COMMISSIONS 27 AND 42 OF THE IAU
INFORMATION BULLETIN ON VARIABLE STARS
Number 4573

Konkoly Observatory
Budapest
25 March 1998

HU ISSN 0374 – 0676

SPECTROSCOPIC AND PHOTOMETRIC VARIATIONS OF HR 5

M. WEBER, K. G. STRASSMEIER

Institut für Astronomie, Universität Wien, Türkenschanzstr. 17, A-1180 Wien, Austria

e-mail: weber@astro.univie.ac.at, strassmeier@astro.univie.ac.at

We report on the discovery of radial velocity variations of the B component of the visual binary HR 5AB (=ADS 61, A-B separation: $1''\!.455\pm0''\!.004$; ESA 1997) with an orbital period of 1.026 days. Simultaneous photometric observations confirm the low-amplitude variability of similar periodicity originally discovered by Brettman et al. (1983). HR 5AB is a bright ($V\approx 6^m$) visual binary with a period of 106.83 years (Baize 1943, Lippincott 1963). Component A has been classified as dG4 and component B as dG8 (see Wilson 1953), but Lippincott (1963) found individual masses of 1.3 $M_\odot$ and 1.5 $M_\odot$, respectively and already noted that the fainter star is also the more massive.

Our spectroscopic data were obtained at the National Solar Observatory (NSO) with the McMath–Pierce telescope and the stellar spectrograph with a 800^2 TI CCD (TI-4 chip, 15μ pixels). The resolving power was R=40,000 and covered a useful wavelength range of about 45 Å. The observations were made within a two-month interval between October 31, 1996 and January 8, 1997 and consist of a total of 23 spectra centered at 6430 Å. The radial velocities were obtained from cross correlating the HR 5 spectra with nightly spectra of the IAU velocity standard α Ari (v_r=-14.3 km s^{-1}).

The photometric data were obtained with the Wolfgang 0.75-m automatic photoelectric telescope (APT), part of the Vienna Wolfgang-Amadeus twin APT at Fairborn Observatory in southern Arizona (Strassmeier et al. 1997). The observations were made differentially through Strömgren b and y filters with respect to HD 663 as the comparison star (V=6.68 mag, B$-$V=1.212), and HD 224784 as the check star (V=6.18 mag, B$-$V=1.032). Altogether, 48 data points were gathered between JD 2,450,395 and JD 2,450,441 and 7 additional points between JD 2,450,625 and 2,450,630.

Table 1. Preliminary orbital elements of HR 5B

Orbital element	Value
P (days)	1.0260±0.0013
T_0 (HJD)	2,450,393.95
γ (km s^{-1})	–12.1±0.6
K_1 (km s^{-1})	8.1±0.9
e	0.0 (adopted)
$a_1 \sin i$ (km)	0.114±0.013 $\times$ 10^6
$f(M)$	0.57±0.19 $\times$ 10^{-4}

