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Orbital elements of binary systems with a chemically peculiar star*

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Abstract. When binary systems with a chemically peculiar (CP) star are compared with normal-star binary systems, they present: a lower incidence, a deficiency of short periods, rather eccentric orbits, and companions of low mass. Unfortunately these results are based on a relatively small (~ 50) number of CP-star binary systems with known orbital parameters and a similar analysis has not yet been carried out for helium-peculiar stars, as there is only one helium-weak star with known orbital elements.

With the aim to contribute to the study of binary systems whose brightest component is a CP star, we have performed spectroscopic observations and determined the orbital elements for seven of these systems. Of these we have included two helium-weak and two helium-strong stars.

The values found for the orbital elements confirm the deficiency of short periods and the lack of circular orbits for CP stars: only HD 15144 has an orbital period shorter than 3 days (the orbital period distribution of normal stars peaks at 3 days) and a circular orbit. As to helium-peculiar stars, we have determined orbital periods longer than 12 days and large eccentricity values (0.26–0.40).

As O$-$A star binary systems have circular orbits only when their orbital periods are less than two days, we conclude that CP-star binary systems are characterised only by long orbital periods with respect to normal stars. Probably a small component separation and/or a massive companion, which are associated with short orbital periods, is responsible for such a strong atmospheric mass motion on the stellar surface to prevent the element separation which is at the basis of the CP star phenomenon.

The amplitude of the radial velocity curve of the helium-strong star HD 36485 is only $8\,\mathrm{km\,s^{-1}}$, one of the smallest known values for a CP star, which appears to be consistent with the small ($\sim 10^{\circ}$) inclination of the rotational axis.

Key words: stars: individual: HD 36485 – stars: chemically peculiar – stars: binaries: spectroscopic

1. Introduction

Abt (1970) reports that the number of binary systems in clusters increases when the average stellar rotational velocity decreases. Since chemically peculiar (CP) stars usually present smaller rotational velocities than normal main sequence stars, the incidence of binaries among CP stars is expected to be higher than among normal main sequence stars. This aspect of CP stars could be related to the atmospheric stability that is necessary to explain the observed non-homogeneous distribution of chemical elements on the stellar surface.

In contradiction to the correlation between rotational velocity and binary frequency found by Abt (1970), the incidence of binary systems among CP stars appears to be lower than among normal stars (Jaschek & Jaschek 1976). Jaschek & Gomez (1970) found an incidence of 47$\pm$5% of binaries which is rather constant from B to M main sequence stars. Gerbaldi et al. (1985) determined the incidence of binaries among CP star subgroups and concluded that: *a*) there is a deficiency of binaries among He-weak, Si, SiCr and SiSr stars, *b*) the incidence of binaries among the coolest CP stars and the HgMn stars is not different from that among normal main sequence stars. For cool CP stars a different result was obtained by North (1993), who performed a Coravel survey and estimated an incidence of spectroscopic binaries equal to 19% and not larger than 30%.

A further difference between CP and normal main sequence stars is the distribution of eccentricity as a function of the orbital period (Jaschek & Jaschek 1976). Gerbaldi et al. (1985) found that there is a lack of circular orbits for peculiar stars. The previous period-eccentricity relation is based on a relatively small number of cases: 14 cool CP stars, 22 HgMn stars, 12 Si stars and 1 He-weak star.

With the aim to increase the number of CP stars with known orbital parameters and to extend the period-eccentricity relation to helium peculiar stars, we have carried out spectroscopic observations and determined the orbital elements of 2 cool CP stars, 1 Si star, 2 helium-weak stars and 2 helium-strong stars.

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* Partially based on observations collected at the European Southern Observatory, LaSilla Chile.

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Table 1. Observed CP stars. Spectral and peculiarity classes are from Renson et al. (1991). Spectroscopic observations have been carried out with CAT and 1.5 m telescope of ESO, with the 2.1 m telescope of CASLEO and 0.9 m telescope of the Catania Astrophysical Observatory (SLN).

Star HD	Spec.Type Pec. Class	Observatory
11753	$A0HgPt$	$ESO(CAT)$
15144	$A5SrCrEu$	$ESO(CAT)$
25267	$A0Si$	$ESO(CAT)$
36485	$B2He$	$ESO(CAT) + CASLEO$
37017	$B2He$	$ESO(1.5m) + CASLEO + SLN$
142096	$B3Hewk$	$ESO(CAT) + SLN$
189178	$B5Hewk$	SLN

Table 2. A sample of N stars with constant and well known radial velocity has been observed. For any instrument, the average difference $\Delta(VR_{lit} - VR_{obs})$ between the radial velocity values from the literature and our measurements estimates possible systematic errors. For any template star we have computed the average radial velocity value and standard deviation (σ). The largest σ is reported to quantify random errors on our measurements of radial velocity. See the text for a description of the used instrumental configuration.

