## A review of Am star studies recently made at the 2-m RCC telescope of the Rozhen NAO \*

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(Conference talk)

Abstract. A detection of a secondary spectrum in five spectroscopic binary systems is reported here. High signal-to-noise high-resolution spectroscopic observations have been carried out at the Rozhen NAO concerning mainly Am stars in binary systems. We reach the conclusion that photographic data for early type binaries with long orbital periods (where the orbital Doppler shifts are less than or comparable to the rotational broadening of the spectral lines) and which have only a few broad lines, should be revised or at least used with caution. We demonstrate that discovery of the binary nature or secondary spectra in many currently unresolved SB1 systems is possible through CCD-observations, even with 2-m class telescope. We were able to determine directly the mass-ratios for the newly discovered SB2 systems and to show that old data could lead to doubtful orbits. For two of the systems radial-velocity curves were obtained also.

Key words: spectroscopic binaries, Am stars

# Обзор на изследвания на Am звезди, извършени напоследък с 2-м телескоп на НАО-Рожен

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Съобщава се за детектиране на вторичен спектър в пет спектроскопично-двойни звезди. В НАО - Рожен бяха проведени спектроскопични наблюдения с високо разрешение и с високо отношение сигнал/шум, обхващащи глявно Am звезди в днойни системи. Ние стигнахме до заключението, че фотографическите данни за двойни звезди от ранни типове с дълги орбитални периоди (където орбиталните доплерови отмествания са по-малки или сравними с ротационните разширявания на спектралните линии), които имат само няколко широки линии, би трябвало да се преразгледат или поне да се използват предпазливо. Ние показваме, че откриване на двойствена природа или на вторични спектри в множество текущо нерарешими SB1 системи е възможно чрез CCDнаблюдения даже с телескоп от 2-м клас. Ние успяхме да определим пряко отношенията на масите на новооткритите SB2 системи и да покажем, че старите данни биха могли да доведат до съмнителни орбити. За две от системите бяха получени и кривите на лъчевите скорости.

### Introduction

Detailed study of Am binaries is necessary for finding the physical reason for their abundance anomalies and for clarifying the role of tidal interactions and diffusion in stellar atmospheres. Am stars belong to a group of chemically-peculiar stars of the upper main sequence (MS). They have A0 to F4 spectral types (temperature scale 10000 K to 7000 K). Their typical features are (Preston [1974]): presence of strong lines of metals, weak lines of Ca, Sc and other light elements, lack of spectroscopic and photometric variability (although the instability strip crosses MS in the region of Am stars), absence of magnetic fields, high frequency in binary systems (up to 90%) and low rotational velocities ( $v \sin i < 100 \text{ km s}^{-1}$ ). Am peculiarity seems to be more pronounced with increasing eccentricity and orbital period of the binary system (Budaj [1997], Iliev et al. [1998]). A recent survey of 192 Am stars (Debernardi [2002]) showed a high rate of SB2 systems within 100 pc. The role of duplicity in driving peculiarity in metallic line stars was indicated once more.

 $<sup>^{\</sup>star}$  Based on observations collected at the Rozhen National Astronomical Observatory

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#### 1 Observations, Data Reduction

Our spectroscopic observations were carried out with the 2-m RCC telescope of the Bulgarian NAO Rozhen during the period 2000–2004. A Photometrics AT200 camera with a SITe S1003AB chip ( $1024 \times 1024$ ,  $24\mu$ m pixels) was used in the Coudé spectrograph in order to obtain spectra in 100 Å wide spectral regions centered at 6440 Å and 6507 Å with a resolving power R = 32000. The typical S/N ratio reached was about 300. Standard IRAF procedures were used for bias subtraction, flat-field division and wavelength calibration. Hot, fast rotating stars were used for removal of telluric lines. Radial velocities of the components were computed with noao.rv.rvidlines IRAF procedure, after correction for heliocentric motion and cross-correlation function using KOREL code (Hadrava [1995]). Spectral lines were identified using the SYNSPEC code (Hubeny et al. [1994], Krtička [1998]) for spectrum synthesis. The atmospheric parameters were derived from Geneva photometry using calibrations of Kobi & North [1990]. The line list for the spectrum synthesis was created with the VALD atomic line database (Kupka et al. [1999]).



Фиг. 1. HD 434 – the two spectra were shifted by -0.15 in relative intensity; BËaBË denotes the lines of the primary and BËbBË – of the secondary star.

#### 2 Resuts

We briefly present the five newly discovered SB2 systems from the observed target list of 27 Am-stars.

HD 434 (HIP 728) was first found to be an SB1 system by Shajn [1951], who determined its spectral type as A2s. A few years later Palmer et al. [1968] found its rotational velocity  $v \sin i$  to be 60 km s<sup>-1</sup> and classified it as an A4Vm star. In 1985 Hube & Gulliver [1985] succeeded in calculating its preliminary orbital elements using 38 photographic 15 Å mm<sup>-1</sup> spectra. These elements were confirmed by Margoni et al. [1992]. Sreedhar Rao & Abhyankar [1992] analysed 33 spectra with dispersion of 33 Å mm<sup>-1</sup> and speculated the presence of a second spectrum, at least 1<sup>m</sup>5 fainter. The secondary spectrum of the system (see Fig.1) was observed by Iliev et al. [2001]. CCD observations revealed the strong peculiarity of the primary ([Ca/Fe] = 0.27) (Burkhart & Coupry [1989,1997]) and it was noticed its  $v \sin i$  is about half of the published value of 60 km s<sup>-1</sup>. Direct mass-ratio  $M_1/M_2 = 1.19 \pm 0.06$  was derived, and systemic velocity was obtained to be 12 km s<sup>-1</sup> (Budaj et al. [2003]).

