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CCD OBSERVATION OF MWC 560 = V694 Mon

ISHIOKA, R.; UEMURA, M.; KATO, T.

Dept. of Astronomy, Kyoto University, Kyoto 606-8502, Japan
e-mail: ishioka@kusastro.kyoto-u.ac.jp, uemura@kusastro.kyoto-u.ac.jp, tkato@kusastro.kyoto-u.ac.jp

MWC 560 (= V694 Mon) is a symbiotic-like star whose character is still not clear. This star was discovered as an emission-line object $V = 12^{\mathrm{m}}.5$ by Merrill and Burwell (1943). Sanduleak and Stephenson (1973) gave a spectral classification of M4ep. One interesting phenomenon of MWC 560 is its flickering. Bond et al. (1984) first noted the rapid variation with amplitudes of about $0^{\mathrm{m}}.2$ and time scales of a few minutes. Flickering is a common property of CVs, but is rarely seen on symbiotic stars (Dobrzycka et al. 1996).

Tomov et al. (1990) reported an outburst reaching $V = 9^{\mathrm{m}}.1$, associated with remarkable blue-shifted absorption lines with velocities up to -6500 km s^{-1}. The strong shift implied a high-velocity and highly-collimated jet. These absorption lines showed rapid variability (Tomov et al. 1990, 1997). The magnitude dropped to $V \simeq 10.2$ by 1993 and has remained at this mean value up to now. The interval between the 1990 outburst and the 1995 small maxima agrees with the orbital period ~ 1930 day (Mikołajewski et al. 1998). At present the orbital phase may be the same as in 1990 and 1995, but the object is not in outburst now.

In this paper, we report time-resolved CCD observations of MWC 560 to detect flickering. The CCD photometric observations were done on 13 nights using ST-7E (unfiltered or R_c-filtered) and ST-7 (unfiltered) cameras attached to a 25-cm Schmidt–Cassegrain telescope at Kyoto University and an R_c-filtered PixelVision camera (SITe SI004AB chip, CryoTiger-cooled) attached to a 60-cm reflector at Ouda Station (Ohtani et al. 1992). The exposure times were 15 s and 5 s, respectively. The images were dark-subtracted, flat-fielded and analyzed with the Java$^{\mathrm{TM}}$-based aperture photometry package developed by one of the authors (TK) and with IRAF APPHOT package (IRAF is distributed by National Optical Astronomy Observatories in U.S.A.), respectively. We determined the differential magnitude of MWC 560 using the comparison star GSC 5396.1090 (Tycho $V = 10.66$, $B - V = 1.73$, so $R_c \simeq 9.7$, Skiff, 1998) whose constancy was confirmed with the check star GSC 5396.491. Table 1 is a summary of the observations.

R_c-magnitude of MWC 560 is about $9^{\mathrm{m}}.8$. Although the nightly average magnitudes seem to show slight variability both of the R_c-filtered and unfiltered data sets, more observation is needed to confirm this.

We analyzed the data set observed on six nights at Kyoto using DFT (discrete Fourier transform) algorithm. The light curves used for DFT analysis and the results are shown in Fig. 1. The abscissa is time in Julian Date or frequency, and the ordinate is differential magnitude or relative power. These spectra are shown at the frequencies higher than

