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**THE PULSATION FREQUENCIES OF  $\beta$  CMa**

$\beta$  CMa is one of the brightest  $\beta$  Cep stars in the sky. As such, it is a difficult object to observe without the use of neutral density filters or other techniques of preventing saturation of the photomultiplier. This perhaps explains why there are no photometric observations since those of Shobbrook (1973).

$\beta$  CMa is the second brightest object in the sky in the spectral range 500 - 700 Å (the brightest being  $\epsilon$  CMa). Observations of  $\epsilon$  CMa in the EUV are presented by Cassinelli et al. (1995); results of observations of  $\beta$  CMa in the EUV by the same group are in press. It turns out that there are several anomalies regarding the continuum of  $\beta$  CMa at these short wavelengths. It is possible that this may have something to do with the re-distribution of pulsational energy. The link between the EUV excess and pulsation is being studied further by Cassinelli and co-workers. Since the EUV and the optical portions of the spectrum form at different heights in the atmosphere, it is important to obtain contemporaneous optical photometry for the star.

Strömgren *uvby* photometry of  $\beta$  CMa was obtained in 1996 January 2 – 15 using the 0.5-m reflector of the SAAO. A total of 106 data points in all four colours was obtained. A 2.5 mag neutral density filter was employed. As comparison stars we used the nearby B-type stars HR 2266 and HR 2271. These were observed without neutral density filters to maximise the signal. The ND filter was calibrated by observing one of these stars with and without the filter through each of the four bands. In addition, we included in the analysis 40 *uvby* measurements made with the same telescope and equipment in 1987 November 5 – 15. The same comparison stars were used.

A periodogram of the 1987 data shows the main pulsation at  $f_2 = 3.99$  cycles d<sup>-1</sup> having a semi-amplitude of  $11.0 \pm 1.2$  mmag. There is no sign of additional periods in our data with semi-amplitudes in excess of 3.5 mmag. The results for the 1996 data are the same: there is a strong peak in the periodogram at  $f_2 = 3.98$  d<sup>-1</sup>, but nothing further with a semi-amplitude in excess of 3 mmag. The periodograms of the *b* data for the two seasons are shown in Fig. 1. Shobbrook (1973) obtains the following frequencies and semi-amplitudes:  $f_2 = 3.979331(\pm 5)$ ,  $A_2 = 10.5$ ;  $f_1 = 3.9995(\pm 6)$ ,  $A_1 = 2.2$ ;  $f_3 = 4.1834(\pm 7)$ ,  $A_3 = 1.5$  (cycles d<sup>-1</sup> and mmag respectively). The time span within our two separate runs is too short to resolve  $f_1$  and  $f_2$ , but is sufficient to resolve  $f_3$ . Evidently, our observations are of too short a duration to reduce the noise level to a point where  $f_1$  and  $f_3$  become visible.

The frequency of  $f_2$  determined by Shobbrook (1973) fits the combined data from 1987 and 1996 very well if the frequency is revised slightly to  $f_2 = 3.979326$  d<sup>-1</sup>. We obtain the following ephemeris for maximum light in all four colours (there is no appreciable phase shift between any two colours):  $T_{max} = JD\ 2450000.0591 + 0^d2512988E$ . The following semi-amplitudes are obtained (in mmag):  $A_y = 8.8 \pm 0.7$ ;  $A_b = 10.3 \pm 0.8$ ;  $A_v = 11.2 \pm 0.9$ ;  $A_u = 23.4 \pm 2.9$ . There is a very large increase in amplitude in the *u*-band, but at the

