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The early-type double-lined spectroscopic binary HD 141929

F. Carrier*,**

Observatoire de Genève, 51 Chemin des Maillettes, 1290 Sauverny, Switzerland

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Abstract. Optical spectroscopy of the early-type HD 141929 reveals this star to be a double-lined binary system. We obtained the first orbit, consisting of an eccentric solution ($e = 0.393$) with a period of 49.699 d and semi-amplitudes of 9.95 and 10.58 km s^{-1}. The mass ratio reaches only 0.94 and both components have the same spectral type A0/1V, however, the secondary is rotating slower than the primary.

Key words. stars: binaries: spectroscopic – stars: individual: HD 141929 – techniques: radial velocities

1. Introduction

Multiplicity plays an essential role in the formation and perhaps the evolution of A-type stars. The cross-correlation method, being applied to the radial velocity (RV) determination of late-type stars, is now also a powerful tool to calculate the RVs of early-type stars. This method is tested with a previously unknown double-lined early-type star HD 141929, whose lines are blended and whose velocity amplitudes are relatively small.

HD 141929 is classified in SIMBAD as A0V (Houk & Cowley 1975). This star was measured by the Tycho (Hipparcos) mission, however, due to its faint luminosity (about 9.6 mag) and most likely to the over-population of the field close to the star, the Tycho magnitudes are unusable (Grenon 2002).

HD 141929 was monitored in radial velocity by using the CORALIE spectrograph. The results of this spectroscopic survey are presented in this paper.

2. Observations

HD 141929 was measured with the CORALIE high-resolution fiber-fed echelle spectrograph (Queloz et al. 2001) mounted on the Nasmyth focus on the 120 cm Swiss telescope at La Silla (ESO, Chile) from May 2000 until October 2001. CORALIE has a resolving power of 50 000 ($\lambda/\Delta\lambda$). The CORALIE spectra were extracted at the telescope, using a software package called INTER-TACOS (INTERpreter for the Treatment, the Analysis and the COrrelation of Spectra), developed by D. Queloz and L. Weber at the Geneva Observatory (Baranne et al. 1996). 30 echelle-spectra were obtained during the 17 months of the survey. These observations cover 68 orders in the spectral range 3875–6820 Å. The S/N ratios of the spectra vary from 14 to 50 at 4500 Å and from 17 to 60 at 6000 Å.

3. Radial velocity determination

The main problem in determining radial velocities for hot stars is that the spectra of these stars contain only a few lines. The applied method consists of the correlation between the considered spectrum and a mask created from a reference synthetic spectrum. Since early-type star spectra present significant feature changes from one spectral type to another, it is important to use a template as similar as possible to the real spectrum (Verschueren et al. 1999). Thus, synthetic spectra could be calculated in a grid as dense as necessary to closely match the observed stellar spectrum. The spectrum synthesis of the spectral region 3875–6820 Å was accomplished using the SYNSPEC (Hubeny et al. 1994) code with the model atmospheres interpolated from Kurucz ATLAS9 (1994) grid. Vienna Atomic Line Database (VALD-2) was used to create a line list for the spectrum synthesis (Kupka et al. 1999). This program uses a LTE-model, which is efficient enough for the calculation of radial velocities. First, the synthetic spectrum is computed without rotation, with a solar composition and a microturbulent velocity of 2 km s^{-1}. Next, the obtained spectrum is broadened with profiles to take the rotation and the resolving power of the observed spectra into account. Finally, a mask is calculated using each non-blended line from the synthetic spectrum, the hydrogen lines being eliminated due to their too large contributions to the correlation. Many tests were conducted employing several templates to discover which yielded the strongest and sharpest cross-correlation function. The final mask comprises about 70 lines with normalized intensities between 0.02 and 0.24 with an average at 0.07.

* Based on observations collected at the Swiss telescope at the European Southern Observatory (La Silla, Chile).

** e-mail: Fabien.Carrier@obs.unige.ch

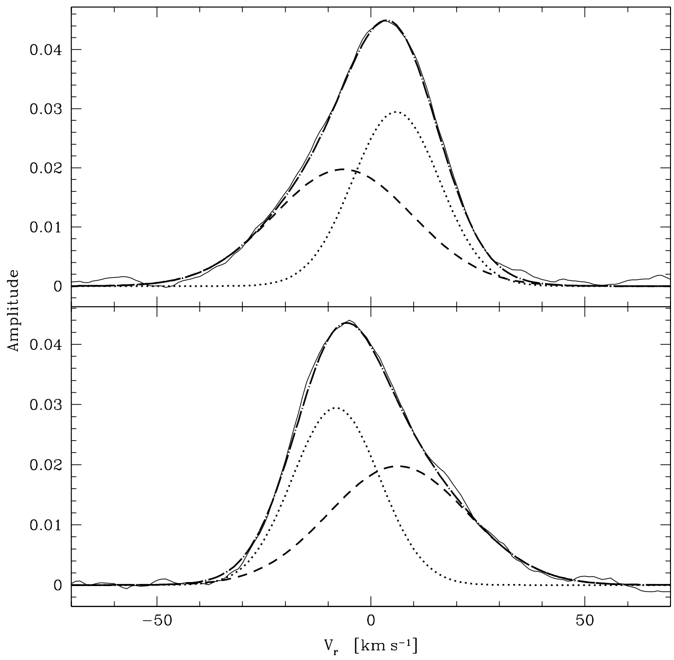

Fig. 1. Cross-correlation functions of HD 141929 at two different epochs: HJD = 2 452 078.676407 (top) and 2 452 000.860427 (bottom). The primary and secondary Gaussians are indicated by the dashed and dotted lines respectively and the sum by the dot-dashed lines.

