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Single Channel UBV Photometry of Long Period Eclipsing Binary VV Cephei

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Abstract

With a period of 20.3 years, VV Cephei is the second longest known eclipsing binary system. The last eclipse was in 1997-98. The observation of long period eclipsing binaries requires a special kind of dedication. Few of these systems are followed in detail between eclipses. These stars are bright, and so obtaining telescope time for extended periods at professional observatories is nearly impossible. Therefore, amateur photometrists with modest backyard observatories and time to devote can make an important contribution by monitoring these stars. To this end, the Hopkins Phoenix Observatory started a dedicated effort in the summer of 2005 to obtain UBV data for VV Cep around the predicted time of secondary eclipse, which has never been observed for this system. This paper will summarize the current observing program and present the data.

1. Introduction

During August 2005 the Hopkins Phoenix Observatory was contacted by Philip Bennett and asked to include the long period eclipsing binary star system VV Cephei in its UBV observing program. In addition to monitoring the system for light variations at different wavelengths, there was hope that the elusive secondary eclipse estimated for the fall/winter of 2005 could be observed.

VV Cephei (M2~Iab +B0-2V, Vmax = 4.91) is the second longest known eclipsing binary, having a period of 20.34 years and an eclipse lasting 490 days. The longest period eclipsing binary system is Epsilon Aurigae with a period of 27.1 years. A secondary eclipse for VV Cephei was predicted in 2005 based on the orbit of Wright (1977) [1]. The Hopkins Phoenix Observatory monitored this system from August 2005 to February 2006.

This star system is interesting from several points. With a diameter 1,000 times that of the Sun, the primary super giant star is amongst the largest known stars. Primary eclipse occurs when the B star goes behind the M star and produces a drop in the shorter wavelength radiation. Secondary eclipse occurs when the much smaller B star passes in front of the M star and should result in a slight decrease in the longer wavelength radiation.

The two stars of the system are in quite different evolutionary stages. The primary star is an evolved super-giant M star, while the secondary is a hot B star still on the main sequence. Both stars appear to be intrinsically variable.

The primary displays intrinsic photometric variability typical of M supergiant, while the hot secondary shows large changes in continuum flux in the ultraviolet. The hot star has an associated accretion region, which may account for the ultraviolet variability. Because of the difference in color between the primary and secondary stars, its variability can be seen and separated using filtered photometry.