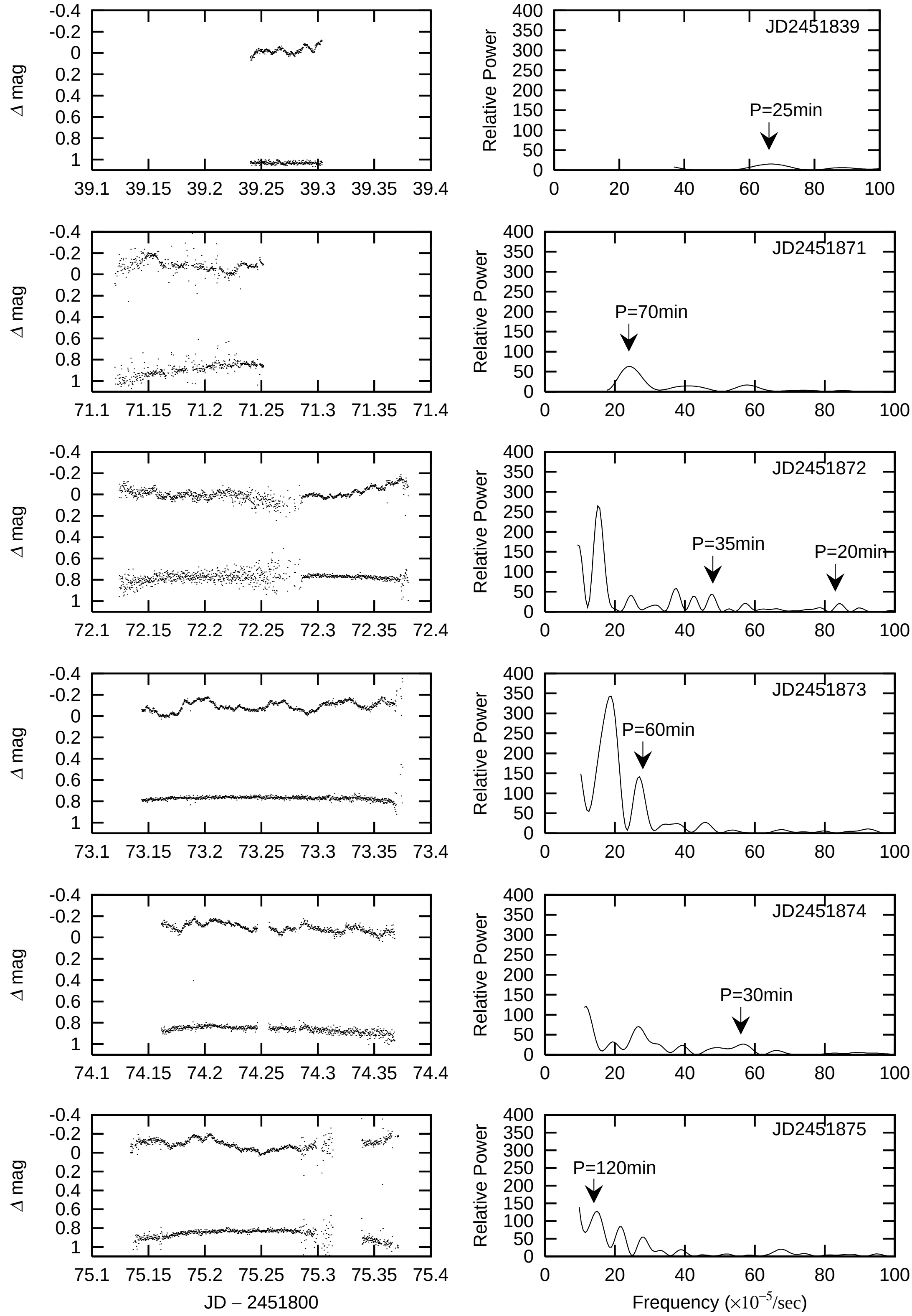

Figure 1. Light curve and power spectrum on individual night data

Table 1: Summary of observations

Start / end (JD − 2450000)	N^a	Exp (sec)	Filter	σ^b (mag)	Δmag^c (mag)	Site^d
1834.191 / .311	637	5.0	R_c	0.037	0.383	O
1839.240 / .303	295	15.0	none	0.027	−0.024	K1
1844.242 / .283	401	5.0	R_c	0.020	0.427	O
1849.314 / .332	55	5.0	R_c	0.037	0.450	O
1850.295 / .359	310	5.0	R_c	0.025	0.408	O
1852.280 / .327	471	5.0	R_c	0.026	0.272	O
1855.205 / .245	220	15.0	R_c	0.043	0.193	K2
1858.279 / .352	59	15.0	R_c	0.064	0.250	K2
1871.120 / .251	469	15.0	none	0.077	−0.084	K2
1872.124 / .372	975	15.0	none	0.045	−0.004	K2
1873.144 / .369	961	15.0	none	0.016	−0.091	K2
1874.161 / .367	810	15.0	none	0.031	−0.091	K2
1875.134 / .371	832	15.0	none	0.052	−0.087	K2

[a] number of frames
[b] standard deviation of differential magnitudes of the comparison star: comparison − check
[c] nightly averaged differential magnitude of MWC 560
[d] O: at Ouda, K1: at Kyoto with ST-7, K2: at Kyoto with ST-7E

that corresponding to the period equal to the half-duration of each observational run. The arrows in Fig. 1 are put for help and do not show precise peaks. 1 sigma of the comparison is about $0^{\rm m}_{\cdot}02$–$0^{\rm m}_{\cdot}08$, so the variation is real.

As shown in Fig. 1 left, we detect quasi-periodic modulation from minutes to hours with typical amplitude about $0^{\rm m}_{\cdot}2$. Fig. 1 right shows some peaks from 20 min to 2 hours, but there is no peak coherent over the whole data set. The resultant time scales of variability and the apparent lack of rigid coherence have confirmed the findings in previous studies: Michalitsianos et al. (1993) found quasi-periodic variations with periods of 24, 35, and 58 min, superposed on hourly variability. Tomov et al. (1996) detected a periodicity of 70 min which was coherent over a few days. Dobrzycka et al. (1996) obtained 22 min period.

Our observation seems to suggest that the general characteristics of short-term variability in V694 Mon have been stable nearly a decade. The lack of coherence suggests that these dominant oscillations are quasi-periodic, rather than strictly periodic as expected from the magnetic rotator model (Tomov et al. 1992; Shore et al. 1994). We are going to continue this observation in order to clarify the nature of these periodicities.

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