COMMISSIONS 27 AND 42 OF THE IAU
INFORMATION BULLETIN ON VARIABLE STARS
Number 5365

Konkoly Observatory
Budapest
21 January 2003
*HU ISSN 0374 – 0676*

# ON THE VARIABILITY OF THE DWARF NOVA EM CYGNI

SPOGLI, CORRADO[1]; FIORUCCI, MASSIMO[1]; RAIMONDO, GABRIELLA[2]

[1] Department of Physics and Astronomical Observatory, Perugia University, Perugia, Italy

[2] INAF-Teramo Astronomical Observatory, Collurania, Teramo, Italy

Dwarf novae (DNe) are a type of cataclysmic binary stars that undergo quasi periodic eruptions of a few magnitudes. In EM Cyg the increase in brightness is of about 2 mag, from $V \simeq 14\overset{\mathrm{m}}{.}4$ to $V \simeq 12\overset{\mathrm{m}}{.}5$ (Downes & Shara 1993), and generally occurs every 20-30 days. The variable is both an eclipsing binary and a double-lined spectroscopic binary. Initially it was classified as a nova-like, but successive observations allowed the classification to be refined and EM Cyg was included in the class of DNe. The usually regular eruption cycle is occasionally interrupted by irregular low-amplitude fluctuations in brightness which suggested that it belongs to the Z Cam type subclass (see Downes & Shara 1993). As usual for this class of objects, the infrared emission of EM Cyg is dominated by the late-type (K2V) secondary star (Jameson et al. 1981), whereas optical data suggest that the primary's light is dominated by the contributions of accretion disk and bright spot.

From measurements of the radial velocity variations, Robinson (1974) was able to derive the orbital elements and the masses of the components of the binary system. However, the spectrum of the secondary star was heavily veiled by the strong continuum arising from the accretion disk, and the measured radial velocities were of relatively low accuracy. More accurate results were obtained by Stover et al. (1981), who estimated the orbital period (P=6.98 h), the masses of the accreting white dwarf and the mass-losing secondary star: $M_1 = (0.56 \pm 0.05)M_\odot$ and $M_2 = (0.76 \pm 0.10)M_\odot$. Recently, North et al. (2000) discovered that the spectrum is contaminated by light from a K2-5 V star, in addition to the K-type mass donor star. They revised the value of the mass ratio that combined with the orbital inclination $i = 67^\circ \pm 2^\circ$ leads to masses of $M_1 = (1.12 \pm 0.08)M_\odot$ and $M_2 = (0.99 \pm 0.12)M_\odot$.

We observed this dwarf nova at the Perugia Astronomical Observatory from June to October 1997, and from August to October 2000. We have also observed EM Cygni at the Teramo Astronomical Observatory in August-September 1998, for a total of 45 different observational nights. Table 1 shows all the $BVR_CI_C$ magnitudes with the Julian Date and the date of the night (not the UT date). The results presented here are part of a project devoted to gain multi-band light curves of a sample of DNe, with the goal of increasing the historical database and information on this class of variable sources. In particular we are interested in identifying the accretion disk emission during all the outburst cycle, because DNe offer the best conditions in which to study the uncertain physics of the disk.

All the data are obtained in the $BVR_CI_C$ Johnson-Cousins broad bands. The instruments used and the photometric techniques have been already described in Spogli

