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LIGHT VARIABILITY OF THE HELIUM-STRONG STAR HD 96446

HD 96446 [V = 6.68, B-V = -0.16, U-B = -0.87, sp. B1IVp - B2Vp (Hoffleit and Jaschek 1982)] was first recognized as a helium-strong star by Jaschek and Jaschek (1959). Its spectrum indicates that helium is roughly equal in number abundance to hydrogen and oxygen is deficient by a factor of ~13, while other metal abundances appear normal (Wolf 1973).

We had included HD 96446 in a list of 7 candidates to search for β Cephei variables among the He-strong stars (see Matthews and Bohlender 1988) during an observing run at the Las Campanas Observatory in March 1987. Because much of the observing time was instead devoted to studying the recently discovered SN 1987, and additional time was lost to nonphotometric weather, only HD 96446 was observed often enough to produce meaningful results. The presence of variations at β Cephei timescales cannot be established from our data alone. The observations *do*, however, clearly demonstrate that HD 96446 is a broadband light variable. We have used these data to address the question of this star's rotation period.

Measurements were obtained by J.M.M. during UT 19 - 22 March 1987 with the 0.6-m telescope of the University of Toronto located on Las Campanas, Chile, using a photometer equipped with an S25 phototube and UBV filter set. In addition to the programme star HD 96446, a comparison star [HR 4342: V = 6.87, B-V = -0.09, U-B = -0.44, sp. B7III] and a check star [HR 4361: V = 5.73, B-V = -0.12, U-B = -0.71, sp. B3] (Hoffleit and Jaschek 1982) were also monitored. The standard observing routine was: HD 96446, sky, HR 4342, sky, HD 96446, sky, HR 4361, sky, HD 96446, sky, (repeat). For each star, 30-second integrations through U, B, and V filters were recorded in sequence.

TABLE I.
Differential photometry of HD 96446

HJD (2446800+)	V	B	U
HD 96446 - HR 4342			
73.78011	-0.310	-	-0.784
73.78761	-0.319	-0.361	-0.801
73.79483	-0.319	-	-
73.80808	-0.312	-0.360	-
73.81650	-0.313	-0.365	-0.785
73.82267	-0.311	-0.347	-0.784
73.83525	-0.309	-0.350	-0.777
73.84744	-0.311	-	-0.772
73.85389	-0.314	-0.347	-0.775
73.85994	-0.310	-0.354	-0.779
73.86575	-0.313	-0.352	-0.779
73.87628	-0.311	-	-0.775
73.88273	-0.310	-0.354	-0.784
73.88833	-0.318	-0.343	-0.775
74.67382	-0.320	-0.364	-
74.68134	-0.319	-0.363	-
74.68764	-0.321	-0.367	-
74.70911	-0.320	-0.364	-0.793
74.71515	-0.315	-0.365	-0.799
74.72122	-0.313	-0.365	-0.797
74.75543	-0.316	-0.359	-0.791
74.76110	-0.320	-0.367	-0.804
74.76690	-0.315	-0.356	-0.798
74.78460	-0.321	-0.367	-0.801
74.79134	-0.316	-0.362	-0.796
74.79684	-0.315	-0.359	-0.797
74.80199	-0.314	-0.355	-0.790
74.80801	-0.317	-0.353	-0.789
75.77596	-0.307	-0.350	-0.792
75.77753	-0.307	-0.351	-0.790
75.78607	-0.305	-0.351	-0.790
75.79278	-0.309	-0.348	-0.783
75.80291	-0.309	-0.359	-0.791
75.80923	-0.305	-0.352	-0.786
75.81551	-0.306	-0.360	-0.791
75.82175	-0.299	-0.356	-0.786
75.83845	-0.298	-0.344	-0.772
75.84406	-0.296	-0.342	-0.778
75.85232	-0.301	-0.342	-0.778
75.85850	-0.303	-0.344	-0.776
75.87151	-0.295	-0.341	-0.772
75.87781	-0.298	-0.343	-0.785
76.80495	-0.297	-0.344	-0.780
76.81127	-0.293	-0.345	-0.773
76.81731	-0.292	-0.337	-0.776
76.82756	-0.296	-0.344	-0.783
76.84217	-0.293	-0.343	-0.760
76.84773	-0.290	-0.331	-0.762
76.85364	-0.296	-0.331	-0.767
76.85967	-0.295	-0.338	-0.775
76.86813	-0.290	-0.338	-
HR 4342 - HR 4361			
73.78398	1.188	1.161	-
73.81253	1.183	1.158	1.428
73.83818	1.189	1.165	1.421
73.85676	1.188	1.167	1.430
73.87946	1.192	1.165	1.430
74.67794	1.188	1.159	1.434
74.71204	1.186	1.166	1.424
74.75816	1.186	1.163	1.421
74.78831	1.185	1.163	1.424
74.80447	1.185	1.162	1.419
75.78131	1.188	1.166	1.428
75.80636	1.190	1.171	1.435
75.81875	1.182	1.169	1.425
75.83563	-	1.164	1.426
75.84918	1.184	1.163	-
75.87449	1.185	1.171	1.427
76.80851	1.186	1.171	1.429
76.82487	1.188	1.165	1.434
76.83862	1.186	1.163	1.426
76.85052	1.188	1.165	1.425
76.86431	1.185	1.165	1.431

Figure 2.

