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Variability of the He I λ5876 Å line in early type chemically peculiar stars. II*

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Abstract. To try to understand the behavior of helium variability in Chemically Peculiar stars, we continued our on-going observational campaign started by Catanzaro, Leone & Catalano (1999). In this paper we present a new set of time resolved spectroscopic observations of the He I 5876 Å line for a sample of 10 stars in the spectral range B3 - A2 and characterized by different overabundances.

This line does not show variability in two stars: HD 77350 and HD 175156. It shows instead an equivalent width variation in phase with the Hipparcos light curve for two stars: HD 79158 and HD 196502. Antiphase variations have been found in 4 stars of our sample, namely: HD 35502, HD 124224, HD 129174 and HD 142990. Nothing we can say about HD 115735 because of the constancy of Hipparcos photometric data, while no phase relation has been observed for HD 90044.

In the text we discuss the case of HD 175156, according to photometric calibration and our spectroscopic observations we rule out the membership of this star to the main sequence chemically peculiar stars.

We confirm the results obtained in the previous paper for which phase relations between light, spectral and magnetic variations are not dependent on stellar spectral type or peculiarity subclass.

Key words: stars: chemically peculiar – stars: early-type – stars: abundances – stars: atmospheres

1. Introduction

Along the main sequence, Chemically Peculiar (hereafter CP) stars are objects whose spectral type is between B and F and for which spectral, photometric and magnetic variability are observed with a common period. This evidence has been explained in the *Oblique Rotator Model* proposed by Stibbs (1950), for which chemical elements are not homogeneously distributed over the stellar surface and the observed variations are due to the stellar rotation.

The problem regarding phase relations among spectroscopic, light and magnetic variability has been discussed in literature for a long time. Preston (1970) suggested that the light variability of the CP stars is directly linked to the spectrum variations. He supposed that changes in the continuous opacity in the ultraviolet region, due to silicon in particular, are the origin of the light variations. Molnar (1973) confirms this conclusion analyzing Copernicus observations of α^2 CVn. This model has been applied in detail to the Ap star HD 24712 to explain the relationship between magnetic and spectrum variations (Preston 1972) and between spectrum and light variations (Bonsack 1979).

The helium spectral variability has firstly explored by Peterson (1966) who carried out spectroscopic observations of the He I λ4471 Å and found an antiphase relation with light variations of HD 124224 and 56 Arietis. This author interpreted this relation in terms of regions with enhanced helium concentration on the cooler surface of the stars. Later on, Pedersen (1976) and Pedersen & Thomsen (1977) performed photometric observations of the strength of the line He I λ4026 Å by the R index defined as the ratio between the line and the continuous intensity. Catalano & Leone (1996) used these data to search for phase relations between helium spectroscopy and their uvby observations carried out for a sample of He weak stars. As a result they found a clear antiphase relation between light and spectroscopic variability. In the attempt to clarify the nature of this correlation, these authors compared the emerging fluxes of two atmosphere models with the same effective temperature ($T_{eff} = 15000$ K) and gravity ($\log g = 4.0$) but with different helium abundance. The models were computed by means of the ATLAS9

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code (Kurucz 1993) and are characterized by solar and zero helium abundance. By comparing these fluxes, they found no observable magnitude difference and concluded that the photometric variations presented by helium weak stars cannot be entirely ascribed to the non homogeneous distribution of helium on the stellar surface.

To investigate the behavior of helium in different classes of peculiarity and its relations with light variability, we started a spectroscopic program based on the observation of the HeIλ5876 Å line (Catanzaro, Leone & Catalano (1999), hereafter Paper I). In that paper, we studied 16 CP stars, but we did not found a unique relation between light and spectral curves, and this fact is independent of the spectral type.

With the purpose to continue the work started in the Paper I, we performed new spectroscopic observations of HeI5876 Å line for a sample of 10 CP stars. When available we compared the spectral variations with photometric and magnetic observations taken from literature. In particular regarding light curves we queried Hipparcos (ESA 1997) database where we found data for all the stars of our sample.

2. Observation and data analysis

For the CP stars listed in Table 1 echelle spectra were obtained in 1995 at the 2.1 m telescope of the Complejo Astronómico El Leoncito equipped with a Boller & Chivens cassegrain spectrograph and at the 91 cm telescope of the Catania Astrophysical Observatory equipped with a Czerney-Turner echelle spectrograph during an observing campaign from 1997 up to 2001.

The data were analyzed by using IRAF package. The lines of the wavelength calibration lamp show that R=16000 for the Catania data set and R=13000 for the Casleo data set. The achieved S/N was between 100 and 200. Whenever it was possible, equivalent widths were measured by a Gaussian fit of spectral lines after having removed possible continuum slope; otherwise a measurement of the area between the line profile and the continuum was obtained. Following Leone, Lanzafame & Pasquini (1995), we estimated the error in the measured equivalent width with the relation:

$$\Delta W = \frac{1}{2}\left(2\frac{v_e \sin i}{c}\lambda\right)\frac{1}{S/N} \qquad (1)$$

where the quantity in brackets is the total extension of the line as deduced from the rotational broadening. Adopted $v_e \sin i$ values are from SIMBAD database.

