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Stars with Discrepant v sin i as Derived from the Ca II 3933 and Mg II 4481 Å Lines

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Abstract. Axial rotation of a star plays an important role in its evolution, physical conditions in its atmosphere and the shape of its spectrum. Methods of determining $v \sin i$ are based on comparison of the observed profiles of spectral lines with the theoretical ones. Their accuracy depends on the type and quality of spectrograms, as well as on the algorithms used. A frequently used method is a simple comparison of one line, e.g. the Ca II at 3933 Å or Mg II at 4481 Å. This, however, may result in a false value of $v \sin i$ in the case when low-dispersion spectra are used. We investigate the spectra of stars with a significant discrepancy of their rotational velocities introduced in various sources, and analyze the corresponding spectral region from the point of view of possible admixed features, which may mask the true line profiles. We use the CCD spectra of the stars having this discrepancy to compare with theoretical spectra. We also studied the photographic spectra, obtained during the 1970s and 1980s.

1 Introduction

Selecting chemically peculiar stars using an ambiguous classification of their peculiarity types from the catalogue by Bertaud & Floquet (1974), we found large differences between the values of $v \sin i$ introduced in the catalogs of Palmer et al. (1968) and Wolf & Preston (1978). While the former work is based on the Ca II 3933 Å line, the latter uses the Mg II 4481 Å line. One of the stars was 53 Aur in which we detected a spectrum of a companion (Zverko et al., 2008). We found other 24 such stars, five of which were classified as chemically peculiar in Bertaud & Floquet (1974), and further three in Renson (1991). The stars are listed in Table 1. Besides the main discrepancy, two groups can be easily distinguished, namely, 15 stars with $v \sin i\,(\mathrm{Ca}) > v \sin i\,(\mathrm{Mg})$, and 9 stars of the opposite inequation.

In this paper we bring a progress report on our investigations of high dispersion, high S/N CCD spectra of the stars collected. We also investigate the photographic spectra obtained during the seventh and eighth decades of the past century, which may help to disclose how the misestimation of the value of the rotational velocity could occur. They may also contain information on the eventual radial velocity variation.

Table 1: List of program stars and actual observations

	v sin *i*		Classification		Observations
HD	*Palm*	*Wolff*	*Palm*	*Cowley*	
2913	260	125		B9.5 V	MSS
8837	135	35		A0 III	MSS
9531	215	175	::Si	B9 IV	MSS
25152	50	250		A0 V	MSS, NAO, E
31592	170	50		A0 V	MSS
44783	65	300		B8 Vn	E
45563	50	125	?SiSr	B9 V	
47964	95	50		B8 III	MSS, NAO
51688	120	50	Si, var	B8 III	
53744	160	350	?Pec	B9 V	
90599	90	13	Ap	A0p Si(Cr)	MSS, NES, NAO, E
113797	0	175	Si, var	B9 V	NAO
114376	0	125		B7 III	NAO
129174	60	16		B9p MnHg	NES
136849	180	350		B9 Vn	NAO, E
138527	0	175	B8V	B9 V[1)]	NES, NAO
172044	75	40	Ap	B8 HgMn	NES
175132	95	42		B9p	NES
182255	70	25		B6 He w[1)]	MSS, NES, E
183986	100	30		B9.5 III	MSS
188485	95	150		A0 III	
199892	100	25	:	B7 III	
204862	190	120		B9.5 V	MSS
214923	180	125		B8 V[2)]	MSS, E

Palm = Palmer et al. (1968), *Wolff* = Wolff & Preston (1978), *Cowley* = Cowley et al. (1969)

[1)] Renson (1991)

[2)] Hoffleit (1964)

2 Observations, the Method

The photographic spectra were obtained with the coude spectrographs of the 2–m telescopes at the Astronomical Institute of the Academy of Sciences of the Czech Republic, Ondřejov and the National Astronomical Observatory, Bulgarian Academy of Sciences, Rozhen (NAO). The spectral region was usually $\lambda\,3650-4900$ Å, Kodak IIaO or IIaOb emulsion, reciprocal dispersion 8.5 Å/mm. These spectra are digitized using a computerised microdensitometer in the Astronomical Institute, Tatranská Lomnica.