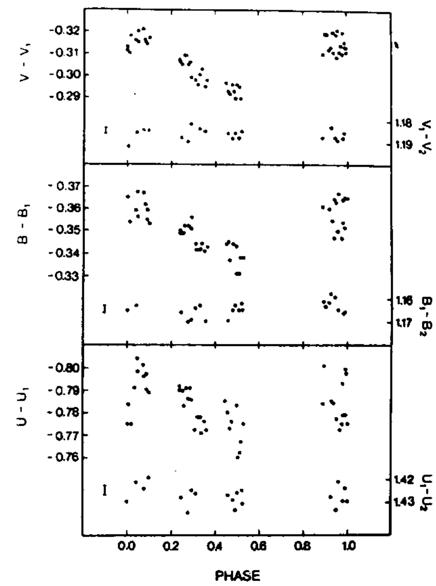
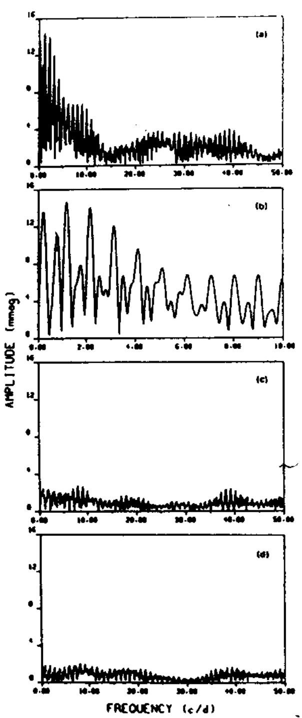


Figure 1.



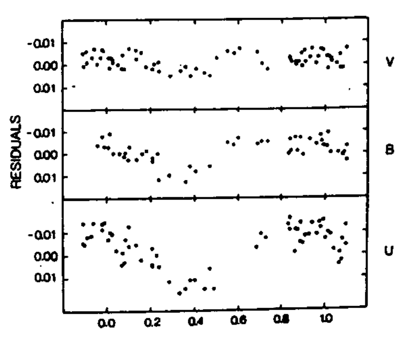


Figure 3.

The raw counts were corrected for coincidence-counting ("dead time") effects and sky background, and converted into instrumental magnitudes. The comparison and check star values were plotted against air mass to derive local extinction coefficients, which were then used to correct the magnitudes for mean air mass extinction. Finally, interpolated values of the comparison and check star magnitudes were determined to produce the differences (HD 96446 - HR 4342) and (HR 4342 - HR 4361) in the three bandpasses. These data are listed in Table I.

There is no indication of variability in HR 4342 or HR 4361; the standard deviations of the magnitude differences are $\sigma_V = 0^m.0025$, $\sigma_B = 0^m.0032$ and $\sigma_U = 0^m.0044$. The larger scatter in U is expected, since sky stability usually worsens at shorter wavelengths.

To search for periodicities in the data, the measurements of HD 96446 were analysed using a Fourier periodogram routine for unequally spaced time series (Matthews and Wehlau 1985). A Fourier amplitude spectrum of the differential V data, spanning the frequency range 0 - 50 d^{-1}, is shown in Figure 1*a*; the range 0 - 10 d^{-1} is reproduced at a larger scale in Figure 1*b*. The largest peak is centred at a frequency of $\nu_1 = 1.178 \pm 0.001$ d^{-1}, corresponding to a period of $P_1 = 0.8490 \pm 0.0007$ d. This peak is accompanied by an extended comb of 1 d^{-1} aliases, including alias peaks "reflected" about zero frequency.

The UBV measurements are displayed in Figure 2, folded at the 0.8490 d period. Both the programme-comparison and comparison-check differences are plotted. The variability of HD 96446 is obvious from these phase diagrams. When a sinusoid of period 0.8490 d and amplitude $0^m.011$ is removed from the V data of Figure 2*a*, the periodogram of the residuals (Figure 1*c*) shows no signs of additional variations with amplitudes much greater than the observational scatter. There are indications of power - suggested by 1 d^{-1} aliasing patterns just barely rising above the noise - at frequencies of 8.047 and 39.219 d^{-1}. We will return to these shortly. The ± 1 d^{-1} aliases of the 0.8490-d periods (at periods of 5.6225 and 0.4592 d) are also possible solutions to the data, although the residual Fourier spectra and fits to the phase diagrams are noticeably worse.

