Peremennye Zvezdy (*Variable Stars*) **32**, No. 1, 2012

Received 1 January; accepted 8 February.

Photometric Activity of the Herbig Ae star WW Vul

S. N. Udovichenko

Astronomical observatory of Odessa National University, Marazliyevskaya 1v, Odessa 65014, Ukraine, e-mail: udovich222@ukr.net

Photometric CCD observations of the pre-main-sequence Herbig Ae star WW Vul on separate nights during 2007–2011 are presented. The star exhibited long-term non-periodic variability in the range of $0\overset{\mathrm{m}}{.}8$; rapid variations with a small amplitude were superimposed. The results of a search for periodicity in the light variations are reported.

The star WW Vul (HD 344361, Sp A3ea), its maximum amplitude of brightness variations being $2\overset{\mathrm{m}}{.}7$ (GCVS database, Samus et al. 2011) belong to pre-main-sequence (PMS) Herbig Ae/Be stars with unusual photometric activity due to variable circumstellar extinction caused by gas-and-dust disks surrounding them. To learn what dust fragments rotate about the star, attempts to determine rotation periods were undertaken. From the photoelectric observations by Zajtseva (1983), a period of 404^{d} exists. Fourier analysis by Volchkova (1993) of photoelectric observations by various authors in a 22-year range did not confirm it, but found two quasi-periods: 274^{d} and 1100^{d}. However, the star does not always quite follow these periods. Bernabei et al. (2004) report that the star might pulsate at low frequencies, $\approx 5\mathrm{d}^{-1}$, but only one night of observations was available for the star. During their evolution towards the main sequence (MS), Herbig Ae/Be stars of intermediate mass ($1.5M_{\odot} < M_{\odot} < 4M_{\odot}$) cross the pulsation instability region of more evolved δ Scuti stars (Ripepi et al. 2011). At least a part of activity of such PMS stars is due to stellar pulsation. Up to now, several candidates were detected from precise observations (Bernabei et al. 2004, Marconi et al. 2010).

Our CCD photometry of WW Vul was performed at the astronomical station near Odessa in 2007–2011. The 48-cm AZT-3 reflector, with the $f/4.5$ Newtonian focus and a CCD photometer equipped with an UAI CCD (Sony ICX429ALL, Peltier-cooled) and a V filter, was used. Three stars were chosen as the comparison and check stars (comp=GSC 1612–393, $V = 10\overset{\mathrm{m}}{.}17$; check=GSC 1612–527, $V = 10\overset{\mathrm{m}}{.}76$ or GSC 1612–151, $V = 12\overset{\mathrm{m}}{.}38$).

Reductions of the CCD frames were carried out with the MUNIPACK (*http://c-munipack.sourceforge.net/*) software. Our procedures for aperture photometry consisted of dark-level and flat-field corrections, followed with the determination of the instrumental magnitude and uncertainty. Relative magnitudes of WW Vul were measured with respect of the comparison star. Table 1 summarizes the log of the photometric data.

All our observations are shown in Fig. 1. Individual measurements are accessible in the html version of this paper as data.dat.

WW Vul has the following observed and model characteristics: $B-V = 0.35$, $L_*/L_{\odot} = 80$ (Krivova and Il'in 1997), $M_*/M_{\odot} = 2.5$ (Montesinos et al. 2009), confirming the star's location in the instability region of δ Scuti stars (Rodriguez and Breger 2001). Taking into

Table 1. Photometric observations of WW Vul

Year	JD	No. of nights	Typical uncertainty, mag
2007	2 454 262–2 454 303	12	0.01–0.02
2008	2 454 650–2 454 651	2	0.01–0.02
2009	2 455 033–2 455 095	8	0.005
2011	2 455 795–2 455 803	4	0.005

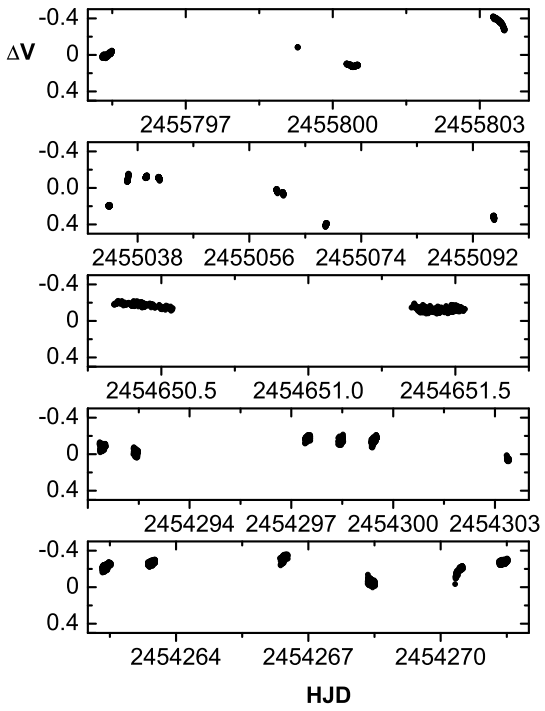

Figure 1. All observations of WW Vul obtained in 1997–2011.