Instrumental configuration	N	$\Delta(VR_{lit} - VR_{obs})$ $km\,s^{-1}$	σ
ESO(CAT) + CES	7	0.2 ± 3.8	0.7
ESO(1.5m) + ECHELEC	7	0.3 ± 2.3	2.6
CASLEO + B&C spectrograph	4	-0.9 ± 3.7	3.4
SLN + REOSC spectrograph	2	0.8 ± 0.4	1.1

2. Observations and data reduction

Radial velocities for the chemically peculiar stars that are listed in Table 1 have been measured with different instruments:

- the 1.4 m *Coude Auxiliary Telescope* equipped with the *Coude Echelle Spectrometer* of the *European Southern Observatory* has been used to observe the stars HD 11753, HD 15144 and HD 25267 in the 545 nm region with a linear dispersion of 1 Å mm^{-1}, the lines of the wavelength calibration lamp show that the instrumental broadening can be reproduced with a FWHM = 3 km s^{-1} Gaussian. This instrument has also been used to observe HD 36485 in the H_α region and HD 142096 in the D3 region with a 1.4 Å mm^{-1} linear dispersion and a FWHM = 5 km s^{-1} Gaussian instrumental broadening.
- the 1.5 m ESO telescope equipped with *ECHELEC* has been used to observe HD 37017 in the H_β region with a 3 Å mm^{-1} linear dispersion and a FWHM = 11 km s^{-1} Gaussian instrumental broadening.
- the 2.1 m telescope of the *Complejo Astronómico El Leoncito* by using a Boller & Chivens Cassegrain spectrograph has been used to observe HD 36485 and HD 37017 in the D3 and H_α regions at a 10 Å mm^{-1} linear dispersion and a FWHM = 25 km s^{-1} Gaussian instrumental broadening.
- the 0.9 m telescope of the *Catania Astrophysical Observatory*, which is fibre linked to a REOSC echelle spectrograph (Frasca & Catalano 1994), has been used to observe the stars HD 37017, HD142096 and HD 189178 in the D3 region with a 6 Å mm^{-1} linear dispersion and a FWHM = 24 km s^{-1} Gaussian instrumental broadening.

All data have been reduced using the IRAF package. The achieved S/N was between 100 and 200.

For each observed star, radial velocities have been measured by cross-correlating the observed spectra with SYNTHE (Kurucz & Avrett 1981) spectra. ATLAS9 (Kurucz 1993) model atmospheres have been adopted for these calculations.

Hauck & North (1993) concluded that *classical* photometric methods can be reliable to infer the effective temperature of helium peculiar stars. Thus we have determined the effective temperatures and gravities of these stars from Strömgren photometry according to the grid of Moon & Dworetsky (1985) as coded by Moon (1985). The photometric colours have been de-reddened with the Moon (1985) algorithm. For the remaining peculiar stars we have determined the effective temperature by using the Napiwotzki et al. (1993) algorithm. The source of the Strömgren photometric data was SIMBAD. Abundances have been changed in order to improve the matching between observed and computed spectra.

To evaluate statistical and systematic errors on our radial velocities, during each night we have observed stars with constant and well known radial velocity. For any of these stars we have computed the average radial velocity and standard deviation (σ). The largest σ value is reported in Table 2 to estimate the statistical errors. Systematic errors are quantified with the average difference between radial velocity values from the literature and our measurements (Table 2). Since the errors are smaller than few km s^{-1}, the measured radial velocities of program stars were not corrected for.

The measured radial velocities and heliocentric Julian Date are listed in Table 3.

3. The determination of orbital parameters

Describing orbits by:

a semi-major axis
e eccentricity
P period
i inclination angle
ω longitude of periastron
T_o time of periastron passage

the expected radial velocities are

$$V_r = K[\cos(\theta + \omega) + e\cos\omega] \quad (1)$$

where

$$K = \frac{2\pi a \sin i}{P\sqrt{1-e^2}} \quad (2)$$

Table 3. Heliocentric Julian Date and measured radial velocities for program stars.