The initial ephemeris for the program stars was taken from Renson & Catalano (2001) and references therein. If necessary, periods were established using our spectral observations and Hipparcos photometry[1]. A least squares fit of measured EW's and HIP magnitudes has been performed by adopting the function:

$$A_0 + A_1 \sin(2\pi(t-t_0)/P + \phi_1) + A_2 \sin(4\pi(t-t_0)/P + \phi_2) \qquad (2)$$

[1] The Hipparcos filter, referred to as HIP, extends from 3550 Å to 8900 Å with the maximum at 4350 Å. The typical accuracy of Hipparcos measurements, at the 8th magnitude, is given as 0.0015 mag (ESA 1997).

where t is the JD date, t_0 is the assumed initial epoch, P is the period in days. A sine wave and its first harmonic appear to be quite adequate functions to describe the light curves and the spectral variations (North 1984; Mathys & Manfroid 1985). The error in the period value has been evaluated according to the relation given in Horne & Baliunas (1986).

Because of the abundance anomalies which modify the flux distribution of CP stars (Leckrone, Fowler & Adelman 1974), classical methods cannot be used to estimate the effective temperature of these stars and *ad hoc* methods are necessary. As to helium peculiar stars, Hauck & North (1993) found that *classical* methods are still reliable to determine their effective temperature. Thus, for our program stars with the exception of the helium peculiar objects, we used the relation established by Napiwotzki, Schönberner & Wenske (1993) and for helium peculiar stars we have used the Moon & Dworetsky (1985) grids as coded by Moon (1985). The source of Strömgren photometry was Hauck & Mermilliod (1998).

To ascertain if the selected stars present a peculiar helium abundance we have compared the measured equivalent widths of the HeIλ5876Å line with the NLTE computations of Leone & Lanzafame (1998) for solar composition stars with log g = 3.5, 4.0 and 4.5 and 9000 K $<$ T$_{\rm eff}$ $<$ 22000 K. Results are shown in Fig. 1.

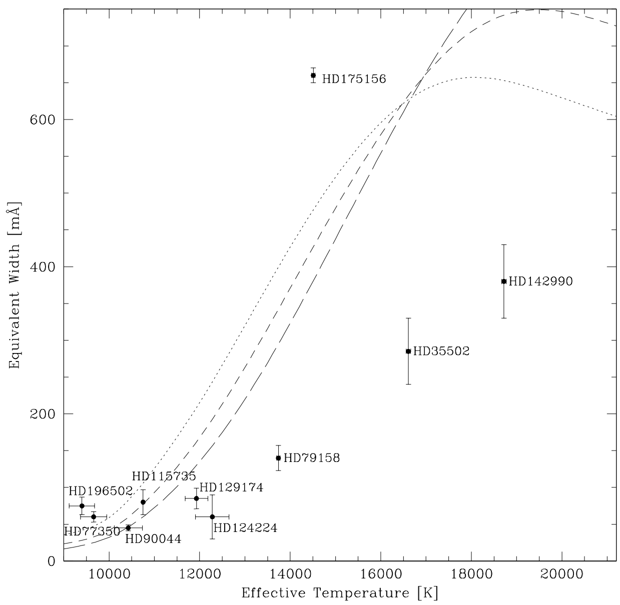

Fig. 1. Behavior of equivalent width versus effective temperature for our sample of CP stars. Points represent the observations, error bars extend by 1σ. Curves represent the NLTE calculations by Leone & Lanzafame (1998) for three different values of $\log g$: 3.5 (long dash), 4.0 (short dash) and 4.5 (dot).

Table 1. Average equivalent width ⟨EW⟩ and its standard deviation σ for the observed chemically peculiar stars. Spectral type and peculiarity class are taken from *The General Catalogue of Ap and Am stars* (Renson, Gerbaldi & Catalano 1991). $T_{\rm eff}$ and log g have been computed according to Napiwotzki et al. (1993) except for the He weak stars and for HD 175156 for which we used Moon (1985) calibration. N refers to the number of spectra, P to the variability period in days with the relative reference. Source for V magnitudes and $v_e \sin i$ was SIMBAD database. The *"constant"* remark indicates the absence of EW variations; *"in phase"*, the coincidence of maxima of the EW and photometric variations; and *"antiphase"*, the coincidence of maxima of the EW variation with the minima of photometric variations.