account this fact, an attempt to search for periodicity of light variations was made. The frequency analysis for short periodicity was carried out with the Period04 package (Lenz & Breger 2005), which applies both the Fourier and least-squares algorithms and permits simultaneous fitting of multiple sinusoidal variations. Only the data of 2009 and 2011 were analyzed for periodicity, they being more precise and suited for calculations. The data were de-trended with the aid of polynomial fitting (Fig. 2b). The first two frequencies and the signal-to-noise ratio (in the amplitude) for each frequency are presented in Table 2.

Table 2. The frequencies and amplitudes of WW Vul

N	Frequency 2011, d^{-1}	Signal-to-noise	Amplitude mag	Frequency, d 2009, d^{-1}	Signal-to-noise	Amplitude mag
F1	9.34 ± 0.4	2.1	0.0029 ± 0.0003	9.06 ± 0.01	2.4	0.0018 ± 0.0003
F2	18.23 ± 0.6	2.2	0.0023 ± 0.0004	17.91 ± 0.02	2.5	0.0012 ± 0.0002

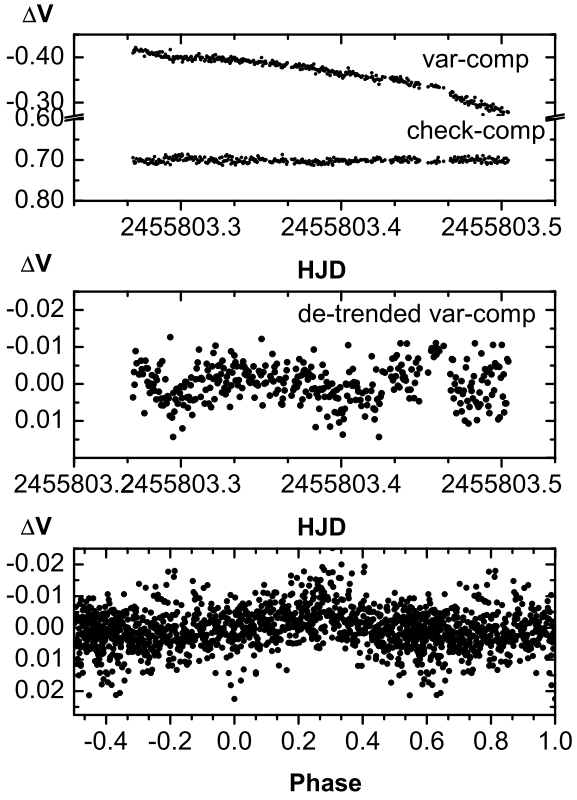

Figure 2. From top to bottom: (a) one night of observations of WW Vul: differences variable – comparison star and comparison star – check star; (b) de-trended light curve; (c) phase curve for the season 2011 with the first frequency, 9.34 d^{-1}.

Analytical uncertainties were calculated as a results of the least-squares fit and Monte Carlo simulation in the Period04 package. Unfortunately, the signal-to-noise ratio is too small for reliable determination of the significance of the detected frequencies because of the influence of circumstellar clouds and gas that obscure the star from the observer and cause light variations or to other reasons. However, Fig. 2c exhibits the low-amplitude phase curve for the season of 2011 with the first frequency, 9.34 d^{-1}. Very detailed light curves and account of the envelope influence are needed for reliable confirmation of the short periodicity for WW Vul.

References:

Bernabei S., Ripepi V., Marconi M. et al. 2004, *Proc. IAU Symposium No. 224*, p.812
Krivova N.A., Il'in V.B. 1997, *Astronomy Letters*, **23**, 791
Lenz P., Breger M. 2004, *Comm. in Asteroseismology*, No. 144, 41
Marconi M., Ripepi V., Bernabei S. et al. 2010, *Astrophys.& Sp. Sci.*, **328**, 109
Montesinos B., Eiroa C., Mora A., Merin B. 2009, *Astron.& Astrophys.*, **495**, 901
Ripepi V., Cusano F., Di Criscienzo M. et al. 2011, *Mon. Not. R. Astron. Soc.*, **416**, 1535
Rodriguez E., Breger M. 2001, *Astron.& Astrophys.*, **366**, 178

Samus N.N., Durlevich O.V., Kazarovets E V., Kireeva N.N., Pastukhova E.N., Zharova A.V. et al. 2011, General Catalogue of Variable Stars (GCVS database, Version 2011Jan)
Volchkova N.A. 1993, *Astrofizika*, **36**, 61
Zajtseva G.V. 1983, *Perem. Zvezdy*, **22**, 1