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VW Peg: FIRST PHOTOELECTRIC OBSERVATIONS AND REVISED ELEMENTS

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ACHTERBERG, H.[1,4]; FRANK, P.[2,4]; HUSAR, D.[3,4]

[1] Liegnitzer Str. 12, D-22850 Norderstedt, Germany

[2] Hauptstr. 4, D-84149 Velden, Germany, e-mail: frank.velden@t-online.de

[3] Himmelsmoor 18, D-22397 Hamburg, Germany, e-mail: husar_d@compuserve.com or husar.d@gmx.de

[4] Bundesdeutsche Arbeitsgemeinschaft für Veränderliche Sterne e.V. (BAV), Munsterdamm 90, D–12169 Berlin, Germany

The Algol-type variable VW Pegasi (= GSC 2753.649 ($11\overset{m}{.}06$ mag); USNO-A2.0: $B = 12\overset{m}{.}0$; $R = 11\overset{m}{.}2$) was — after the photographic discovery in 1901 — first studied by Williams (1914) indicating a period of 5.26792 days. A new period of 2.642758 days resulted from some observations of Maggini (1916). As Zinner (1922) reported, he was not able to confirm any of the proposed periods. He even discussed a reclassification supposedly due to some misleading visual observations. Further observations from the Cracow observatory (observers: J. Kordylewska and K. Kordylewski), collected by Szafraniec (1962) were published; based on these observations two new suggestions on the period were made by Dworak (1976): 1.170648 days or 2.341295 days. By means of a reanalysis of the known data B.-C. Kämper suggested the period of 21.0717 days, which was only briefly communicated by Busch (1994). The variety of periods caused some confusion; many observations may have failed and in consequence even the possibility of VW Peg being constant was discussed by Dahm (1996).

In order to resolve the issue regarding the value of the period, a series of systematic CCD observations was started in 1997. These CCD observations finally indicated the occurrence of two different types of minima.

As principal comparison star we used GSC 2753.1568 ($11\overset{m}{.}44$ mag); (USNO-A2.0: $B = 12\overset{m}{.}6$; $R = 11\overset{m}{.}2$). Cracow observers used this star as well, but assuming $11\overset{m}{.}38$ mag (v). The star was observed to be constant within $\pm 0\overset{m}{.}02$.

Through several complete observation series, the primary and secondary minima were characterized in amplitude and width (cf. Figures 1 and 2).

The amplitudes Δm (measured with red sensitive, unfiltered CCD chip, the errors are estimated), and durations D of the minima are:

$$\text{Min I}: \quad \Delta m \approx 0.71 \pm 0.03 \text{ mag}; \; D = 320^{\rm m} \pm 25^{\rm m} \approx 0\overset{d}{.}22 \quad [D_{1/2} = 125^{\rm m} \pm 10^{\rm m} \approx 0\overset{d}{.}09],$$
$$\text{Min II}: \quad \Delta m \approx 0.65 \pm 0.03 \text{ mag}; \; D = 430^{\rm m} \pm 0^{\rm m} \approx 0\overset{d}{.}30 \quad [D_{1/2} = 180^{\rm m} \pm 12^{\rm m} \approx 0\overset{d}{.}13].$$

(Definition of $D_{1/2}$: full width at half amplitude of the minima — which has been introduced as it allows to be determined more exactly than the time of eclipse D. The errors

Table 1: Observed times of primary (Min I) and secondary (Min II) minima for VW Pegasi, epochs and residuals computed according to the linear ephemeris (1) and (2), respectively.

Min I						Min II					
JD hel. − 2400000	±*	T**	E_1	$O-C_1$	Ref.	JD hel. − 2400000	±*	T**	E_2	$O-C_2$	Ref.
15729.462	.020	P	−1660	0.0043	[1]	16704.482	.020	V(x)	−1614	−0.0040	[1]
16635.541	.014	V(x)	−1617	−0.0020	[1]	17526.280	.014	V(x)	−1575	−0.0041	[1]
17478.414	.014	V(x)	−1577	0.0009	[1]	26650.354	.011	V	−1142	0.0040	[2]
17815.560	.010	V	−1561	−0.0011	[1]	50756.4271	.0035	E(x)	2	−0.0001	[3]
26307.474	.010	V	−1158	−0.0028	[2]	50756.4278	.0010	E	2	0.0006	ATB
28372.517	.014	V	−1060	0.0086	[2]	51030.3606	.0042	E(x)	15	0.0007	HSR
50708.5621	.0014	E	0	−0.0024	FR	51346.441	.010	E(x)	30	0.0049	HSR
50708.5626	.0050	E(x)	0	−0.0019	[3]	51388.5777	.0021	E_R	32	−0.0019	HSR
50982.494	.010	E(x)	13	−0.0033	HSR	51388.5785	.0014	E	32	−0.0011	HSR
51045.7134	.0035	E(x)	16	0.0008	HSR	51388.5790	.0025	E_I	32	−0.0006	HSR
51319.647	.006	E(x)	29	0.0017	HSR	51388.5813	.0011	E_V	32	0.0017	HSR
51509.2913	.0021	E	38	0.0002	FR	51578.2235	.0028	E(x)	41	−0.0018	ATB
51509.2930	.0010	E	38	0.0019	HSR	51599.297	.010	E(x)	42	0.0000	ATB