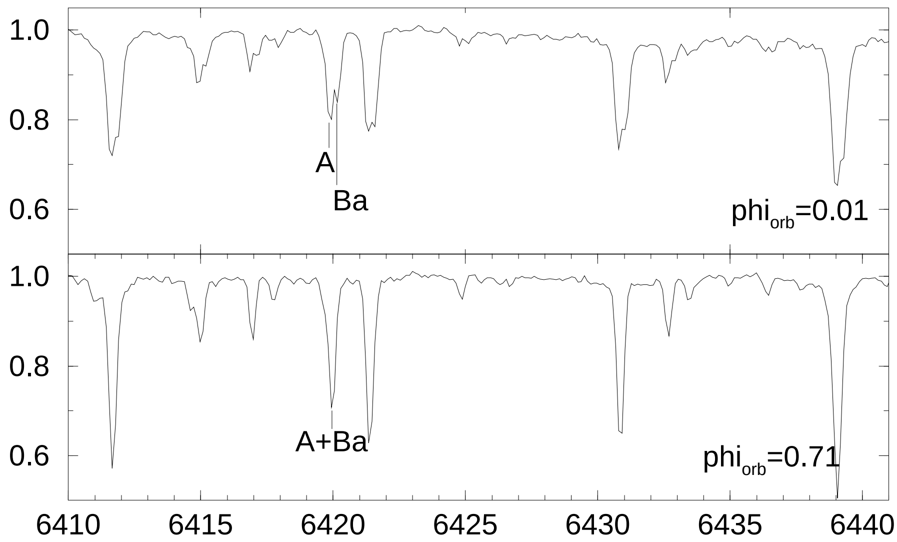

Figure 1. Two representative spectra of HR 5 taken on Dec. 2, 1996 (JD 2,450,420, top panel) and on Dec. 14, 1996 (2,450,432, bottom panel). HR 5A is the stationary component and Ba the variable but always red-shifted component with respect to A.

Figure 1 shows two representative spectra where the AB components are either clearly resolved (top panel) or blended (bottom panel). The stronger line is identified with the stationary A component while the weaker line is due to the variable Ba component. The Bb component is invisible. To measure precise radial velocities, we fitted two Gaussians to the doubled cross-correlation peaks. The resulting velocities for the A and Ba component are plotted in Figure 2. The standard error of a measure of unit weight is 1.1 km s^{-1} for component A and 4.0 km s^{-1} for component Ba. To estimate the projected rotational velocities of the two components, we also fitted two Gaussians to the blended spectral lines and obtained $v \sin i(\mathrm{A}) = 4.7 \pm 1.7$ km s^{-1} and $v \sin i(\mathrm{Ba}) = 4.7 \pm 1.3$ km s^{-1} for component A and Ba, respectively. A radial-tangential macroturbulence model of 3 km s^{-1} has been adopted for both components according to Gray (1992).

A period analysis of the radial velocities of component B showed a strong peak at 1.0260 days (Figure 2) and this was adopted to be the orbital period of Ba and Bb. We then used a modified version of the differential-correction program of Barker et al. (1967) to compute a SB-1 orbit for Bab. The elements are listed in Table 1. Note that a circular orbit was finally assumed since the error in e was larger than its optimized value. Figure 2 also shows the radial velocities of the A-component. Its standard deviation is 1.1 km s^{-1} while the B-component's are much larger (4 km s^{-1}).

The photometric data show a marginally significant period of 1.127±0.008 day (Figure 3) which is – formally – not consistent with the 1.082±0.002-day period found by Brettman et al. (1983). Due to the small amplitude of just ≈10 mmag in b and y, and because our time coverage was just two months with one measure per night, we believe that the two periods are still consistent.

The Hipparcos catalog (ESA 1997) lists HR 5 with a parallax of 49.3±0.87 milli-arcseconds corresponding to a distance of 20.28±0.43 pc and with magnitudes in the Hipparcos system of 6.488±0.004 and 7.427±0.009 for the A and B component, respectively. The respective Johnson UBV magnitudes are V(A)=6.352 and V(B)=7.291 mag, which add up to 5.97 mag for the whole A+Ba+Bb system. The magnitude difference