**Table 1:** $BV(RI)_C$ magnitudes of EM Cyg

| Date | JD (2450000+) | $B$ | $V$ | $R_C$ | $I_C$ |
|---|---|---|---|---|---|
| 28/06/97 | 628.585 | 13.41 ± 0.11 | 12.95 ± 0.05 | 12.59 ± 0.05 | |
| 02/07/97 | 632.550 | 13.88 ± 0.09 | 13.20 ± 0.07 | 12.72 ± 0.05 | 12.32 ± 0.05 |
| 06/07/97 | 636.537 | 14.05 ± 0.09 | 13.45 ± 0.03 | 12.93 ± 0.05 | 12.34 ± 0.04 |
| 07/07/97 | 637.547 | 14.01 ± 0.08 | 13.40 ± 0.02 | 12.91 ± 0.04 | 12.33 ± 0.04 |
| 08/07/97 | 638.565 | 14.26 ± 0.08 | 13.58 ± 0.03 | 13.04 ± 0.04 | 12.42 ± 0.04 |
| 09/07/97 | 639.551 | 14.06 ± 0.08 | 13.48 ± 0.03 | 12.92 ± 0.04 | 12.35 ± 0.04 |
| 10/07/97 | 640.562 | 14.21 ± 0.08 | 13.45 ± 0.04 | 13.03 ± 0.04 | 12.43 ± 0.04 |
| 11/07/97 | 641.529 | 14.14 ± 0.10 | 13.50 ± 0.03 | 12.95 ± 0.03 | 12.40 ± 0.04 |
| 12/07/97 | 642.541 | 14.11 ± 0.09 | 13.57 ± 0.04 | 12.98 ± 0.03 | 12.38 ± 0.04 |
| 25/07/97 | 655.441 | 12.52 ± 0.08 | 12.35 ± 0.04 | 12.12 ± 0.03 | 11.72 ± 0.04 |
| 26/07/97 | 656.443 | 12.64 ± 0.08 | 12.45 ± 0.03 | | |
| 28/07/97 | 658.446 | 12.99 ± 0.06 | 12.72 ± 0.02 | 12.42 ± 0.04 | 11.96 ± 0.04 |
| 30/07/97 | 660.455 | 13.50 ± 0.08 | 13.17 ± 0.02 | 12.79 ± 0.04 | 12.28 ± 0.05 |
| 01/08/97 | 662.421 | 13.95 ± 0.08 | 13.23 ± 0.03 | 12.80 ± 0.04 | 12.30 ± 0.04 |
| 04/08/97 | 665.412 | 14.40 ± 0.08 | 13.81 ± 0.03 | 13.24 ± 0.05 | 12.65 ± 0.05 |
| 07/08/97 | 668.419 | 14.20 ± 0.11 | 13.45 ± 0.05 | 13.10 ± 0.05 | 12.50 ± 0.05 |
| 14/08/97 | 675.405 | 12.97 ± 0.05 | 12.65 ± 0.04 | 12.35 ± 0.03 | 11.95 ± 0.05 |
| 18/08/97 | 679.399 | 14.27 ± 0.04 | 13.54 ± 0.03 | 13.05 ± 0.03 | 12.59 ± 0.04 |
| 20/08/97 | 681.395 | 14.15 ± 0.11 | 13.57 ± 0.03 | 13.15 ± 0.03 | 12.53 ± 0.05 |
| 22/08/97 | 683.391 | 14.18 ± 0.10 | 13.46 ± 0.04 | 12.98 ± 0.03 | 12.55 ± 0.04 |
| 29/08/97 | 690.384 | 13.55 ± 0.08 | 13.14 ± 0.02 | | |
