# THE PERIOD OF THE EXTREME HELIUM STAR BD+1°4381

C.S.Jeffery, P.W.Hill and K.Morrison
University Observatory
Buchanan Gardens
St Andrews
Fife KY16 9LZ
Scotland

ABSTRACT. Photometry of the variable extreme helium star BD+1°4381 is used to improve the 21.2 day period found by Jeffery & Malaney (1985). The amplitude of the light-curve appears to be variable, resembling that of RY Sgr. Variability in the extreme helium star BD-1°3438 is also reported.

## 1. INTRODUCTION

The extreme helium star BD+1°4381 was found to be variable with an amplitude of $0^{m}.04$ and a provisional period of 21.2 days by Jeffery and Malaney (1985). It was suggested that the variations were probably due to radial pulsations such as those found in the R Coronae Borealis stars (Alexander et al. 1972). This discovery is important because masses can sometimes be obtained for pulsating stars (e.g. V652 Her: Hill et al. 1981, Lynas-Gray et al. 1984). The effective temperature of the star is 9 500 K (Drilling et al. 1984) making it one of the coolest known extreme helium stars and placing it midway between the variable hot extreme helium stars (e.g. BD-9°4395: Jeffery et al. 1985) and the R CrB stars (e.g. R CrB: Fernie 1982). The discovery of a singly periodic variation in one of the extreme helium stars would enable, in time, possible period changes to be investigated and hence provide a test for theories regarding the evolutionary status of the star. Experience with determining period changes in V652 Her (Kilkenny & Lynas-Gray 1982, 1984) shows that it is important to monitor the period of the star regularly in order to avoid ambiguities. Further observations have been made to ensure these conditions are satisfied for BD+1°4381 and to search for similar variables amongst the cooler extreme helium stars.



*K. Hunger et al. (eds.), Hydrogen Deficient Stars and Related Objects, 95–100.*

## 2. OBSERVATIONS

Strömgren photometry has been carried out in 1985 with the SAAO 0.5m telescope. The observing programme contained the known variable BD+1°4381 and two new candidates, BD-1°3438 (McConnell et al. 1972) and CPD-58°2721 (Drilling 1980). The last of these is discussed in another paper (Morrison et al. 1986). BD-1°3438 was first reported as variable by Landolt (Walker & Kilkenny 1980). Data were obtained on 25 nights during a 6 week observing run, data acquisition and reduction techniques follow precisely those described by Jeffery et al. (1985).

## 3. RESULTS

### 3.1. BD+1°4381.

The light and colour curves of BD+1°4381 for the 1985 observing season are shown in Fig. 1. We note that the shape of the light curve appears to be variable, a feature also present in the light curves of the R CrB stars (Alexander et al. 1972, Fernie 1982). This introduces a difficulty when attempting to determine the period of the star. Assuming the slow variations in the light curve to be independent of the fundamental period, they were removed by applying a high-pass filter to the data. The data from both 1984 and 1985 observing seasons were combined. A single sine function was then swept over a range of periods between 15 and 30 days in order to obtain the best fit to the data. The goodness of fit was determined from a number of statistical parameters, including the multiple correlation coefficient. The data are still insufficient to determine the period unambiguously, an uncertainty of 1 cycle per year remaining in the frequency. The two best values for the period are 21.529 day and 23.026 day, for which ephemerides are given in Table I. It is now possible to determine the mean amplitudes of the light and colour variations more precisely. The amplitude of the light curve is $0^m\!.057 \pm 0^m\!.003$ and in u-b the variation is $0^m\!.015 \pm 0^m\!.002$. The variations in b-y and v-b are somewhat smaller and at $0^m\!.005 \pm 0^m\!.002$ are comparable with the scatter in the data. The maximum change in either surface gravity or effective temperature that can be produced by the observed colour changes may be estimated from model atmospheres for extreme helium stars (Heber & Schönberner 1981). Taking the reddening free colour index [u-b] (ibid), the maximum expected change in $T_{eff}$ would be 200 K, while the maximum change in log g would be 0.22.