The CCD spectra were obtained at the NAO and the Special Astrophysical Observatory, Nizhnii Arkhyz, Russia (SAO RAS). The NAO spectra were taken with the Photometric AT200 CCD camera with the SITe SI003AB 1024×1024 at the 3rd optical camera of the coude spectrograph of the 2–m RCC telescope, with $R = 22\,000$. The IRAF standard procedures were used for the spectra reduction. The Ca II region extends from 3898 to 3967 Å and the Mg II one from 4447 to 4550 Å. The SAO spectra were obtained either with the Nasmyth Echelle Spectrograph (NES), equipped with a 2048×2048 CCD camera with resolution $R = 50\,000$ (Panchuk et al., 2002), and the Main

Stellar Spectrograph (MSS), equipped with a 2048×2048 CCD camera with $R = 17\,000$ using a Zeeman analyser with the slicer (Chountonov, 2004) of the 6–m BTA telescope of the SAO. The NES spectral region is 4226 – 5654 Å, while the MSS spectra were obtained within 4453 – 4695 Å. The `ZEEMAN` context (Kudryavtsev, 2000), written with the ESO MIDAS, and `REDUCE` software package (Piskunov & Valenti, 2002) were used to reduce the SAO spectra.

The available public archival data were also used.

The `SYNSPEC` code (Hubeny et al., 1994; Krtička, 1998) was used to compute the synthetic spectra, detailed line profiles of the Ca II 3933 and Mg II 4481 lines, and to derive the elemental abundances by means of comparing with the observed lines. The atmosphere models are interpolated from the grid of Castelli & Kurucz (2003). Effective temperature and surface gravity values were derived using the codes `UVBYBETA` (Moon & Dworetsky, 1985) and `TEFFLOGG` (Smalley & Dworetsky 1995) with the $uvby\beta$ data extracted from SIMBAD.

Radial velocities were derived using the CCF method (Zverko et al., 2007).

3 First Results

HD 2913

$T_{\rm eff} = 11\,120$ K, $\log g = 4.31$. The Catalog of Components of Double and Multiple Stars (Dommanget, 1983) gives a remark "Double or Multiple Star". Two MSS spectra, $S/N = 1000$, separated by 8 months do not indicate radial velocity or line profile change. Apparently the lines of two different values of $v \sin i$ are present in the spectra. While for the strong lines of Mg II at 4481 and of He I at 4471 Å $v \sin i = 170$ km/s is suitable, the weak lines need a remarkably lower value. At the same time, the abundance of weak lines indicates a lower effective temperature. Tentatively we summed two synthetic spectra, one of which with temperature, gravity and $v \sin i$ as introduced above, and the other with $T_{\rm eff} = 7\,500$ K, $\log g = 4.0$, and $v \sin i = 45$ km/s. This shows that the observed spectrum may be composed of two components that contribute in a ratio $L_1 : L_2 = 0.9 : 0.1$. The stronger component seems to be mildly underabundant in helium by a factor of 0.8 and overabundant in magnesium by a factor of 3. The spectrum of the weak component is shifted by RV $= -15$ km/s relative to the stronger one. The barycentric radial velocity values derived from the two CCD spectra correspond to $-24.0\,(\pm 0.7)$ and $+26\,(\pm 0.7)$ km/s, while the relative velocities of the two components remain constant. Two photographic spectra were separated by 3.3 years. Radial velocities were derived by using the central sections ± 2.5 Å from the central wavelength of the Balmer lines H4 – H11. The barycentric values were $3.0\,(\pm 4.1)$ and $5.6\,(\pm 3.4)$ km/s. The BS catalogue (Hoffleit, 1964) gives $+19$ km/s.

HD 25152

$T_{\rm eff} = 10\,530$ K, $\log g = 3.94$. MSS ($S/N = 300$) and NAO ($S/N = 180$) spectra fit perfectly the value of $v \sin i = 127$ km/s. Helium and calcium are in deficit (0.9× and 0.45×, magnesium is slightly overabundant (1.5×) with respect to the solar abundances, the microturbulence is zero. Around the Ca II line, ($S/N = 110$) in the continuum, weak lines of Al and He are compatible with $v \sin i = 127$ km/s. A narrow absorption, shifted 0.3 Å longward from the centre of the Ca II line, and 0.42 Å (32 km/s) of FWHM with EW $= 33$ mÅ may be of interstellar origin. Welsh et al. (2010) give for the nearest star HD 23625, which is 380 pc distant, the equivalent width EW $= 66$ mÅ for the interstellar component. The distance of HD 25152 is 123 pc.