Table 1. Strömgren photometry of  $\beta$  CMa

	HJD	<i>V</i>	<i>b</i>	<i>v</i>	<i>u</i>		HJD	<i>V</i>	<i>b</i>	<i>v</i>	<i>u</i>
	2447104.3852	1.991	1.878	1.849	1.813		2447114.5511	1.993	1.887	1.863	1.822
	2447104.4252	1.997	1.880	1.854	1.827		2447114.5695	1.989	1.883	1.858	1.817
	2447104.4597	1.997	1.893	1.868	1.821		2447114.5874	1.982	1.888	1.859	1.814
	2447104.4965	1.992	1.885	1.866	1.812		2450085.3337	1.994	1.908	1.881	1.740
	2447104.5513	1.981	1.874	1.853	1.797		2450085.3666	2.002	1.907	1.885	1.736
	2447104.5815	1.982	1.873	1.847	1.800		2450085.4016	1.999	1.905	1.890	1.758
	2447104.5985	1.970	1.874	1.848	1.798		2450085.4350	1.995	1.897	1.878	1.745
	2447105.4095	1.984	1.886	1.869	1.823		2450085.4676	1.989	1.895	1.872	1.738
	2447105.4336	1.994	1.895	1.864	1.810		2450086.3619	1.999	1.907	1.895	1.780
	2447105.4728	1.988	1.893	1.873	1.821		2450086.3895	1.994	1.900	1.879	1.767
	2447106.3517	2.013	1.863	1.847	1.807		2450086.4642	1.980	1.888	1.865	1.731
	2447106.3907	1.973	1.875	1.864	1.831		2450086.4885	1.988	1.890	1.869	1.741
	2447107.3600	1.982	1.861	1.836	1.829		2450086.5121	1.978	1.889	1.859	1.727
	2447107.3851	1.985	1.864	1.856	1.806		2450086.5387	1.988	1.894	1.867	1.708
	2447107.4094	1.988	1.868	1.857	1.804		2450086.5758	2.007	1.915	1.883	1.683
	2447107.4376	1.989	1.883	1.865	1.823		2450087.4432	2.002	1.912	1.897	1.759
	2447107.4621	1.996	1.898	1.866	1.822		2450087.4677	1.983	1.886	1.867	1.722
	2447107.4902	1.999	1.896	1.873	1.829		2450087.4891	1.981	1.889	1.861	1.739
	2447107.5163	1.997	1.885	1.869	1.823		2450087.5298	1.974	1.881	1.863	1.688
	2447107.5446	1.988	1.885	1.859	1.821		2450087.5618	1.996	1.901	1.893	1.711
	2447107.5699	1.984	1.876	1.855	1.808		2450088.3642	1.990	1.897	1.870	1.771
	2447107.6046	1.973	1.878	1.851	1.796		2450088.3877	1.998	1.905	1.880	1.743
	2447113.3505	2.013	1.858	1.833	1.814		2450088.4105	1.996	1.901	1.885	1.734
	2447113.3765	1.978	1.876	1.853	1.810		2450088.4319	1.992	1.906	1.877	1.754
	2447113.4013	1.982	1.876	1.865	1.804		2450088.4540	2.011	1.912	1.887	1.767
	2447113.4278	1.979	1.875	1.853	1.796		2450088.4760	1.986	1.891	1.868	1.735
	2447113.4530	1.995	1.879	1.855	1.813		2450088.4965	1.986	1.888	1.861	1.732
	2447113.4788	1.997	1.887	1.863	1.815		2450088.5191	1.996	1.895	1.862	1.716
	2447113.5031	1.999	1.897	1.866	1.820		2450088.5406	1.990	1.892	1.863	1.701
	2447113.5269	1.999	1.888	1.869	1.818		2450088.5572	1.988	1.890	1.866	1.703
	2447113.5501	1.992	1.886	1.869	1.815		2450088.5731	1.999	1.901	1.871	1.683
	2447114.3537	1.968	1.880	1.851	1.826		2450089.2962	1.973	1.883	1.857	1.681
	2447114.3765	1.983	1.878	1.850	1.812		2450089.3157	1.984	1.895	1.862	1.681
	2447114.3997	1.972	1.880	1.850	1.800		2450089.3418	1.992	1.895	1.862	1.714
	2447114.4236	1.990	1.885	1.857	1.813		2450089.4320	2.000	1.903	1.877	1.747
	2447114.4474	2.007	1.891	1.859	1.822		2450089.4701	1.995	1.894	1.866	1.699
	2447114.5327	1.999	1.886	1.867	1.826		2450089.4932	1.991	1.892	1.864	1.703

Table 1 (continued)