While further photometry is necessary to resolve the period ambiguity, radial velocity measurements covering the pulsation cycle are a matter of urgency.

https://doi.org/10.1017/S0252921100090655 Published online by Cambridge University Press

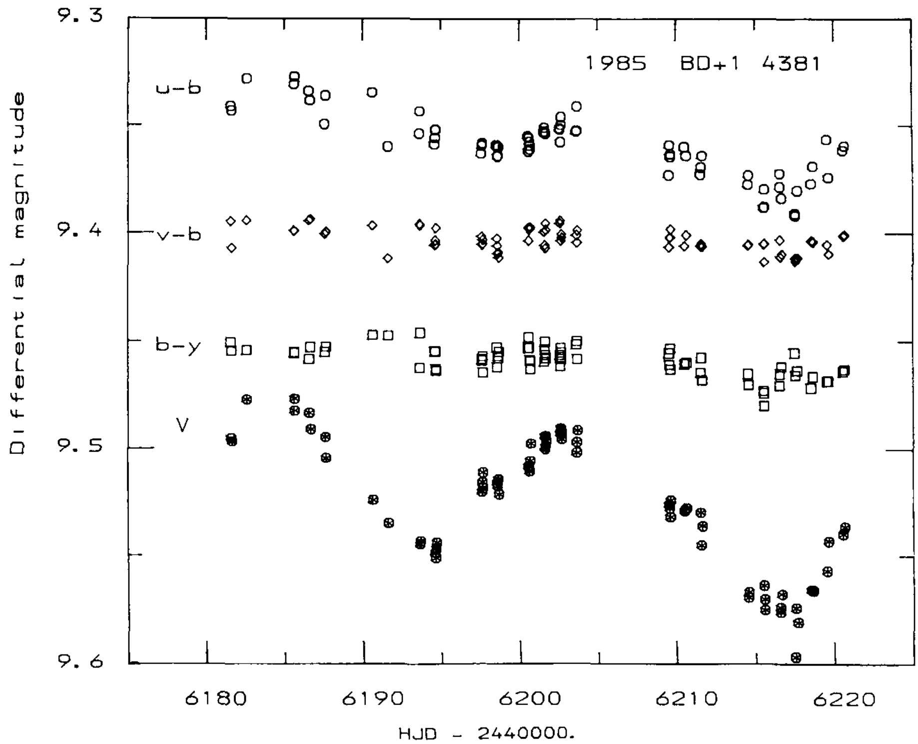


Figure 1. Differential Strömgren photometry of the extreme helium star BD+1°4381 obtained at SAAO during 1985.

TABLE I. Ephemerides for BD+1°4381.

$$V = \langle V \rangle + a \cdot \sin(2\pi(HJD - t_0) / P)$$

$\langle V \rangle = 9^m.530 \pm 0^m.001$

$a = 0^m.026 \pm 0^m.001$

| | P (day) | $t_0$ (HJD) |
|---|---|---|
| 1. | 21.529 ± 0.05* | 2445860.122 ± 0.161 |
| 2. | 23.026 ± 0.05* | 2445859.223 ± 0.168 |

* estimated from experiments with modified data samples

https://doi.org/10.1017/S0252921100090655 Published online by Cambridge University Press

