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HIGH-FREQUENCY STELLAR OSCILLATIONS. IX. THE PECULIAR BLUE VARIABLE, BD−7°3007

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ABSTRACT

The peculiar star BD−7°3007 varies rapidly with amplitudes less than 0.10 mag. The power spectra show no harmonic features; however, significant low-amplitude transient activity exists in the 100–1000 s range; and there are persistent broad-banded peaks at about 21 and 10.3 minutes. Scanner observations, showing Hα emission, broad, weak Hγ absorption, and an approximately blackbody continuum with $T_e \approx 10^4$ ° K, imply that the star is degenerate and deficient in hydrogen. The available data admit the presence of two degenerate stars with circumstellar material.

I. INTRODUCTION

MacConnell and Cowley (1972) and Cowley and MacConnell (1972) have found that the spectrum of BD−7°3007 consists of shallow, broad absorption features of H, He I, Ca II, and possibly some weaker lines; variable central emission causes the hydrogen and Ca lines to appear double. Spectroscopically analogous stars are WZ Sge (Greenstein 1957), CD−42°14462 (Bond and Landolt 1971), and HDE 310376 (Stephenson, Sanduleak, and Schild 1968; Schild 1969). The *UBV* colors of BD−7°3007 place it near the blackbody line and close to the empirical blue boundary of the region occupied by DA white dwarfs (Eggen and Greenstein 1965), while its large m_1 index suggests emission activity in the 4600 Å region. Furthermore, there is high-frequency photometric activity superposed on a complex, low-frequency light curve (Hesser and Lasker 1972*a*); we describe herein further photometric and spectrophotometric observations of these phenomena.

II. OBSERVATIONS FOR HIGH-FREQUENCY VARIABILITY

a) *Photometric Data*

Discovery of high-frequency optical variability in BD−7°3007 was made on 1972 March 11/12 using conventional single-channel photometric equipment, an on-line fast-Fourier-transform program, and integration times of 0.074 s.[1] Although no features were apparent in the power spectrum at high frequencies, it was found that the star was a low-amplitude variable at lower frequencies, and that flickering was taking place at frequencies in excess of 1.0 s^{-1} (see table 1).

Subsequent observations on three nights in 1972 March (table 1) used experimental and analytical techniques standard to our variable-star program (Hesser and Lasker 1972*b*), while on four nights in April–May simultaneous *B*, *V* observations were obtained with a two-channel photometer. As usual, quiescency standards were taken before and after observations of BD−7°3007.

Typical monitoring data shown in figure 1 illustrate the complexity of the photo-

* Operated by the Association of Universities for Research in Astronomy, Inc., under contract with the National Science Foundation.

[1] All observations described herein were made using the Cerro Tololo data system (Lasker 1971, 1972) and were taken on photometric nights of good, stable seeing. The fast-Fourier-transform program will be described in a subsequent publication.

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TABLE 1

SUMMARY OF AVAILABLE TIME-SERIES PHOTOMETRY

Date (1972)	Starting UT (h:m:s)	τ* (seconds)	N	Q†	A_{max} (mag)	$T(A_{max})$ (seconds)	Comments‡ Photocell	Filter	Aperture
March 11–12......	04:32:44	0.074	20480	0.020	0.010	§	1P21	NF	91 cm
March 12–13......	03:36:13	1.000	13817	0.020	0.0062	964	1P21	NF	91
March 14–15......	05:44:05	1.000	6503	0.020	0.0054	512	1P21	NF	152
March 15–16......	04:54:52	1.000	9184	0.027	0.0058	585	1P21	NF	152
April 28–29.......	00:22:23	5.000	2832	0.013	0.0028	1025	RCA 4516	B	91
April 29–30.......	23:12:14	5.000	4617	0.013	0.0044	1460	RCA 4516	B	91
April 30–May 1...	23:03:25	5.000	4743	0.014	0.0071	1280	RCA 4516	B	91
May 1–2.........	23:04:08	5.000	4665	0.021	0.0050	1205	RCA 4516	B	91

* On all nights except 1972 March 11/12 the values of τ specify the exact spacing used, the integration times having been 0ˢ010 shorter.

† A noise statistic defined in Hesser *et al.* (1969); quiescent white dwarfs and central stars of planetary nebulae typically have values of $Q \sim 0.010$ (Lasker and Hesser 1971).

