COMMISSIONS 27 AND 42 OF THE IAU
INFORMATION BULLETIN ON VARIABLE STARS

Number 5509

Konkoly Observatory
Budapest
12 March 2004

HU ISSN 0374 – 0676

DISCOVERY OF THE SECONDARY IN THE SPECTRUM OF THE SB1 SYSTEM HD 861

BUDAJ, J.[1,2]; ILIEV, I. KH.[3]; FEŇOVČÍK, M.[4]; BARZOVA, I.[3]; RICHARDS, M.T.[1]; GEORDZHEVA, E.[5]

[1] Dept. of Astronomy and Astrophysics, Penn State Univ., Davey Lab. 525, University Park, 16802 PA, USA

[2] Astronomical Institute, Slovak Academy of Sciences, 059 60 Tatranská Lomnica, Slovak Republic

[3] Institute of Astronomy, National Astronomical Observatory, P.O.B. 136, BG - 4700, Smolyan, Bulgaria

[4] Univ. of Pavol Jozef Safarik, Košice, Slovak Republic

[5] Technical University Sofia, Plovdiv Branch, Bulgaria

e-mail: http://www.ta3.sk/~budaj, iliani@astro.bas.bg, fenovcik@ta3.sk, mtr@astro.psu.edu

This star (HD 861, SAO 11044, HIP 1063, BD +61 16) is a well known SB1 binary but has been rarely studied although it is quite bright and close. Duflot & Fehrenbach (1956a, 1956b) mentioned that it had variable radial velocities. The orbital elements were determined by Acker (1971) from 14 observations combined with 3 additional older observations of Boulon (1956, 1957). Its orbital elements are: $P_{\rm orb} = 11\overset{\rm d}{.}2153, K = 43.8\,{\rm km\,s^{-1}}, {\rm e} = 0.22, {\rm V_0} = -12.5\,{\rm km\,s^{-1}}, \omega = 21\overset{\circ}{.}0$. It was classified as A2 based on the CaIIK line and as F2 based on the metallic lines by Slettebak & Nassau (1959). Calcium was found to be underabundant by about 0.4dex by Künzli & North (1998) who also determined the following parameters: $v \sin i = 35\,{\rm km\,s^{-1}}, \xi_{\rm turb} = 3.2\,{\rm km\,s^{-1}}, {\rm T_{eff}} = 7715\,{\rm K}, \log {\rm g} = 3.9$. It is thus an Am star. Hipparcos lists $V = 6\overset{\rm m}{.}63, \pi = 8.55 \pm 0.63\,{\rm mas}$ (ESA 1997). The photometric database of Mermilliod et al. (1997) lists the UBV observations of Bouigue et al. (1961) $V = 6.64, B - V = 0.19$. Geneva photometry can be found in Rufener (1980).

Our spectroscopic observations were carried out with the 2m RCC telescope of the Bulgarian National Astronomical Observatory in the frame of our observational program on Am stars in binary systems. The Photometrics AT200 camera with a SITe SI003AB 1024×1024 CCD chip, ($24\,\mu$m pixels) was used in the Third camera of the Coudé spectrograph to provide spectra in the 6400–6500 Å region with R = 32000. The typical S/N ratio is about 300. IRAF standard procedures have been used for bias subtracting, flat-fielding and wavelength calibration. Telluric lines have been removed using spectra of hot, fast rotating stars. Wavelength calibration has the r.m.s. error of 0.005 Å. Three spectra of HD861 were used in this study. The log of observations is listed in Table 1.

Spectra No.2 and No.3 have very little time difference and were coadded to increase their S/N ratio for the display in Fig.1. The spectra are displayed over a range of wavelengths centered at 6430Å in the vicinity of CaI λ6439 line. We have chosen this line as it is almost free of blends. It is apparent that there are two systems of lines that shift in opposite directions through the spectra. While the primary spectrum shifts towards

Table 1: List of observations: Date, HJD of the beginning of the exposure, effective exposure and radial velocity of the primary and secondary.