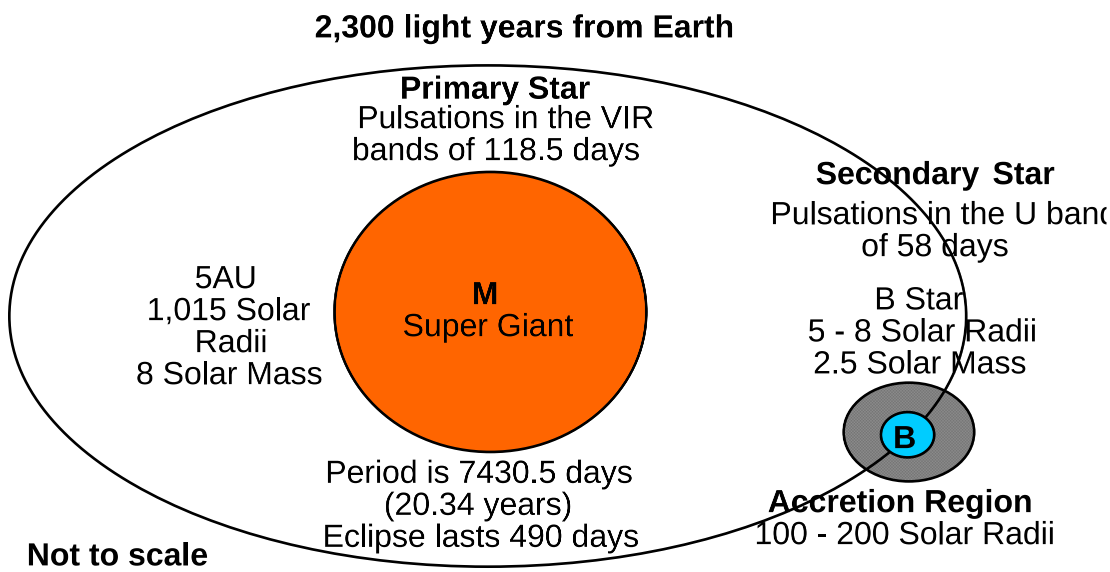


Figure 1. VV Cephei Star System Schematic

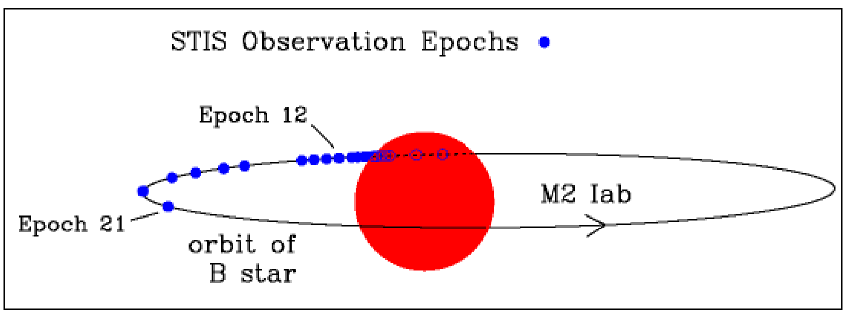


Figure 2a. VV Cephei Star System, SITS Observations

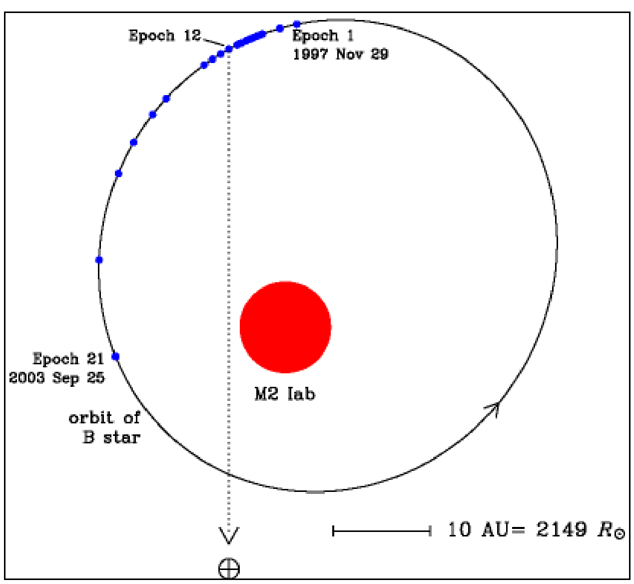


Figure 2b. VV Cephei Star System – Orbital Plane, SITS Observations

Figures 2a and 2b show the orbit of VV Cephei to scale from the Wright (1977) [1] positions of the B star at different epochs as derived from observations with the Hubble Space Telescope's Space telescope Imaging Spectrograph (HST/STIS) by Bennett and Bauer [5].

2. Hopkins Phoenix Observatory Photometry

2. 1. Equipment

UBV band photometry uses an HPO photon counting photometer with a 1P21 photomultiplier tube with standard filters and 8" Celestron C-8 telescope (see Figure 2). The C-8 has been adapted to a Meade LX-90 fork mount. The photometric system has been calibrated using standard stars.

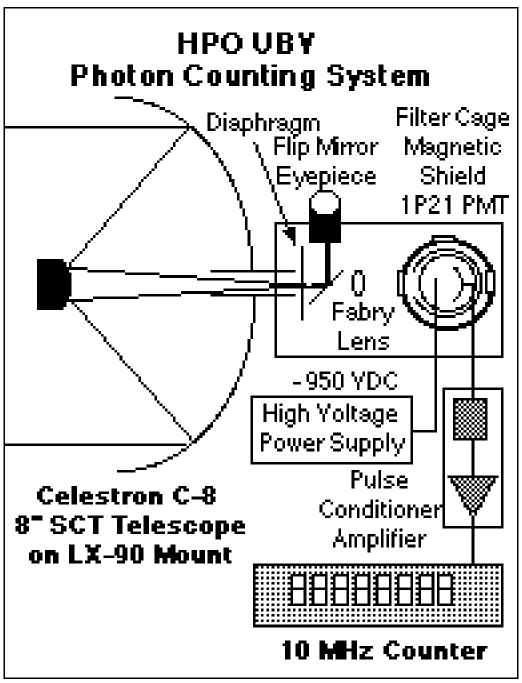


Figure 2 HPO UBV System Block Diagram

3. Hopkins Phoenix Observatory Observations

The Hopkins Phoenix Observatory (latitude 33.48 degrees North, longitude 112.22 degrees West. Altitude 1,097 feet ASL) has been obtaining UBV data of VV Cephei starting late summer of 2005.

