SEARCH FOR VARIABILITY IN HYDROGEN-POOR STARS

I: *Preliminary Results of Photoelectric Observations for Six Stars*

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(Received 22 September, 1981)

Abstract. The evolutionary status of hydrogen-poor stars is analyzed.

Photoelectric observations of six objects are reported as a first step of a long-term project devoted to search for variability of a large sample of hydrogen-poor stars.

The observed stars show phenomena of microvariability with an amplitude of the order of $0\overset{m}{.}1$ or less.

Two extreme helium stars have been examined: a period in the range of $0\overset{d}{.}162$–$0\overset{d}{.}164$ has been found for BD + 10° 2179, and $P = 0\overset{d}{.}1079962$ for BD + 13° 3324.

The mass-losing O subdwarf (sdO) BD + 37° 443 presents short-term fluctuations with a time-scale of several minutes and long-term variations on a scale of months. The 'standard' sdO BD + 75° 325 is probably non-variable, although light variations of very small amplitude ($\Delta m \simeq 0.03$) with a time-scale of about 1 hr might be present. The high gravity sdO BD + 25° 4655, which is very close to the white dwarf stage, also presents variability on a time-scale of about 13 minutes, and might be an analog of the recently discovered pulsating sdO, or 'hot' white dwarf, PG 1159–035.

The variability of the intermediate helium star HD 37776 is finally confirmed.

1. Introduction

The class of 'hydrogen-deficient stars' includes a large variety of objects distributed in many spectral types. Their classification in distinct groups can be done in different ways according to what properties of the stars are taken into account (Warner, 1967; Hack, 1967; Dinger, 1969; Hunger, 1975). However, since the only common property is of being hydrogen-deficient, "the practice of analyzing just one typical star of a subclass and then generalizing for the whole must be warned against" (Hunger, 1975). Furthermore, notice that even the concept of 'hydrogen deficiency' may be misleading: some stars may be completely hydrogen deprived. For instance the analysis of the atmospheres of 'extreme' helium stars allows one to put stringent upper limits on their hydrogen content ($n_{\rm H}/n_{\rm He} \sim 10^{-3}$ in number fractions, or even lower – Hunger, 1975). Some other stars may be so hot that hydrogen lines in the visible are not present, even if the hydrogen content is non-negligible. This may be the case of some nuclei of planetary nebulae and of some sdO. It resembles the situation occurring among the hottest white dwarfs (WD) (spectral type DO) for which only the accurate

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Astrophysics and Space Science **83** (1982) 287–310. 0004–640X/82/0832–0287$03.60.

analysis of the atmosphere is able to quantify the hydrogen deficiency (Koester *et al.*, 1979). An important conceptual difference exists between the 'hydrogen deficient' stars and the 'helium rich' stars. The first group exposes the helium rich layers built in the star during the previous nuclear evolution, allowing a kind of 'autopsy' of the star. In the second case, the remains of the hydrogen envelope are still present, so that we obtain information only on the more external layers, generally CNO cycled. In some cases the helium enrichment might even in part be attributed to superficial processes like the action of radiation pressure on the helium lines and could be of no particularly significant evolutionary interest.

The task of separating observationally hydrogen deficient from helium rich stars is a question of spectroscopy and of the analysis of atmospheres.

A different subdivision can be attempted using observations, namely the separation of binaries from single stars. This subdivision constitutes one of the motivations of the present research project, and is very important from an evolutionary standpoint.

Binary evolution may lead to the total loss of a star's hydrogen envelope according to modalities which may differ considerably from what happens in single stars, as nuclear evolution may be stopped at any stage due the occurrence of tidal interaction with the secondary. If this happens during the hydrogen-shell burning phases, or during the asymptotic giant branch (AGB) evolution, the star may become hydrogen deprived (as an example, see Lauterborn, 1970). Theory predicts also that the evolution with mass exchange in this phase is catastrophic, implying considerable loss of mass and angular momentum for the system and the formation of a 'common envelope', short-period binary (Paczynski, 1976). The recent discovery of binary nuclei of planetary nebulae with periods shorter than a day (Bond, 1976) provides a confirmation of this evolutionary scheme. The short period sdO binary HD 49798 (Thackeray, 1970; Kudritzki and Simon, 1978) is probably the outcome of the same kind of evolution.

Single star stellar evolution with mass loss predicts that some hydrogen deprived stars could be the result of the evolution following the AGB phase. We must warn that the models computed up to the present never have produced the complete loss of the hydrogen envelope (e.g., Schönberner, 1979), but Renzini (1979, 1980) gives a clear, although speculative, evolutionary frame in which some classes of hydrogen deficient stars are formed. He suggests that some AGB stars could lose completely their hydrogen-rich envelope and expose the intershell regions. This may occur due to different processes like: (i) mass loss via a quiescent stellar wind; (ii) envelope ejection through the 'superwind' mechanism (Renzini, 1981); (iii) interaction between helium-shell flashes which take place in the envelope when its mass is smaller than $10^{-5}\,M_{\odot}$ and intershell convection. Depending on the mass of the star, the mass of the envelope at the end of the AGB phase, and the relative importance and efficiency of the processes quoted above, any type of hydrogen-poor star can probably be produced. Moreover, during its evolution towards the white-dwarfs stage, a star might pass through more than one single configuration of the hydrogen-deficient stages.

According to the considered evolutionary scenario, which could lead both binary and single star to reach the hydrogen-poor stage, different abundances of carbon (C) and nitrogen (N) should be observed in the two cases. Binary stars are in fact expected to be N-abundant (N by mass of the order of 0.01), at least if case B mass transfer (Paczynski, 1971a) took place. C-overabundance (C by mass of the order of 0.2–0.5; Renzini and Voli, 1981) should be observed on the contrary in single stars and in binaries which experienced case C contact. This deduction is supported by Bidelman's (1979) consideration that the two 'unquestionably binaries, KS Per and υ Sgr', appear to be N-rich.

In this context, the case of the hydrogen-poor sdO's is very important and intriguing. Their study is extremely difficult since non-LTE analysis is required due to their high effective temperatures (Kudritzki, 1976). Moreover even this subgroup is inhomogeneous with respect to the chemical composition (see, for instance, the N-group made by Richter (1971)), the possible binary nature (Kudritzki and Simon, 1978), the mass loss recently found for some stars from ultraviolet observations (Darius *et al.*, 1979; Rossi *et al.*, 1980).

The list of objects which deserve detailed observations to allow a complete understanding of the post-AGB and pre-WD stages includes, therefore, the so-called 'hydrogen-deficient carbon stars' (HdC) (Warner, 1967), the nuclei of planetary nebulae, the non-DA WD's (Weidmann, 1975), the 'helium-rich stars' (Hunger, 1975), the sdO's and the luminous 'UV-bright stars' in globular clusters (Zinn *et al.*, 1972; Zinn, 1974).

We planned to make a photoelectric monitoring of a sample of these stars. The aim of these observations is to check the existence and the origin of light variability in these objects.

Light variability has already been found by many observers in stars evolving in the post-AGB phase. The R CrB-variables, for instance, are surely related to these stages (Paczynski, 1971b; Schönberner, 1975, 1979; Renzini, 1979, 1980). For some helium-rich stars photometric evidence of variability has been found by Landolt (1968, 1973, 1974, 1975) and Hill (1969). Small-scale variations have been found in the central stars of some planetary nebulae (Kohoutek, 1964; Lawrence *et al.*, 1967; Liller and Shao, 1968; Zhiljaev and Totochava, 1980), and variability in some UV-bright stars in globular clusters is also suspected (Samus, 1976; Chu, 1977; Bonifazi *et al.*, 1981). The cause of the light variations is different in the various objects.

