PHOTOELECTRIC PHOTOMETRY AND FURTHER DISCUSSIONS OF V CEPHEI

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Abstract

Photoelectric observations on 34 nights during a 428-day interval in 1986-87 indicate that V Cep and the comparison star HR 158 (NSV 235) were constant within ±0.02 magnitude. An explanation for the variability found by some visual observers is discussed.

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Hoffleit (1985) has reviewed the rather puzzling observational history of V Cephei = HR 9056 = HD 224309 (A3V, +6.59 **V**, +0.05 **B-V**). Over the past century, several observers reported light variations of 0.5 - 0.7 magnitude with cycle lengths of 270 - 400 days. However, other observers failed to detect variability greater than the natural uncertainties of the observations.

One definite conclusion can be drawn from the observational record: visual or photographic estimates cannot resolve the question of variability. Therefore, two of us, Milton and Williams, measured 49 photoelectric mean differential magnitudes of V Cep in the **V** passband on 34 nights between October 11, 1986, and December 13, 1987 (Table III).

Milton observed with a 20-cm Schmidt-Cassegrain telescope and pulse-counting photometer with a 1P21 photomultiplier tube. Williams observed with a 20-cm Newtonian reflector and Optec SSP-3 solid-state photodiode photometer. HR 158 = HD 3440 (dF6, +6.40 **V**, +0.55 **B-V**) was used as the comparison star, and HR 240 = HD 4853 (A4V, +5.62 **V**, +0.09 **B-V**) was the check star. The observations have been corrected for differential extinction and transformed to the Johnson **V** system. The results are summarized in Table I.

The comparison star HR 158 is a suspected variable, NSV 235. However, the photoelectric observations show that the difference between V Cep and HR 158 did not vary by more than ±0.02 magnitude during the 428-day interval.

Hoffleit has continued to examine the literature on V Cep (see Hoffleit 1985 for earlier discussion and references). Chandler first detected variability in 1882 (Chandler 1893). All subsequent observers except Shapley, whose short series of observations did not show variability, used HR 158 as a comparison star. M. Zverev (1936) explains that V Cep was declared constant because he decided that HR 158 was probably the actual variable. He concluded that the observed periods for V Cep represented systematic errors due to the changing angle of orientation of V Cep and its comparison stars resulting from celestial rotation. After determining and correcting for this effect in his own observations, Zverev found a small residual amplitude of 0.35 magnitude - a rather dubious amplitude for that era - which he tentatively attributed to HR 158.

The apparent difference in brightness between two stars can vary by several tenths of a magnitude as the orientation of the stars changes (Zverev 1936; Williams 1987). This angle-error effect is especially difficult to avoid for a star like V Cep, just 8 degrees from the celestial pole. If observations are made at about the same time each night, the field will rotate about 1 degree per night and the apparent variation will have a period of about one year. It is highly suspicious that all but one of the maxima collected by Hoffleit (1985) fit a period of 362 days.

The maxima occur in March for Chandler's 1883 observations; December to February 1890-1907 for the observations of Yendell and Luizet; in November 1916, August-September 1917, and January 1918 for Luyten's observations, and September 1928 for Zverev's observations. But apparent maxima resulting from the angle-error effect need not occur at the same time of year for all observers.

Angle error is part of each observer's "personal equation," and the greatest and least apparent differences in brightness between two stars may occur at different orientations for different observers. Also, some observers of V Cep may have used instruments with erect images while others may have used instruments with reversed images. Finally, different choices of comparison stars will produce different net angle-error effects.

There remains the problem of Luyten's observations (Luyten 1922; Hoffleit 1985). These show an amplitude of 0.56 magnitude, considered a sufficient visual range for acceptance as a true variable by the **General Catalogue of Variable Stars** (Kholopov et al. 1985) (GCVS). An analysis for angle-error effects as demonstrated by Zverev (1936) would be desirable.

Luyten used two comparison stars that happen to be nearly co-linear with the variable, the line making an angle of about 60 degrees with the hour circle through V Cep. Unfortunately, Luyten did not publish the Julian Day decimals, or time of night, of his observations. Assuming that they were all made at about the same local time, we should expect the observations of a nonvariable star to be correlated with the time of year, the orientation of the line being horizontal twice a year at intervals of six months and vertical halfway between. The angle-error effect would be close to zero for the horizontal orientations, and at alternately positive and negative values in between. No such correlation is indicated, the one well-defined cycle in Luyten's observations being 270 days.