Even though the 0.8490-d period accounts well for the V variations, it is apparent from Figures 2*b* and *c* that the scatter of the B and particularly the U measurements about such a sinusoid exceeds that indicated by the (comparison - check) star data. When a sinusoid of period 0.8490 d and amplitude $0^m_.012$ is subtracted from the U data, frequency analysis of the residuals shows evidence for periodicity with a timescale between roughly 0.25 - 0.35 d and a peak-to-peak amplitude in U of $0^m_.02$. A phase diagram of the best fit to the residuals, at a period of $P_2 = 0.2570$ d is shown in Figure 3. (We note that when a sinusoid of this period and an amplitude of only $0^m_.0025$ is filtered from the V residuals, the two possible aliasing patterns - centred near $P_2/2$ and $P_2/10$ - are no longer obvious in the periodogram (Figure 1*d*).)

We believe this may indicate variability in HD 96446 comparable to that seen in the β Cephei stars. Unfortunately, the strongest indicator of such short-term variations in our data is the U residual curve. Although the (comparison - check) U values are well-behaved, the U transparency of the atmosphere is notoriously unreliable even at good sites. Therefore, we must await more extensive photometric (and hopefully corroborating radial velocity measurements) to confirm if these variations are indeed real.

Many of the He-strong stars exhibit photometric variations which are believed to correspond to their rotation periods, in the context of the oblique rotator model. Well-determined periods are available for at least 9 He-strong stars (Hunger 1986; Bohlender *et al*. 1987), ranging from 0.90 to 9.53 d. The value of 0.849 d we propose for HD 96446 falls at the low end of this range; the alias period of 5.623 d is also consistent with this range. If this star is an oblique rotator, its spectroscopic variations (if any) should have the same period as the light variability.

Pedersen and Thomsen (1977) searched for periodic variability in the He I λ4026 line strength among several He-strong stars, including HD 96446. They obtained 21 observations of this star from which they derived a period of 23 ± 6 d. Their data show no correlation with either the 0.849107-d or the 5.623-d period, nor do any of the aliases of their period correspond to these values. It is possible that He line strength variations in this star are not linked to rotation as simply as in some other He-strong stars (Landstreet, private communication). Even so, we have some concerns about the reliability of their R index data for the purpose of period determination in the case of HD 96446. The changes they detected in this star were the smallest of any in their sample for which they claimed variability, and the amplitude was roughly the same as the standard error in each measurement.

If HD 96446 is rotating with a period of 0.849 d, we can use Wolf's (1973) estimate of the radius of the star ($R = 3.6 \pm 0.8\ R_\odot$) to derive an equatorial rotation velocity $v_{eq} \simeq 200 \pm 30$ km s^{-1}. This is consistent with the range of rotation rates determined for early BIV-V stars by Wolff *et al.* (1982). However, so too is the value $v_{eq} \simeq 33$ km s^{-1} which we find by using the 5.623-d period, if the star belongs to the subset of early B stars with slow rotation inferred by Wolff *et al.* On the other hand, Pedersen and Thomsen's period of 23 ± 6 d yields $v_{eq} \simeq 9 \pm 4$ km s^{-1}, which is exceptionally low for such a star.

Walborn (1983) has set an upper limit on the projected rotation velocity of HD 96446 at $v\sin i \leq 30$ km s^{-1}. Of the 9 He-strong stars with accurately-determined periods, six have periods less than 2 d; of these, the values of $v\sin i$ range from 170 to <30 km s^{-1}. The three remaining stars all have $v\sin i \leq 30$ km s^{-1}. Therefore, the existing sample is compatible with periods of 0.85 *or* 5.6 d and a $v\sin i$ of ≤ 30 km s^{-1}.

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References:

Bohlender, D.A., Brown, D.N., Landstreet, J.D. and Thompson, I.B.: 1987, *Ap. J.* **323**, 325.
Hoffleit, D. and Jaschek, C.: 1982, *Bright Star Catalogue, 4th Edition* (Yale).
Hunger, K.: 1986, in *Hydrogen Deficient Stars and Related Objects*, ed. K. Hunger *et al.* (Dordrecht: Reidel), p. 261.
Jaschek, M. and Jaschek, C. 1959, *Pub. A.S.P.* **71**, 465.
Matthews, J.M. and Bohlender, D.A. 1988, *Pub. A.S.P.*, submitted.
Matthews, J.M. and Wehlau, W.H.: 1985, *Pub. A.S.P.* **97**, 841.
Pedersen, H. and Thomsen, B.: 1977, *Astr. Ap. Suppl.* **30**, 11.
Walborn, N.R.: 1983, *Ap. J.* **268**, 195.
Wolf, R.E.A.: 1973, *Astr. Ap.* **26**, 127.
Wolff, S.C., Edwards, S. and Preston, G.W.: 1982, *Ap. J.* **252**, 322.