For example, the R CrB-variability is attributed to a dust shell (carbon?) surrounding the star (Feast, 1975, 1979). The hot helium-rich star MV Sgr presents also a R CrB-variability (Herbig, 1964; Hoffleit, 1959). It would be important to verify whether this kind of variability (on a smaller scale) is present also in hotter helium stars, like BD 10° +2179, which in this case could represent a more advanced evolutionary stage of R CrB variables.

Another possible cause of variability of many highly evolved stars of low mass with high luminosities and high effective temperatures are pulsations excited by the K-mechanism operating in the He and/or C ionized zones. In fact, due to the lack of hydrogen, the instablity mechanism cannot be related to hydrogen and helium ionization as in the Cepheid variables, but instabilities might be found related to the unusual abundances. In the two schematic cases exposed above (He by mass ~ 0.99, N ~ 0.01) and (He ~ 0.8–0.5, C ~ 0.2–0.5), pulsations driven by helium, and helium and carbon, respectively, might be expected. Preliminary calculations made by Starrfield *et al.* (1980) and Cox *et al.* (1980) with abundances similar to these values confirm that helium and carbon ionizations are both effective as excitations mechanism for pulsation in stellar envelopes with these peculiar abundances. Carbon, in particular, can contribute with different degrees of ionization so that driving zones might be located at different depths in the envelope. This fact implies that a wide spectrum of observed periods may be expected and matched with various overtones as found for instance by Starrfield *et al.* (1980) for the 'hot' WD PG 1159–035. Photoelectric observations might be therefore useful also for the discrimination of their evolutionary history.

This paper gives preliminary results for six stars as a first step of a long-term project devoted to test for variability as many stars as possible among the list of objects quoted above.

2. Observations

The photoelectric observations were usually made with the 60-cm reflector of the Loiano Astronomical Station having at its Cassegrain focus (f/13.3), a three channel photoelectric photometer equipped with an EMI 9502 B photomultiplier (Piccioni, 1972; Oculi *et al.*, 1978). The response curve of each filter-photomultiplier combination compared with Johnson's Standard System are given in Cacciari *et al.* (1977). For a few nights, observations were also made with the 150-cm telescope of Loiano using a simultaneous, fast, double-head *UBV* photometer (Piccioni *et al.*, 1979) equipped with two EMI 62565 photomultipliers. Data reductions have been made using a specially developed software on a Selenia GP 160 computer. As a rule, and always for the observations made at great zenith distance, we used individual extinction coefficients for each night; when this was impossible we introduced the mean monthly coefficients of Loiano. The color effects have been taken into account. The standard error of the mean of a single difference of magnitude is about $0\overset{m}{.}01$ for the three channel photometer, while it is less than $0\overset{m}{.}004$ for the difference of magnitudes with the double head photon counting system.

The search for periodicities has been tried by applying a Fourier analysis

TABLE I

Summary of data for the observed stars

Name	α_{1950}	δ_{1950}	b_{II}	SpTy	V	$B-V$	$U-B$	T_{eff}	Log g	Classification
BD + 10° 2179	10^h36^m	+ 10° 19′	+ 56	B3	10.0	− 0.18	− 0.90	18 000	2.5	Extreme He-rich
BD + 13° 3224	16 46	+ 13° 21	+ 34	B2	10.5	− 0.19	− 0.97			(sd-O)
										Extreme He-rich
BD + 37° 443	1 56	+ 38° 19	− 23		10.0	− 0.28	− 0.90	50 000	4.5	(Extreme He-rich)
										sd-O
BD + 75° 325	8 05	+ 75° 07	+ 31	05	8.9			55 000	5.3	sd-O
BD + 25° 4655	21 57	+ 26° 12	− 22	06	9.8	− 0.27	− 1.20	43 000	6.7	sd-O
HD 37776	5 38	− 1° 32	− 16		7.0					Intermediate He-rich

technique to the differential magnitudes. Observations of about a dozen stars have been undertaken at this stage. Results are here given for six objects included in the list of hydrogen-poor, helium-rich stars made by Hunger (1975). Table I gives a collection of relevant data for the six stars. Table II gives the list of the comparison stars used and the number of observing nights for each object.

3. Results

3.1. BD +10° 2179

The star BD +10° 2179 is a typical member of the group of extreme helium stars. It was discovered by Klemola (1961) and was spectroscopically analyzed in the optical region by Hunger and Klinglesmith (1969). Their data were rediscussed by Schönberner and Wolf (1974). The UV-spectra are now available (Schönberner and Hunger, 1978; Heber and Schönberner, 1980). The detailed analysis of the spectral features is extremely difficult. A remarkable agreement has been found by Heber and Schönberner (1980) between UV and optical data and the theoretical models constructed with the assumptions: $n_{\rm H} = 5 \times 10^{-4}$, $n_{\rm He} = 0.99$, $n_{\rm C} = 0.01$, $n_{\rm Si} = 3 \times 10^{-5}$ (by number fractions), $T_{\rm eff} = 18\,000$ K, $\log g = 2.5$. These values are, however, in contrast with the expectations as discussed in the

TABLE II

Observations and comparison stars

Name	Comparison stars	60-cm telescope	152-cm telescope
BD + 10° 2179	BD + 10° 2188 (A) BD + 9° 2380 (B)	6 nights from to 1977, Dec. 16–1979, May 28	–
BD + 37° 443	BD + 37° 442 (A) BD + 37° 447 (B)	10 nights from to 1977, Nov. 6–1978, March 15	1 night
BD + 13° 3224	BD + 13° 3220 (A) BD + 13° 3233 (B)	4 nights from to 1979, May 28–May 31	–
BD + 75° 325	BD + 74° 356 (A) BD + 76° 307 (B)	7 nights from to 1977, Dec. 20–1978, May 2	–
BD + 25° 4655	BD + 26° 4323 (A) BD + 25° 4658 (B) BD + 27° 4219 (C)	25 nights from to 1977, Sept. 8–1979, Oct. 19	2 nights
HD 37776	HD 37674 (A) HD 37393 (B)	6 nights from to 1977, Nov. 10–1978, Gen 7	–

introduction, whilst in better agreement would be the abundances given by Hunger (1975) who gave: $T_{\mathrm{eff}} = 16\,000$ K, $\log g = 2.8$, $Y = 0.45$ (mass fraction of helium), $Z_{\mathrm{C}} = 0.55$ (mass fraction of carbon). No evidence of mass loss has been found for wind velocity $v_{\mathrm{wind}} > 600$ km s^{-1} (Heber and Schönberner, 1980). The spectrum resembles those of other extreme helium stars like HD 168476, HD 124448, BD $-9°$ 4395. Phosphorus is apparently overabundant. If confirmed, this anomaly might be important since, as noticed by Kaufmann and Schönberner (1976), it seems to be a common property for this small subclass of stars. The overabundance of phosphorus might show that *s*-processes actually took place as a consequence of the burning of the envelope mixed with the intershell during the final helium-shell flashes as suggested by Renzini (1980), or it might be merely an atmospheric diffusion effect.