Figure 3. Hopkins Observatory UBV Equipment

Typical observations of a star consisted of 3-10 second readings of each star (star + sky) in each band followed by 1-10 second reading of the sky in each band. Observations were made using differential photometry with the sequence of comparison, program, comparison, program, comparison, program, comparison and check star as the last star measured.

Initial data reduction adjusts for dead time for the photon counting data and adjusts for counts per second. The three star observations for each band are averaged and sky readings subtracted. The air mass of the observation is also calculated. The air mass for the middle observation was used as the air mass for the final data point.

Data were then transferred into another program to calculate magnitudes and adjust for extinction and color coefficients. Three differential values were then calculated referenced to the comparison star. The results were then normalized to the comparison star's published value. The three readings were averaged and a standard deviation determined as an indication of the data spread. Typical UBV data have standard deviations of better than 0.01 magnitudes and often approach 0.001 magnitudes.

Observing season for VV Cephei at the latitude of the Hopkins Phoenix Observatory begins in the spring and runs through January. However, because of the extreme weather in the summer in Phoenix, Arizona, observations are limited due both to seasonal storm activity and observatory temperatures that can exceed 100 degrees F at midnight.

4. Data

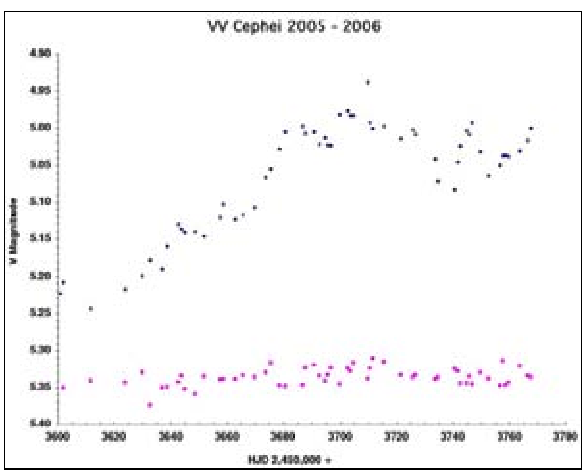
The comparison star used was 20 Cephei (HR8426) using the assumed magnitudes of U=8.46, B=6.68, and V=5.27.

The check star used was 19 Cephei (HR8428). Observational data for August 2005 through January 2006 are shown in the table below.

