich material is channeled to the magnetic poles of the white dwarf, emitting most of the observed light of the system. When found in star clusters, they provide us with the rare opportunity to study their formation environment and extract information such as their age, distance and metalicity. Globular clusters favor the formation of CVs via tidal interactions in their dense environment, although an intriguing aspect is that a large fraction of the globular cluster CVs appear to be magnetic, raising the possibility that they reflect a new class of objects (Grindlay et al. 1995).

Only three CVs are known to populate open clusters in spite of relevant searches (see for example Kafka et al. 2004). One of them, EU Cnc, is a magnetic CV in the central region of the rich and old (4.0±0.5Gy; Percival & Salaris 2003) open cluster M67 (Gilliland et al. 1991). Its discovery was followed by X-ray studies (e.g. Belloni et al. 1993, 1998; Van den Berg et al. 2004) confirming the magnetic nature of the system. Low-resolution spectra of EU Cnc (Pasquini et al. 1994) revealed a quite variable spectrum with the He II 4686 line in emission and cyclotron humps. Being the only MCV in an open cluster, EU Cnc can be the representative of a unique open cluster CV population, providing valuable information on the properties of a system that was likely formed through a common envelope process, representing more accurately field MCVs. We recently monitored the system in one filter confirming its orbital period and light curve characteristics as presented in the discovery paper of Gilliland et al. (1991). In the followings, we describe our data and data reduction techniques, and present a discussion on our findings, placing EU Cnc in the larger framework of globular cluster CVs and field polars.

The observations were made on 26-Feb-2004 with the Mini-Mosaic CCD camera on the 3.5-m WIYN telescope at Kitt Peak. A total of 32 300-s V-band exposures were obtained under photometric conditions. Data processing (bias subtraction and flat fielding) was conducted using the standard IRAF routines. An additional step of masking was performed using the IRAF routines IMUTIL/IMEXPR, to eliminate ghost images due to cross-talk between the amplifiers of the CCD; bad pixel masking was also applied. For data reduction, we used IRAF/DAOPhot for PSF photometry. The instrumental magnitudes from DAOPhot were then supplied to AstroVar, a custom interactive program based on the method of incomplete ensemble photometry (Honeycutt 1992), optimized for the detection and study of variables. Secondary stars from Gilliland et al. (1991)

were used to fix the zero point of the incomplete ensemble photometry. The 2.09h period from Gilliland et al. (1991) was verified by both periodogram analysis (Horne & Baliunas 1986) of the new data and by folding the new data on this period. Finally, we searched for variability of the X-ray sources in the field of M67 (Belloni et al. 1998). Although the systems are reported to be variable, no variability was detected, likely due to the short duration of our observations.

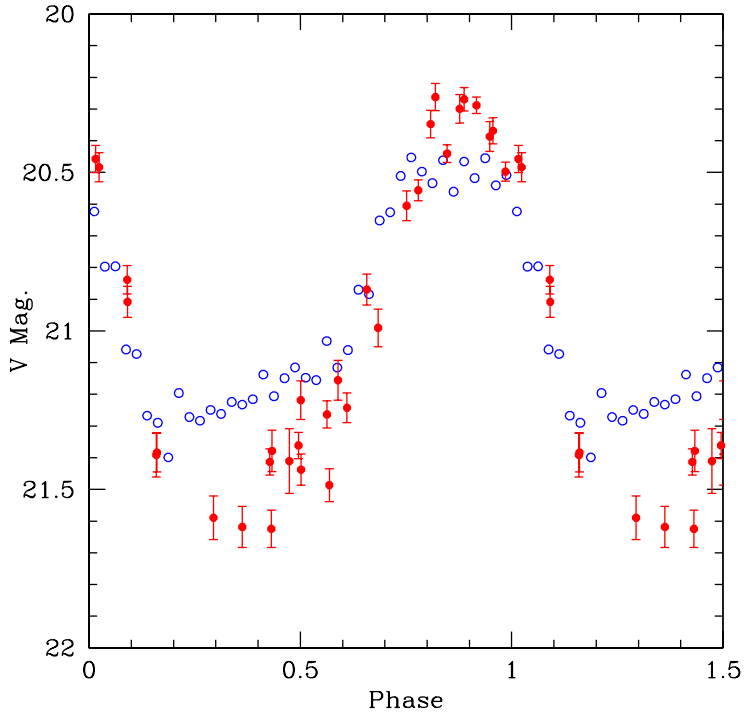

Figure 1. Folded light curves of EU Cnc. Filled circles with error bars are the 2004 WIYN data, while the open circles are the 1988 data of Gilliland et al. (1991).

Fig. 1 and Table 1 compare the 1988 and 2004 light curves. Noticeable similarities of the 1988 light curve of the system with that of VV Pup first suggested its the magnetic nature (Gilliland et al. 1991). The two light curves in Fig.1 have similar shapes, with a 30% larger amplitude in the 2004 light curve. Such changes are common in polars in the high optical state, and are likely due to changes in the mass accretion rate and/or accretion geometry. On the other hand, Gilliland et al. (1991) used a $CuSO_4$ filter which had an effective bandpass that covers both B and V. This could partially explain the light curve differences between the two epochs, since our 2004 data were obtained using a V filter. For an M67 distance modulus of 9.60±0.09 (Percival & Salaris 2003), the M_V range of EU Cnc is 12.0 to 10.6, which can be compared to field and globular cluster MCVs. We searched the literature (e.g Warner 1995, Berriman 1987, Cropper 1990, Harrison et al. 2004) for information on the absolute magnitudes (M_V) of polars. For field CVs, distance uncertainties result in large (1-2 mag) differences in the calculated M_V values. Parallactic distances are available for only two field polars (Thorstensen 2003); most of the distances of individual field MCVs we took from the literature used indirect methods. Fig. 2 shows the distribution of M_V for both the high and low states of MCVs, with the mean M_V of EU Cnc marked.