Light variability has been suggested for this star by Landolt (1968, 1973) who found that the V magnitude changed by $0\overset{\mathrm{m}}{.}04$ in two successive nights. Our data (given in Table III) clearly confirm the existence of the suspected variability with respect to both of the comparison stars. As far as the period search is concerned, a wide range has been tested. Many possible periods have been found in the range $0\overset{\mathrm{d}}{.}162$–$0\overset{\mathrm{d}}{.}164$. Light curves obtained with the best period found, $P = 0\overset{\mathrm{d}}{.}162645$, are shown in Figure 1. This value, however, does not fit Landolt's (1973) data which might be fitted instead by $P = 0\overset{\mathrm{d}}{.}163349$. Period and amplitude, if confirmed, fall in the range found for the pulsations of high luminosity stars. At this low T_{eff}, the helium ionization zones are deep enough in the envelope that helium itself may be responsible for the opacity mechanism driving the pulsations.

3.2. BD +13° 3224

This star was found to be peculiar by Berger and Greenstein (1963) who noticed: (a) the faintness of the H lines; (b) the great strength of He I lines; (c) the absence of carbon in any stage of ionization and the faintness of O II lines; (d) the strength of interstellar H and K lines. Hunger (1975) classified this object O-subdwarf, but it is included by Kaufmann and Schönberner (1977) among the extreme helium-rich stars like BD +10° 2179, HD 124448 and HD 160641.

Photoelectric observations of this star were carried out by Landolt (1973, 1975). He found a variability with an amplitude of $\sim 0\overset{\mathrm{m}}{.}1$ and a period of $0\overset{\mathrm{d}}{.}107995$. Our data, reported in Table IV, confirm these results obtained by Landolt including the presence of a secondary maximum. Therefore the light variations of this star can be considered definitely assured. One point not yet discussed concerns the stability of the period. The analysis was carried out by determining from all the available observations the times of maximum brightness given in Table V, from which, assuming a constant period, the following light elements were derived:

$$\text{JD max light} = \underset{\pm 5}{2\,442\,261.8043} + \underset{\pm 3}{0\overset{\mathrm{d}}{.}10799624}E.$$

TABLE III

Data for BD + 10° 2179 plotted in Figure 1

JD-2 440 000	Phase	Δu	Δb	Δv
3494.663	0.86	–	0.90	1.54
3494.666	0.88	–	0.90	1.52
3494.668	0.90	–	0.91	1.50
3494.671	0.91	–	0.91	1.53
3494.675	0.94	–	0.87	1.50
3494.683	0.99	–	0.89	–
3514.314	0.68	0.10	0.89	1.51
3514.348	0.89	0.11	0.89	1.51
3578.648	0.23	0.08	0.93	1.49
3578.654	0.27	0.11	0.91	1.50
3578.659	0.30	0.09	0.89	1.47
3578.664	0.33	0.06	0.91	1.47
3578.669	0.36	0.06	0.89	1.45
3631.446	0.85	0.10	0.90	1.52
3631.452	0.89	0.10	0.90	1.54
3631.457	0.92	0.10	0.93	1.51
3631.463	0.96	0.12	0.91	1.52
3631.468	0.99	0.12	0.92	1.52
3631.473	0.02	0.11	0.90	1.52
3631.479	0.06	0.11	0.91	1.52
3631.484	0.09	0.09	0.90	1.53
3937.546	0.86	0.11	0.90	1.54
3937.554	0.91	0.12	0.89	1.54
3937.561	0.96	0.13	0.90	1.53
3937.569	0.01	0.12	0.89	1.53
3937.576	0.05	0.13	0.91	1.53
3937.583	0.10	0.11	0.89	1.52
3937.590	0.14	0.12	0.89	1.52
4022.381	0.46	0.01	0.83	1.43
4022.384	0.48	0.01	0.84	1.44
4022.392	0.53	0.03	0.86	1.46
4022.398	0.57	0.08	0.88	1.49
4022.407	0.63	0.09	0.91	1.50
4022.417	0.68	0.08	0.89	1.49
4022.422	0.71	0.09	0.89	1.49
4022.427	0.74	0.11	0.89	1.51
4023.419	0.84	0.12	0.89	1.51
4023.515	0.43	0.03	0.85	1.44

3.3. BD +37° 442 (BD +37° 443)

Rebeirot (1966) found a peculiar star close to the cluster NGC 752. She identified the star as BD +37° 442, but according to our measurements this is a normal red star with $B-V \simeq 0.9$. The hot hydrogen-poor star is BD +37° 443. This object was classified extreme-helium-rich star by Hunger (1975), but IUE observations can be fitted (Rossi *et al.*, 1980; and references therein) with a model resembling a hot O-subdwarf with $T_{\mathrm{eff}} = 50\,000$ K, $\log g = 4.5$ and $Y = 0.99$. The UV-spectra, similar to those of the sdO stars BD +37° 1977 and BD +48° 1777, are

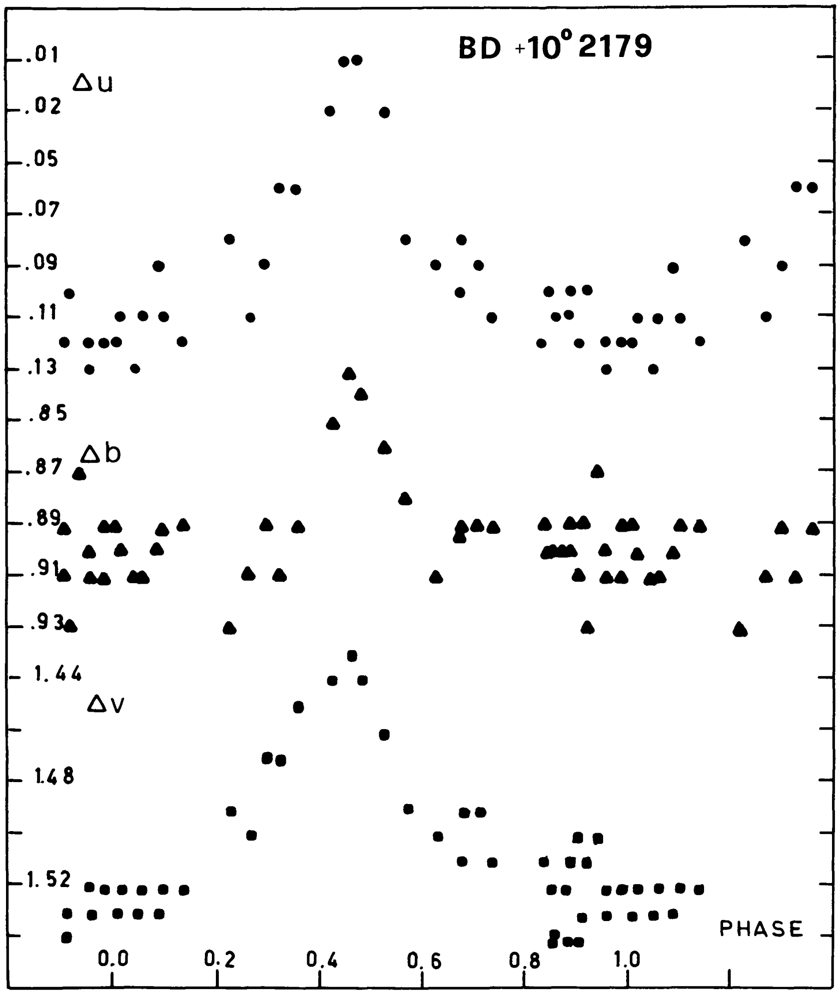

Fig. 1. *u*, *b*, *v*, light curves of BD +10° 2179 with respect to comparison star B. $P = 0^d.162645$.