HD	Sp. Type	V	$v_e \sin i$ km s^{-1}	$T_{\rm eff}$ K	log g	N	⟨EW⟩ mÅ	Remarks	P days
35502	B6 He wk	7.36	290	16610 ± 50	4.41 ± 0.04	17	285 ± 45	antiphase	1.69519 ± 0.00005^a
77350	B9 SiCrHg	5.48	10	9660 ± 290	3.55 ± 0.03	15	60 ± 7	constant	
79158	B9 He wk	5.28	40	13740 ± 40	3.63 ± 0.02	13	140 ± 17	in phase	3.8346 ± 0.0003^a
90044	B9 SiCrSr	5.97	15	10425 ± 310	4.21 ± 0.02	9	45 ± 4		4.37900^b
115735	B9 He wk Si	5.15	90	10750 ± 20	3.99 ± 0.03	19	80 ± 17		0.963145 ± 0.000007^a
124224	B9 Si	5.01	115	12280 ± 370	4.26 ± 0.02	17	60 ± 30	antiphase	$0.5206788 \pm 0.0000002^c$
									$0.52070308 \pm 0.00000019^c$
129174	B9 MnHg	4.91	30	11930 ± 250	4.09 ± 0.02	23	85 ± 14	antiphase	4.5751 ± 0.0003^a
142990	B7 He wk	5.44	200	18720 ± 50	4.22 ± 0.04	31	380 ± 50	antiphase	0.979070^d
175156	B3 II	5.10	20	14510 ± 40	2.69 ± 0.02	18	660 ± 10	constant	
196502	A2 SrCrEu	5.20	10	9420 ± 280	3.73 ± 0.03	10	75 ± 12	in phase	20.279 ± 0.001^e

a) This work - b) Manfroid & Renson (1994) - c) Pyper et al. (1998) - d) Catalano & Leone (1996) - e) Leone, Catanzaro & Catalano (2000)

3. Individual stars

3.1. HD 35502 (= BD −2 1246 = HIP 25327)

HD 35502 is a star belonging to ORI OBI_b association whose helium content is about 2 times lower than normal field stars of the same spectral group (Nissen 1976).

A first hint of variability is due to a study on magnetic decay in Orion association performed by Borra (1981). He found a possible period of 1.7 days phasing his 6 magnetic observations with a mean value of 1490±140 gauss.

By using Hipparcos photometry together with our spectroscopic measurement we refined Borra's period getting the following ephemeris:

$$JD(\mathrm{HIP_{max}}) = 2447913.914 + (1.69519 \pm 0.00005)E \quad (3)$$

Our observations of the equivalent width of the HeIλ5876 Å give a mean value of 285 ± 45 mÅ, that according to the calculated $T_{\rm eff}$ confirms the helium underabundance of this object.

The error in phase determination expected for our spectroscopic curve is $\Delta\phi = 0.03$. Light and spectroscopic variations are in anti-phase within this error.

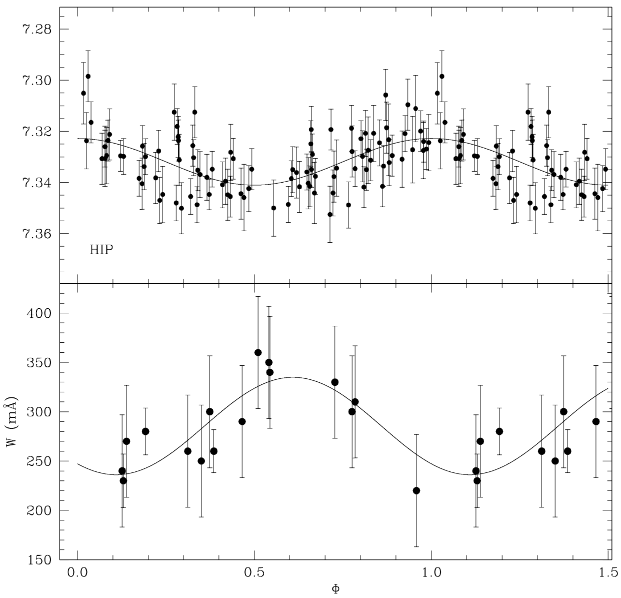

Fig. 2. Equivalent width variations of HD 35502. Error bar is equal to the error in the equivalent width as given by Eq. 1. Photometry is taken from Hipparcos (ESA 1997)

3.2. HD 77350 (= HR 3595 = HIP 44405 = 69 Cnc)

First attempts to discover photometric variability on this star date back to early 70's. Burke, Rolland & Boy (1970) and Winzer (1974) found that this moderately sharp-line star does not present light variation. Abt & Snowden (1973) suggested that it could be a long period (1401.4 days) spectroscopic binary. Kozlova, Glagolevskii & Klochkova (1975) found spectrophotometric variations with a possible period of 4.191±0.003 days.

Magnetic variability has also been checked with a null result by Bohlender, Landstreet & Thompson (1993).

We observed this star for 15 nights spanning more than 4 years and no evidence of variability in the strength of the helium line has been found. The mean equivalent width observed is 60 ± 7 mÅ, this value together with the estimated $T_{\rm eff} = 9660$ K place the star in the standard strip defined in Fig. 1. Absence of photometric variability has been confirmed also by Hipparcos data.