The radial-velocity curve (Fig. 2) was obtained by Atanasova et al. [2006] using PHOEBE (Physics Of Eclipsing BinariEs) software, developed on the Wilson-Devinney code (Prśa & Zwitter [2005]).



Фиг. 2. Radial-velocity curve of HD 434. The photographic velocity curve (open circles) was computed with data from Hube & Gulliver [1985], Sreedhar Rao & Abhyankar [1992] and Margoni et al. [1992]. The CCD velocity curve shows higher semi-amplitudes of the primary (bullets) and secondary (black triangles) respectively ( $K_1 = 37 \text{ km s}^{-1}$ ,  $K_2 = 47 \text{ km s}^{-1}$ ). The mass-ratio is  $M_1/M_2 = 1.26 \pm 0.03$ .

HD 861 (HIP 1063) is a well known SB1 binary but has been rarely studied although it is quite bright and close:  $V = 6^{\rm m}3$ . Duflot & Fehrenbach [1956] mentioned that it had variable radial velocities. It was first classified as a metallic-line A-type star by Slettebak & Nassau [1959]. They classified it as A2 based on the CaIIK line and as F2 based on the metallic lines. The orbital elements were determined by Acker [1971]: Porb = 11<sup>d</sup>.2153,  $K = 43.8 \text{ km s}^{-1}$ , e = 0.22,  $V_0 = -12.5 \text{ km s}^{-1}$ . The first detection of the secondary in its spectrum was reported by Budaj et al. [2004] (see Fig. 3). The most probable explanation of the newly found sharp lines was that they originate from the so far unseen secondary component of the binary system. A preliminary synthetic spectrum of the primary was calculated and a preliminary abundance analysis was performed. The projected rotational velocity was estimated to be  $v \sin i = 37 \text{ km s}^{-1}$ . A preliminary mass-ratio of about 2 was indicated by obtaining radial velocities of the components. Budaj et al. also pointed out that their measurements of the radial

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velocities do not fit well the predicted radial-velocity curve. It was confirmed later and not published yet that  $Porb = 15^{d}.97$ .



Фиг. 3. HD 861 – the apparent strong lines of the primary are shifted to the blue, the fine and sharp components are shifted to the red as the arrows indicate.

HD 108642 (HIP 60880,  $V = 6^{\rm m}5$ ) is an SB1 system with Porb = 11<sup>d</sup>215, e = 0.0,  $K = 41 \rm \,km \, s^{-1}$ ,  $V_0 = 0.7 \rm \,km \, s^{-1}$ . Its SB2 nature was only suspected, indirect estimations give  $M_1/M_2 = 1.9$ . Slow rotation ( $v \sin i < 5 \rm \,km \, s^{-1}$ ) of both components facilitates clear recognizing of the secondary (Budaj et al. [2003]). Our first direct determination of the mass-ratio shows that  $M_1/M_2 = 1.8$ . Due to orbital motion BTbhabTbk and BTbhbbTbk line systems exchange places what is exhibited in Fig. 4.

HD 178449 (17 Lyr, HIP 93917,  $V = 5^{\text{m}}2$ ). It is the A component of ADS 12061 and an SB1 system as well. The B component is a 9<sup>m</sup>0 star 4"away from A. We have included HD 178449 in our target list mainly for using it as a reference object for the synthetic spectrum procedures at high rotational velocities ( $\approx 130 \text{ km s}^{-1}$ ). The star itself turned out to be very interesting and we spent a large amount of observing time to investigate the origin of the sharp features seen in the bottom of most lines (Budaj & Iliev [2003]). Their nature is neither interstellar, nor shell, they do not belong to the B component. A comprehensive analysis including synthetic spectrum calculations (the dashed line in Fig. 5) shows that the weak details originate from a G-dwarf companion, which is apparently a newly discovered Ab component of the system. A small part of the spectrum of HD 178449 with  $S/N \approx 1700$ , carefully aggregated for more than 11 hours of total exposure time is shown here.

HD 216608 (ĤIP 113048) is a visual binary system. Component B (F6V star) orbits the primary with Porb = 105 years. There is an optical companion C (11<sup>m</sup> star) also. The brightest member HD 216608A has Am characteristics and it is considered to be an SB1 system. This is the reason it was included in our target list. The published orbital elements are (Abt & Levy [1985]): Porb = 24<sup>d</sup> 164, e = 0.2, K = 10 km s<sup>-1</sup>. Spectroscopic observations reveal the triple structure of the line profiles. Precise analysis



Фиг. 4. HD 108642 – Two spectra shifted by -0.25 in relative intensity are shown here; BËaBË denotes the lines of the primary and BËbBË – of the secondary star.



Фиг. 5. HD178449 – see the text for more details.

(Iliev et al. [2001]) shows that sharp moving details both belong to the cool B component which seems to be a newly discovered SB2 system. The two systems of lines are marked as вЪњВавЪќ and вЪњВbвЪќ, while вЪњАвЪќ stands for lines related obviously with the hot A component. Heavy blends resolved partially here could affect all previous measurements of radial velocities in lower spectral resolution leading to false orbits. The very SB1 nature of HD 216608A should be revised as well (see Fig. 6).

#### Conclusion

Observations of a larger sample of binaries with Am-components and refining orbital elements of the systems require high-quality spectroscopic data. More accurate values for these elements,  $v \sin i$  and chemical abundances would give support to the tidal



Фиг. 6. HD 216608 – While Ba and Bb lines are clearly separated in the first spectrum, they shade in the next spectrum to become separated again in the third spectrum. The lines of the A component are much wider and do not seem to have moved.

mixing and stabilization hypothesis of Budaj [1996, 1997, 1999]. Acknowledgments. This work was supported in part by Bulgarian NSF grant F-1403/2004.

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