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DETECTION OF A TERNARY SPECTRUM IN HD 216608

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This star (HD 216608, HR 8708, SAO 52465, HIP 113048, BD +43 4331) is a visual binary system ADS 16345 AB. The B companion (F6V star) revolves about the primary with a period of 105 yr, major semi-axis of 0."60 and $M_{\rm A} + M_{\rm B} = 2.62 M_\odot$ (Finsen & Worley 1970, Söderhjelm 1999). HIPPARCOS lists the visual B companion separated by $0\farcs95$ (ESA 1997). Fabricius & Makarov (2000) obtained the following magnitudes in the Tycho passbands: $B_T = 6\overset{m}{.}29, V_T = 6\overset{m}{.}01$ for the A companion and $B_T = 8\overset{m}{.}43, V_T = 7\overset{m}{.}81$ for the B companion. There is also an optical C companion, $10\overset{m}{.}7$, at $28\farcs0$ (Abt & Levy 1985). The brightest member (HD 216608A) is an SB1 binary. It was first reported as variable in radial velocity by Young (1939). Later on this was confirmed by Abt et al. (1980). Its Am characteristics were discovered by Walker (1966) who also are A2V spectral type and $v \sin i = 50$ km s^{-1}. Cowley et al. (1969) classified the star as A3m, Abt (1981) as Am and A3/F0V/F4 from the CaII K/Hydrogen/Metallic lines (abbreviated usually as K/H/M). Another classification is proposed by Sreedhar Rao & Abhyankar (1991) according to the K, m39, m43 and SrII 4077 lines: A3V, F2III/IV, F2III/IV and Ap, respectively. Orbital elements ($P_{\rm orb} = 24\overset{d}{.}1635$, $e = 0.2$, $K = 10.1$ km s^{-1}) were derived by Abt & Levy (1985) from the photographic plates with a resolution of 0.4 Å and a dispersion of 16.9 Å mm^{-1}. They also give spectral types A2/A8/F2 from the K/H/M lines, respectively. Abt & Moyd (1973) measured $v \sin i = 35$ km s^{-1} while Abt & Morrell (1995) obtained $v \sin i = 46$ km s^{-1} from CCD spectra with a resolution of 0.33 Å. They also reclassified the star as Am (A2/F1/F2). Tokovinin (1997) estimated the following masses for the companions: $M_{\rm Aa} = 2.54 M_\odot$, $M_{\rm Ab} \geq 0.27 M_\odot$, $M_{\rm B} = 1.25 M_\odot$.

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 μm 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. The log of observations is listed in Table 1.

Table 1: List of observations: Date, HJD of the beginning of the exposure and effective exposure time.

Sp.No.	Date	HJD (2450000+)	Eff. exp. (in seconds)
1	10.6.2001	2071.496	3000
2	30.8.2001	2152.408	7210
3	2.9.2001	2155.364	4280

A small portion of all the three spectra in the vicinity of CaI 6439 which is most illustrative is depicted in Fig. 1. We have chosen this line as it is free of blends. It is apparent that there are two systems of sharp lines travelling and crossing in the spectra. Nevertheless, all the lines in the spectra are broader and stronger than what could be expected from a simple sum of both sets of sharp lines (note e.g. the Fe lines). This fact seems to be caused by a third faster rotating star which does not seem to have moved in our 3 spectra within the precision of measurements.