Star	HJD 2400000+	RV $km\,s^{-1}$	Star	HJD 2400000+	RV $km\,s^{-1}$	Star	HJD 2400000+	RV $km\,s^{-1}$
HD 11753	50373.746	−3.8	*HD* 37017	48903.803	−13.4	*HD* 189178	50623.581	−53.8
	50374.708	−3.0		48905.766	−6.0		50624.588	−55.3
	50375.793	−3.5		48906.822	−6.7		50628.594	−58.1
	50376.687	−3.6		48908.798	34.0		50629.587	−58.9
	50377.808	−4.2		50057.719	13.9		50630.592	−60.9
	50378.754	−4.4		50058.683	0.1		50644.517	−11.8
				50060.706	−11.1		50645.499	−5.7
				50061.752	−6.0		50646.514	5.1
HD 15144	50373.756	−10.5		50062.698	2.6		50648.538	25.5
	50374.718	−3.8		50063.669	13.9		50649.526	26.2
	50375.803	19.4		50737.570	48.1		50650.522	31.7
	50376.697	−9.7		50740.617	40.4		50651.542	31.3
	50377.819	0.5		50762.664	55.2		50737.331	0.60
	50378.765	19.2					50744.319	−12.7
			HD 142096	49787.877	−40.0		50746.356	−17.8
				50498.630	−33.0		50748.358	−21.9
HD 25267	50373.800	59.4		50500.641	24.5			
	50374.844	44.0		50501.634	32.1			
	50375.829	8.7		50502.653	24.4			
	50376.725	−23.4		50503.612	18.1			
	50377.845	2.9		50505.614	1.6			
	50378.790	37.7		50506.604	−8.8			
				50621.415	−34.8			
				50622.422	−37.8			
HD 36485	50057.672	8.0		50623.389	−32.3			
	50058.672	7.7		50624.415	5.4			
	50060.693	9.6		50625.415	19.2			
	50061.740	11.1		50627.405	13.6			
	50062.675	13.4		50628.401	9.7			
	50063.651	18.4		50629.433	−1.0			
	50063.655	19.6		50630.406	−8.6			
	50373.865	28.8		50644.334	−21.4			
	50374.873	27.3		50645.330	−28.2			
	50375.858	28.0		50646.367	−32.6			
	50376.849	28.5		50648.344	−26.7			
	50377.873	27.7		50649.342	−0.6			
	50378.876	26.4		50650.334	17.3			
	50444.652	10.9		50651.356	18.1			

and θ is the angular position of the star measured from the centre of mass at a given instant.

Orbital elements have been determined by a least-squares fitting of observed radial velocities to Eq. (1) with the following steps: one degree for ω, 0.5 $\mathrm{km\,s^{-1}}$ for velocities and 0.01 for e. Errors have been estimated as the variation in the parameter which increases the rms deviation of the observed radial velocities with respect to the fitted curve by $1\,\sigma$.

For each star, Table 4 reports the determined orbital elements, their errors and the mass function:

$$f(m) = \left(\frac{M_2}{M_1 + M_2}\right)^2 M_2 \sin^3 i \qquad (3)$$

4. Individual stars

4.1. HD 11753 = HR 558 = ϕ Phe

Dworetsky et al. (1982) suggested that the radial velocity of the HgMn star HD 11753 is variable with a period longer than 30 days.

By combining our radial velocities of HD 11753 with the measurements of Dworetsky and co-workers, we found that the most probable orbital period is 41.489±0.019 days (Fig. 1).

In the Oblique Rotator Model (ORM) proposed by Stibbs (1950), the common period of the photometric, spectroscopic and magnetic variations for a CP star is the stellar rotational period. The photometric observations obtained by the Hipparcos satellite (SP-ESA 1200, Vol. 17) for HD 11753(=HIP8882)

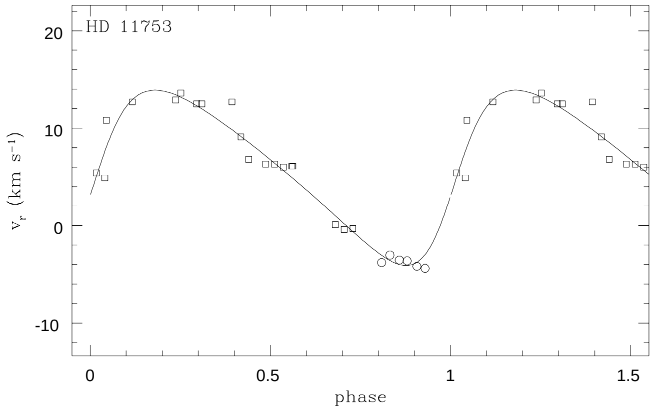

Fig. 1. Radial velocity curve of HD 11753. Squares represent Dworetsky et al. (1982) observations, circles our observations. The full-drawn curve is a least-squares fit of data using Eq. (1). Relative orbital parameters are listed in Table 4.