3.3. HD 79158 (= HR 3652 = HIP 45290 = 36 Lyn)

HD 79158 is listed as He weak in *The General Catalogue of Ap and Am stars* (Renson, Gerbaldi & Catalano 1991). Magnetic measurements carried out by Shore et al. (1990) indicated a period of 3.834 days. This period has been confirmed

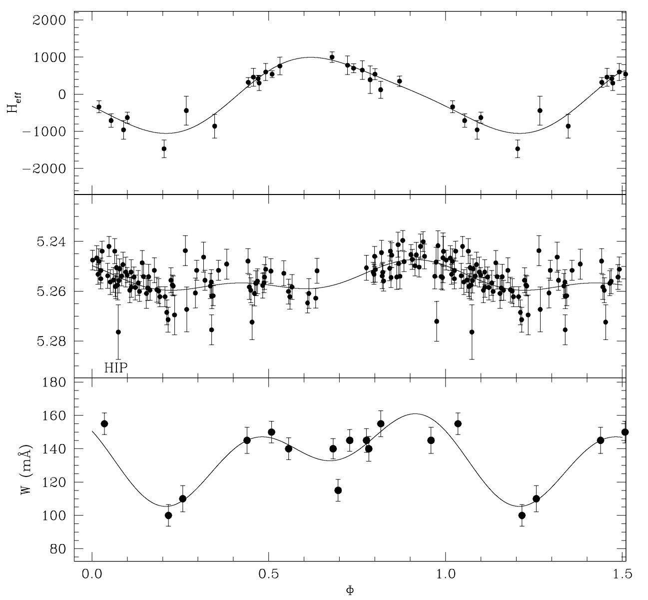

Fig. 3. Equivalent width variations of HD 79158. Error bar is equal to the error in the equivalent width as given by Eq. 1. Magnetic data displayed in the top panel come from Shore et al. (1990). Photometry is taken from Hipparcos (ESA 1997).

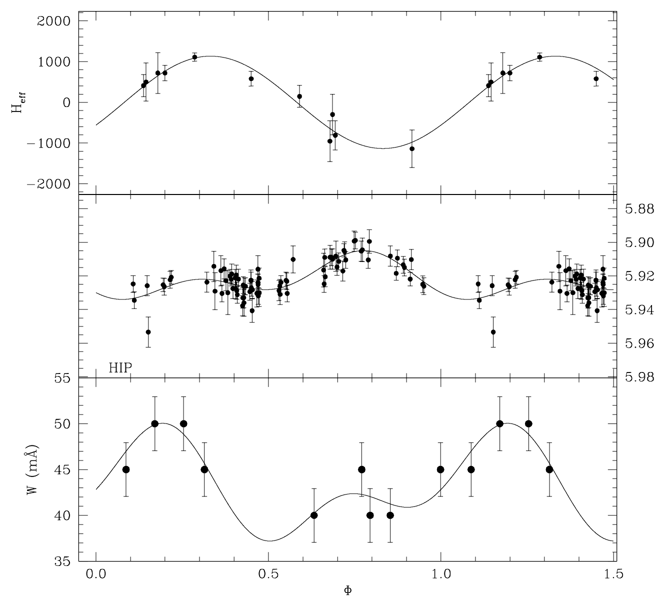

Fig. 4. Equivalent width variations of HD 90044. Error bar is equal to the error in the equivalent width as given by Eq. 1. Magnetic data coming from Bohlender et al. (1993) and Leone & Catanzaro (2001) (upper panel). Photometry is taken from Hipparcos (ESA 1997).

by Adelman (2000) uvby photometric data. Magnetic observations have been used by Bohlender (1994) to improve the period and he gave the new value of 3.83483 days.

Since we have a long baseline spectroscopy we refined that period performing a Fourier analysis taking into account also the Hipparcos photometry. Our new ephemeris is:

$$JD(\mathrm{HIP}_{\max}) = 2447976.394 + (3.8346 \pm 0.0003)E \quad (4)$$

A double wave sine curve has been needed to fit the data. In spite of the evidence that our value is very close to the one found by Bohlender (1994), the χ^2 calculated using our estimate is smaller than the one obtained with Bohlender's period.

Fig. 1 shows that helium abundance of HD 79158 is lower than the expected one for a main sequence star with equal T_{eff}.

A phase relation among the three types of variability has been observed. The maximum of equivalent width of the helium line ($\phi = 0.91 \pm 0.03$) corresponds with the maximum of light curve ($\phi = 0.91 \pm 0.02$) and with the second zero of the magnetic variation ($\phi = 0.93 \pm 0.03$). The first zero of magnetic data seems to coincide with the secondary maximum of the equivalent width curve.

3.4. HD 90044 (= HR 4082 = HIP 50885 = 25 Sex)

HD 90044 is a well studied B9 SiCrSr star, whose spectrum variability has been discovered by Bonsack (1974) observing the SrII and CaII lines.

The light variability has been studied by Manfroid & Renson (1980) and by Manfroid & Renson (1983), who found a period of 4.37 days. A value confirmed later by Mathys & Manfroid (1985). Catalano & Leone (1993) and later on Manfroid & Renson (1994) refined the period by using their own uvby observations together with the data collected in the Long-Term Photometry of Variables (LTPV) project (Manfroid et al. 1991). The ephemeris is:

$$JD(u_{\min}) = 2445659.000 + 4.37900E \quad (5)$$

The validity of this period has been recently confirmed by Adelman (1997) and by near IR bands J, H, and K observations by Catalano, Leone & Kroll (1998). It was also confirmed by magnetic data carried out by Bohlender et al. (1993) and Leone & Catanzaro (2001).

In Fig. 4 we show our HeIλ5876 Å equivalent width measurements phased with the ephemeris reported in Eq. 5. A comparison with Hipparcos and magnetic data is also shown. Even if the expected error of phase determination is relatively small ($\Delta\phi = 0.01$), no phase relation has been higlilighted.