Luyten's published observations of short-period variables show nightly runs of five hours or more (a change in position angle of some 75 degrees). The estimates of V Cep could have been made at any time during an interval of hours on each given night, and such a large uncertainty would frustrate any analysis for errors dependent on orientation angles.

The Harvard visual magnitudes Luyten adopted for his comparison stars are shown in Table II, together with their modern photoelectrically determined **V** magnitudes. The **V** magnitude difference is only 70 percent of the old Harvard visual difference. If Luyten's total observed range is reduced by the same factor, the revised amplitude becomes 0.39 magnitude, rendering the detection of real variability doubtful.

Could V Cep have varied in brightness in the past, but be constant now? Stars very different from V Cep in spectral type (for example, RU Cam and V725 Sgr) have exhibited intervals of nearly constant light before or after intervals of periodic variability. However, these stars remain small-amplitude (~0.1 magnitude) variables even during quiescence. The photoelectric data reported here show that V Cep and HR 158 were mutually constant during the 428-day span of observations. These observations support the conclusion that neither V Cep nor HR 158 is now variable; that either varied in the past must be seriously questioned.

We do not want to close this discussion without a corrective word in support of visual observations. The fact that V Cep was confirmed as a variable star by several observers does not mean that their visual estimates were unreliable. Some observers may have detected variability because they expected to find it. But it should be emphasized that careful visual investigators of V Cep observed real changes in the apparent brightness of this star. In this sense, their visual estimates were too good. Less accurate observations could have masked the small but systematic perceptual effects that mimic periodic variability.

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TABLE I

Mean Differential **V** Magnitudes for V Cep and HR 240

Observer	(V Cep - HR 158)		(HR 240 - HR 158)	
	Δ**V**	σ_1	Δ**V**	σ_1
Milton	+0.187	±0.009	-0.791	±0.017
Williams	+0.183	±0.014	-0.791	±0.013
All Data	+0.186	±0.010	-0.791	±0.016

TABLE II

Luyten Comparison Stars for V Cep

HD	BD	Harvard m_V	**V**
3440	+81° 13	6.38	6.40
7471	+80° 36	6.74	6.65

TABLE III

Photoelectric Mean Differential **V** Magnitudes of (V Cephei - HR 158)

HJD	O	(n)	ΔV	σ_1	HJD	O	(n)	ΔV	σ_1
2446714.692	W	(4)	+0.174	±0.005	2446965.759	M	(3)	+0.198	±0.006
6722.743	W	(5)	0.222	0.038	.804	M	(3)	0.199	0.003
6723.533	W	(4)	0.185	0.014	.841	M	(3)	0.196	0.002
6734.650	W	(3)	0.169	0.024	.878	M	(3)	0.188	0.009
6744.688	W	(3)	0.182	0.010	.917	M	(3)	0.177	0.009
6765.733	M	(3)	0.179	0.004	6974.842	W	(3)	0.194	0.014
6770.526	W	(3)	0.183	0.003	6980.800	M	(3)	0.190	0.004
.569	W	(3)	0.176	0.008	6987.832	M	(3)	0.195	0.011
6774.653	M	(3)	0.190	0.011	6988.737	M	(3)	0.191	0.008
6776.525	W	(3)	0.183	0.012	.764	M	(3)	0.181	0.007
6792.663	M	(3)	0.178	0.005	.803	M	(3)	0.202	0.005
6805.640	M	(3)	0.181	0.008	.829	M	(3)	0.191	0.010
6807.654	M	(3)	0.180	0.010	.859	M	(3)	0.190	0.009
6815.620	M	(3)	0.172	0.002	.897	M	(3)	0.203	0.003
6822.648	W	(3)	0.167	0.024	.927	M	(3)	0.187	0.010
6858.595	W	(3)	0.181	0.022	7002.755	M	(3)	0.197	0.002
6862.624	W	(3)	0.179	0.015	7016.741	M	(3)	0.185	0.001
6882.936	M	(3)	0.193	0.012	7036.801	M	(3)	0.183	0.024
6894.613	W	(3)	0.167	0.022	7037.733	W	(3)	0.198	0.002
6904.862	M	(3)	0.191	0.009	7052.684	W	(3)	0.189	0.006
6952.789	M	(3)	0.194	0.008	7071.646	M	(3)	0.186	0.007
.826	M	(3)	0.174	0.026	7103.681	M	(3)	0.178	0.008
.877	M	(3)	0.186	0.004	7127.671	M	(3)	0.184	0.006
.902	M	(3)	0.184	0.017	7142.701	M	(3)	0.172	0.007
.918	M	(3)	0.176	0.013					