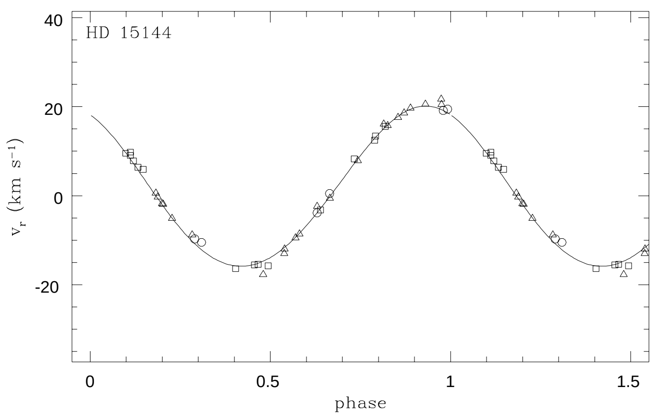

Fig. 2. Radial velocity curve of HD 15144. Triangles represent Bonsack et al. (1981) observations, squares Tokovinin (1997) observations and circles our observations. The full-drawn curve is a least-squares fit of data using Eq. (1). Relative orbital parameters are listed in Table 4.

present no evidence of periodic variability: H_p = 5.107±0.008. Thus it is not directly possible to know if the orbital and rotational motions are synchronised.

From our spectra, we measured a projected rotational velocity $v \sin i$ = 14 km s^{-1}. For this value, the relation:

$$v \sin\, i = 50.6 \frac{R_* \sin i}{P} \tag{4}$$

(where i is the angle between the rotational axis and the line of sight, R_* is the stellar radius in solar radii, velocities are in km s^{-1} and P is the stellar rotational period in days) gives $R_* >$ 13 $R_\odot$ if P is equal to the orbital period. This value of the stellar radius is too large for a main sequence star with $T_{\rm eff} = 9950$ K and makes it implausible that the rotational and orbital periods for HD 11753 are synchronized.

4.2. HD 15144 = HR 710

Babcock (1958) found that the A5 SrCrEu star HD 15144 presents radial velocity variations with a 2.997814 day period. Even though the few photometric observations of this star obtained by van Genderen (1971) appear to be variable with the orbital period, there is no evidence of periodic variability in the Hipparcos photometric data of HD 15144 (= HIP 11348): H_p = 5.92±0.01. This result confirms Adelman & Boyce (1995) statement that HD 15144 is not a photometric variable. According to Bonsack (1981), HD 15144 has a rotational period equal to the 2.997824 day orbital period. Moreover Bonsack concluded that the magnetic field variations, with a 15.88 day period, are intrinsic variations in the field strength or geometry. Tokovinin (1997) has recently determined an orbital period equal to 2.997812 ± 0.000004 days.

The least-squares fit of Bonsack (1981), Tokovinin (1997) and our radial velocities by using Eq. (1) gives the orbital period equal to 2.99781 ± 0.00001 days (Fig 2). The eccentricity is very low (e = 0.04): HD 15144 is one of the few CP stars with circular orbit.

In the framework of the ORM, the period of the magnetic field variation is the stellar rotational period, thus we should conclude that in spite of the short orbital period and the almost circular orbit the HD 15144 binary system is not synchronised. Anyway as our observations span a seven day interval, they rule out a spectral variability with a 15.88 day period and support the 2.99781 day period. If we consider that the effective magnetic field variation, reported by Bonsack (1981) assuming the 15.88 day period, is not accurately defined it cannot be excluded that the HD 15144 binary system is synchronised. Further spectroscopic observations and measurements of the effective magnetic field should be obtained to check the rotational period of HD 15144.

4.3. HD 25267 = HR 1240 = τ^9 Eri

The A0 silicon star HD 25267 is the brightest component of a binary system whose orbital period is equal to 5.95367 days (Sahade 1950). According to Borra & Landstreet (1980) this period is also representative of the magnetic field variation. Manfroid et al. (1985) found that the HD 25267 binary system shows two periodicities in the photometric variations. The 1.210005 day period, being also representative of the magnetic variation, is attributed to the CP component. The origin of the variation with the second period (3.8 days) remains uncertain, as the spectral lines of the secondary component are almost invisible.