The average equivalent width is 45 ± 4 mÅ, which according to the estimated T_{eff}, means that a normal abundance of helium is present.

3.5. HD 115735 (= HR 5023 = HIP 64906 = 21 CVn)

The peculiar nature of this star has been suggested and then confirmed by Zverko (1984). He found an almost normal silicon abundance and a variability in the strength of helium lines. Regarding the luminosity variability, he carried out medium-band photometry with a filter centered at 526 nm and half-width of 19 nm for 13 consecutively nights. This author reports about a variation with an amplitude of 0.04 mag and a period of 0.767 days.

We found a clear variability of the equivalent width of our observed line but we do not confirm the period found by

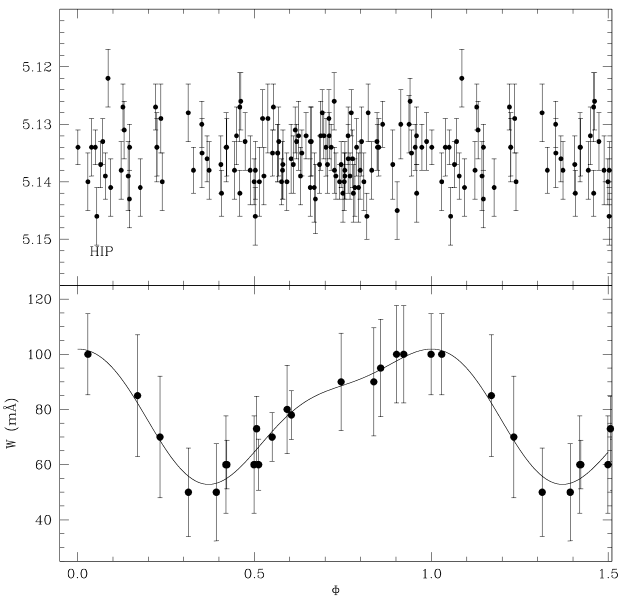

Fig. 5. Equivalent width variations of HD 115735. Error bar is equal to the error in the equivalent width as given by Eq. 1. Photometry is taken from Hipparcos (ESA 1997).

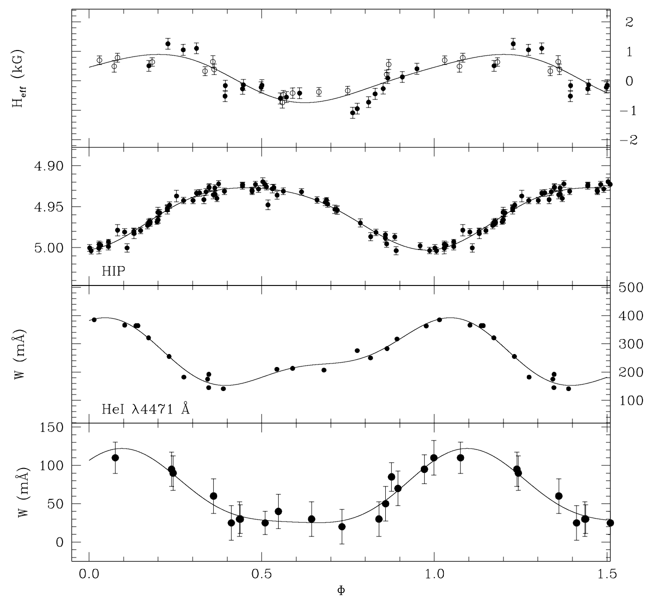

Fig. 6. Equivalent width variations of HD 124224. Error bar is equal to the error in the equivalent width as given by Eq. 1. Equivalent widths of the HeIλ4471 Å has been taken from Kuschnig et al. (1999). Magnetic data are displayed with different symbols: open circles for Borra (1980) data while filled circles for Pyper et al. (1998). Photometry is taken from Hipparcos (ESA 1997).

Zverko (1984). Our data are in agreement with a bit longer period, whose ephemeris is:

$$JD(\mathrm{EW_{max}}) = 2447872.362 + (0.963145 \pm 0.000007)E (6)$$

In any case, Hipparcos photometry does not show variability. As we can see in Fig. 1, according to the estimated effective temperature and gravity, this stars has a normal helium content.

3.6. HD 124224 (= HR 5313 = HIP 69389 = CU Vir)

The variability of CU Vir has been known since the first spectroscopic measurements carried out by Deutsch (1952), who found a period of 0.5207 days. Several authors observed this star, Hardie (1958), Peterson (1966), Blanco & Catalano (1971) and Winzer (1974). From those papers it appears that a period of 0.520675 $\pm$ 0.000005 days is consistent with all the observations. This period has been confirmed from magnetic observations by Borra (1980). Adelman, Dukes & Pyper (1992) refined the period of CU Vir, using the UBV data consisting of 357 values obtained over a span of 26 months. They found the period of 0.5206800 $\pm$ 0.0000005 days.