Sp.No.	Date [dd.mm.yyyy]	HJD (2450000+)	Eff. exp. [sec]	RV1 [$\mathrm{km\,s^{-1}}$]	RV2 [$\mathrm{km\,s^{-1}}$]
1	30.8.2001	2152.496	7230	-26.0 ± 1.5	62.3
2	4.10.2003	2917.280	5400	-41.0 ± 1.2	92.6
3	4.10.2003	2917.348	3980	-40.4 ± 1.0	91.8

the blue there are weak sharp features which move towards the red. The latter spectral lines are illustrated by the arrows. Moreover, these weak sharp lines are seen only in the vicinity of CaI and FeI lines, although there are much stronger FeII lines from the primary that are not accompanied by such sharp fine components. The weak sharp lines thus form at a cooler place than the photosphere of the primary. The fact that the fine lines are sharper also rules out their origin in the photosphere of the primary star.

We have calculated preliminary synthetic spectra and performed an abundance analysis of the primary. For this purpose we determined the effective temperature and gravity ($T_{\rm eff} = 8130\,{\rm K}, \log {\rm g} = 3.97$) from the Geneva photometry using the calibration of Kobi & North (1990). Model atmospheres were interpolated from Kurucz (1993). The VALD atomic line database (Kupka et al. 1999) also containing Kurucz (1990) data was used to create a line list for the spectrum synthesis. A detailed spectrum synthesis of the spectral regions was accomplished using the code SYNSPEC (Hubeny et al. 1994, Krtička 1998). The synthetic spectrum was convolved with the 0.2 Å instrumental profile and with the rotational profile. We estimated the projected rotational velocity $v \sin i = 37\,{\rm km\,s^{-1}}$. Observed and synthetic spectra are compared in Fig.2. Synthetic spectrum was shifted in wavelength to match the observed spectrum. There are no predicted theoretical lines at the points that we identify with the secondary which strengthens our claims above. Radial velocities of the primary were then measured by means of the cross-correlation with this synthetic spectrum. Radial velocities of the secondary were measured from the corresponding components of CaI λ6439, CaI λ6462 lines relative to their primary component lines which were assumed to have the velocity obtained from the cross-correlation of the whole spectrum. The estimated rms error of the radial velocity of the secondary star is about 2 $\mathrm{km\,s^{-1}}$. The velocities obtained in this way are listed in Table 1. They indicate a preliminary mass ratio of about 2. Also, we would like to point out that our radial velocities do not fit well on the predicted RV curve and more observations are under way to improve the orbital elements and determine the precise mass ratio of the system.

In summary, several independent arguments were presented to demonstrate convincingly that there are weak sharp features in the spectrum of HD861 which cannot be attributed to the primary star and that we have discovered the spectrum of the secondary which is a cooler, fainter and less massive star with considerably slower rotation than the primary.

This paper again underlines our feeling that our knowledge of bright and nearby stars is still incomplete. This is true especially for binary and multiple systems and when our knowledge is based on older photographic techniques only. Particularly photographic data involving the longer orbital periods (where the orbital Doppler shift is less or comparable to the rotational broadening of the spectral lines) and early type stars (that have few and broad lines) need to be used with caution. Our suspicion is that one might find more cases where the unresolved secondary lines and continuum may have led to previous