By combining our radial velocity measurements with those by Sahade (1950), we found that the most probable orbital period for the HD 25267 binary system is 5.9538 ± 0.0001 days (Fig 3).

Our measurement of the projected radial velocity (30 km s^{-1}), the stellar radius ($R_* = 3.1 \pm 0.4\, R_\odot$) measured by North (1998) from Hipparcos parallaxes and the measurements by Borra & Landstreet (1980) of the effective magnetic field seem to exclude synchronisation for the HD 25267 system. Eq. (4) gives an inclination $i \sim 13°$ for P ∼ 1.2 days and $i \sim 90°$ for P ∼ 5.9 days. As the effective magnetic field changes from 0 to -400 gauss during a rotational period, an inclination angle i close to $90°$ has to be ruled out.

On the hypothesis that the rotational axis of HD 25267 is perpendicular to the orbital plane we can estimate the mass of the secondary star. North (1998) has determined the mass of HD 25267 as equal to 3.35 $M_{\odot}$; for this value of M_1 and $i \sim 13°$ Eq. (3) gives $M_2 = 2.25 M_{\odot}$. This value is typical for a main sequence A5 star whose characteristics are consistent with the statements by Manfroid et al. (1985) on the HD 25267 binary system. These authors found that the spectral lines of the secondary star are almost invisible and the MgII line can be attributed to the secondary star.

Jaschek & Jaschek (1976) compared the frequency of $Y = f(M)/M_1$ for normal and CP stars. They noted that normal stars peak at $\log Y = -2$ and that there is an excess of companions of low mass in CP star binary systems. As to HD 25267, we obtain $\log Y = -2.9$ which confirms Jaschek & Jaschek's (1976) conclusion.

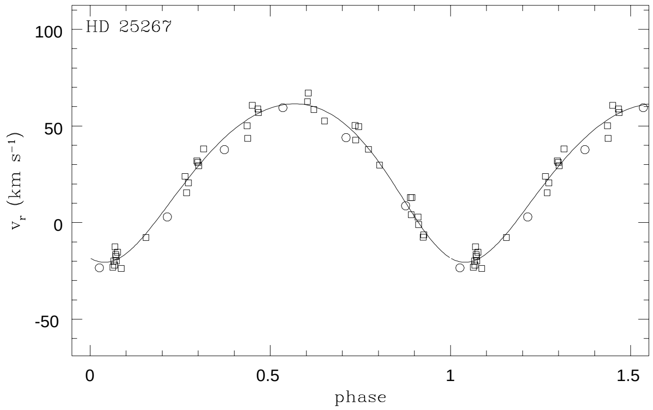

Fig. 3. Radial velocity curve of HD 25267. Squares represent Sahade (1950) observations, circles our observations. The full-drawn curve is a least-squares fit of the data using Eq. (1). Relative orbital parameters are listed in Table 4.

4.4. HD 36485 = HR 1851 = δ Ori C

Morrell & Levato (1991) noted that there is some confusion in the literature concerning the observations of the helium-strong star HD 36485. By combining their observations with data from the literature, Morrell & Levato (1991) found that HD 36485 shows radial velocity variations with a 9.9144 day period and $K = 55 \pm 18$ km s^{-1}. Bohlender (1994) found that HD 36485 shows emission features in the H_{α} line with a 1.4778 day period. Because of possible emission also in the helium lines, we have measured the radial velocity of HD 36485 from the two carbon lines at 657.8 and 658.3 nm.

Our radial velocities are incompatible with the 1.4778 day rotational period and they exclude that we are observing the rotating non-homogeneous stellar surface of HD 36485. Moreover the measured radial velocity does not vary with the orbital period given by Morrell & Levato (1991).

Combining our data with the observations by Abt (1970), we found that the most probable orbital period is 25.592 ± 0.001 days. In this case, it appears that the radial velocity amplitude is very small, only 8.0 km s^{-1}. Such a value is consistent with a constant effective magnetic field (Bohlender et al. 1987) and an inclination of the rotational axis of $10°$ for HD 36485 (Bohlender 1989).