Recently, Pyper et al. (1998) analyzing all available observational data proposed to fit them with two periods: 0.5206778 days for data with JD $<$ 2446000 and 0.52070308 days for those with JD $>$ 2446000. As they did not find any observational evidence of binarity, they ruled out the possibility that the period decrease has been caused by mass exchange phenomenon. Nevertheless, they discussed some possible solutions that could be account for the observed change in the rotational period, i.e.: mass loss by stellar wind or migrating spots over its surface. However, they concluded that any of those possibilities can account for the abrupt change in the period.

Stepien (1998) stated that if one abandons the assumption of rigid rotation, the strength of the observed magnetic field is sufficient to modify the moment of inertia of the outer envelope of the star by the required amount.

Recently, Kuschnig et al. (1999) published a multi-element doppler imaging of CU Vir. Regarding helium distribution, they found a spot at about 200° longitude, 30° latitude and with a diameter of about 40°. It seems that this spot coincides with a magnetic pole. In Fig. 6 we compare their measured equivalent width of HeIλ4471 Å with our own helium variations. The two curves show in phase variability.

We used Pyper et al. (1998) periods to phase both literature and our spectroscopic data.

The observed equivalent width is 60 $\pm$ 30 mÅ, according to the effective temperature the star shows a moderate helium underabundance.

Besides there is a clear antiphase relation between spectroscopic and light and between spectroscopic and magnetic variations, the coincidence of the extrema of the curves are not so strict as for HD 79158. Only the Hipparcos maximum ($\phi = 0.45 \pm 0.01$) lies at the same phase of the first magnetic zero ($\phi = 0.43 \pm 0.01$).

In any case the conclusion reached by Kuschnig et al. (1999) seems to be still valid.

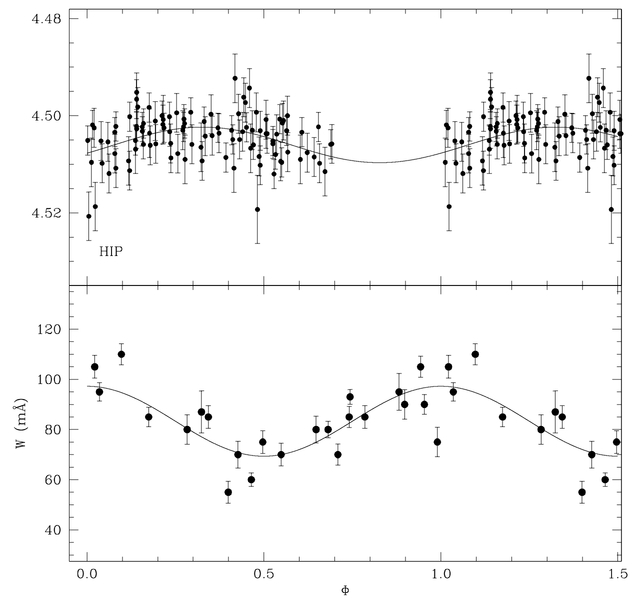

Fig. 7. Equivalent width variations of HD 129174. Error bar is equal to the error in the equivalent width as given by Eq. 1. Photometry is taken from Hipparcos (ESA 1997).

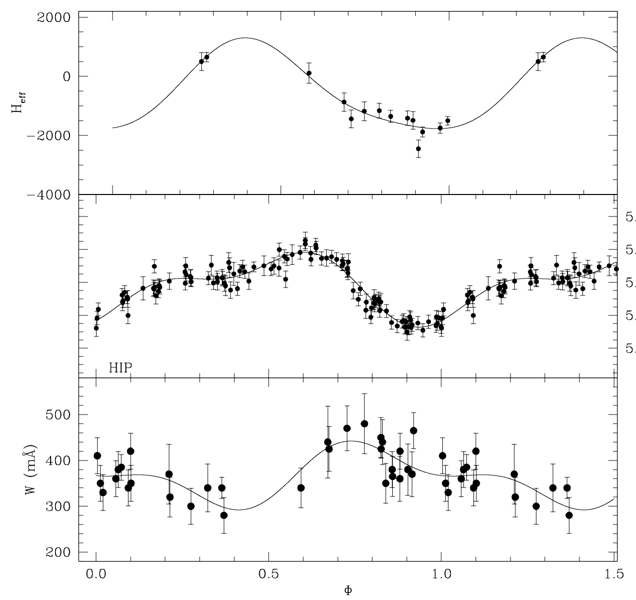

Fig. 8. Equivalent width variations of HD 142990. Error bar is equal to the error in the equivalent width as given by Eq. 1. Photometry is taken from Hipparcos (ESA 1997). Magnetic observations come from Borra et al. (1983).

3.7. HD 129174 (= HR 5475 = HIP 71762 = 29 Boo A)

HD 129174 has been classified as He weak in *The General Catalogue of Ap and Am stars* (Renson et al. 1991).

A first spectroscopic study of this star has been performed by Deutsch (1947), who found a periodicity of 2.2445 days in the variations of line strength of the MnIIλ4206 Å. This period has also been taken into account by Winzer (1974) to phase his photometric data.

Recently, Hipparcos photometric variations of HD 129174 have been analyzed in order to search for candidates MAIA variables with null results (Percy & Wilson 2000).