This star is a double-lined binary whose lines are completely blended. Therefore, the radial velocities were obtained by fitting two Gaussians from the cross-correlation function (CCF). However, by fitting each CCF with two Gaussians, there are six free parameters: the mean, amplitude and width for both Gaussians. Thus, the radial velocity errors are dominated by the poorly constrained fit due to the blend.

Therefore, the CCFs for all observations are fitted together with the same parameters. The widths and the amplitudes of the primary and secondary Gaussians are each supposed to be constant and do not vary from one observation to another. The AMOEBA (multidimensional minimization by the downhill simplex method, Numerical Recipes) algorithm was required to do the non-linear least square fit. The continuum of each CCF was fixed to zero. For our 30 measurements, only the width and the amplitude for both Gaussians and all radial velocities have to be adjusted (see Fig. 1). The large noise coming from the fit of six parameters on each CCF disappears completely by fitting about only 2.1 parameters per CCF.

A realistic radial velocity error is given by the O–C of the binary (see Table 2). The radial velocity measurements and their corresponding errors are given in Table 1.

4. Orbital solution

According to our measurements, HD 141929 is a new double-lined binary with a period of 49.699 d. The orbit is eccentric ($e = 0.393$) and the semi-amplitudes 9.95 and 10.58 $\mathrm{km\,s^{-1}}$ are quite small, revealing a low angle of view i. The radial velocity curve is shown in Fig. 2 and the orbital parameters are listed in Table 2. The orbit confirms that both components are similar with a mass ratio of 0.94. The orbital solution is very accurate, taking into account the early spectral type and the so small amplitudes.

Table 1. Journal of the radial velocity observations of HD 141929. The phases are computed from the ephemeris given by Table 2.

HJD (−2 451 000)	Phase	V_A $\mathrm{km\,s^{-1}}$	σ_{V_A}	V_B $\mathrm{km\,s^{-1}}$	σ_{V_B}
51689.681329	0.889	−2.02	0.48	1.22	0.44
51701.710911	0.131	7.82	0.42	−9.40	0.39
51707.713750	0.252	1.84	0.46	−2.44	0.42
51741.552195	0.933	3.40	0.65	−4.00	0.59
51745.558649	0.013	12.39	0.49	−13.61	0.46
51756.549126	0.234	3.10	0.32	−3.70	0.30
51979.859023	0.728	−6.03	0.57	6.03	0.53
51981.911285	0.769	−6.04	0.59	6.39	0.54
51982.832722	0.787	−5.56	0.68	5.63	0.62
51984.857910	0.828	−4.99	0.67	4.40	0.62
51987.899216	0.889	−0.10	0.67	0.70	0.62
51995.828378	0.049	12.54	0.86	−15.16	0.79
52000.860427	0.150	6.37	0.83	−8.15	0.76
52003.890636	0.211	4.52	1.31	−5.22	1.20
52039.495799	0.928	2.92	1.03	−3.52	0.95
52047.678225	0.092	11.78	1.04	−11.86	0.95
52051.737652	0.174	6.37	1.15	−7.17	1.05
52055.523994	0.250	2.15	1.40	−2.86	1.28
52072.670005	0.595	−6.21	0.67	5.61	0.61
52075.618327	0.654	−7.39	0.73	6.66	0.67
52078.676407	0.716	−6.52	0.72	5.89	0.65
52129.640376	0.741	−6.04	0.66	5.39	0.60
52133.564598	0.820	−5.49	0.94	4.89	0.86
52136.633585	0.882	−2.53	0.63	1.70	0.58
52140.561486	0.961	6.72	0.63	−8.32	0.57
52144.507830	0.041	13.10	0.67	−14.73	0.60
52201.489948	0.187	5.40	0.70	−5.72	0.65
52202.499691	0.207	4.57	0.80	−5.09	0.75
52207.506346	0.308	−0.49	0.88	0.11	0.83
52208.493941	0.328	−0.63	0.75	−0.07	0.70

5. Stellar parameters

T_eff was estimated by fitting the wings of Balmer lines with synthetic spectra. Only the core of these lines are affected by the rotational broadening. A grid of synthetic spectra was built with the SPECTRUM code (Gray & Corbally 1994). The broadening by instrumental effects was taken into account. The effective temperature T_eff for both components is estimated to $9500 \pm 250\,\mathrm{K}$. Log g was estimated of the same way to 4.1 ± 0.2. These parameters imply spectral types of A0/1V (Gray & Corbally 1994). This estimations are reinforced by the mass ratio of 0.94 and by the fact that the area of the peaks