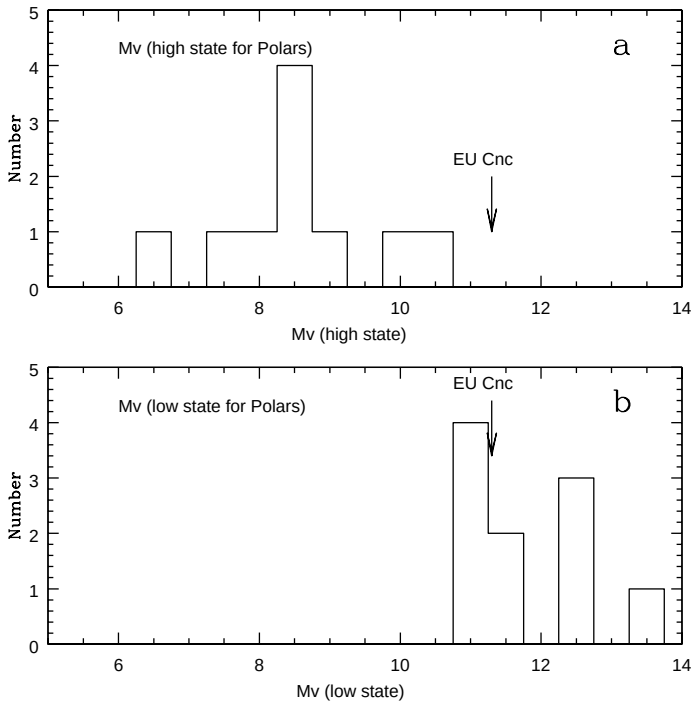

Figure 2. Histogram of M_V in the high (top) and low (bottom) photometric state for field polars. The position of EU Cnc is noted with arrows.

Note that the location of EU Cnc in Fig. 2 suggests that it is in a low optical state. However its large, 1-mag orbital modulation is characteristic of polars in the high state (low-state polars usually have variability of only a few tenths of a magnitude).

Fig. 3 shows a histogram of the absolute magnitude of globular cluster CVs taken from the literature, the majority of which appear to be magnetic, based on their X-ray properties. On the other hand, globular clusters systems are not observed well enough to assess high/low state magnitudes; therefore, Fig. 3 presents the mean "snapshot" magnitude of the systems. It is interesting that EU Cnc is about a magnitude fainter than globular cluster CVs, again suggesting a low state behavior.

Table 1: Parameters of EU Cnc

Epoch	m_V	M_V	Amplitude
1988	21.4-20.5	11.8-10.9	0.9
2004	21.6-20.3	12.0-10.7	1.3

More data are needed for further exploration of the properties of this understudied CV, including the long-term variations in its optical light curve and its spectroscopic properties. Considering that open clusters more accurately represent the galactic disk population, EU Cnc might shed light on the environment and timescales for CV formation and evolution. Alternatively, it may turn out to be a part of a different CV population, affected by the metal rich environment of open clusters.

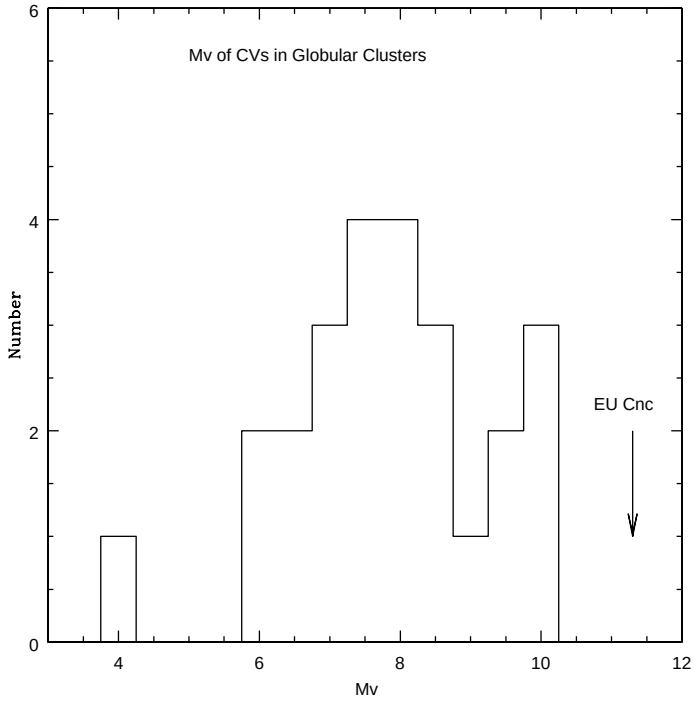

Figure 3. Histogram of M_V of the known globular cluster CVs. The position of EU Cnc in this graph is noted with an arrow

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