‡ V-band data simultaneously acquired with an FW 130 photocell during 1972 April–May closely mimic the B-band data tabulated; NF indicates no filter.

§ Only a typical value of A is available for these data taken with a live-time Fourier analysis program; hence, no T is given.

metric behavior. In particular, we note the following.

i) Luminosity variations of 0.02–0.04 mag taking place in 5–10 min, with maximum excursions in more than 30 min of ~0.07 mag amplitude.

ii) Rapid, quasi-periodic variations of very low amplitude (see also § II*b* and table 1) superposed on the slower variations.

iii) Low-amplitude flickering persisting to high frequencies. Preliminary analysis suggests that the flickering does not disappear during the 31.6 hours of available data.

Thus the magnitude changes found by Hiltner in February (see Cowley and MacConnell 1972) occur on a more rapid timescale than previously realized. On the April-May nights the relative intensity records of B and V are quite similar, and no substantial changes in $B - V$ have yet been determined.

Attempts to phase features from different nights have not been successful, even though tantalizing coincidences have been noted. No identification of a minimum due either to the eclipse of a binary component (Kraft 1964; Mumford 1967) or to the occulation of a "hot spot" (Smak 1971; Warner and Nather 1971) has been made, but the morphological complexity of the variations is such that further analysis may be required to isolate such features.

b) *Power Spectral Analyses*

In an effort to isolate periodic features in the light curves obtained in March–May, we have subjected nearly all of the data to power spectral analysis (e.g., Hesser and Lasker 1972*b;* Hesser, Ostriker, and Lawrence 1969). As the spectra from individual nights contain many apparently random components, we have presented the arithmetic mean of the power spectra of the three March nights and of the four April–May nights in figure 2.

Figure 2 provides a much more reliable estimate than previously available (Hesser and Lasker 1972*a*) of those peaks that may be persistent. In particular, broad-banded peaks of low amplitude at ~1280 and 620 s appear to have been present on most nights.

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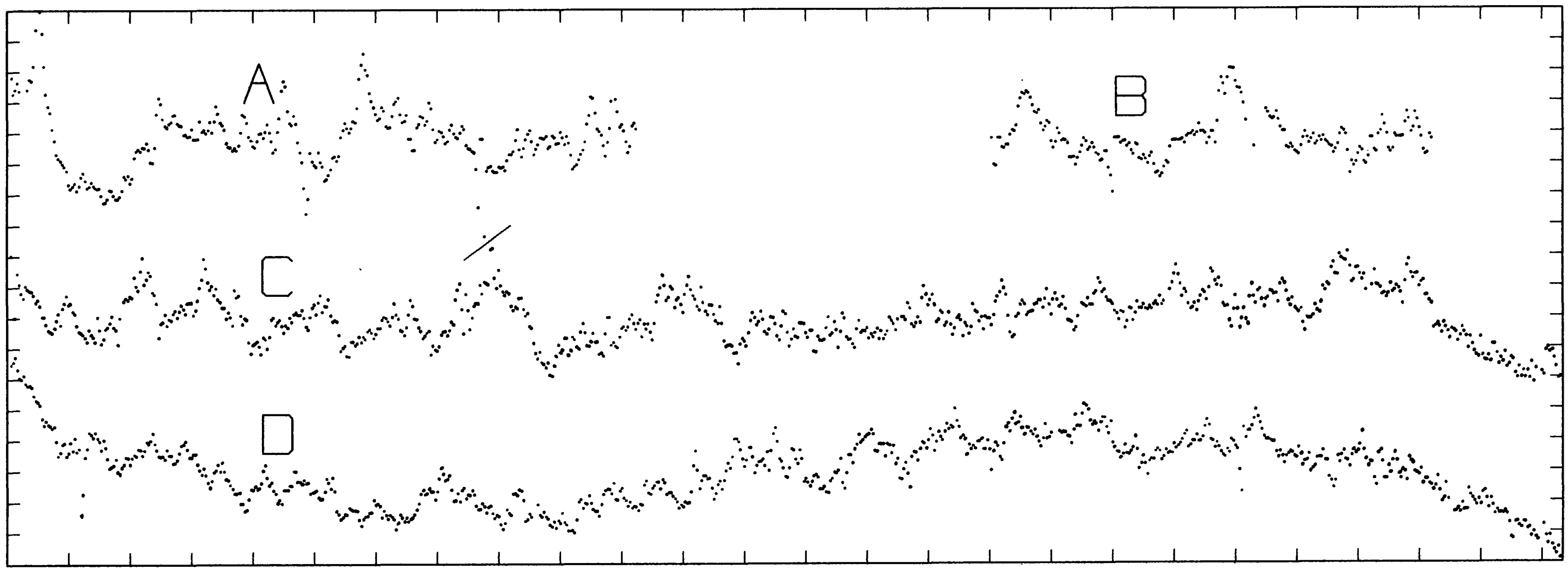