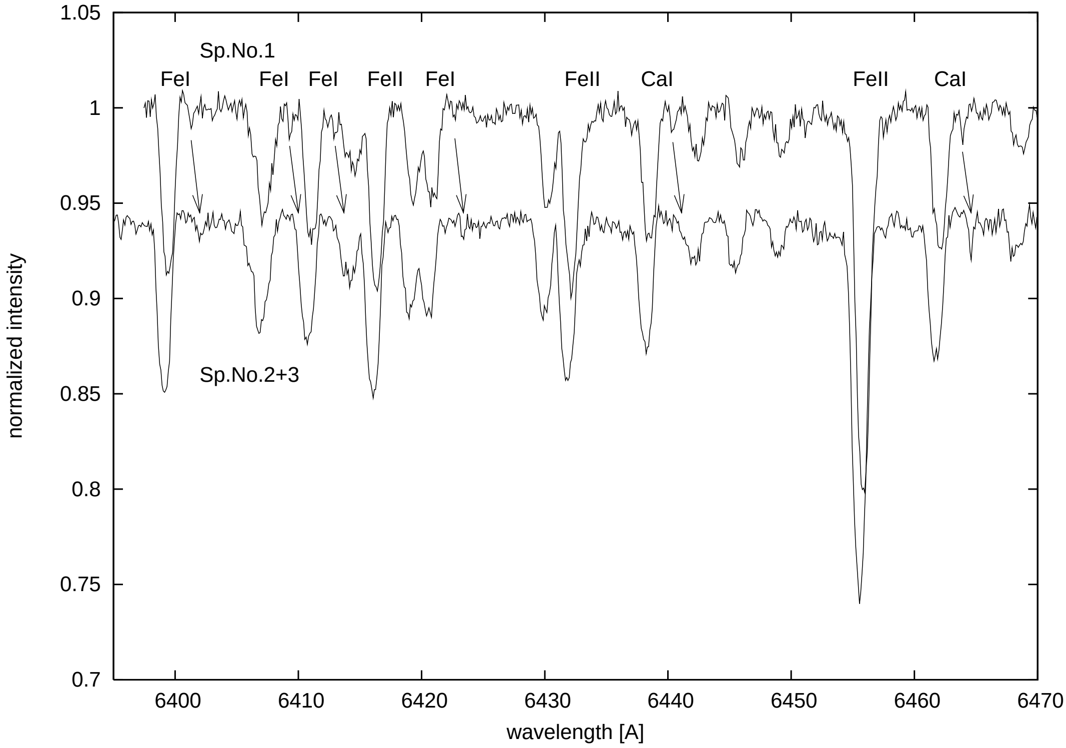

Figure 1. Two successive spectra of HD 861. While the strong lines of the primary are apparent and are shifted to the blue the fine and sharp components are sifted to the red as indicated by the arrows.

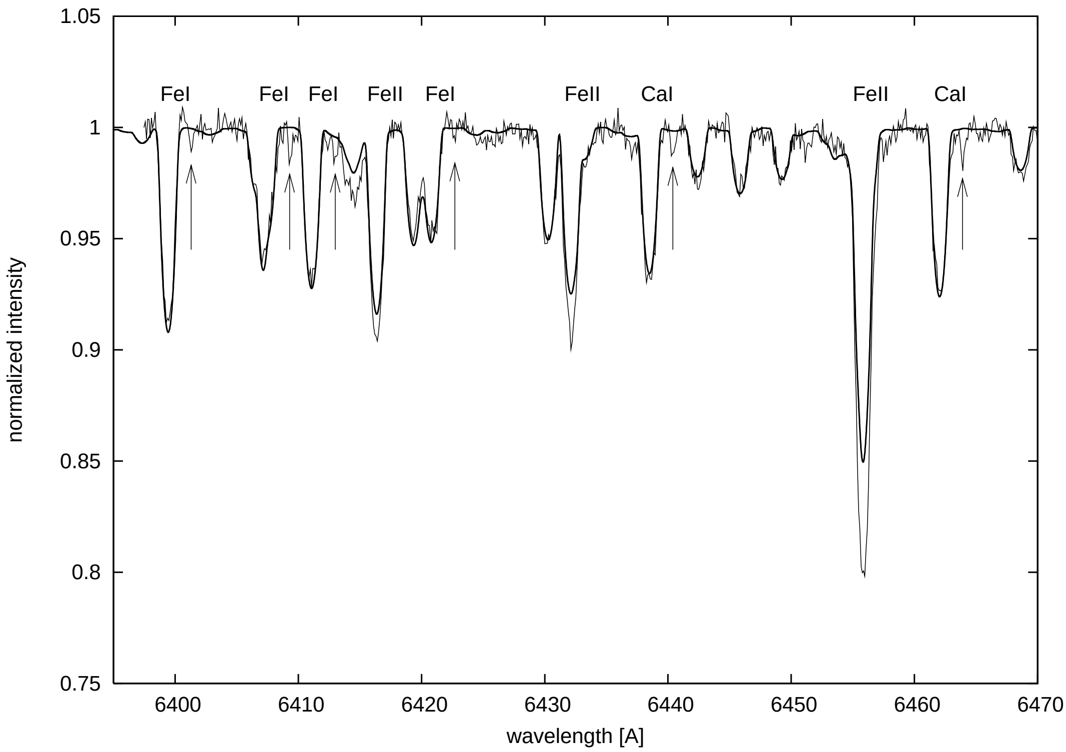

Figure 2. The observed spectrum No.1 (thin line) and the synthetic spectrum (thick line) of HD 861. Arrows indicate the position of secondary lines. There are no predicted theoretical lines at these points.