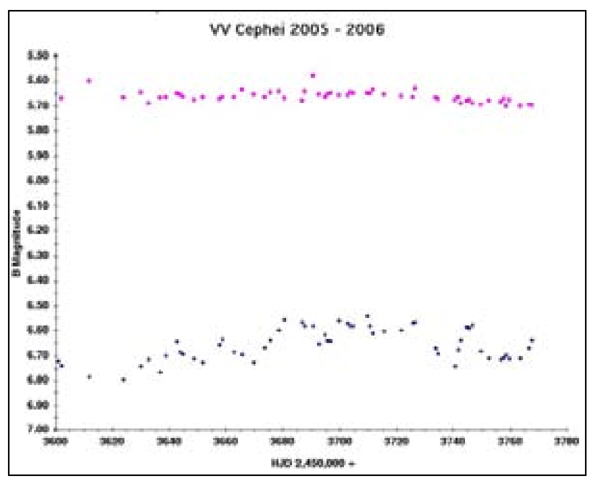
HJD	X	V	#	SD	B	#	SD	U	#	SD
January 2006										
2453767.59	1.8497	5.000	3	.006	6.637	3	.0077	7.088	3	.007
2453766.59	1.8021	5.016	3	.003	6.669	3	.0133	7.170	3	.030
2453763.59	1.7433	5.030	3	.004	6.712	3	.0182	7.222	3	.002
2453759.58	1.6629	5.039	3	.001	6.714	3	.0105	7.228	3	.013
2453758.58	1.6463	5.037	3	.005	6.698	3	.0041	7.181	3	.012
2453757.60	1.7032	5.038	3	.013	6.708	3	.0180	7.216	3	.013
2453756.58	1.5834	5.050	3	.009	6.717	3	.0037	7.191	3	.006
2453752.59	1.5882	5.063	3	.040	6.711	3	.0338	7.110	3	.050
2453749.57	1.4464	5.032	3	.004	6.681	3	.0429	7.107	3	.077
2453746.57	1.4219	4.992	3	.011	6.578	3	.0096	7.027	3	.001
2453745.58	1.4303	5.008	3	.009	6.589	3	.0061	7.025	3	.012
2453744.60	1.5121	5.003	3	.012	6.585	3	.0072	6.990	3	.020
2453742.59	1.4336	5.024	3	.003	6.637	3	.0033	7.016	3	.038
2453741.61	1.5435	5.046	3	.007	6.676	3	.0100	7.099	3	.005
2453740.56	1.3324	5.082	3	.007	6.742	3	.0140	7.161	3	.010
December 2005										
2453734.57	1.3074	5.072	3	.029	6.692	3	.0060	7.089	3	.009
2453733.56	1.2774	5.042	3	.013	6.670	3	.0108	7.023	3	.006
2453726.56	1.2276	5.008	3	.004	6.566	3	.0128	6.847	3	.049
2453725.60	1.3324	5.002	3	.018	6.568	3	.0116	6.905	3	.020
2453721.58	1.2551	5.015	3	.005	6.598	3	.0073	6.992	3	.005
2453715.55	1.1826	4.997	3	.004	6.602	3	.0035	6.976	3	.004
2453711.56	1.1742	5.001	3	.003	6.610	3	.0029	6.974	3	.006
2453710.56	1.1730	4.992	3	.007	6.579	3	.0187	6.957	3	.017
2453709.56	1.1708	4.938	3	.027	6.541	3	.0143	6.913	3	.015
November 2005										
2453704.56	1.1611	4.983	3	.002	6.579	3	.0076	6.934	3	.007
2453703.56	1.1615	4.983	3	.003	6.580	3	.0047	6.941	3	.004
2453702.62	1.2259	4.977	3	.002	6.570	3	.0023	6.937	3	.001
2453699.59	1.1759	4.982	3	.004	6.561	3	.0019	6.952	3	.011
2453696.56	1.1559	5.023	3	.016	6.641	3	.0208	7.052	3	.050
2453695.61	1.1807	5.022	3	.003	6.639	3	.0077	7.008	3	.008
2453694.62	1.1950	5.013	3	.003	6.618	3	.0055	6.968	3	.014
2453692.55	1.1567	5.021	3	.007	6.652	3	.0071	7.011	3	.007
2453690.59	1.1611	5.005	3	.002	6.579	3	.0204	6.873	3	.023
2453687.59	1.1573	5.007	3	.010	6.579	3	.0082	6.859	3	.008
2453686.63	1.1804	4.997	3	.008	6.564	3	.0057	6.839	3	.004
2453680.61	1.1572	5.005	3	.002	6.556	3	.0021	6.819	3	.005
2453678.64	1.1673	5.028	3	.004	6.597	3	.0079	6.873	3	.007

HJD	X	V	#	SD	B	#	SD	U	#	SD
October 2005										
2453675.66	1.1763	5.055	3	.008	6.636	3	.0061	6.966	3	.012
2453673.67	1.1878	5.067	3	.006	6.666	3	.0029	7.018	3	.012
2453669.67	1.1772	5.107	3	.006	6.727	3	.0070	7.070	3	.008
2453665.72	1.2303	5.117	3	.008	6.695	3	.0198	7.023	3	.009
2453662.71	1.2007	5.123	3	.004	6.686	3	.0103	6.940	3	.019
2453658.73	1.2049	5.103	3	.001	6.635	3	.0062	6.956	3	.019
2453657.71	1.1826	5.121	3	.008	6.656	3	.0085	6.947	3	.006
2453651.72	1.1780	5.147	3	.001	6.729	3	.0092	7.034	3	.008
2453648.74	1.1876	5.140	3	.011	6.714	3	.0104	6.963	3	.010
September 2005										
2453644.74	1.1797	5.141	3	.006	6.694	3	.0113	6.942	3	.005
2453643.76	1.1903	5.137	3	.005	6.686	3	.0069	6.917	3	.018
2453642.76	1.1964	5.130	3	.002	6.643	3	.0043	6.869	3	.003
2453638.78	1.2094	5.158	3	.006	6.701	3	.0023	6.946	3	.003
2453636.76	1.1780	5.190	3	.002	6.765	3	.0025	7.042	3	.006
2453632.77	1.1762	5.178	3	.003	6.717	3	.0129	6.960	3	.010
2453629.80	1.2010	5.199	3	.005	6.743	3	.0074	6.925	3	.008
2453623.78	1.1638	5.217	3	.008	6.798	3	.0481	7.122	3	.012
August 2005										
2453611.80	1.1590	5.243	3	.008	6.785	3	.0172	7.110	3	.005
2453601.93	1.3019	5.208	3	.012	6.741	3	.0043	6.922	3	.026
2453600.94		5.223	1		6.720	1		6.976	1	