TABLE IV

Data for BD + 13° 3224

JD-2 440 000	Phase	Δu (Var. – Comp. B)	Δb	Δv	Δu (Var. – Comp. A)	Δb	Δv
4022.447	0.37	0.17	1.27	1.66	– 0.57	0.47	1.03
4022.457	0.47	0.17	1.29	1.67	0.59	0.48	1.03
4022.465	0.53	0.17	1.29	1.66	0.59	0.49	1.05
4022.472	0.60	0.16	1.28	1.67	0.60	0.48	1.05
4022.479	0.66	0.20	1.30	1.67	0.56	0.51	1.07
4022.486	0.73	0.15	1.29	1.66	0.57	0.51	1.07
4022.492	0.78	0.16	1.27	1.65	0.59	0.48	1.05
4022.498	0.84	0.12	1.23	1.62	0.64	0.44	1.02
4022.505	0.90	0.10	1.26	1.64	0.64	0.46	1.05
4022.513	0.97	0.13	1.26	1.65	0.64	0.44	1.00
4022.521	0.05	0.15	1.26	1.67	0.61	0.47	1.06
4022.530	0.13	0.17	1.29	1.67	0.62	0.48	1.05
4022.545	0.27	0.17	1.30	1.66	0.55	0.52	1.06
4022.552	0.33	0.16	1.29	1.65	0.57	0.51	1.05
4022.557	0.39	0.16	1.30	1.66	0.56	0.51	1.06

Table IV (Continued)

JD-2 440 000	Phase	Δu (Var.–Comp. B)	Δb	Δv	Δu (Var.–Comp. A)	Δb	Δv
4022.563	0.44	0.21	1.30	1.69	0.53	0.52	1.08
4022.575	0.55	0.21	1.31	1.66	0.58	0.51	1.05
4022.582	0.62	0.19	1.34	1.71	0.59	0.55	1.11
4023.477	0.90	0.12	1.24	1.63	0.65	0.44	1.01
4023.482	0.94	0.19	1.29	1.66	0.60	0.47	1.04
4023.489	0.02	0.16	1.30	1.69	0.60	0.50	1.07
4023.494	0.06	0.19	1.30	1.68	0.60	0.49	1.04
4023.509	0.20	0.19	1.30	1.65	0.60	0.49	1.02
4023.514	0.25	0.17	1.30	1.68	0.62	0.49	1.05
4023.520	0.30	0.25	1.33	1.67	0.55	0.49	1.04
4023.528	0.38	0.20	1.31	1.69	–	0.47	1.06
4023.535	0.44	–	1.30	1.68	–	0.48	1.05
4023.541	0.50	–	1.30	1.66	0.50	0.51	1.05
4023.546	0.54	0.21	1.29	1.66	0.57	0.49	1.05
4023.553	0.60	0.22	1.30	1.70	0.52	–	1.07
4023.560	0.67	0.20	1.30	1.66	0.50	0.51	1.05
4023.566	0.73	0.20	1.30	1.65	0.58	0.50	1.03
4023.571	0.77	0.19	1.30	1.65	0.61	0.50	1.01
4023.576	0.82	0.16	1.28	1.64	0.57	0.46	1.01
4023.581	0.86	0.13	1.30	1.67	0.65	0.47	1.03
4024.423	0.66	0.21	1.31	1.69	0.56	0.48	1.06
4024.431	0.74	0.14	1.28	1.66	0.63	0.47	1.03
4024.440	0.82	0.12	1.24	1.61	0.68	0.44	0.98
4024.446	0.88	0,10	1.24	1.63	0.69	0.42	1.00
4024.454	0.95	0.19	1.30	1.68	0.58	0.50	1.07
4024.462	0.03	0.19	1.32	1.70	0.59	0.50	1.06
4024.471	0.11	0.17	1.28	1.68	−0.63	0.47	1.05
4024.481	0.20	0.19	1.31	1.69	−0.61	0.49	1.06
4024.490	0.28	0.14	1.27	1.67	0.62	0.47	1.06
4024.500	0.37	0.17	1.27	1.64	0.57	0.48	1.02
4024.509	0.46	0.19	1.28	1.68	0.51	–	1.06
4024.519	0.55	0.21	1.32	1.69	0.57	0.52	1.09
4024.525	0.61	0.19	1.29	1.68	0.58	0.50	1.07
4024.531	0.66	0.19	1.30	1.69	0.56	0.51	1.06
4024.537	0.72	0.17	1.26	1.64	0.59	0.47	1.05
4024.543	0.77	0.16	1.25	1.63	0.61	0.46	1.04
4024.549	0.83	0.11	1.25	1.64	0.64	0.46	1.03
4024.557	0.90	0.12	1.27	1.64	0.64	0.47	1.02
4024.565	0.97	0.16	1.31	1.67	0.60	0.54	1.08
4024.573	0.05	0.19	1.33	1.69	0.59	0.53	1.07
4025.385	0.57	0.23	1.31	1.72	–	0.51	–
4025.393	0.65	0.24	1.30	1.69	0.41	0.49	1.05
4025.399	0.70	0.20	1.30	1.69	–	0.49	1.05
4025.411	0.81	0.14	1.25	1.65	0.53	0.56	1.03
4025.418	0.87	–	1.28	1.69	0.70	0.38	0.95
4025.477	0.42	0.19	1.30	1.63	0.58	0.50	1.01
4025.555	0.14	0.18	1.31	1.69	0.56	0.52	1.06
4025.562	0.21	0.17	1.28	1.66	0.62	0.47	1.02
4025.569	0.27	0.18	1.29	1.64	0.62	0.47	0.99
4025.576	0.34	0.20	1.29	1.66	−0.55	0.49	1.03

TABLE V

Times of maximum for BD + 13° 3224

JD-2 400 000	Epoch	O–C
39 998.7777	− 20 538	0.0002
42 216.8043	0	0.0
44 022.5018	16 720	0.0004

characterized by very high excitation photospheric lines and intense interstellar lines of possible circumstellar origin. Moreover, they give evidence for the presence of mass outflow from the star. Landolt (1968, 1973) found that it was probably not variable. We have found that the star is almost surely variable. On the basis of our data (see Table VIA, B) two types of fluctuations might be suspected. From the 60-cm observations a long-term variability with an amplitude of about $0\overset{m}{.}08$ has been derived as shown in Figure 2. Moreover, from the

TABLE VIA

Data for BD +37° 443

JD-2 440 000	Δu	Δb	Δv	No. of observations
3454.416	− 1.47	− 0.31	0.48	2
3458.478	− 1.43	− 0.29	0.46	5
3462.480	− 1.43	− 0.29	0.46	14
3483.412	− 1.45	− 0.31	0.51	5
3494.531	–	− 0.28	0.53	6
3495.367	–	− 0.27	0.54	13
3498.347	− 1.43	− 0.27	0.54	9
3514.325	–	− 0.27	0.53	4
3516.373	–	− 0.23	0.54	8
3583.353	− 1.47	− 0.31	0.48	3

TABLE VIB

Data for BD +37° 443 (double-head photometer)

JD-2 440 000	Δu	σ_u	JD-2 440 000	Δv	σ_v
4185.435 96	− 2.418	0.004	4185.425 63	− 0.534	0.003
4185.436 53	− 2.423	0.003	4185.426 21	− 0.530	0.001
4185.437 11	− 2.422	0.005	4185.426 79	− 0.522	0.003
4185.437 69	− 2.413	0.005	4185.427 37	− 0.519	0.003
4185.438 27	− 2.403	0.002	4185.427 95	− 0.507	0.002
4185.438 85	− 2.405	0.004	4185.428 52	− 0.507	0.004
4185.439 43	− 2.399	0.003	4185.429 10	− 0.506	0.003
4185.440 01	− 2.391	0.005	4185.429 68	− 0.520	0.004
4185.440 59	− 2.393	0.004	4185.430 26	− 0.521	0.004
4185.441 16	− 2.394	0.004	4185.430 84	− 0.523	0.003