* Estimated errors of the minimum timings (reflecting errors in magnitude, as well as total number and distribution of the measured values with regard to time).
** P, V, and R denotes photographic, visual, and CCD observed minima, respectively. Observations with $V/R/I$-filters are marked as $E_V/E_R/E_I$, respectively. Those marked with (x) were extrapolated minima.
References: [1] reevaluated timings, based on data from Williams (1914); [2] reevaluated timings, based on data from Szafraniec (1962); [3] based on data from Quester (1999). Data from the observers: ATB = Achterberg / FR = Frank / HSR = Husar (this paper).
Information on the used equipment:
H. Achterberg: 20-cm SC refl. with a SBIG ST6 camera (CCD chip: TI TC241), without filter.
P. Frank: 28.8-cm flat-field-refl. with a OES-LcCCD11 camera (CCD chip: Kodak KAF400), without filter.
D. Husar: 20-cm SC refl. with a SBIG ST7 camera (CCD chip: Kodak KAF400), without filter or Bessel-type $V/R/I$-filters.
W. Quester: 20-cm MC refl. with a SBIG ST7 camera (CCD chip: Kodak KAF400), with IR-cutoff-filter KG5/2mm.

are estimated.) There may well be constant phases of $d \leq 7^{\rm m}$ during Min I and $d \leq 10^{\rm m}$ during Min II.

The observations of 11 different new minima of VW Peg with 17 independent timings are contributed by this paper and included in Table 1.

Based on the data of the almost completely observed minima, two sets of polynomials were derived by least-squares fitting procedures to describe the light curves in Min I and Min II. By matching these polynomials to the data of only partly observed minima we were able to determine the time and in most cases even the type of the aforementioned minima with considerable reliability. In Table 1 these minima are marked as extrapolated (x).

The published minima as derived from the visual observations from Williams and from the Cracow observers were reevaluated from the well documented original estimates. As given in Table 1 these minima include some small corrections compared with the earlier publications. In the original data of Williams two further (secondary) minima were found which were not published until now. Regarding one minimum he had been mislead by using a deviating magnitude for the mentioned comparison star (his star b), the other was mentioned only as discordant observation. The data from the Cracow observers J. Kordylewska and K. Kordylewski for the minimum HJD 2426307.474 due to the scatter of the data were put together for our fitting procedure in order to obtain the minimum timing with better reliability (reduced estimated error for the observation).

In Table 1 the visual observations of Maggini (1916) were excluded from the analysis as they appeared to be in contradiction to most other observations. The reported minimum at JD = 2450824.278 of the visual minima timings of Peter (as published in the BBSAG

Bulletins) disagreed for unknown reasons with a CCD observation in normal light, and caused all minima of Peter to be completely excluded from further analysis.

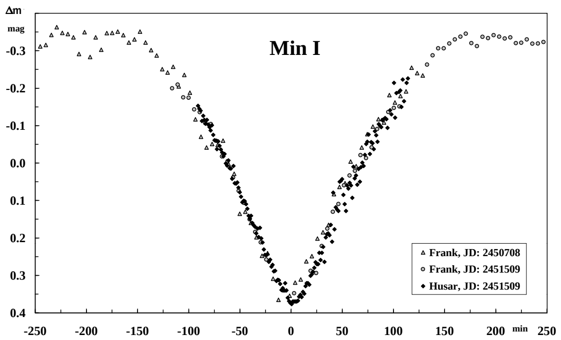

Figure 1. Light curve of Primary Minimum of VW Peg (symbols are explained in the figure).

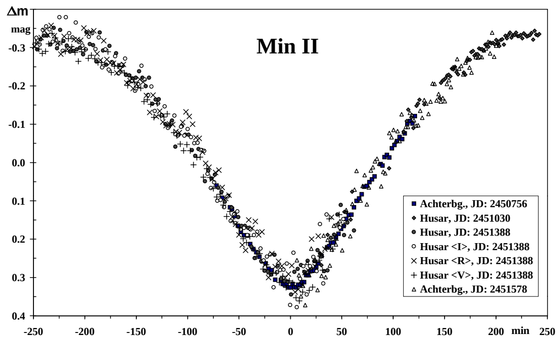

Figure 2. Light Curve of Secondary Minimum of VW Peg (symbols are explained in the figure).