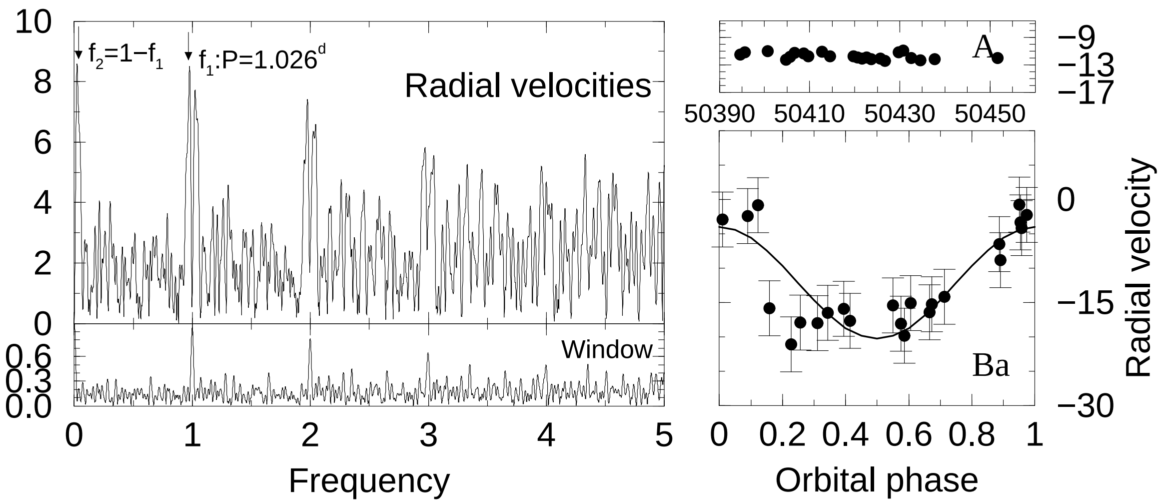

Figure 2. Periodogram and radial-velocity curve for component Ba. The best-fit period is indicated as f_1 (1.026 days) and its $1 - f_1$ alias as f_2 (39.5 days). The observed velocities are plotted as dots with error bars, while the line is the orbit from Table 1. Also shown are the radial velocities of component A.

B–A is 0.94 mag, i.e. larger by almost 0.2 mag compared to Wallenquist's (1954) 0.75-mag value from photographic plates. The fact that the photometric period is almost equal to the orbital period of Ba+b (different by just 9%) suggests that the weaker of the two visual components, the Ba component, is the photometric variable. Of course, our photometry contains both visible components but we may subtract the (presumably constant) A-component from the total light and derive the maximum V magnitude for B of $V_{\rm max}$(B)=7.181 mag (transformed from Strömgren y to Johnson V with the relation of Olsen 1983). The corrected amplitude of Ba is then 0.015 mag.

With the new Hipparcos distance, we first obtain absolute magnitudes for the two visual components of M_V(A)=+4.82±0.05 mag and $M_V(\rm Ba + b)$=+5.65±0.05 mag, and also revise the total mass of 2.8±0.6 $M_\odot$ from the visual orbit (Lippincott 1963) to 2.25±0.14 $M_\odot$ (the semi-major axis a is revised to 29.5±0.6 A.U.). According to Gray (1992), the magnitudes match G3V and ≈G8V stars for A and Ba and, in case we neglect interstellar absorption, suggest individual masses of 1.04 $M_\odot$ and ≈0.88 $M_\odot$ and radii of 0.99 $R_\odot$ and 0.87 $R_\odot$, respectively. The relative mass ratio $M_{\rm B}/(M_{\rm A} + M_{\rm B})$ of 0.546±0.006 was computed by Lippincott (1963) from the brightness difference $\Delta m_{\rm pg} = 0.75$ (Wallenquist 1954; note that Wilson (1953) listed a Δm of 0.9). The luminosity ratio $L_{\rm B}/L_{\rm A}$ from the Hipparcos brightness difference of $\Delta m_{\rm Hip} = 0.94$ is ≈0.42 and agrees with the line ratio of 0.69±0.07 (1σ) measured from our red-wavelength spectra corresponding to $\Delta m_{\rm R} = 0.40$ in the R-band.

Finally, with the revised total mass of 2.25 $M_\odot$, we obtain $M_{\rm Ba+b}$=1.23±0.09 $M_\odot$ and $M_{\rm A}$=1.02±0.23 $M_\odot$ for the two visual components. The former value would leave just 0.35 $M_\odot$ for $M_{\rm Bb}$ in case the tabulated mass of a G8-dwarf is used for $M_{\rm Ba}$. The mass function from Table 1 further constrains the minimum Bb mass to $M_{\rm Bb} \sin i$ ≈0.044 $M_\odot$. If we assume that the light-curve variability is due to starspots, which is very likely for a G8-dwarf and was already suggested by Brettman et al. (1983), and thus the photometric period is equal to the rotation period of the Ba component, our measured $v \sin i$ would correspond to a minimum radius for Ba of $R \sin i$(Ba)=0.10±0.04. This would require

