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SPECTRAL AND PHOTOMETRIC OBSERVATIONS OF MWC 560 IN 2009 – 2012

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The peculiar object MWC 560 was discovered as an emission star by Merrill & Burwell (1943). It consists of a red giant and a white dwarf. Its orbital period, as estimated by Gromadzki et al. (2007), equals to $P_{\rm orb} = 1931 \pm 162$ days. Photometry of this object has been obtained by Doroshenko et al. (1993), Tomov et al. (1996), Zamanov et al. (2011) and Goranskij et al. (2011). The spectrum of MWC 560 contains several emission lines of H I, FeII, superimposed on the late-type continuum. The most spectacular feature of the spectrum is the highly blue-shifted broad absorption components of the hydrogen lines. During a stable state the absorption components show a maximum outflow speed of $\sim 1580 - 2140$ km s^{-1} and widths of $500 - 1400$ km s^{-1}.

The first large outburst took place in 1989 – 1990, when the brightness of the object reached V=9.$^{\rm m}$2, and the absorption components were shifted with up to -6500 km s^{-1}. Then, in 1993 and 1998, blue-ward velocities of the absorption components of more than 3000 km s^{-1} were observed (Iijima, 2002). These authors proposed a classification of the absorption profiles and defined four types: A, B - for a stable state and C, D - for an active state.

The faint stable stage of the object, which continued between January 2008 and December 2009, was followed by the flash, registered on December 24, 2010 by Goranskij et al. (2011).

Our observations in Fessenkov Astrophysical Institute have been made before and after the last flash. B, V, $R_{\rm C}$ magnitudes were measured using the 1-meter Carl Zeiss Jena and the 70-cm AZT-8 reflectors equipped with CCD ST-8 (1530×1020, 9 μ) and of B, V, $R_{\rm C}$ filters. All frames were dark subtracted and flat field corrected. The stars HD 62834, HD 163355 and HD 58457 were adopted as standards. The obtained B, V, $R_{\rm C}$ magnitudes are listed in Table 1. They supplement the data of Goranskij et al. (2011). Photometric phases were computed according to the ephemeris:
JD$_{\rm max}$=2 448 080 + 1931×E (Gromadzki et al., 2007).

Spectral observations have been carried out with the slit spectrograph for faint emission objects, attached to the AZT-8 telescope and with the UAGS spectrograph, attached to the 1-m telescope. Both spectrographs were equipped with ST–8 CCD cameras. The slit width was between $3' - 4'$. Wavelength calibration was done using a laboratory source of HeI, NeI and ArI emission lines. Spectra of standard stars obtained just before or after

Table 1: Photometric results

Date	HJD	Phase	B	V	R
	2400000+		mag	mag	mag
10.02.2010	55238.234	0.707	10.76±0.05	10.46±0.06	8.94±0.05
10.11.2010	55511.444	0.848	10.26±0.05	9.90±0.04	9.20±0.05
13.11.2010	55514.410	0.850	10.25±0.04	9.89±0.04	9.12±0.04
13.02.2012	55971.151	0.087	10.39±0.05	10.13±0.05	8.96±0.04
03.03.2012	55990.130	0.096	10.90±0.05	10.22±0.04	9.22±0.06

the target were used for flux calibration. All spectrograms were corrected for atmospheric extinction.

All Balmer lines from Hβ to Hδ produce the strong and deep jet absorptions. For Hα the absorption is less deep due to the significant contribution of the red giant spectrum to the total continuum. Table 2 presents the spectral parameters of the Hβ and Hα lines: equivalent widths (EW) and the absolute fluxes ($F_{\rm abs}$) of the absorption and emission components and the spectral resolution of observations. $F_{\rm abs}$ values are expressed in erg cm^{-2}s^{-1} with the multiplier 10^{-12}. Observations on 13.02.2012 were carried out only in the red wavelength range. For some dates only equivalent widths of the lines are presented, because the absolute spectral calibration was absent. Figure 1 shows the normalized profiles of Hα and Hβ.