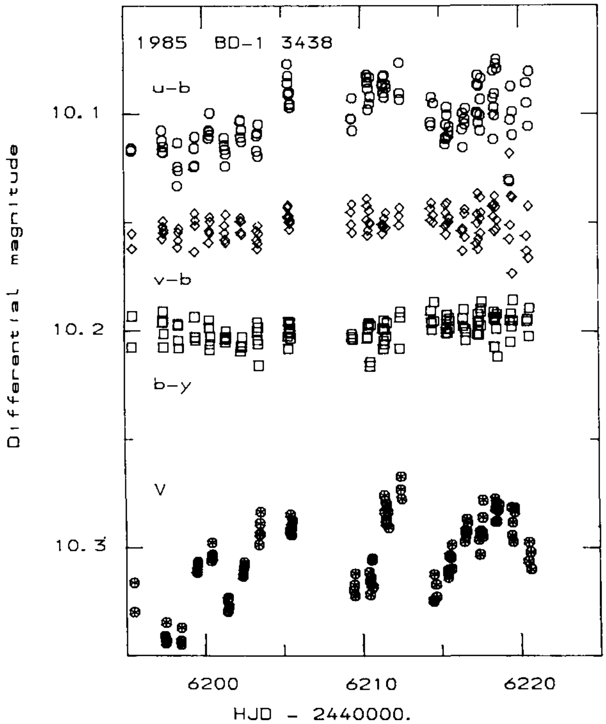


Figure 2. Differential Strömgren photometry of the extreme helium star BD-1°3438 obtained at SAAO during 1985.

### 3.2. BD-1°3438.

The light and colour curves of BD-1°3438 are shown in Fig. 2. Being nearly a magnitude fainter than BD+1°4381 the photometry was somewhat noisier, particularly when the moon was bright. Its mean magnitude and colours and those of two comparison stars were:

| | ⟨V⟩ | ⟨b-y⟩ | ⟨m1⟩ | ⟨c1⟩ | n |
|---|---|---|---|---|---|
| BD-1°3438 | 10.304 | 0.381 | 0.028 | 0.248 | 138 |
| BD-1°3435 | 7.966 | 0.152 | 0.064 | 0.940 | 138 |
| BD-0°3406 | 10.518 | 0.358 | 0.072 | 0.124 | 131 |

The star is clearly variable by $0^m_.07$ in V. Colour variations are much smaller, but appear at least to be present in (u-b). The timescale of the light variations is of the order of 5 to 8 days, with some evidence for systematic trends within a night. A frequency analysis may be premature for the number of data points in our sample, likewise it would be unwise to attempt to attribute the light variations to any particular type of stellar oscillation at this stage.

## 4. DISCUSSION

Drilling et al. (1984) derived effective temperatures for 12 extreme helium stars. These temperatures are listed in table II for those stars for which variability studies have been published. It would appear that a period - temperature sequence is emerging, which is consistent with theoretical models for pulsation in cool luminous helium stars (Wood 1976, Saio & Wheeler 1985), but theoretical studies of pulsation in hot luminous extreme helium stars have not been published. BD+1°4381 appears to represent a straightforward extension of radial pulsation in RCrB stars to higher temperatures, but the absence of confirmed variablility at temperatures between 15 000 K and 20 000 K and the mode of oscillation in the hottest extreme helium stars require further attention.

TABLE II.

| Star | | $T_{eff}$ (K) | Light curve | Period (days) |
|---|---|---|---|---|
| HD160641 | V2076 Oph | 31 900[1] | Multiperiodic | 0.7,1.1,...[4,5] |
| BD-9°4395 | | 23 000[1] | Multiperiodic | 3.5,11.2,...[6] |
| BD+10°2179 | | 17 700[1] | Not variable[7,8] | |
| HD124448 | | 15 500[1] | Suspected variable[4,9] | |
| HD168476 | PV Tel | 12 400[1] | Irregular | ?[4,10] |
| BD-1°3438 | | 10 900[1] | Irregular | 5 - 8 [11] |
| BD+1°4381 | | 9 500[1] | Periodic | 21.5[11,12] |
| | RY Sgr* | 7 100[2] | Roughly periodic | 38.6[13] |
| | R CrB* | 7 000[3] | Roughly periodic | 46[14] |

Notes:

1 Drilling et al. (1984)
2 Schönberner (1975)
3 Cottrell & Lambert (1982)
4 Walker & Kilkenny (1980)
5 Lynas-Gray et al. (1986)
6 Jeffery et al. (1985)
7 Hill et al. (1984)
8 Grauer et al. (1984)
9 Hill (1969)
10 Walker & Hill (1985)
11 This paper
12 Jeffery & Malaney (1985)
13 Kilkenny (1982)
14 Fernie (1982)

* Excluding deep RCrB-type minima

ACKNOWLEDGMENTS

The authors are grateful to the UK Panel for the Allocation of Telescope Time and to the SAAO for generous awards of observing time, to SAAO staff for assistance with the data reduction, to Mr.I.Skillen for the use of his frequency analysis program and to Dr.A.J.Adamson for assistance with the presentation.

REFERENCES

Alexander,J.B., Andrews,P.J., Catchpole,R.M., Feast,M.W., Lloyd Evans,T., Menzies,J.W., Wisse,P.N.J. & Wisse,M., 1972. *Mon.Not.R.astr.Soc.*, 158,305.
Cottrell,P.L. & Lambert,D.L., 1982. *Astrophys.J.*, 261,595.
Drilling,J.S., 1980. *Astrophys.J.*, 242,L43.
Drilling,J.S., Schönberner,D., Heber,U. & Lynas-Gray,A.E., 1984. *Astrophys.J.*, 278,224
Fernie,J.D., 1982. *Publs.astr.Soc.Pacif.*, 94,172.
Grauer,A.D., Drilling,J.S. & Schönberner,D., 1975. *Astr.Astrophys.*, 133,285.
Heber,U., & Schönberner,D., 1981. *Astr.Astrophys.*, 102,73.
Hill,P.W., 1969. *Inf.Bull.Variable Stars No.* 357.
Hill,P.W., Kilkenny,D., Schönberner,D. & Walker,H.J., 1981. *Mon.Not.R.astr.Soc.*, 197,81.
Hill,P.W., Lynas-Gray,A.E. & Kilkenny, D., 1984. *Mon.Not.R.astr.Soc.*, 207,823.
Jeffery,C.S. & Malaney,R.A., 1985. *Mon.Not.R.astr.Soc.*, 213,61p.
Jeffery,C.S., Skillen,I., Hill,P.W., Kilkenny,D., Malaney,R.A., & Morrison,K., 1985. *Mon.Not.R.astr.Soc.*, 217,710
Kilkenny,D., 1982. *Mon.Not.R.astr.Soc.*, 200,1019.
Kilkenny,D. & Lynas-Gray,A.E., 1982. *Mon.Not.R.astr.Soc.*, 198,873.
Kilkenny,D. & Lynas-Gray,A.E., 1984. *Mon.Not.R.astr.Soc.*, 208,673.
Lynas-Gray,A.E., Schönberner,D., Hill,P.W. & Heber,U., 1984. *Mon.Not.R.astr.Soc.*, 209,387.
Lynas-Gray,A.E., Kilkenny,D., Skillen,I. & Jeffery,C.S., 1986. *in 'Hydrogen-deficient stars and related objects'*, eds. K.Hunger, N.K.Rao & D.Schönberner.
MacConnell,D.J., Frye,R.L. & Bidelman,W.P., 1972. *Publs.astr.Soc.Pacif.*, 84,388.
Morrison,K., Drilling,J.S, Heber,U., Hill,P.W., & Jeffery, C.S., 1986. *in 'Hydrogen-deficient stars and related objects'*, eds. K.Hunger, N.K.Rao & D.Schönberner.
Saio,H. & Wheeler,J.C., 1985. *Astrophys.J.*, 295,38.
Schönberner,D., 1975. *Astr.Astrophys.*, 44,383.
Walker,H.J. & Hill,P.W., 1985. *Astr.Astrophys.Suppl.*, 61,303.
Walker,H.J. & Kilkenny,D., 1980. *Mon.Not.R.astr.Soc.*, 190,299.
Wood,P.R., 1976. *Mon.Not.R.astr.Soc.*, 174,531.