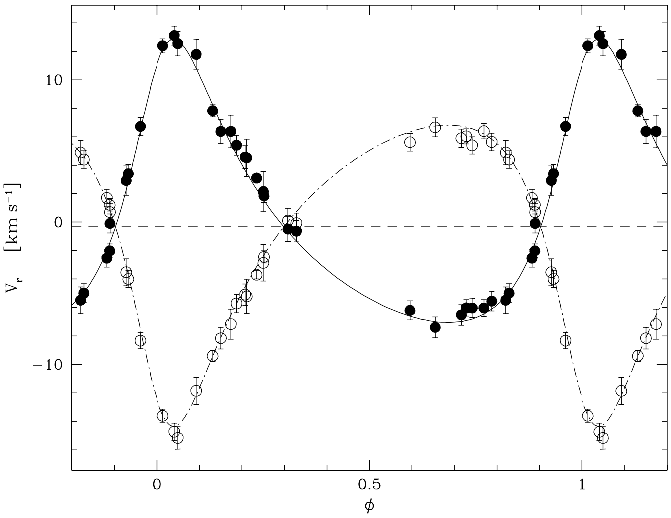

Fig. 2. Radial velocity curve of HD 141929. The period is 49.699 d.

Table 2. Orbital parameters of the binary. T_0, time at phase 0, corresponds to the periastron passage. The O–C is the ponderated RMS of the observed velocity residuals about the calculated velocity curve.

P [d]	49.699 ± 0.016
T_0 [HJD-2 451 000]	993.39 ± 0.19
e	0.393 ± 0.008
γ [km s^{-1}]	-0.33 ± 0.08
ω_1 [°]	325.7 ± 1.7
ω_2 [°]	145.7 ± 1.7
K_1 [km s^{-1}]	9.95 ± 0.17
K_2 [km s^{-1}]	10.58 ± 0.16
$q = K_2/K_1$	0.94 ± 0.02
$a_1 \sin(i)$ [Gm]	6.25 ± 0.11
$a_2 \sin(i)$ [Gm]	6.65 ± 0.11
$M_1 \sin^3(i)$ [$M_\odot$]	0.01789 ± 0.00067
$M_2 \sin^3(i)$ [$M_\odot$]	0.01681 ± 0.00064
$N_1 = N_2$	30
O–C [km s^{-1}]	0.562

in the cross-correlation function are nearly the same for both components. Assuming a mass of 2.9 $M_\odot$ for the primary (Schmidt-Kaler 1982), the secondary mass has a value of 2.73 $M_\odot$, and the inclination of the orbit is about 11°.

Rotational velocity ($v \sin i$) was estimated by comparison between two artificially broadened synthetic spectra (for A and B) and the spectrum of the star (Brown & Verschueren 1997). $v \sin i$ of 30 ± 2 and 15 ± 2 km s^{-1} were found for the primary and secondary respectively. From the $v \sin i$ and the angle $i = 11°$, determined above, true rotational velocities $v_1 = 82$ and $v_2 = 164$ km s^{-1} were obtained.

6. Conclusion

This radial velocity survey allowed detection of the new double-lined spectroscopic binary HD 141929. Both components are A0/1V stars, having different rotational velocities of 30 and 15 km s^{-1} for the primary and secondary respectively. As expected, this binary with a period of 49.699 d and an eccentric orbit is not synchronized. HD 141929 is an excellent system to study the rotation, since both components have the same physical parameters, the same age, but do not rotate at the same velocity.

Finally, we note that in spite of the fact that CORALIE is a spectrograph dedicated to searching for planets, it is also well adapted for hot star surveys. Its accuracy is sufficient to improve the statistics of double systems among early-type stars, in particular, to detect low-amplitude double-lined spectroscopic binaries.

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References

Baranne, A., Queloz, D., Mayor, M., et al. 1996, A&AS, 119, 1
Brown, A. G. A., & Verschueren, W. 1997, A&A, 319, 811
Gray, R. O., & Corbally, C. J. 1994, AJ, 107, 742
Grenon, M. 2002, private communication
Houk, N., & Cowley, A. P. 1975, Catalogue of two-dimensional spectral types for the HD stars, vol. I (Univ. of Michigan, Ann Arbor)
Hubeny, I., Lanz, T., & Jeffery, C. S. 1994, TLUSTY and SYNSPEC: A User's Guide, Newslett. on Analysis of Astronomical Spectra (Univ. of St. Andrews)
Kupka, F., Piskunov, N. E., Ryabchikova, T. A., Stempels, H. C., & Weiss, W. W. 1999, A&AS, 138, 119
Kurucz, R. L. 1994, CD-ROM 19 (Solar abundance atmosphere models for $0, 1, 2, 4, 8$ km s^{-1})
Queloz, D., Mayor, M., Pepe, F., et al. 2001, Messenger, 105, 1
Schmidt-Kaler, Th. 1982, in Landolt-Bornstein, ed. K.-H. Hellwege (Springer), Group VI, Subvolume 2b, 31
Verschueren, W., David, M., & Griffin, R. E. M. 1999, A&AS, 140, 107