| 17/09/97 | 709.349 | 14.34 ± 0.11 | 13.59 ± 0.03 | 13.03 ± 0.03 | 12.45 ± 0.05 |
| 18/09/97 | 710.350 | 14.14 ± 0.09 | 13.50 ± 0.02 | 13.00 ± 0.03 | 12.39 ± 0.05 |
| 24/09/97 | 716.325 | 12.99 ± 0.05 | 12.67 ± 0.02 | 12.38 ± 0.03 | 11.95 ± 0.05 |
| 04/10/97 | 726.308 | 14.04 ± 0.08 | 13.41 ± 0.02 | 12.95 ± 0.03 | 12.37 ± 0.04 |
| 05/10/97 | 727.321 | 14.12 ± 0.13 | 13.48 ± 0.04 | | |
| 16/10/97 | 738.253 | 13.55 ± 0.06 | 13.07 ± 0.03 | | |
| 17/10/97 | 739.329 | 12.51 ± 0.05 | 12.31 ± 0.03 | 12.08 ± 0.03 | 11.70 ± 0.04 |
| 18/10/97 | 740.285 | 12.35 ± 0.06 | 12.20 ± 0.03 | 11.98 ± 0.04 | 11.62 ± 0.04 |
| 19/10/97 | 741.286 | 12.61 ± 0.06 | 12.39 ± 0.03 | 12.19 ± 0.04 | 11.80 ± 0.05 |
| 22/10/97 | 744.282 | 13.05 ± 0.06 | 12.77 ± 0.04 | 12.45 ± 0.03 | 12.02 ± 0.04 |
| 31/08/98 | 1057.450 | 13.52 ± 0.04 | 13.03 ± 0.04 | 12.61 ± 0.04 | 12.27 ± 0.05 |
| 01/09/98 | 1058.416 | 13.54 ± 0.04 | 13.08 ± 0.05 | 12.58 ± 0.04 | 12.18 ± 0.05 |
| 02/09/98 | 1059.333 | 13.07 ± 0.04 | 12.74 ± 0.04 | 12.46 ± 0.04 | |
| 19/08/00 | 1776.357 | 13.45 ± 0.04 | 13.04 ± 0.04 | 12.72 ± 0.04 | 12.18 ± 0.04 |
| 20/08/00 | 1777.385 | 13.37 ± 0.04 | 12.98 ± 0.04 | 12.69 ± 0.04 | 12.21 ± 0.04 |
| 21/08/00 | 1778.333 | 13.60 ± 0.07 | 13.01 ± 0.05 | 12.66 ± 0.04 | 12.07 ± 0.04 |
| 25/08/00 | 1782.328 | 13.21 ± 0.05 | 12.83 ± 0.05 | 12.61 ± 0.05 | 12.09 ± 0.05 |
| 29/08/00 | 1786.331 | 13.45 ± 0.05 | 13.06 ± 0.06 | 12.68 ± 0.05 | 12.16 ± 0.05 |
| 11/09/00 | 1799.313 | 13.04 ± 0.09 | 12.75 ± 0.06 | 12.42 ± 0.04 | 11.98 ± 0.05 |
| 12/09/00 | 1800.312 | 12.77 ± 0.08 | 12.59 ± 0.04 | 12.39 ± 0.03 | 11.96 ± 0.04 |
| 15/09/00 | 1803.308 | | 13.01 ± 0.04 | 12.67 ± 0.04 | 12.14 ± 0.04 |
| 22/09/00 | 1810.299 | 14.22 ± 0.04 | 13.54 ± 0.04 | 13.04 ± 0.03 | 12.43 ± 0.05 |
| 12/10/00 | 1830.293 | | | | 11.74 ± 0.04 |
| 28/10/00 | 1846.246 | | | | 12.38 ± 0.04 |