Neither our spectroscopic measurements nor Hipparcos photometry are in agreement with the 2.2445 days period. Thus, we performed a fourier analysis getting the following ephemeris:

$$JD(\mathrm{EW_{max}}) = 2447936.981 + (4.5751 \pm 0.0003)E \qquad (7)$$

According to the mean value of the measured equivalent width, HD 129174 has a slight helium underabundance if compared with stars of the same $T_{\rm eff}$.

An antiphase relation between spectral and light curves seems to exist, even if there is not coincidence among their extrema.

3.8. HD 142990 (= HR 5942 = HIP 78246 = V913 Sco)

HD 142990 is a well known helium weak star whose peculiar nature was first noted by Garrison (1967).

Borra, Landstreet & Thompson (1983) found a large and variable magnetic field. Unfortunately, besides their 14 days observations, they were unable to define a period. Nevertheless their data seem to be representative of two of the shortest periods proposed by Pedersen & Thomsen (1977): 0.97843 and 0.492585.

A new determination of the period of photometric variability has been established by Catalano & Leone (1996) using their own uvby data together with Pedersen & Thomsen (1977) and LTPV observations. All this photometric data give:

$$JD(uvby_{\rm min}) = 2442820.017 + (0.979070 \pm 0.000011)E \quad (8)$$

Both our spectroscopy and Hipparcos photometry are in agreement with this value. The mean value of HeIλ5876 Å equivalent width is 380 $\pm$ 50, a value lower than the normal one expected for its adopted temperature.

The following phase relations seem to exist: maximum of magnetic field ($\phi = 0.39 \pm 0.02$) with minimum of equivalent width ($\phi = 0.41 \pm 0.03$) and the second magnetic zero ($\phi = 0.58 \pm 0.02$) with Hipparcos primary maximum ($\phi = 0.60 \pm 0.01$).

3.9. HD 175156 (= HR 7119 = HIP 92814)

This star was classified as He-weak by Guthrie (1965). It has also been studied by Vilhu, Tuominen & Boyarchuk (1976) who find a slight He underabundance and a strong Fe and Ti overabundance, while C, Si, Cr and Sr are normal. They included this star in the Sr-Ti subgroup.

According to Borra, Landstreet & Thompson (1983), it does not appear to be a magnetic star being his 8 magnetic observations null.

No variability has been found neither from our spectroscopic data nor from Hipparcos photometry.

According to SIMBAD database this star is classified as B3 supergiant (B3 II). Considering the correct spectral

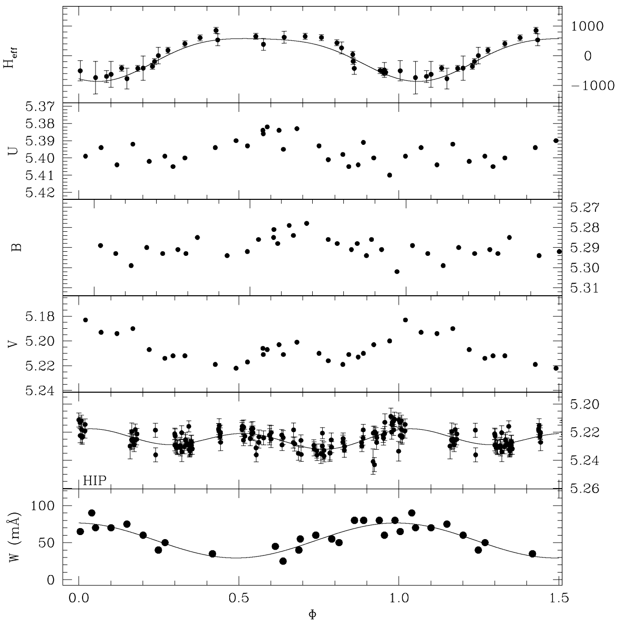

Fig. 9. Equivalent width variations of HD 196502. Error bar is equal to the error in the equivalent width as given by eq 1. Magnetic data are taken from Leone et al. (2000) while photometric data (UBV) from Stepien (1968) and Hipparcos (ESA 1997).

type and luminosity class, Moon & Dworetsky (1985) algorithm give the following parameters: $T_{eff} = 14510 \pm 40$ K and $\log g = 2.69 \pm 0.02$. This fact led us to exclude HD 175156 from the list of chemically peculiar stars of the main sequence. The absence of magnetic, spectroscopic and light variability could be a strong hint supporting this conclusion.

It is also worthy to note that according to the measured equivalent width and calculated effective temperature the helium content of this star is even greater then normal, in contrast to that reported by Guthrie (1965).

3.10. HD 196502 (= HR 7879 = HIP 101260 = 73 Dra)

Magnetic observations of HD 196502 have been carried out by Preston (1967), who obtained a period of 20.2754 days. This period has been confirmed by Musielok & Madej (1988). Using their β index measurements, they found a variation of 0.015 mag.

Photometric observations have been performed by Stepien (1968). These data are in agreement with Preston (1967) ephemeris and show a clear double wave variations of luminosity.

Magnetic observations carried out by Leone, Catanzaro & Catalano (2000), are compatible with the following period:

$$JD(uvby_{\min}) = 2426904.071 + (20.279 \pm 0.001)E \qquad (9)$$

Our spectroscopic data were phased by means of the previous ephemeris element, see Fig. 9.