HD 44783

A spectrum (4000 – 6800 Å) of this star was retrieved from the ELODIE public archive. It shows a shell feature in the Balmer line, as well as in many metal lines. The high value of $v \sin i$ derived by Wolf & Preston (1978) from the Mg II line corresponds to this type of stars. The low value given by Palmer et al. (1968) corresponds to the narrow absorption peak at the Ca II line.

HD 47964

$T_{\rm eff} = 12\,360$ K, $\log g = 3.43$. The projected $v \sin i = 60$ km/s fits Mg II as well as the Ca II line. The Ca II line itself, however, features a peak shifted from the central position. Its EW = 41 mÅ measured under the synthetic profile is in agreement with the observation by Welsh et al. (2010).

HD 90569

$T_{\rm eff} = 10\,710$ K, $\log g = 3.97$. The value of projected rotational velocity derived from the Mg II line in the NES spectrum corresponds to $v \sin i = 8$ km/s. In the NAO spectra, the profiles of the Ca II and Mg II lines satisfy $v \sin i = 13$ km/s. Fe and Cr are overabundant by factors of 15 and 70, while He and Ca are in deficit by the factors of 0.05 and 0.15, respectively.

HD 113797

$T_{\rm eff} = 11\,200$ K, $\log g = 4.16$. The value of the projected rotational velocity is $v \sin i = 137$ km/s. Magnesium is overabundant by a factor of 2, while calcium is in deficit by a factor of 0.5. A weak narrow feature is seen near the centre of Ca II line corresponding to $v \sin i \approx 8$ km/s, and EW = 14 mÅ. Welsh et al. (2010) give EW = 13.6 mÅ for the interstellar component.

HD 114376

$T_{\rm eff} = 14\,030$ K, $\log g = 3.53$. The projected rotational velocity corresponds to $v \sin i = 125$ km/s. Helium and calcium are underabundant by the factors of 0.55 and 0.1, respectively. A narrow feature near the centre of the Ca II line of EW = 0.48 mÅ is present. This star, 351 pc away, is only 1° in l and b off the previous star which is 87 pc away.

HD 136849

$T_{\rm eff} = 10\,970$ K, $\log g = 4.24$. The value of the projected rotational velocity is $v \sin i = 220$ km/s. Magnesium is mildly overabundant by a factor of 2, while calcium is in a deficit by a factor of 0.5. The value of the projected rotational velocity is too high for the He I 4471 line, for which $v \sin i = 185$ km/s is more suitable. A narrow peak occurs at the center of the wide Ca II 3933 line. Its central depth under the mean profile amounts to 0.03 corresponding to EW = 5 mÅ. Welsh et al. (2010) has measured the interstellar extinction for HD 138749, which is 3° off HD 136849 and 95 pc away. They give EW(Ca II) = 6.7 mÅ. HD 138749 is 76 pc away.

HD 138 527

$T_{\rm eff} = 11\,200$ K, $\log g = 4.08$. For Mg II 4481 line $v \sin i = 140$ km/s, for the Ca II 3933 line $v \sin i =$ 120 km/s. Mg and Ca are underabundant by the factors of 0.5 and 0.15, respectively. A narrow feature at the centre of Ca II 3933 line is present. Its EW = 9 mÅ, Welsh et al. (2010) give 8 mÅ. the absence of metal lines when comparing with the synthetic spectrum suggests a possible λ Boo–type star. However, a need of remarkably lower abundances to reach the fit of the Mg II 4481, Ca II 3933, and He I 4471 Å lines does not exclude a possible component star, contributing its fraction to the spectrum.

HD 172044

$T_{\rm eff} = 14\,480$ K, $\log g = 3.60$. The value $v \sin i = 40$ km/s is confirmed by our observations. Abundances of helium, nitrogen and sulphur must be reduced by factors of 0.01, 0.5 and 0.5 respectively in order to fit the observed spectrum. The same reason leads to the abundances of phosphorus, manganese and gallium increased by factors of 30, 2000 and 10 000.

HD 175132

$T_{\rm eff} = 11\,360$ K, $\log g = 3.18$, $v \sin i = 30$ km/s. Abundances reduced for helium (by a factor of 0.1), magnesium (0.2), aluminium (0.1) and sulphur (0.1) and increased for silicon (4), chromium (10), manganese (20) and iron (8) fits the observed spectrum. However, there remain many weak unidentified lines.

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