FIG. 1.—Representative light curves from the nights of (*a*) March 15/16; (*b*) March 14/15; (*c*) April 30–May 1; and (*d*) May 1–2. Each point is a 30-s integration, and the timescale is 15 min per horizontal division with an arbitrary zero point for each night. Similarly, the vertical scale is 0.05 mag per division with an arbitrary zero point for each data set. The first three moments have been removed from each data set; accordingly, the lowest-frequency phenomena in this display are not significant.

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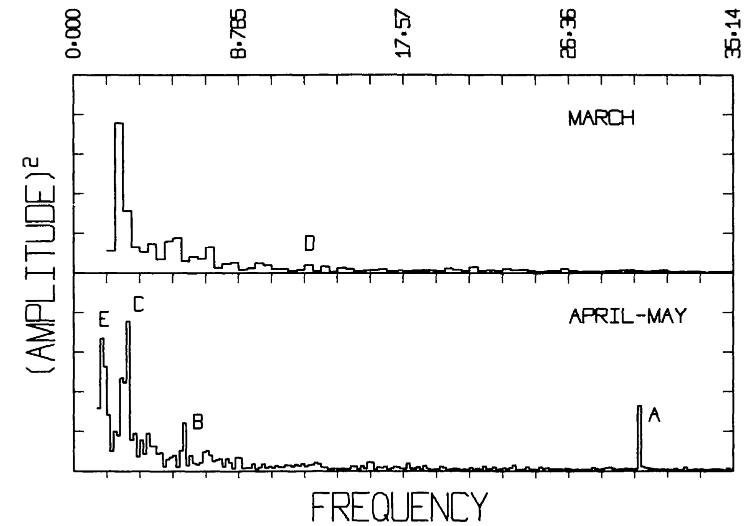

FIG. 2.—Combined power spectra for the March and the April–May data. The frequency scale, in cycles per hour, is the same for both portions. The amplitude scales are normalized such that frequency C corresponds to 0.0067 mag in the upper portion and to 0.0050 mag in the lower portion. Frequencies A, B, C, D, and E correspond to periods of 120, 620, 1280, 293 s, and 43.6 min, respectively; clearly (cf. table 1) peak E lies within the statistically unreliable portion of the power spectra. These spectra mirror the complex behavior of the light curves and they indicate that a continuum due to "flickering" is present.

The observed quasi-periods are reminiscent of those found in the white dwarfs HL Tau 76 (Landolt 1968; Warner and Nather 1972) and G44–32 (Lasker and Hesser 1969). Following various tests, we tentatively conclude that the narrow peak at 119.8 s, corresponding to the periodic error of the 91-cm telescope, probably resulted from an increased sensitivity to this error caused by the use of the dichroic beamsplitter.

The data, in both the time and the frequency domain, suggest that stochastic processes are a major, if not dominant, factor in the luminosity variation observed in BD$-7°$3007, even though suggestions of quasi-periodic phenomena are sufficiently strong that the search for the possible physical resonances should not be abandoned.

c) Scanner Observations

Data obtained with the CTIO scanner on one night at the 152-cm telescope and two nights at the 91-cm telescope show that Hγ is varying on a timescale of minutes to days. There was virtually no absorption in Hβ and Hγ on May 2/3 while the equivalent width of Hγ was 4 Å on May 12/13. The width of Hγ at half-maximum of 60 Å is indicative of a degenerate star. On the latter night Hα showed an emission peak 13 percent above the continuum as measured with a 20 Å exit slot (see fig. 3*a*).

Continuous fluxes based on the calibration of Oke and Schild (1970) were also obtained on May 12/13 at 3571, 4255, 5556, and 7100 Å. The resolution was 80 Å for the first two points and 160 Å for the last two. The results are fairly close to those for a 12,000° K blackbody distribution. This implies that it is very deficient in hydrogen; otherwise the Balmer jump would be larger and the Balmer lines stronger (see fig. 3*b*).