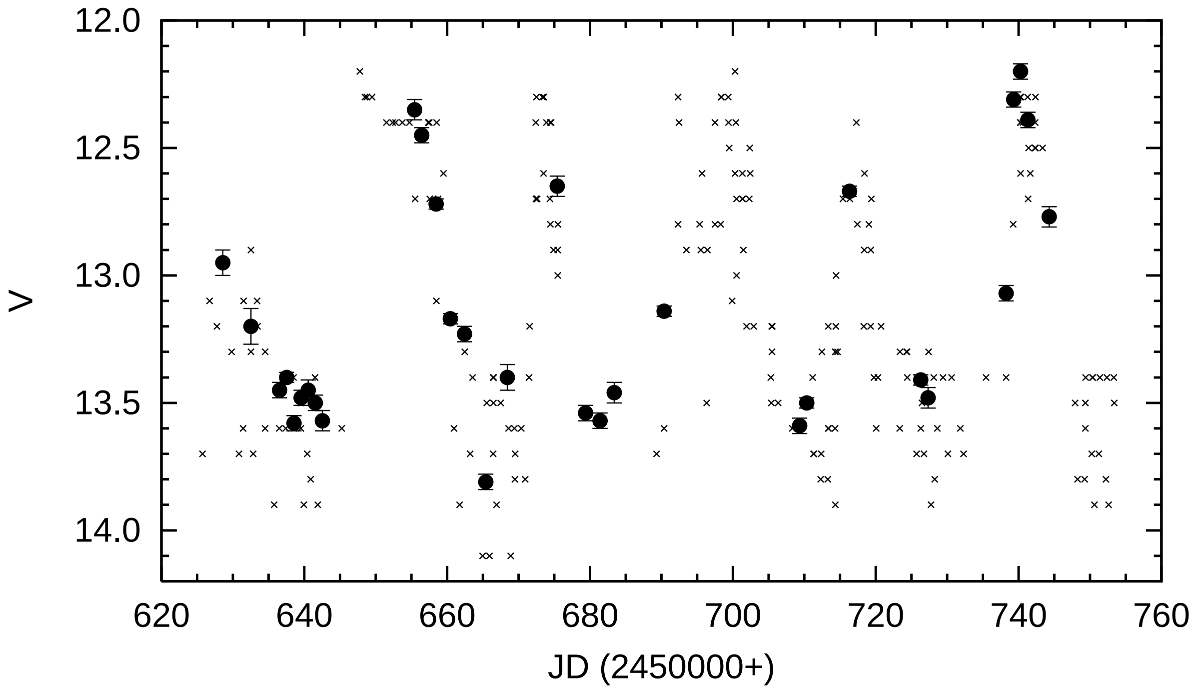


**Figure 1.** $V$ light curve of EM Cyg during the summer-autumn 1997. Circles represent the data here reported, while the small crosses are visual estimates available from VSNET

et al. (1998). In this work, we used the calibration stars reported in Misselt (1996) with the number 2, 4, 5, 8, and 11. Moreover we calibrated these comparison stars with the $I_C$ filter by observing, on photometric nights, several standard stars (Landolt 1992) having $(B-V)$ from $-0.2$ to 1.4, over a wide range of airmass. The weighted means and standard deviations of the obtained values are: $I_C(2) = 12.28 \pm 0.06$, $I_C(4) = 12.51 \pm 0.06$, $I_C(5) = 13.00 \pm 0.05$, $I_C(8) = 10.99 \pm 0.05$, and $I_C(11) = 12.12 \pm 0.08$.

Figure 1 shows the V data during the summer-autumn 1997, and the visual estimates available from VSNET (`http://vsnet.kusastro.kyoto-u.ac.jp/vsnet/`). The comparison shows that we have a good coverage of all the outburst phases. Table 2 remarks the principal photometric characteristics of all the dataset: the extreme magnitudes and the average color indices at maximum and at minimum.

**Table 2:** Photometric characteristics of EM Cyg from our observations

| | $B$ | $V$ | $R_C$ | $I_C$ | $(B-V)_{ave}$ | $(V-R_C)_{ave}$ | $(V-I_C)_{ave}$ |
|---|---|---|---|---|---|---|---|
| Maximum | 12.3 | 12.2 | 12.0 | 11.6 | 0.2 | 0.2 | 0.6 |
| Minimum | 14.4 | 13.8 | 13.2 | 12.7 | 0.7 | 0.5 | 1.1 |

We computed the flux density of EM Cyg using the same procedure described in Spogli et al. (1998), adopting the interstellar reddening $E(B-V)$=0.03 as reported by Bruch (1984). The spectral distribution is dominated by the emission of the secondary star during the minimum, and we tried to isolate its contribution with the simple assumption that the overall emission is mainly due to the secondary and the accretion disk. In this phase we have neglected the presence of another red star (North et al. 2000) because the spectral types are similar (K2-5V). Figure 2 shows an example of decomposition of the spectral emission in two components. We have considered the canonical emission of a