Assuming T_{eff} = 19000 K for HD 36485, Bohlender (1989) determined: *a*) M = 8±2 $M_{\odot}$ and R = 6±2 $R_{\odot}$ on the hypothesis of a helium-rich spot on the stellar surface, *b*) M = 11±3 $M_{\odot}$ and R = 10±4 $R_{\odot}$ if helium is stratified in the atmosphere. We can thus estimate the mass of the secondary star of the binary system assuming that the HD 36485 rotational axis is orthogonal to the orbital plane. From Eq. (3), for the two previous hypotheses the values for the secondary star mass are 4.0 $M_{\odot}$ and 4.9 $M_{\odot}$ respectively. In this case $\log Y < -3.5$ and HD 36485 provides further confirmation that in binary systems with a primary CP star the secondary star is not massive.

Since the secondary star is at least one V magnitude fainter than HD 36485 and the rotational velocity (= 32 km s^{-1} Bohlender 1989) is much larger than the orbital radial velocity, as observed, we are dealing with a single line spectroscopic binary system.

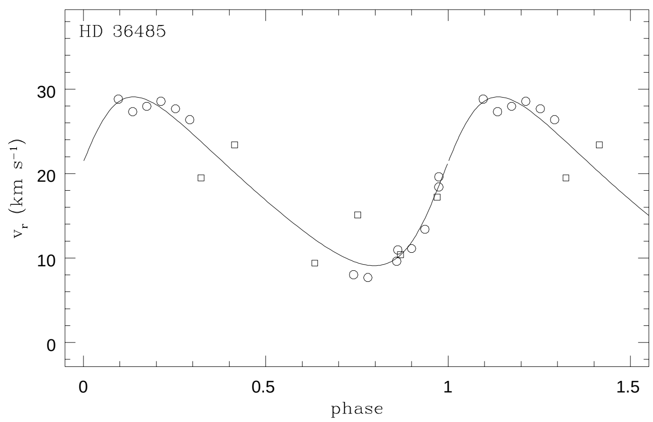

Fig. 4. Radial velocity curve of HD 36485. Squares are Abt (1970) observations, circles our observations. The full-drawn curve is a least-squares fit of data using Eq. (1). Relative orbital parameters are listed in Table 4.

As the rotational period is equal to 1.4778 days and the orbital period to 25.592 days, the binary system of the helium-strong star HD 36485 is not synchronised.

4.5. HD 37017

Blaauw & van Albada (1963) suggested that the helium strong star HD 37017 is a spectroscopic binary with an orbital period of 18.65 days. Morrell & Levato (1991) concluded that the orbital period is 18.622 days.

Bohlender et al. (1987) found that the rotational period is 0.901195 days and that the inclination of the rotational axis is in the range $23°$–$37°$. Moreover, these authors report that according to Dr C.T. Bolton the orbital inclination is between $30°$ and $50°$ and that the secondary is approximately 1 mag fainter than HD 37017.

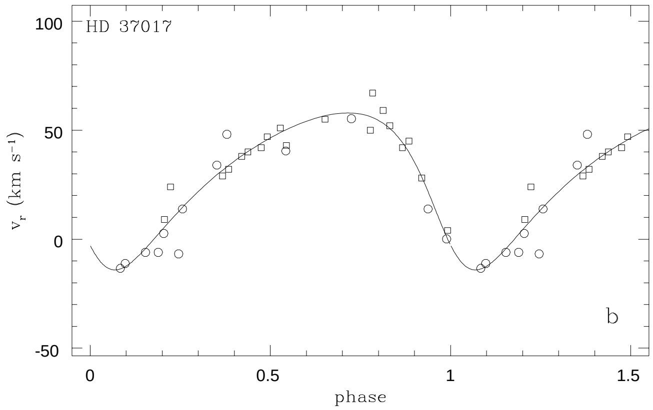

Fig. 5. Radial velocity curve of HD 37017. Squares represent Blaauw & van Albada (1963) observations, circles our observations. The full-drawn curve is a least-squares fit of data using Eq. (1). Relative orbital parameters are listed in Table 4.

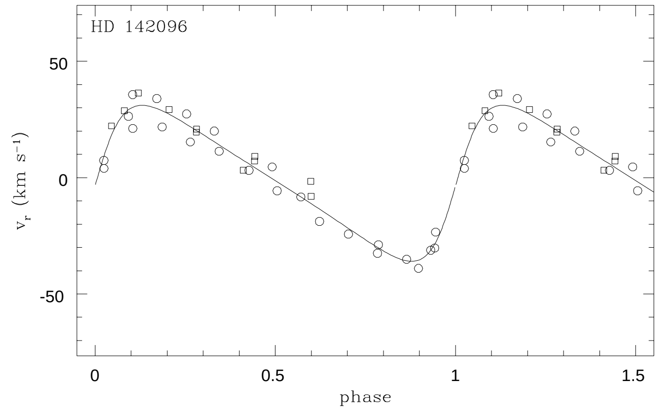

Fig. 6. Radial velocity curve of HD 142096. Squares represent van Hoof et al. (1963) observations, circles our observations. The full-drawn curve is a least-squares fit of data using Eq. (1). Relative orbital parameters are listed in Table 4.