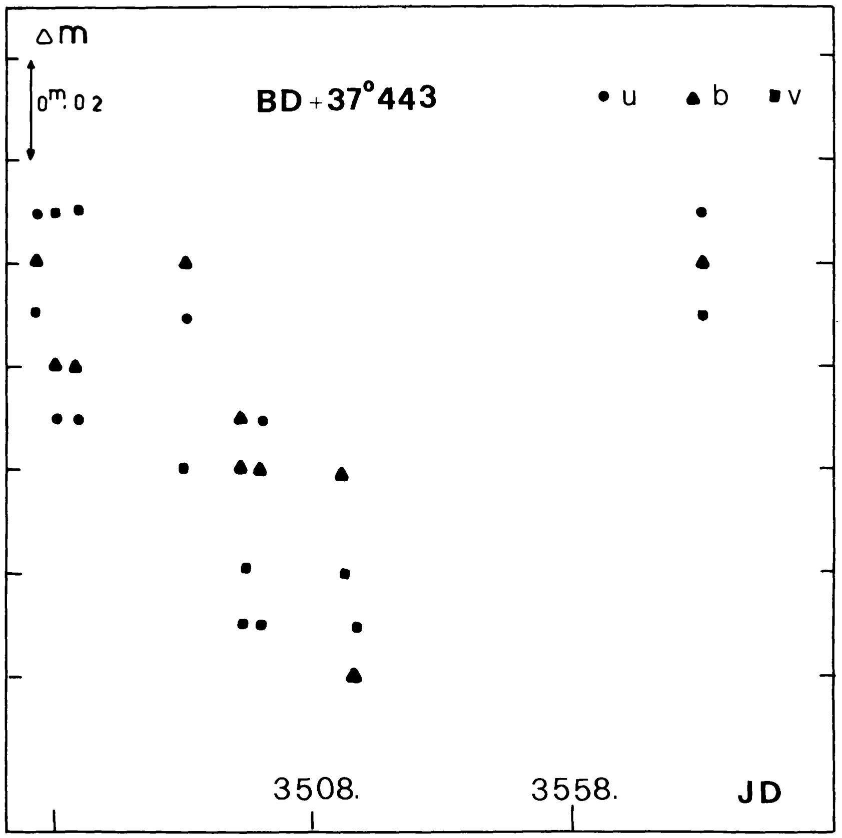

Fig. 2. Long-period variability of BD +37° 443.

very few data obtained with the fast double-head photometer, small scale variations ($\Delta m \simeq 0^m.03$) are evident (see Figure 3). These results do not allow a period determination. However a qualitative estimate gives a time-scale of the order of months for the long-term variations, and of 10–15 min for the short ones.

3.4. BD +75° 325

This star, considered a prototype of the hot O-subdwarfs, has been widely studied both in the optical and in the UV regions of the spectrum. Detailed non-LTE analysis of the IUE spectra have been made by Kudritzki *et al.* (1980; and references therein). The parameters deduced are: $T_{\rm eff} = 55\,000 \pm 2500$ K, $\log g = 5.3 \pm 0.3$, $n_{\rm He}/n_{\rm H} + n_{\rm He} = 0.6$. From these spectra carbon and oxygen appear underabundant while nitrogen is strongly overabundant. The same results have been obtained for the stars HD 127493 and for the binary HD 49798, members with this star of Richter's (1971) N-subgroup. This evidence may suggest the conclusion (Kudritzki *et al.*, 1980) that these stars expose CNO-cycle-processed material, and confirm the general scheme proposed in the introduction according to which N-overabundance could attest a binary origin of the present hydrogen-poor configuration.

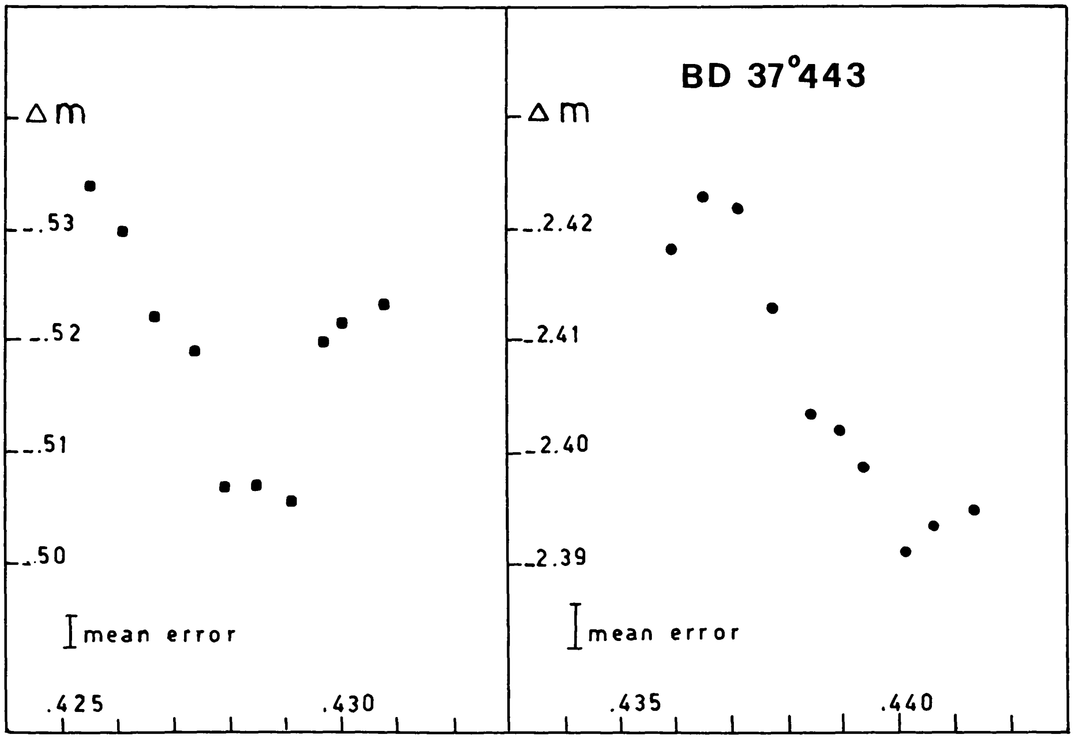

Fig. 3. Short-period u and v variability of BD +37° 443.

No long term variations are evident in this star, while the existence of microvariability ($\Delta m \simeq 0.03$) can be suspected from the data derived on 1978, Jan. 7 as can be seen in Figure 4 where the observations (see Table VII) are phased with the best possible period found, $P = 0\overset{d}{.}0465116$. However, the data derived in the other observing nights (of a shorter duration and poorer quality) are not fitted by this period. It is interesting to notice that the mass losing sd$O$ (BD+37° 443) is variable, whereas this non mass-losing one is probably not variable.

3.5. BD +25° 4655

This star, like BD +75° 325, has also been included by Richter (1971) in the N-subgroup of the O-subdwarfs. The basic atmospheric data, derived from LTE models, are (Richter, 1971): $T_{\rm eff} = 43\,000$, $\log g = 6.7$, $X = 0.02$ (H-mass fraction), $Y = 0.98$ (He-mass fraction), with nitrogen enhancement, and carbon-oxygen deficiency.