The radial velocities of the Hα and Hβ absorption components are listed in Table 3. The errors of the presented values depend on the spectral resolution and the structure of the measured profiles. As it was mentioned above, the period in 2008 – 2009 appeared to be rather stable for MWC 560. However the profiles of Hα and Hβ, registered on 21.12.2008 and 04.01.2009, appeared to be quite unusual. There was flat continuum (up to -800 km s^{-1}) between the emission and an absorption components. Such features have been registered earlier during the active stage (profiles of C-type by Iijima, 2002), but simultaneously they have been followed by a blue shift of absorption component up to -4000 km s^{-1}. On the contrary, the blue sides of our profiles are at about -2100 km s^{-1} the typical value for a stable stage (in accordance with the classification of Iijima, 2002). This feature (the flat continuum between the emission and absorption components) has disappeared from the profiles obtained on 10.02.2010: the blue-ward velocity has not changed, but the velocity of the red wing has shifted to about -500 km s^{-1}. The highly blue-shifted components with RVs up to -3500 km s^{-1} appeared in the profiles of Hα and Hβ on November, 10 – 13 2010, just before the last flash (24.12.2010). On February, 2012 the blue-shifted components returned to $V_r \sim -2000$ km s^{-1}, but the emission flux of Hα remained as high as before the flash.

Table 2: Spectral results

HJD 2400000+	Hβ absorption EW Å	Hβ absorption F_{abs} 10^{-12}	Hβ emission EW Å	Hβ emission F_{abs} 10^{-12}	Hα absorption EW Å	Hα absorption F_{abs} 10^{-12}	Hα emission EW Å	Hα emission F_{abs} 10^{-12}	R=λ/Δλ for Hβ – Hα
54822.34	12.5		21.6		6.7		121.9		10000 – 13000
54836.32	12.1	1.91	16.2	3.31	7.6	0.995	121.2	11.0	3000 – 4500
55238.21	18.2	3.86	17.3	3.74	9.8	2.24	120.6	24.1	7000 – 9000
55511.42	21.0		18.6		22.9		122.5		10000 – 13000
55514.35	23.4	11.92	17.5	9.04	27.1	1.11	127.8	45.1	10000 – 13000
55971.16					14.2	4.44	165.8	54.4	7000 – 9000
55990.12	11.3		30.5		7.7		188.0		7000 – 9000

Table 3: Radial velocities of absorption components of Hβ and Hα

Date	HJD	Hβ absorption			Hα absorption		
	2400000+	blue wing	red wing	centre	blue wing	red wing	centre
21.12.2008	54822.34	−1970	−670	−1320	−2100	−700	−1400
		±40	±40	±40	±30	±30	±30
04.01.2009	54836.32	−2250	−860	−1555	−2200	−740	−1470
		±80	±80	±80	±60	±60	±60
10.02.2010	55238.21	−2260	−420	−1390	−2220	−540	−1380
		±45	±45	±45	±30	±30	±30
10.11.2010	55511.42	−3490	−1590	−2540	−3780	−1100	−2440
		±30	±30	±30	±20	±20	±20
13.11.2010	55514.35	−3370	−780	−2075	−3410	−920	−2165
		±40	±40	±40	±30	±30	±30
13.02.2012	55971.16				−2060	−570	−1315
					±40	±40	±40
03.03.2012	55990.12	−2270	−430	−1350	−1600	−600	−1100
		±45	±45	±45	±40	±40	±40

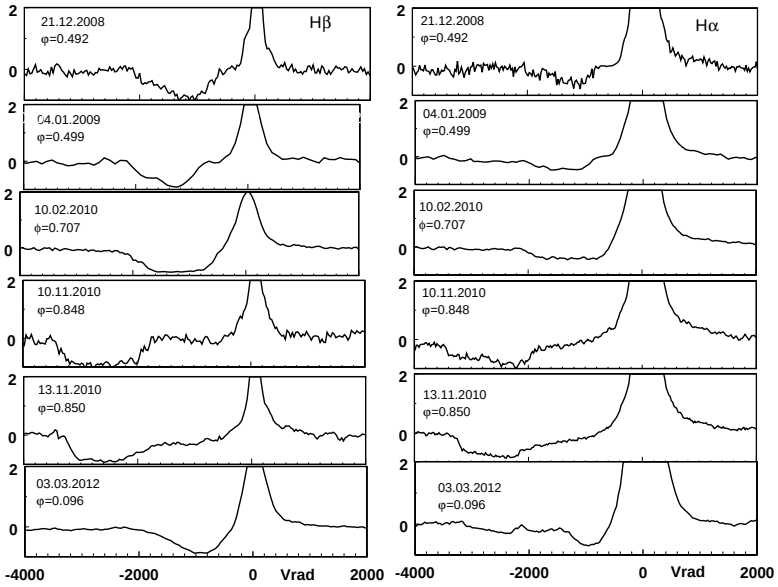

Figure 1. The absorption components of Hβ and Hα profiles. The horizontal axis corresponds to the heliocentric radial velocities.

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