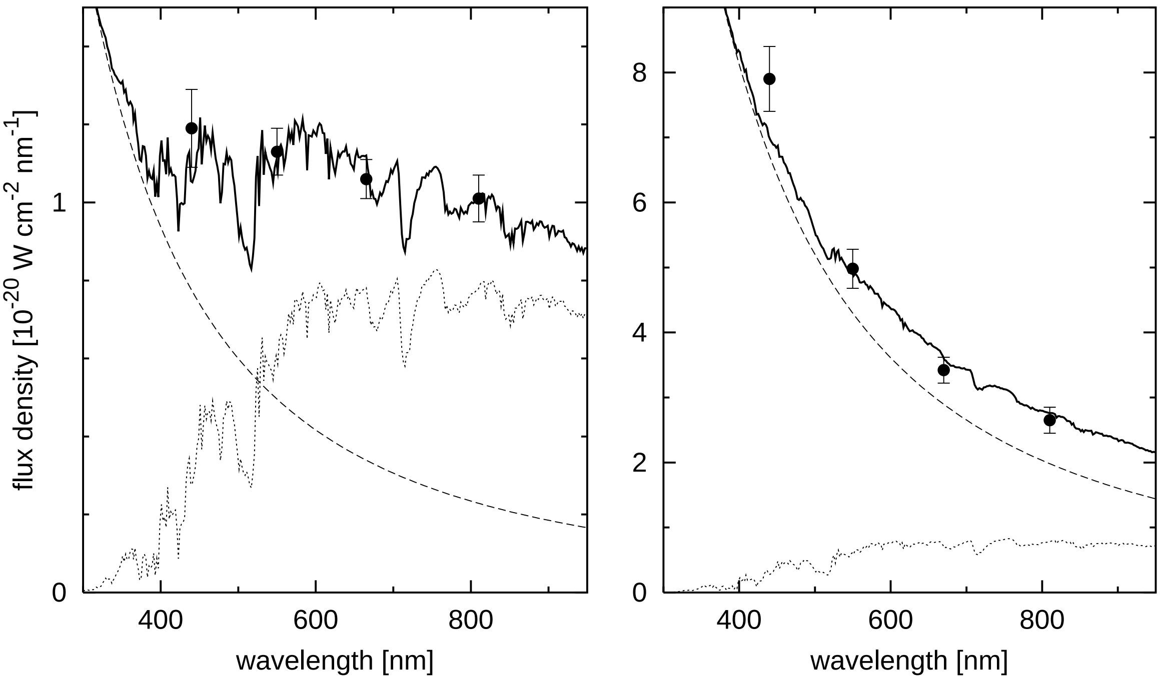


**Figure 2.** $BVR_CI_C$ data points converted in density flux at minimum (left panel) and at maximum (right panel). Dotted lines represent the secondary star, while the dashed lines represent the theoretical emission of a steady-state accretion disk. The integrated light coming from the emission disk and the secondary (bold lines) is a rough but good approximation of the EM Cyg emission in the optical region

steady-state accretion disk $F(\lambda) \propto \lambda^{-7/3}$, while the emission of the secondary is simulated via Kurucz's spectra of dwarf stars with solar metalicity (Kurucz 1993). The best fit in all the phases of the outburst cycle is obtained considering the emission of a 4250 K star, and an accretion disk that varies of a factor ten from the passive cooling of the quiescence to the brightness of the outburst maximum. This model is obviously too simplistic and doesn't take into account all the components of the system, but reproduces quite well the variability dynamics during the outburst. Another component (probably the hot spot) or a physical model of the accretion disk may be necessary to compensate the strong blue emission during the outburst.

References:

Bruch, A., 1984, *A&AS*, **56**, 441
Downes, R. A., Shara, M. M., 1993, *PASP*, **105**, 127
Jameson, R. F., King, A. R., Sherrington, M. R., 1981, *MNRAS*, **195**, 235
Kurucz, R., L., 1993, *ATLAS9 Stellar Atmosphere Programs and Grid (CD-ROM 13)*
Landolt, A. U., 1992, *AJ*, **104**, 340
Misselt, K. A., 1996, *PASP*, **108**, 146
North, R. C., Marsh, T. R., Moran, C. K. J., et al., 2000, *MNRAS*, **313**, 383
Robinson, E. L., 1974, *ApJ*, **193**, 191
Spogli, C., Fiorucci, M., Tosti, G., 1998, *A&AS*, **130**, 485
Stover, R. J., Robinson, E. L., Nather, R. E., 1981, *ApJ*, **248**, 696