The data obtained from our observations (Table VIII) indicate that the star is variable. Moreover, the existence of two types of variations might be suspected. The first, suggested by the slightly rising trend ($\Delta V \simeq 0\overset{m}{.}07$) with respect to the comparison stars over a rather long period of observation, might have a time-scale of the order of several months. The second is seen as a short time-scale and small amplitude variability (see Figure 5) found on some nights. A detailed search for regular periodicities has been unsuccessful except for two

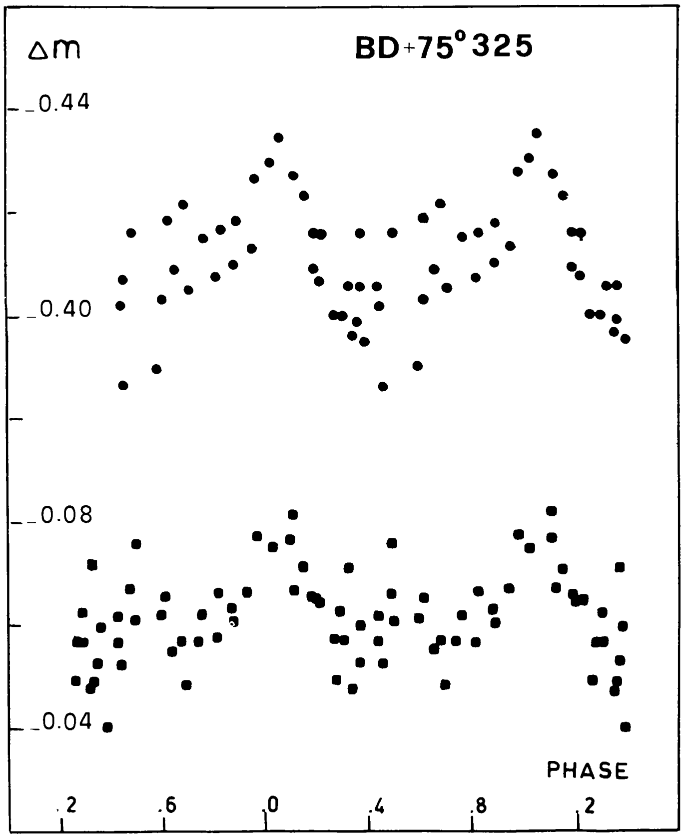

Fig. 4. b and v light curves of BD +75° 325 phased with $P = 0\overset{d}{.}0465116$.

TABLE VIIA

Data for BD +75° 325 (1978, Jan. 7)

JD-2 440 000	Phase	Δb	Δv
3516.519	0.15	− 0.424	− 0.077
3516.528	0.35	0.398	0.057
3516.534	0.49	0.416	0.066
3516.544	0.70	0.405	0.049
3516.550	0.82	0.416	0.067
3516.561	0.05	0.435	0.076
3516.566	0.18	0.409	0.066
3516.575	0.36	0.406	0.052
3516.582	0.50	–	0.061
3516.588	0.65	0.409	0.055
3516.604	0.98	0.428	0.078
3516.610	0.12	0.419	0.067
3516.620	0.33	0.406	0.072
3516.625	0.44	0.402	0.057
3516.633	0.61	0.403	0.066
3516.636	0.68	−0.422	0.057
3516.639	0.74	–	−0.057

Table VIIA (Continued)

JD-2 440 000	Phase	Δb	Δv
3516.642	0.81	−0.407	−0.057
3516.645	0.88	0.410	0.063
3516.649	0.95	0.413	0.067
3516.652	0.02	0.430	0.075
3516.661	0.22	0.416	0.065
3516.664	0.30	0.407	0.063
3516.668	0.37	0.416	0.060
3516.671	0.44	0.406	0.062
3516.686	0.76	0.415	0.062
3516.693	0.89	0.418	0.061
3516.705	0.15	0.414	0.071
3516.711	0.27	0.400	0.057
3516.726	0.60	0.390	0.062
3516.749	0.11	0.427	0.082
3516.754	0.20	0.416	0.070
3516.757	0.27	0.400	0.049
3516.760	0.34	0.396	0.048
3516.763	0.39	0.395	0.040
3516.766	0.46	−0.386	−0.053

TABLE VIIB

Data for BD +75° 325

JD-2 443 000	Δu	Δb	Δv	No. of observations
	(Var. − Comp. A)			
498.440	−0.69	0.64	1.26	7
514.473	−0.71	0.62	1.25	15
515.511	–	0.64	1.26	3
516.678	–	0.63	1.25	16
540.596	−0.70	0.62	1.25	2
583.435	−0.70	0.63	1.25	3
631.405	−0.69	0.63	1.25	6
	(Var. − Comp. B)			
514.420	−1.63	−0.41	−0.06	7
516.647	–	−0.41	−0.06	37
631.402	−1.63	−0.43	−0.07	5

nights: 1978, June 29 and 1977, Sept. 11. The period found from the data of the first night, $P = 0\overset{d}{.}009368$, gives a reasonable fit also for those obtained on the second night, as shown in Figure 5 where the light curves derived from the data phased with this period are given. The existence of this short-period variability might be confirmed by the results derived from the double-head photometer as

TABLE VIIIA

Data for BD +25° 4655

JD-2 440 000	Δu	Δb	Δv	No. of observations
3395.451	0.76	1.71	1.96	12
3398.502	0.76	1.72	1.96	22
3399.485	0.70	1.72	1.96	12
3402.498	0.74	1.72	1.95	17
3430.625	0.72	1.70	1.95	3
3431.332	0.71	1.67	1.94	10
3454.358	0.67	1.68	1.95	3
3458.382	0.73	1.69	1.93	16
3459.406	0.73	1.69	1.94	13
3462.391	0.73	1.73	1.97	2
3465.373	0.71	1.70	1.94	6
3467.280	0.71	1.66	1.94	2
3483.360	0.73	1.68	1.94	7
3494.390	–	1.67	1.92	10
3495.278	–	1.67	1.93	16
3498.267	0.72	1.68	1.93	15
3514.274	–	1.67	1.92	11
3515.285	0.72	1.67	1.93	5
3516.315	–	1.68	1.93	7
3631.587	0.74	1.69	1.95	3
3689.523	0.74	1.68	1.92	39
3788.431	0.70	1.67	1.94	7
4156.429	0.73	1.67	1.93	5
4165.441	0.72	1.66	1.94	26
4166.369	0.72	1.68	1.94	17

TABLE VIIIB

Data for BD +25° 4655

JD-2 440 000	Phase	Δu	Δb	Δv
3659.4946	0.77	0.739	1.674	1.918
3659.4948	0.79	0.754	1.674	1.916
3659.4995	0.29	0.735	1.676	1.922
3659.5000	0.34	0.743	1.680	1.930
3659.5048	0.86	0.745	1.672	1.927
3659.5050	0.88	0.739	1.682	1.925
3659.5053	0.91	0.741	1.681	1.923
3659.5056	0.94	0.749	1.688	1.947
3659.5059	0.97	0.749	1.685	1.927
3659.5062	0.00	0.743	1.691	1.937
3659.5064	0.03	0.749	1.683	1.931
3659.5128	0.71	0.731	1.673	1.904
3659.5131	0.74	0.721	1.670	1.912

Table VIIIB (Continued)