Since 1997 nearly 5000 individual photoelectric observations with VW Peg apparently in normal light were made by Achterberg (18 nights), Frank (11 nights) and Husar (58 nights). These observations are listed electronically as 4916-t2.txt available through IBVS Web-site. The detailed results of these observations are available from the authors.

For the final period analysis we also used the nearly 800 visual observations during normal light from Williams (1904–1914), from the Cracow observers in the years 1930–1950 published by Szafraniec (1962), as well as the ones from 1951–1954 observed by K. Kordylewski and communicated by Kreiner (2000).

In a first run we only used the CCD observations of the minima together with our observations in normal light to check the different assumptions on the period which was realized using a computer program which searches in a wide range of period values. Later the systematic period search was extended to all observations given in Table 1 and to all observations in normal light as mentioned above. The only resulting periods (for Min I and Min II) lie very close to the value supposed by Kämper.

The primary and secondary minima from Table 1 were used separately to calculate the ephemeris for VW Peg using linear least-squares fits (weights were chosen according to the precision of the minimum timings):

$$\begin{array}{rl} \text{Min I} = \text{HJD } 2450708.5645 + 21\overset{d}{.}0717511 \times E. \\ \pm.0007 \qquad \pm.0000013 \end{array} \qquad (1)$$

$$\begin{array}{rl} \text{Min II} = \text{HJD } 2450714.2837 + 21\overset{d}{.}0717458 \times E. \\ \pm\ .0005 \qquad \pm\ .0000017 \end{array} \qquad (2)$$

This means that the secondary minimum is observed at phase 0.27141 ± 0.00004 (for epoch $E = 0$). As the difference of the periods in (1) and (2) is only about 2.5 times the calculated error it seems too early to make a statement on apsidal motion, but the result is seen to be encouraging for future observations.

From the phase of the secondary minimum, period, D_1 and D_2 we calculated the numerical eccentricity e of the orbit to be $e = 0.39 \pm 0.02$.

In the figures of the reduced light curves the relative magnitudes Δm of different observations are in the instrumental system and a minor part has been slightly corrected within $0\overset{m}{.}03$ to match. In Fig. 1 and Fig. 2 the time scale is in minutes, based on the given elements (1) and (2) respectively, with $t = 0$ for the times of minima.

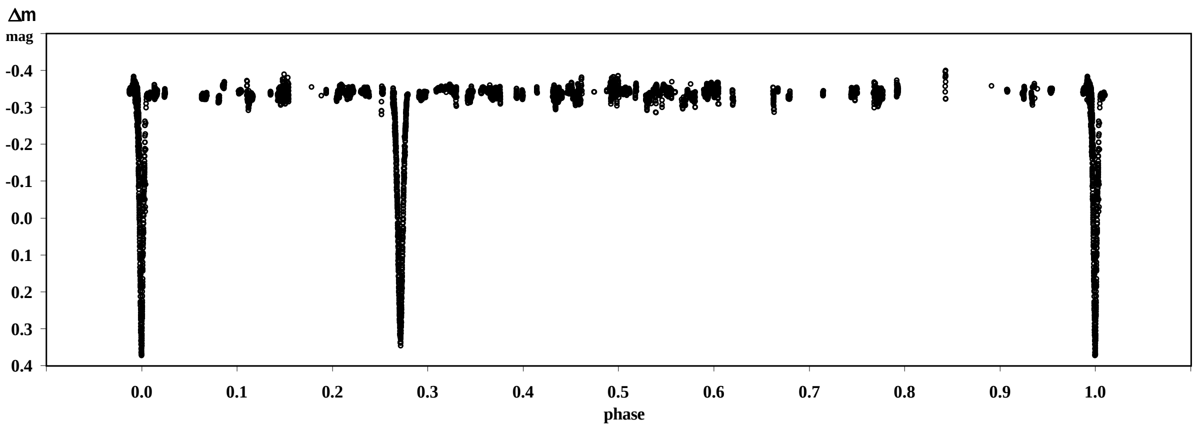

Figure 3. Complete Light Curve of VW Peg (the plotted points represent gliding 5-point mean values of the photoelectric data).

Figure 3 represents the complete phased light curve (only photoelectric data) based on elements (1). The classification of the variable as an eclipsing binary of the type EA is confirmed by the light curve.

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