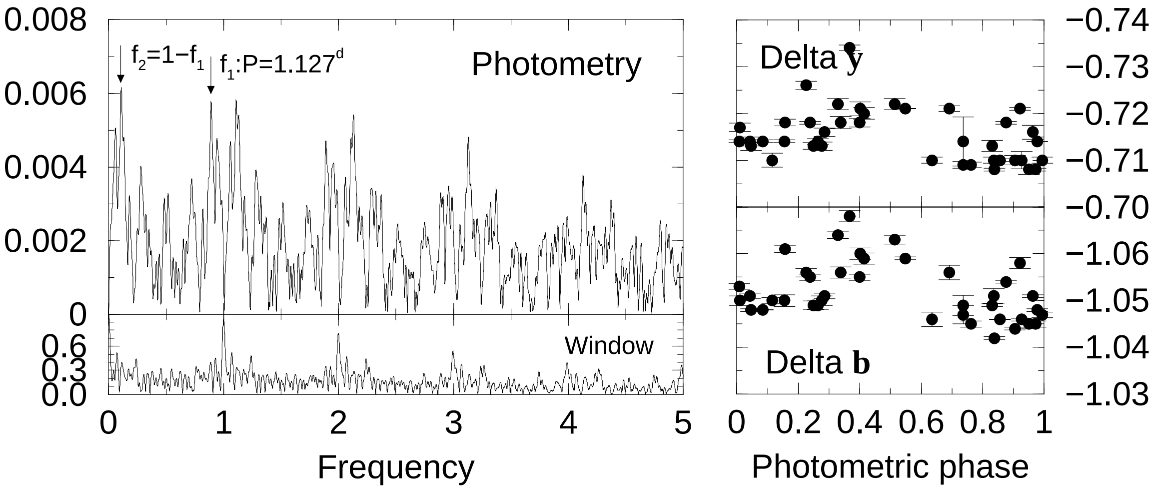

Figure 3. Periodogram and light curves from the Strömgren *by* APT data from Nov.–Jan. 1996/97. A peak at P=1.127 days near the orbital period is seen but is of marginal significance with respect to the average noise level of around 10 mmag. Since the standard error of a single datapoint is just 2.5 mmag for Wolfgang, the large noise level indicates that our sampling did not maintain phase coherence.

the unusual low inclination of the rotation axis of 6°.6±3°.5 to match a typical radius for a late-G dwarf star of ≈0.87 $R_\odot$. If we further assume that the rotation axis of Ba is perpendicular to the orbital plane of Ba–Bb, the minimum mass for Bb corresponds to ≈0.38 $M_\odot$, in good agreement with the mass estimated from the visual orbit. The spectral type for Bb is then most likely M2 or M3. Note that the orbital plane of the spectroscopic binary Bab would then be inclined to the orbital plane of the visual components AB by ≈40°.

We acknowledge support from the Austrian Fond zur Förderung der wissenschaftlichen Forschung (FWF) through grants S7301-AST and S7302-AST.

References:

Barker, E. S., Evans, D. S., Laing, J. D.: 1967, *R. Obs. Bull.* 130
Baize P.: 1943, *Astronomie*, **57**, 44
Brettman, O. H., Fried, R. E., Duvall, W. M., Hall, D. S., Poe, C. H., Shaw, J. S.: 1983, *IBVS*, No. 2389
ESA: 1997, *The Hipparcos Catalogue*, ESA SP-1200
Gray, D. F.: 1992, *The observation and analysis of stellar photospheres*, Cambridge University Press, 2nd edition
Lippincott, S. L.: 1963, *AJ*, **68**, 45
Olsen, E. H.: 1983, *A&AS*, **54**, 55
Strassmeier, K. G., Boyd, L. J., Epand, D. H., Granzer, T.: 1997, *PASP*, **109**, 697
Wallenquist, A.: 1954, *Uppsala Astron. Obs. Ann.*, **4**, 2
Wilson, R. E.: 1953, *General catalogue of stellar radial velocities*