JD-2 440 000	Phase	Δu	Δb	Δv
3659.5237	0.87	0.736	1.691	1.928
3659.5239	0.89	0.738	1.681	1.918
3659.5243	0.93	0.743	1.682	1.929
3659.5244	0.94	0.740	1.685	1.919
3659.5248	0.99	0.747	1.692	1.925
3659.5251	0.02	0.751	1.678	1.925
3659.5254	0.05	0.747	1.682	1.926
3659.5257	0.08	0.740	1.698	1.924
3659.5260	0.11	0.740	1.689	1.920
3659.5262	0.13	0.731	1.695	1.936
3659.5310	0.65	0.730	1.677	1.907
3659.5312	0.67	0.721	1.671	1.908
3659.5315	0.70	0.734	1.681	1.900
3659.5319	0.74	0.728	1.663	1.923
3659.5321	0.76	0.728	1.681	1.923
3659.5324	0.80	0.732	1.678	1.930
3659.5327	0.83	0.730	1.681	1.928
3659.5373	0.32	0.721	1.669	1.917
3659.5375	0.34	0.718	1.681	1.922
3659.5422	0.84	0.735	1.684	1.930
3659.5424	0.86	0.737	1.678	1.926
3659.5483	0.49	0.712	1.673	1.914
3659.5486	0.52	0.708	1.675	1.913
3659.5555	0.26	0.744	1.684	1.918
3398.5152	0.06	0.776	1.752	1.967
3398.5154	0.09	0.763	1.745	1.968
3398.5157	0.12	0.759	1.738	1.966
3398.5160	0.15	0.777	1.725	1.962
3398.5163	0.18	0.751	1.731	1.940
3398.5165	0.21	0.744	1.713	1.934
3398.5168	0.24	0.764	1.710	1.942
3398.5171	0.27	0.754	1.708	1.942
3398.5174	0.30	0.725	1.712	1.960
3398.5177	0.33	0.755	1.696	1.932
3398.5179	0.36	0.764	1.702	1.949
3398.5182	0.39	0.736	1.700	1.946
3398.5185	0.42	0.725	1.701	1.934
3398.5188	0.44	0.739	1.695	1.911
3398.5198	0.47	0.711	1.705	1.916
3398.5193	0.50	0.728	1.693	1.927
3398.5196	0.53	0.722	1.683	1.917
3398.5199	0.56	0.726	1.696	1.896
3398.5202	0.59	0.726	1.694	1.893
3398.5204	0.62	0.737	1.683	1.914
3398.5207	0.65	0.722	1.698	1.898
3398.5210	0.68	0.702	1.677	1.895
3398.5213	0.71	0.722	1.685	1.930
3398.5216	0.74	0.709	1.689	1.922
3398.5218	0.77	0.715	1.679	1.906

TABLE VIIIC

Data for BD +25° 4655 (double-head photometer)

JD-2 444 120	Δ*b*	JD-2 444 120	Δ*b*	JD-2 444 120	Δ*b*
3398.5204	1.765	3398.5229	1.739	3398.5254	1.742
3398.5208	1.763	3398.5233	1.738	3398.5257	1.749
3398.5211	1.761	3398.5236	1.737	3398.5261	1.752
3398.5215	1.747	3398.5240	1.738	3398.5264	1.764
3398.5218	1.753	3398.5243	1.737	3398.5268	1.758
3398.5222	1.742	3398.5247	1.730	3398.5272	1.758
3398.5226	1.740	3398.5250	1.726	3398.5275	1.763

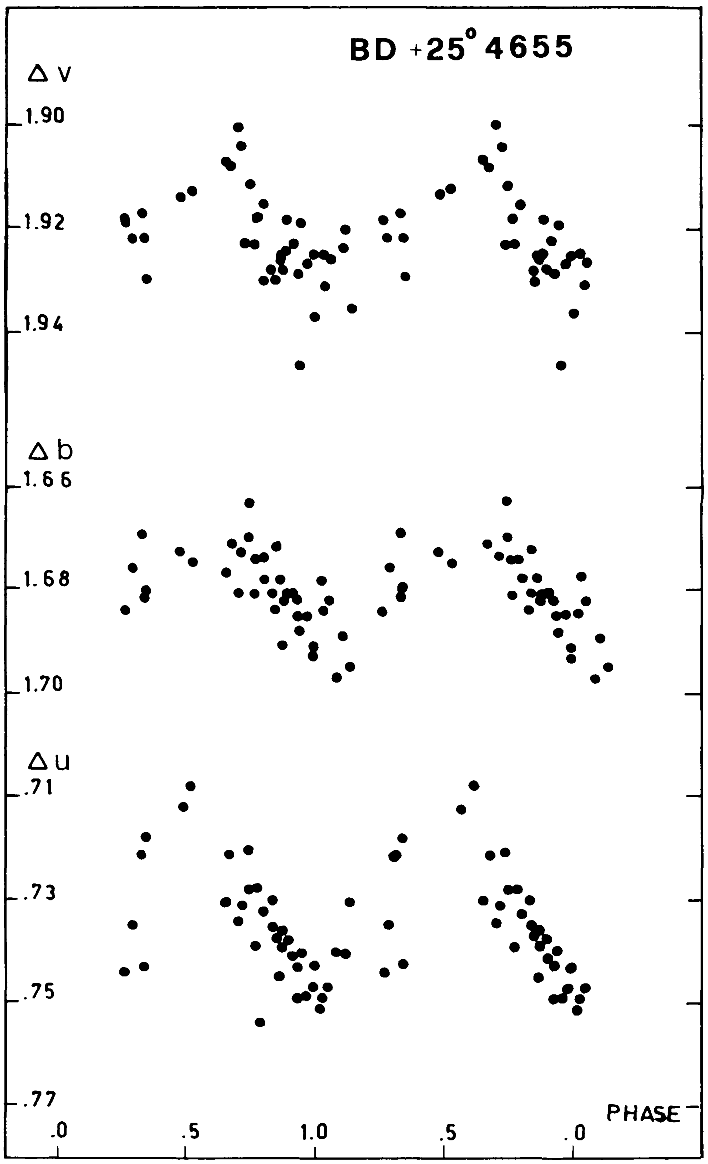

Fig. 5. Short-period u, b, and v light curves of BD +25° 4655 phased with $P = 0^{\mathrm{d}}.00938616$.

can be seen in Figure 6. We could not find a period, however the observations are compatible with a period of the order of ten minutes.

The short time-scale variability of BD +25° 4655 is very interesting. The large gravity of this star implies that it must be considered a 'hot' WD more than a sdO. It is straightforward to compare this result with the ~10 min variability recently found in the hot WD or subdwarf ($T_{\rm eff} > 50\,000$ K), PG 1159–035 (McGraw *et al.*, 1979). This star is probably pulsating (Starrfield *et al.*, 1980), but there is an ambiguous analogy with the 18 min variable HZ 29, a probable binary helium white dwarf having a much lower $T_{\rm eff}$ (~20 000 K, Liebert, 1977). The discovery that BD +25° 4655 is varying with the same kind of period may lead to the recognition of a new class of pulsating objects close to the WD stage. However, an obvious difference between PG 1159–035 and BD +25° 4655 is the following: the spectrum of the first is dominated by carbon lines (McGraw *et al.*, 1979), the spectrum of the second one is overabundant in nitrogen (Richter, 1971). They should, therefore, derive from a different evolutionary path. Nevertheless, it is possible that pulsations are induced in both stars by opacity mechanisms.