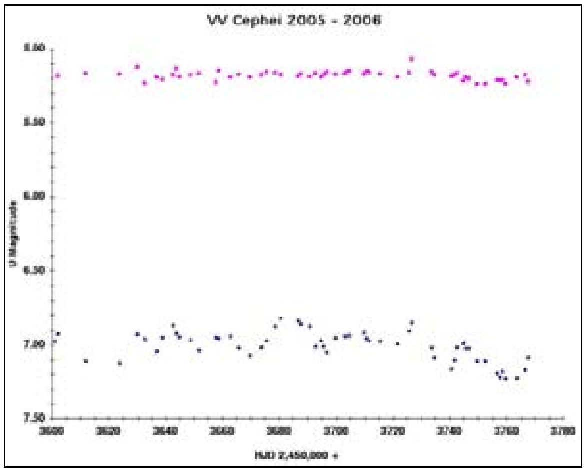
5. Light curves (2005- 2006)



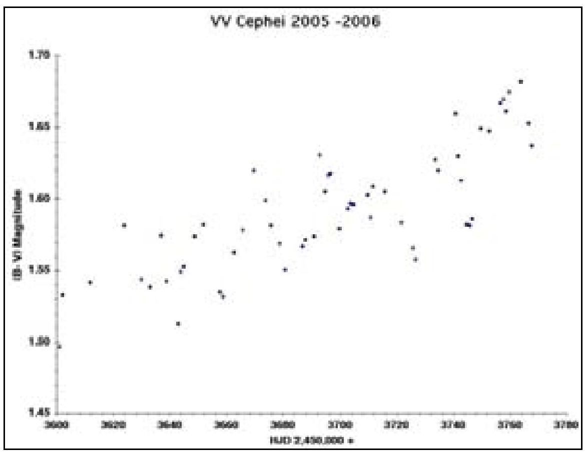
V Magnitudes of VV Cephei (upper plot) and Check Star 19 Cephei (lower plot)



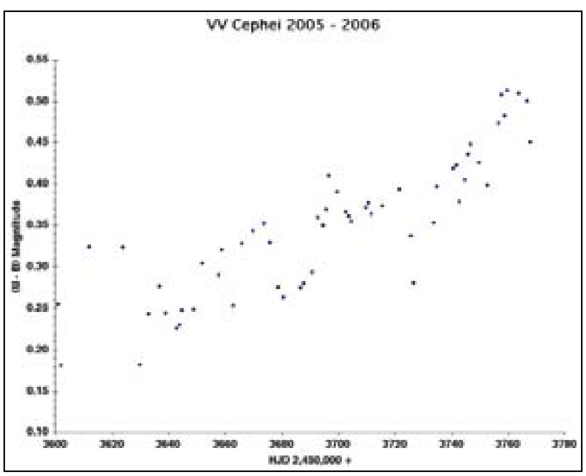
B Magnitudes of VV Cephei (lower plot) and Check Star 19 Cephei (upper plot)



U Magnitudes of VV Cephei (lower plot) and Check Star 19 Cephei (upper plot)



(B - V) Magnitudes of VV Cephei



(U - B) Magnitudes of VV Cephei

6. Conclusions

UBV observations show variations in each band. V data shows an increasing trend of close to 0.3 magnitudes (5.24 to 4.94) and smaller variations of up to 0.1 magnitude (5.08 – 4.99). B variations of around 0.24 magnitudes (6.80 to 6.56) can be seen with a peak near JD 2,453,710. U variations of 0.41 magnitude (7.23 to 6.82) can be seen with a minimum around JD 3,453,760. B-V shows an increase value of 0.18 (1.50 to 1.68) during the observing season. U-B shows a similar increasing value of 0.33 (0.18 to 0.51).

No definite information about a secondary eclipse can be gleaned from the data.

More observations are planned for the next observing season. It may take several seasons to provide sufficient data to determine the precise periods of the variations.

7. References

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