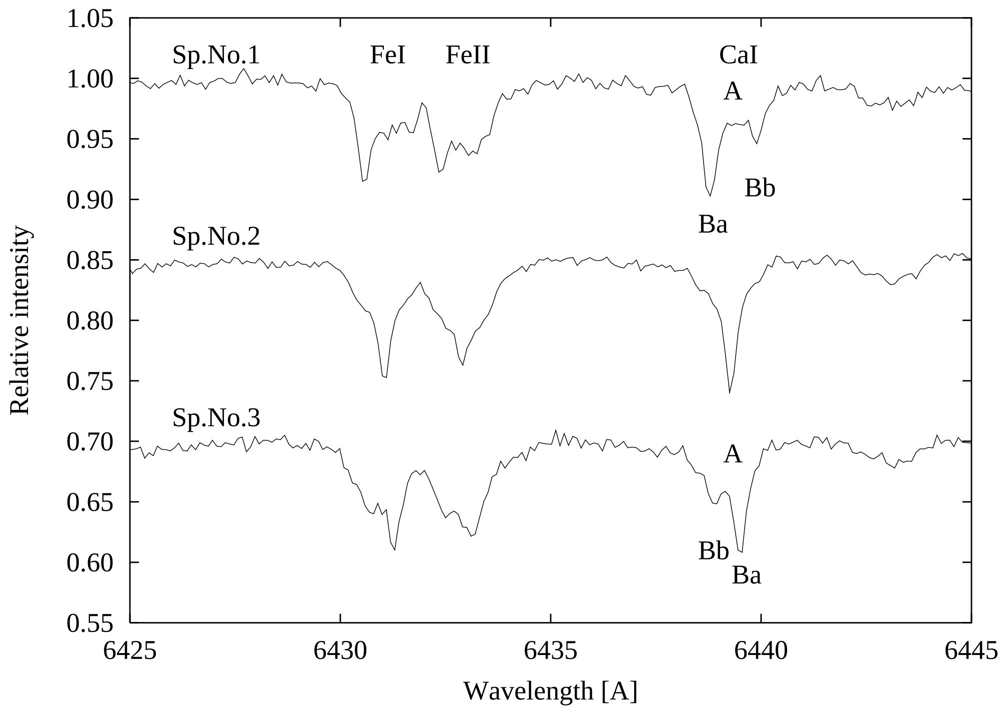

Figure 1. Three successive spectra of HD 216608. While Ba and Bb lines are clearly separated on the first spectrum, they shade in the next spectrum to become separated again in the third spectrum. Lines of the A component are much wider and do not seem to have moved.

Based on what is known about the system, one could conclude that the apparently moving sharp line components are formed in the above mentioned SB1 system HD 216608A while the broad line component belongs probably to the visual B companion. However, this interpretation has serious gaps. The visual A companion is hotter and brighter than the B companion and it is hardly probable that it has much sharper lines than the B one. Considering the synchronization mechanism of Tassoul & Tassoul (1992) stretching to relatively long orbital periods could partly avoid the problem. However, these sharp lines, although very pronounced, carry only a very small amount of the total equivalent width of the ternary blend especially in iron lines. This guides us to suggest that the sharp lines belong rather to the visual B companion which thus seems to be a new SB2 binary. We will denote the deeper lines as the primary (Ba) and the less pronounced sharp lines as the secondary (Bb). The broad lines would then originate from the A companion. The broad components of the Ca lines are relatively much weaker than those of Fe lines what confirms the Am characteristics of HD 216608A making both sharp line components more outstanding in Ca than in Fe.

The above accounts were confirmed by fitting the CaI line with three gaussians (Kratka 1988; Sp. No. 2 only with two gaussians as Ba and Bb overlap). All three spectra give a consistent output as far as the depth and half-widths of all 3 components is concerned what gives firmer footing to the result presented above (see Table 2). This also explains the inconsistent rotational velocities of different authors ranging from 35 to 50 $\mathrm{km\,s^{-1}}$. Under the assumption that the velocity of the mass centre of Ba+Bb did not change during the summer, we get from the Sp. No. 1 and 3 for the mass ratio: $M_{\rm Ba}/M_{\rm Bb} = \Delta v_{\rm Ba}/\Delta v_{\rm Bb} = 47.9/34.4 = 1.39$. This mass ratio then yields radial velocity of the mass center Ba+Bb: $v_{\rm B} = 8.0$ $\mathrm{km\,s^{-1}}$. This value is consistent with the radial velocity of the Ba+Bb blend from Sp. No. 2 where Ba and Bb lines roughly overlap. The estimated 1σ precision of our radial velocity measurements is about 1 $\mathrm{km\,s^{-1}}$ for the sharp Ba and Bb lines and about 4 $\mathrm{km\,s^{-1}}$ for the broad A companion lines.

Finally, we have used the spectrum synthesis code SYNSPEC (Hubeny et al. 1995, Krtička 1998) to fit the spectra and estimated the following values of $v \sin i$: 9, 5, 43 $\mathrm{km\,s^{-1}}$ for Ba, Bb and A component, respectively. An allowance for the instrumental profile was included in the above procedure. In the case of both sets of sharp lines it makes no sense to correct for another free parameter, thus microturbulence was set to zero. Consequently, their rotational velocities are rather upper limits. In the case of broad lines microturbulence of about 2 $\mathrm{km\,s^{-1}}$ was considered which made a better fit of the iron lines. In our opinion sharp Ba and Bb lines cause heavy blends of broad A lines and could have affected previous radial velocity measurements in lower resolution leading to a spurious orbit. The previous mass estimates of all the components and the very SB1 nature of the HD 216608A must certainly be revisited in the future. It is HD 216608B which seems to be a newly discovered SB2 binary.

Table 2: Results of the CaI 6439 line fitting.

Sp. No.	central depth			gaussian half width Å			rad. velocities [$\mathrm{km\,s^{-1}}$]		
	Ba	Bb	A	Ba	Bb	A	Ba	Bb	A
1	0.069	0.026	0.035	0.16	0.11	0.70	-14.2	38.9	12.1
2	0.068		0.041	0.12		0.52	9.6		4.0
3	0.064	0.018	0.035	0.14	0.12	0.60	20.2	-9.0	0.5

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