According to our calculation, with $T_{eff} = 9420$ K this is the coolest star of our sample; the mean equivalent width is 75 ± 12 mÅ. As we can see in Fig. 1, the helium content is close to standard value, even if a moderate overabundance is present.

Regarding phase relation, only between magnetic and spectroscopic curve there is an antiphase variability, being the maximum of equivalent width ($\phi = 0.99 \pm 0.01$) almost coincident with the magnetic minimum ($\phi = 0.06 \pm 0.03$).

4. Discussion and conclusions

In this paper we have presented new spectroscopic observations of the HeIλ5876 Å line for 10 CP stars listed in Tab. 1. For 4 of them: HD 90044, HD 124224, HD 142990 and HD 196502 the period values reported in literature are accurate enough to well represent our observations. No variability has been detected for two stars: HD 77350 and HD 175156. For the latter, we rule out the membership of this star to the CP group. In the case of the remaining stars, i.e. HD 35502, HD 79158, HD 115735 and HD 129174 we have refined the value of the period by using both our own and, when available, literature data.

In the scenario described by the *Oblique Rotator Model* spectroscopic, photometric and magnetic data should vary with the same period. In order to check the phase correlations among these types of variability we searched in literature for photometric and magnetic measurements. Hipparcos photometric catalogue has been queried for light curves and we found data for all stars of our sample, while only for 5 of them we found magnetic observations (HD 79158, HD 90044, HD 124224, HD 142990 and HD 196502).

In the framework of the *Oblique Rotator Model* several attempts have been done in the past decades in order to explain the correlations between helium line strength and magnetic variability. Mihalas (1973) argued that helium line variations could be explained by two helium-rich caps placed symmetrically at the poles of the magnetic axis. Several years later, Heinsler (1979) developed a model to explain the variability of the He weak star HD 175362 in which a He cap is associated to the positive magnetic pole and a Si cap to the negative pole. Both Pedersen & Thomsen (1977) and Borra et al. (1983) agree on the conclusion that the two magnetic poles should be associated with very different helium abundances, supporting in this way the previous model already proposed by Norris & Baschek (1972) developed with the aim to reproduce the observations of the He weak star α Cen (HD 125823).

Regarding our stars, we found 3 stars, namely HD 124224, HD 142990 and HD 196502, for which there is a coincidence between equivalent width and H_{eff} extrema, while HD 79158 presents maximum strength of equivalent width at the same phase of the second zero of the magnetic curve. No phase relation has been observed for HD 90044. In any case for all the stars H_{eff} goes through zero from positive to negative values. In detail, for HD 124224 we observed a maximum of the helium line strength in correspondence of the positive extrema of the effective magnetic field curve, while we found the opposite situation observing HD 196502, that is maximum of the helium line strength in correspondence of the negative extrema of the H_{eff} curve. In the *Oblique Rotator Model* scenario these evidences could be described in terms of an He cap placed around the positive pole for HD 124224 and, on the contrary, around the negative pole in the case of HD 196502. A minimum of equivalent width of helium line has been found in coincidence with the positive extrema of the magnetic curve for HD 142990. This evidence could suggest that there exist a helium depleted zone around the positive pole of this star. Finally, for HD 79158 we found a correspondence with helium maximum and the second magnetic zero. This fact could led to the conclusion that in this star helium is concentrated close to the magnetic equator.

Regarding phase correlation between light and spectral variability we found that 4 stars, HD 35502 (He weak), HD 124224 (Si), HD 129174 (HgMn) and HD 142990 (He weak) show an antiphase correlation. The equivalent width of helium line varies in phase with the photometric variations for the stars HD 79158 (He weak) and HD 196502 (SiCrEu). Taking into account the data already published in Paper I, we can split all our observed stars in two groups: *a)* all the stars showing in phase variability with light and *b)*, the objects showing antiphase variations.

At the first group (in phase variability) belong 5 stars (the two stars here presented plus HD 43819 (B9 Si), HD 171247 (B8 Si) and HD 176582 (B5 He weak) from Paper I). Estimated effective temperatures for these objects spanning the range from 9420 K to 18300 K and periods from about 1.56 days to values larger than 20 days.

At the second group (antiphase variability) belong 7 stars (namely the stars here presented plus HD 28843 (B9 He weak), HD 182255 (B6 He weak) and HD 223640 (B9 SiSrCr) published in Paper I). Also in this case effective temperatures cover a large range between 10425 K to 18720 K and the periods vary from values less than 1 days to about 4.5 days.

These results led us to confirm the conclusions of the Paper I, that is: no-unique correlation exists and this fact is independent of the T_{eff} of observed stars, the peculiarity classes and of the periods of variations.

Fig. 1 shows the measured average value of the equivalent width of the HeIλ5876 Å line together with the theoretical behavior computed in the NLTE approximation by Leone & Lanzafame (1998) for solar composition stars. We conclude that according to estimated T_{eff} and $\log g$ the measured equivalent width is smaller than the theoretical predictions for HD 35502, HD 79158, HD 142990, HD 124224 and HD 129174, slightly larger than the calculations for HD 196502 and roughly consistent with a standard solar composition for HD 77350, HD 90044 and HD 115735.

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