III. DISCUSSION

The photometric activity in BD$-7°$3007 has been shown to consist of moderately strong random activity (~0.1 mag) over a wide bandwidth superposed on weak, (at least) quasi-harmonic activity (~0.005 mag) at 10.3 and 21.3 min. In the 2–50 s range where a zero-temperature white dwarf would be expected to exhibit radial pulsations, we have found amplitudes of, typically, 0.0005 mag. As there is considerable flickering

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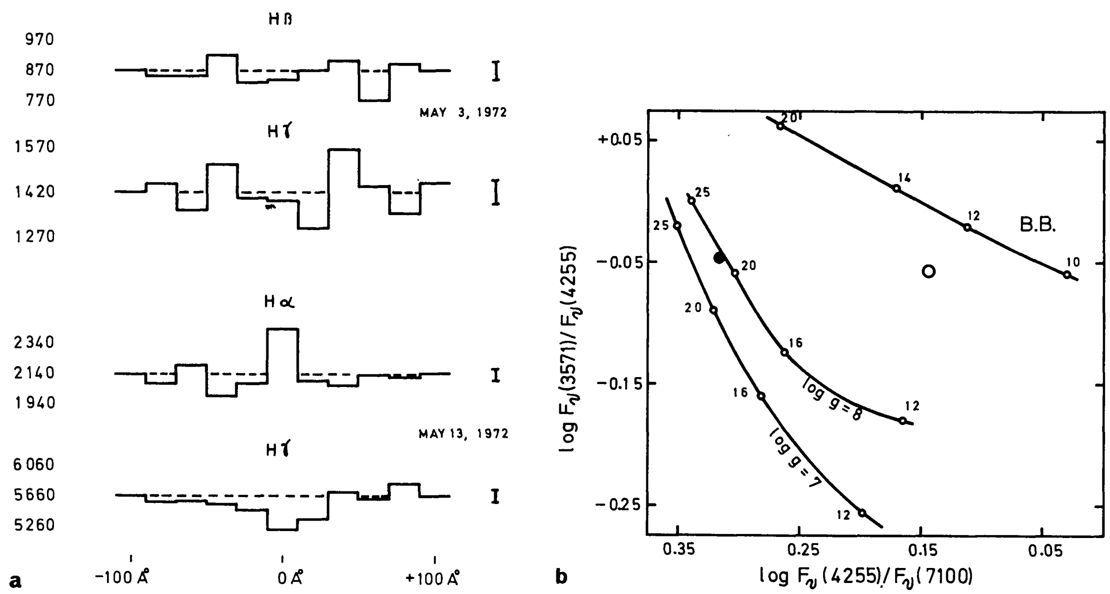

FIG. 3.—(*a*) Line profiles measured with the scanner and a 20 Å exit slot on two different nights. The ordinates are the counts per channel while the vertical lines at right show the standard deviations calculated from the photon statistics.

FIG. 3.—(*b*) Two-color diagram, where log $F_\nu(3571)/F_\nu(4255)$ is a measure of the Balmer jump; and log $F_\nu(4255)/F_\nu(7100)$, of the continuum slope. The solid lines show the blackbody relation (B.B.) and Shipman's (1971) models for DA stars with log $g = 7$ and 8. The numbers adjacent to the curves indicate T_e in units of 10^3 ° K. The open circle represents BD−7°3007, and the filled circle EG 70, a DA white dwarf.

in this frequency range, it is clear that the dynamical coupling between the flickering region and the stellar core is very small.

The present observations and those of MacConnell and Cowley (1972) make it seem unlikely that BD−7°3007 is a single star. No single white dwarf is known to us that has lines of H, He I, and Ca II. Furthermore, the nonperiodic photometric activity and the Hα emission are consistent with models of gaseous streaming in binary systems. Since all the spectral lines appear to be very broad, the interesting possibility exists that both components are degenerate stars.

It seems likely that extensive, coordinated photometric and spectroscopic efforts will be required to construct a detailed model of the system. Furtunately the brightness of BD−7°3007 makes it possible to pursue detailed studies with much greater ease than is usual for degenerate blue variables, and comparisons between the newly discovered variable of similar properties, CD−42°14462 (Hesser, Lasker, and Osmer 1972), and BD−7°3007 may play a key role in the derivation of models for these stars.

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