We have observed HD 37017 in six consecutive nights at LaSilla in October 1992 with the 1.5m telescope and in six consecutive nights at CASLEO in December 1995. The radial velocity variation is not periodic with the stellar rotational period determined by Bohlender et al. (1987).

Combining our data and those of Blaauw & van Albada (1963), we found two possible orbital periods: 1.056576 and 18.6556 days (Fig. 5). By matching the Hβ line profile and the visible flux distribution, and taking into account the helium abundance, Leone (1998) has determined the effective temperature of HD 37017 equal to 19000 K. For a main sequence star with this effective temperature the expected mass is 7.6 $M_\odot$. Solving Eq. (3) for the determined $f(m)$ values and $i \sim 30°$, for the secondary star we get 1.4 $M_\odot$ mass for the shortest period and 4.5 $M_\odot$ mass for the longest one. Thus the spectral type of the secondary star, if a main sequence star, should be F5 and B7 respectively. If the secondary star is one magnitude fainter than HD 37017, as stated by Bolton, the shortest period must be ruled out, as a F5 star would be five magnitudes fainter in the visible than HD 37017.

Like HD 36485, the helium-strong star HD 37017 also belongs to a non-synchronised binary system.

4.6. HD 142096 = HR 5902 = λ Lib

Van Hoof et al. (1963) found that the radial velocity of the helium-weak star HD 142096 is variable. Combining our radial velocities with those of van Hoof and co-workers we obtain an orbital period equal to 12.4619 days.

No variability period is known for the helium-weak star HD 142096. Hipparcos photometry of this star (HIP = 77811) gives H_p = 5.03±0.01 without any clear evidence of variability.

From our spectra (R = 50,000), the measured projected rotational velocity of HD 142096 is 140 km s^{-1}. This value is close to the value given by Brown & Verschuren (1997) who measured 146 km s^{-1}. Assuming that the rotation period is equal to the orbital period (P = 12.4619 days), Eq. (4) gives $R_* > 36$ $R_\odot$ and excludes that the orbital and rotational periods are coincident for the B3 star HD 142096.

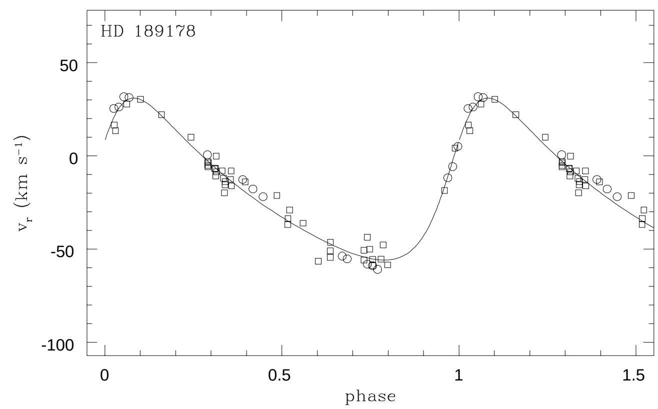

Fig. 7. Radial velocity curve of HD 189178. Squares represent Batten et al. (1982) observations, circles our observations. The full-drawn curve is a least-squares fit of data using Eq. (1). Relative orbital parameters are listed in Table 4.

4.7. HD 189178 = HR 7628A

This star HD 189178 (= HIP 98194) is given as a suspected He-weak star in the *General Catalogue of Ap and Am stars* by Renson et al. (1991). Its rotational period has not been determined yet. From Hipparcos observations, it appears that the star is not a photometric variable with H_p = 5.437 ± 0.006.

Combining our radial velocity measurements and those of Batten et al. (1982), we found that the orbital period is 70.23 ± 0.02 days (Fig. 7).

We measured a projected rotational velocity of 50 km s^{-1} which is much smaller than the Uesugi & Fukuda (1970) value (115 km s^{-1}). Eq. (4) gives $R_* > 69$ $R_\odot$ even for our $v \sin i$ value and excludes that orbital and rotational motions are synchronised.