3.6. HD 37776

This star is classified as an intermediate helium-rich star by Hunger (1975). Although helium-rich and hydrogen-poor, its properties and evolutionary history are probably not homogeneous with the other stars dealt with in this research

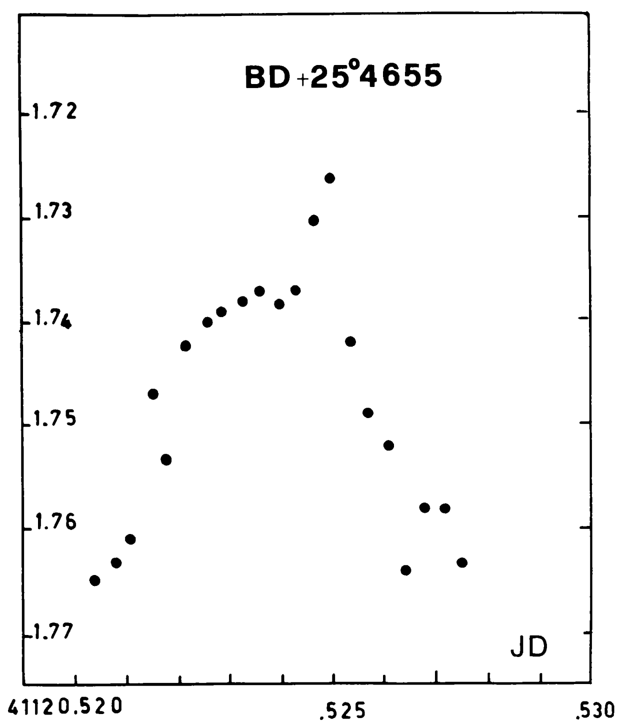

Fig. 6. Short-period variability of BD +25° 4655 with the double-head photometer on 1979, Sept. 3.

TABLE IX

Data for HD 37776

JD-2 443 000	Δu	Δb	Δv
458.5452	−0.955	−0.744	−0.654
458.5550	0.957	0.740	0.654
458.5609	0.949	0.738	0.651
458.5675	0.940	0.732	0.643
459.4705	0.988	0.779	0.678
459.4774	0.975	0.762	0.677
459.4838	0.964	0.747	0.667
459.4911	0.957	0.742	0.670
459.4967	0.960	0.759	0.671
459.5072	0.975	0.765	0.678
459.5176	0.972	0.762	0.672
459.5242	0.976	0.761	0.677
459.5367	0.965	0.763	0.669
459.5429	0.964	0.754	0.667
459.5476	0.972	0.765	0.655
459.5557	0.968	0.758	0.668
459.5599	0.960	0.747	0.656
459.5648	0.963	0.755	0.666
459.5702	0.979	0.771	0.679
459.5735	0.946	0.741	0.654
459.5770	0.968	0.756	0.663
459.5805	0.958	0.748	0.661
459.5838	0.964	0.751	0.666
459.5890	0.962	0.747	0.655
459.5954	0.972	0.762	0.663
459.6028	0.953	0.742	0.658
459.6097	0.952	0.741	0.661
459.6154	0.951	0.743	0.658
462.5575	0.970	0.749	0.669
462.5656	0.956	0.728	0.650
462.5799	0.977	0.745	0.667
462.5831	0.976	0.738	0.679
495.4216	–	0.752	0.666
495.4266	–	0.762	0.667
495.4344	–	0.742	0.656
495.4399	–	0.755	0.666
495.4461	–	0.736	0.653
495.4503	–	0.726	0.647
495.4567	–	0.749	0.656
495.4614	–	0.745	0.654
498.3791	0.959	0.730	0.647
498.3852	0.953	0.735	0.653
498.3876	0.957	0.743	0.654
498.3924	0.960	0.745	0.661
498.4010	0.950	0.727	0.640
514.4250	0.954	0.748	0.657
514.4304	0.972	0.749	0.673
514.4869	−0.957	−0.742	−0.662

Table IX (Continued)

JD-2 443 000	Δu	Δb	Δv
514.4400	−0.975	−0.761	−0.672
516.4291	–	0.759	0.661
516.4360	–	0.763	0.676
516.4440	–	0.770	0.668
516.4520	–	0.760	0.670
516.4606	–	0.762	0.662
516.4697	–	0.762	0.661
516.4792	–	0.756	0.663
516.4826	–	0.752	0.660
516.4929	–	−0.767	−0.668

(Pedersen and Thomsen, 1977). It was, however, inserted in our sample to try to discriminate between the different periods suggested. Lynds (1959) found a variability of about $0^{m}.05$. Nissen (1976) discovered the He-variability of the star. Hill (1977) confirmed the existence of light variations and gave a period of $0^{d}.37968$ suggesting a tentative identification of the star as a β Cephei. The results of Hill (1977) have been, however, doubted by Pedersen and Thomsen (1977), who found $P = 1^{d}.538$ through spectrophotometric observations.

We confirm the variability, but were unable to find a good period from our data (given in Table IX). If they are phased with $P = 0^{d}.37968$ we obtain light curves of rather poor quality. However they closely resemble those given for this star by Hill (1977). By use of $P = 1^{d}.538$ only a very small part of the possible light curve is covered. It is, therefore, impossible to draw a definitive conclusion at this stage.

4. Conclusions

A general discussion of the properties of the stars in this study will be postponed until a larger sample is available.

Table X gives a list of some helium-rich, hydrogen-poor stars checked for variability with the results obtained by various researchers. As can be seen, almost all the stars observed with a certain detail show phenomena of micro-variability. It is however rather difficult to find periodicities. Due to the small amplitude of the variations, very careful observations are required. Moreover, an assiduous monitoring should be done at least for particular objects which could display the evolutionary connections between the different configurations of the hydrogen-deficient stages and the normal stars.

TABLE X

Data on variability of hydrogen-poor stars

Name	Type	Variable	Amplitude	Period	References
BD +10° 2179	Extreme He-rich	yes	$0^{\mathrm{m}}.1$	$0^{\mathrm{d}}.162$–$0^{\mathrm{d}}.164$	Landolt (1968, 1973); This paper
HD 160461	Extreme He-rich	yes	$0^{\mathrm{m}}.1$	$0^{\mathrm{d}}.6$	Landolt (1973); Hill (1969)
HD 168476	Extreme He-rich	yes		secular (?)	Landolt (1973)
HD 124448	Extreme He-rich	no			Hill (1969)
		yes			Landolt (1973)
BD +37° 443	Extreme He-rich	no			Landolt (1973, 1975)
	(sd-O)	yes	$0^{\mathrm{m}}.08$	months (?)	This paper
			$0^{\mathrm{m}}.03$	10–15 minutes	This paper
BD +13° 3224	sd-O (Extreme)	yes	$0^{\mathrm{m}}.1$	$0^{\mathrm{d}}.107995$	Landolt (1973, 1975)
		yes	$0^{\mathrm{m}}.1$	$0^{\mathrm{d}}.107996$	This paper
BD +25° 4655	sd-O	yes	$0^{\mathrm{m}}.07$	months (?)	This paper
			$0^{\mathrm{m}}.04$	$0^{\mathrm{d}}.009$ (?)	This paper
BD +75° 325	sd-O	yes (?)	$0^{\mathrm{m}}.03$	$0^{\mathrm{d}}.0465$ (?)	This paper
HD 113001	sd-O	yes (binary)		5000 yr	Kudritzki and Simon (1978)
HD 128220	sd-O	yes (binary)		870^{d}	Kudritzki and Simon (1978)
BD −3° 5357	sd-O	yes (binary)		$9^{\mathrm{d}}.2$	Kudritzki and Simon (1978)
HD 49798	sd-O	yes (binary)		$1^{\mathrm{d}}.547$	Kudritzki and Simon (1978)

Acknowledgments

The authors are indebted to Prof. A. Renzini for many helpful discussions. This research was partially supported by the National Group of Astronomy (GNA) of the National Research Council (CNR).

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