misinterpretations of the data. CCD observations with even small-medium telescopes can thus discover the binary nature or secondary spectra in many currently unresolved SB1 systems and can thus provide us with important information such as mass ratios as demonstrated recently e.g. by Faraggiana & Gerbaldi (2003), Faraggiana et al. (2001), Iliev et al. (2001a, 2001b), Budaj & Iliev (2003), Budaj et al. (2003) and Ryabchikova (1998).

JB gratefully acknowledges grant support from the Penn State university and wishes to thank Dr. K. Getman for his assistance with computer related problems. This research was supported by the NSF-NATO fellowship (NSF DGE-0312144) and partly by the VEGA grant No. 3014 from the Slovak Academy of Sciences and the Science and Technology Assistance agency under the contract No. 51-000802. This study made use of the Vienna Atomic Line Data Base (VALD) services.

References:

Acker, A., 1971, *A&A* **14**, 189
Boulon, J., 1956, *Publ. Obs. H^{te} Provence* **3**, No.58
Boulon, J., 1957, *Journal des Observateurs* **40**, 107
Bouigue, R., Boulon, J., Pedoussaut, A., 1961, *Ann. Obs. Toulouse* **28**, 33
Budaj, J., Iliev, I. Kh., 2003, *MNRAS* **346**, 27
Budaj, J., Iliev, I. Kh., Barzova, I. S., Žižňovský, J., Zverko, J., Stateva, I., 2003, *IBVS*, 5423
Duflot, M., Fehrenbach, Ch., 1956a, *Publ. Obs. H^{te} Provence* **3**, No.49
Duflot, M., Fehrenbach, Ch., 1956b, *Journal des Observateurs* **39**, 104
ESA, 1997 in *The Hipparcos and Tycho Catalogues*, ESA SP-1200
Faraggiana, R., Gerbaldi, M., 2003, *A&A* **398**, 697
Faraggiana, R., Gerbaldi, M., Bonifacio, P., 2001, *A&A* **380**, 286
Iliev, I. Kh., Budaj, J., Žižňovský, J., Zverko, J., 2001a, *IBVS*, 5051
Iliev, I. Kh., Budaj, J., Žižňovský, J., Zverko, J., Stateva, I., Geordzheva, E., 2001b, *IBVS*, 5199
Hubeny, I., Lanz, T., Jeffery, C.S., 1994, in Newsletter on Analysis of Astronomical spectra No.20, ed. C.S. Jeffery (CCP7; St. Andrews: St. Andrews Univ.), 30
Kobi, D., North, P., 1990, *A&AS* **85**, 999
Krtička, J., 1998, in Dušek J., Zejda M., eds., Proc. 20th Stellar Conf., Nicholas Copernicus Observatory and Planetarium, Brno, p. 73
Kupka, F., Piskunov, N.E., Ryabchikova, T.A., Stempels, H.C., Weiss, W.W., 1999, *A&AS* **138**, 119
Kurucz, R.L., 1990, Trans. IAU, XXB, 168 (CD-ROM 23)
Kurucz, R.L., 1993, ATLAS9 Stellar Atmosphere Programs and 2 km s^{-1} Grid (CD-ROM 13)
Künzli, M., North, P., 1998, *A&A* **330**, 651
Mermilliod, J.-C., Mermilliod, M., Hauck, B., 1997, *A&AS* **124**, 349
Rufener, F., 1980, Third Catalogue of Stars Measured in the Geneva Obs. Phot. System (Obs. de Genève)
Ryabchikova, T., Kotchoukhov, O., Galazutdinov, G., Musaev, F., Adelman, S.J., 1998, *Contributions of the Astronomical Observatory Skalnaté Pleso* **27**, 258
Slettebak, A., Nassau, J.J., 1959, *ApJ* **129**, 88