HJD	<i>V</i>	<i>b</i>	<i>v</i>	<i>u</i>	HJD	<i>V</i>	<i>b</i>	<i>v</i>	<i>u</i>
2450089.5146	1.990	1.892	1.858	1.673	2450095.3130	1.981	1.883	1.857	1.679
2450089.5306	1.987	1.884	1.850	1.655	2450095.3339	1.984	1.889	1.865	1.711
2450089.5441	1.977	1.871	1.850	1.654	2450095.3828	1.999	1.896	1.873	1.736
2450089.5577	1.984	1.890	1.859	1.678	2450095.4033	2.007	1.905	1.879	1.734
2450090.2922	1.972	1.873	1.854	1.665	2450096.3565	1.988	1.889	1.866	1.743
2450090.3135	1.988	1.889	1.869	1.707	2450096.3830	1.997	1.907	1.880	1.752
2450090.3362	1.995	1.899	1.870	1.698	2450096.4089	2.002	1.907	1.883	1.748
2450090.3593	2.000	1.904	1.871	1.720	2450096.4682	1.992	1.903	1.876	1.736
2450090.3788	2.002	1.902	1.879	1.720	2450096.4907	1.989	1.888	1.871	1.714
2450090.4074	2.003	1.902	1.871	1.753	2450096.5097	1.985	1.885	1.864	1.689
2450090.4350	2.002	1.900	1.867	1.743	2450096.5234	1.982	1.881	1.860	1.693
2450090.4543	1.995	1.895	1.864	1.700	2450096.5401	1.984	1.882	1.859	1.660
2450090.4722	1.996	1.891	1.850	1.714	2450096.5573	1.994	1.882	1.866	1.667
2450090.4921	1.991	1.890	1.855	1.685	2450097.3112	1.976	1.886	1.859	1.734
2450090.5177	1.990	1.885	1.847	1.681	2450097.3584	1.986	1.898	1.873	1.670
2450090.5333	1.988	1.884	1.845	1.664	2450097.3826	1.996	1.899	1.875	1.740
2450090.5457	1.991	1.876	1.850	1.654	2450097.4060	1.997	1.914	1.887	1.752
2450090.5591	1.988	1.872	1.854	1.653	2450097.4679	1.992	1.901	1.867	1.720
2450090.5761	1.994	1.889	1.872	1.647	2450097.4929	1.998	1.899	1.860	1.726
2450091.3059	1.981	1.881	1.854	1.706	2450097.5171	1.994	1.896	1.863	1.705
2450091.3676	1.999	1.909	1.877	1.732	2450097.5322	1.981	1.887	1.853	1.662
2450091.4199	2.005	1.902	1.868	1.725	2450097.5459	1.990	1.923	1.893	1.740
2450091.4449	1.998	1.897	1.862	1.693	2450098.3078	1.970	1.882	1.867	1.728
2450091.4732	1.993	1.896	1.859	1.706	2450098.3256	1.976	1.881	1.857	1.721
2450091.5027	1.986	1.888	1.852	1.684	2450098.3427	1.981	1.893	1.864	1.720
2450091.5235	1.997	1.892	1.857	1.644	2450098.3603	1.987	1.891	1.867	1.726
2450091.5362	1.993	1.888	1.852	1.666	2450098.3803	1.989	1.892	1.872	1.738
2450091.5540	1.989	1.883	1.853	1.658	2450098.4006	1.997	1.902	1.880	1.760
2450091.5713	1.995	1.901	1.855	1.638	2450098.4237	2.003	1.905	1.880	1.753
2450092.4729	2.001	1.897	1.868	1.732	2450098.4440	2.001	1.906	1.882	1.764
2450092.5187	1.995	1.889	1.865	1.705	2450098.4640	2.003	1.907	1.880	1.705
2450092.5595	1.992	1.891	1.862	1.649	2450098.4845	1.997	1.901	1.876	1.718
2450093.4104	2.003	1.912	1.887	1.731	2450098.5037	1.996	1.895	1.855	1.682
2450093.4597	2.008	1.915	1.891	1.759	2450098.5250	1.989	1.891	1.856	1.666
2450093.4969	1.988	1.894	1.863	1.695	2450098.5485	1.984	1.887	1.855	1.692
2450093.5530	1.988	1.885	1.853	1.670					

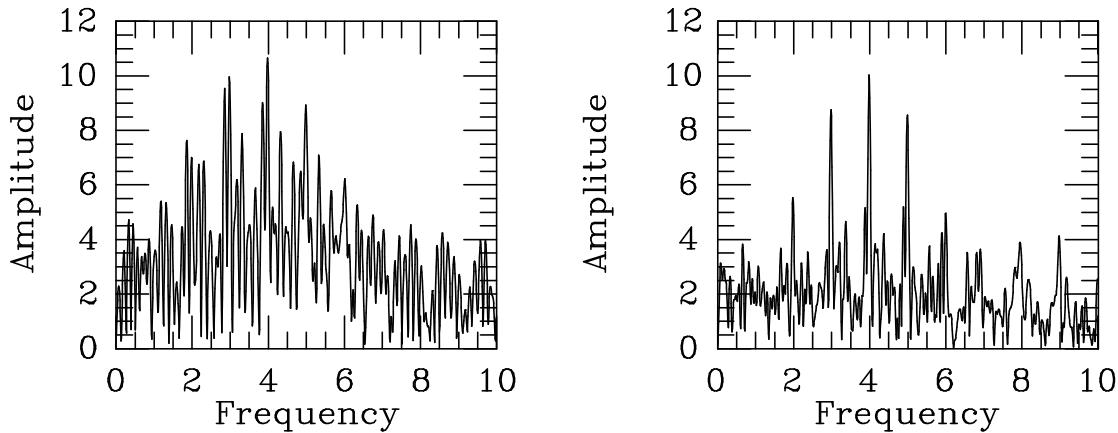


Figure 1. Periodograms of the  $b$  data for  $\beta$  CMa. Left panel: the 1987 data; right panel: the 1996 data. The frequency is in cycles  $d^{-1}$  and the amplitude in mmag.

same time the photometric accuracy is much worse owing to the poor properties of the ND filter.

One can also adopt the three periods as known components and attempt to fit the combined 1987 and 1996 data with these periods. In that case we find semi-amplitudes of 1 – 2 mmag for  $f_1$  and  $f_3$  in the  $y$ ,  $b$  and  $v$  bands. However, the amplitude of  $f_1$  increases to 20.6 mmag in  $u$  and is in fact larger than  $f_2$  (16.7 mmag). Because  $f_1$  and  $f_2$  are not resolved in either of the two seasons, we view this result with suspicion. It is possible that the large rise in amplitude of  $f_2$  in the  $u$ -band may not be entirely real, but could be aided by an even steeper rise in the unresolved component  $f_1$ . It is interesting to note that while  $f_2$  has a much larger amplitude than  $f_1$  in optical photometry, the two have comparable radial velocity amplitudes (Kubiak 1980).

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