Table 4. Orbital parameters and their errors. Errors are defined as the variation in the parameter which increases by one σ the observed radial velocity dispersion around the fitting curve.

Star HD	P day	T_o 2400000+	e	V_o km s^{-1}	K km s^{-1}	ω	$a\sin(i)$ $R_\odot$	$f(m)$ $M_\odot$
11753	41.489	41248.301	0.32	5.5	9.0	258	6.99	$2.66\,10^{-3}$
	±0.019	±0.331	±0.05	±0.5	±0.5	±4	±0.51	$\pm0.59\,10^{-3}$
15144	2.99781	41258.398	0.04	1.5	18.0	27	1.06	$1.81\,10^{-3}$
	±0.00001	±0.003	±0.01	±0.5	±0.5	±1	±0.30	$\pm0.15\,10^{-3}$
25267	5.9538	32105.100	0.13	25.5	41.0	161	4.78	$4.14\,10^{-3}$
	±0.0001	±0.042	±0.03	±0.5	±1.0	±1	±0.14	$\pm0.35\,10^{-3}$
36485	25.592	21601.600	0.26	18.5	10.0	283	4.88	$2.39\,10^{-3}$
	±0.001	±0.205	±0.09	±0.5	±1.0	±5	±0.61	$\pm0.90\,10^{-3}$
37017	18.6556	35461.602	0.31	29.5	36.0	133	12.61	$7.74\,10^{-2}$
	±0.0017	±0.168	±0.05	±1.5	±2.5	±5	±1.09	$\pm2.02\,10^{-2}$
142096	12.4619	35159.000	0.40	−2.0	33.5	268	7.56	$3.74\,10^{-2}$
	±0.0005	±0.087	±0.03	±0.5	±1.0	±3	±0.33	$\pm0.50\,10^{-2}$
189178	70.23	39733.898	0.37	−20.0	43.5	298	56.08	$4.80\,10^{-1}$
	±0.02	±0.351	±0.03	±0.5	±1.0	±1	±2.03	$\pm0.52\,10^{-1}$

5. Conclusions

We have carried out spectroscopic observations and determined the orbital elements of seven binary systems whose brightest component is a chemically peculiar star. The results are summarized in Table 4.

Gerbaldi et al. (1985) have compared the period distribution of binary systems with B6–B9.5 primaries with the period distribution of systems with a CP star. These authors concluded that for normal stars the distribution peaks at $P \sim 3$ days, whereas for cool stars the minimum orbital period is ~ 3 days and the minimum orbital period for Si stars is 4.7 days. Our results for HD 11753, HD 15144 and HD 25267, which belong to the previous spectral range, confirm Gerbaldi and co-workers conclusions on cool CP and Si stars.

As to HD 25267 and HD 36485 whose stellar mass has been determined by North (1998) and Bohlender (1989) respectively, we have estimated the mass of the secondary star and confirmed Jaschek & Jaschek (1976) result that primary CP stars show a deficiency of massive companions.

Of the seven systems studied here, only the cool CP star HD 15144 presents a rotational period which is synchronised with the orbital period and a circular orbit. The lack of circular orbits for binaries with a CP star noted by Jaschek & Jaschek (1976) and Gerbaldi et al. (1985) is also here confirmed.

The helium-peculiar stars HD 37017, HD 36485, HD 142096 and HD 189178 have orbital periods longer than 12 days and large eccentricity values (0.26–0.40). It appears that the hot and cool CP stars show the same behavior with respect to normal-star binary systems.

From the previous results, it appears that when binary systems with a chemically peculiar star are compared with normal star systems, they present a lower incidence, a deficiency of short periods, rather eccentric orbits, and companions of low mass. We suggest that these characteristics of binary systems with a CP star are due to the fact that these stars can exist only in binary systems with long orbital periods. Short orbital periods, which are related to massive companions and small component separations, give origin to strong atmospheric mass motions preventing the element diffusion which is at the basis of the CP star phenomenon[1]. If CP stars cannot exist in binary systems with short orbital period, the incidence of binary systems with a CP star is expected to be lower than for normal-star systems. In binary systems with long orbital periods, the eccentricity-period distribution of CP stars is not different than for other early-type-star binaries. Giuricin et al. (1984) have shown that O–A normal stars present nearly circular orbits only for orbital periods shorter than two days.

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[1] It is generally accepted that non-solar abundances of CP stars are due to element diffusion processes in a stable atmosphere (Michaud 1970).

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