Spectroscopic analysis of the B/Be visual binary HR 1847^{★,★★}

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ABSTRACT

We studied both components of a slightly overlooked visual binary HR 1847 spectroscopically to determine its basic physical and orbital parameters. Basic stellar parameters were determined by comparing synthetic spectra to the observed echelle spectra, which cover both the optical and near-IR regions. New observations of this system used the Ondřejov and Rozhen 2-m telescopes and their coudé spectrographs. Radial velocities from individual spectra were measured and then analysed with the code FOTEL to determine orbital parameters. The spectroscopic orbit of HR 1847A is presented for the first time. It is a single-lined spectroscopic binary with a B-type primary, a period of 719.79 days, and a highly eccentric orbit with $e = 0.7$. We confirmed that HR 1847B is a Be star. Its $H\alpha$ emission significantly decreased from 2003 to 2008. Both components have a spectral type B7–8 and luminosity class IV–V.

Key words. binaries: general – stars: emission-line, Be – stars: individual: HR 1847

1. Introduction

HR 1847 (HD 36408, BD +16°794, HIP 25950, ADS 4131) is a bright visual binary consisting of two B type stars. Throughout this paper, the component at $\alpha(J2000) = 05\ 32\ 14.14$, $\delta(J2000) = +17\ 03\ 29.3$ will be denoted as HR 1847A (or component A) and the one at $\alpha(J2000) = 05\ 32\ 14.56$, $\delta(J2000) = +17\ 03\ 21.8$ as HR 1847B (or component B). The first observations of this binary, which were obtained on 31 December 1782, were reported by William Herschel (see [Herschel 1785](#), star III.93). He observed this binary again on 21 January 1800 (see [Herschel 1821](#), star 124).

Although this visual binary consists of two bright stars and [Plaskett \(1919\)](#) recommended further observations, it was not studied much during the last century. Since HR 1847 is both an X-ray source ([Berghöfer et al. 1996](#)) and an IRAS source ([Coté & Waters 1987](#)), and considering its brightness, lack of observations, and sometimes confusing catalogue information, it has become quite an interesting object for more detailed study.

2. Summary of known properties of HR 1847

In this section we summarize the information currently available for both components of HR 1847, which is scattered throughout the astronomical literature, online catalogues, and databases.

* Based on observations with the Ondřejov and Rozhen 2-m telescopes.

** Appendix is only available in electronic form at <http://www.aanda.org>

2.1. Multiplicity

2.1.1. Angular separation

Angular separation ρ and relative position θ of the components of HR 1847 have already been measured by Friedrich Georg Wilhelm [Struve \(1837, star No. 730\)](#) as an average of 4 measurements obtained in 1829 and 1832 ($\rho = 9''.81$, $\theta = 141^\circ.82$). Later measurements resulted in $\rho = 9''.53$, $\theta = 140^\circ.2$ ([Cannon 1912b](#)), $\rho = 9''.7$, $\theta = 140^\circ.9$ ([Russell & Moore 1929](#)), $\rho = 9''.65$, $\theta = 140^\circ.85$ ([Perryman et al. 1997](#), from HIPPARCOS), $\rho = 9''.65 \pm 0''.006$, $\theta = 140^\circ.5$ ([Fabricius et al. 2002](#), from the Tycho catalogue), $\rho = 9''.61$, $\theta = 140^\circ.8$ ([Mason et al. 2004](#), from speckle interferometry). The angular separation, as reported by [Lindroos \(1983\)](#) and [Abt & Cardona \(1984\)](#) is $9''.6$.

2.1.2. Radial velocity variations

The first radial velocity measurements for both components were reported by [Plaskett & Young \(1919\)](#) and they showed variability. [Plaskett et al. \(1920\)](#) suggested that both components are spectroscopic binaries. [Frost et al. \(1926\)](#) designated HR 1847A (No. 126 in his Table II) as a spectroscopic binary with an unknown orbit using only one spectrum secured at the Dominion Astrophysical Observatory (DAO) in 1919 by Otto Struve. Component A was also reported to be a spectroscopic binary by [Gahm et al. \(1983\)](#) and [Abt et al. \(2002\)](#). However, no attempt has been made to determine the orbital parameters until now.

Table 1. HIPPARCOS and *UBVRJHK* photometry of HR 1847.

band	HR 1847A mag	HR 1847B mag	source
H_p	6.088 ± 0.007	6.455 ± 0.010	HIPPARCOS
B_T	6.036 ± 0.008	6.468 ± 0.004	HIPPARCOS
V_T	6.057 ± 0.009	6.458 ± 0.004	HIPPARCOS
U	5.823 ± 0.030	6.337 ± 0.030	EXPORT
B	6.103 ± 0.037	6.527 ± 0.037	EXPORT
	6.070 ± 0.020	6.520 ± 0.020	Maidanak
V	6.090 ± 0.100	6.490 ± 0.077	EXPORT
	6.090 ± 0.020	6.510 ± 0.020	Maidanak
R	6.037 ± 0.100	6.410 ± 0.077	EXPORT
	6.050 ± 0.020	6.460 ± 0.020	Maidanak
I	6.050 ± 0.150	6.437 ± 0.133	EXPORT
J	5.964 ± 0.019	6.280 ± 0.024	2MASS
H	6.022 ± 0.021	6.275 ± 0.021	2MASS
K	6.016 ± 0.027	6.282 ± 0.016	2MASS

Notes. HIPPARCOS – Perryman et al. (1997), EXPORT – Oudmaijer et al. (2001), Maidanak – Shatskii (1998), 2MASS – Skrutskie et al. (2006).

2.2. Distance

The HIPPARCOS parallax of HR 1847 is 2.92 ± 1.57 mas (Perryman et al. 1997), which corresponds to a distance of 342 ± 184 pc, but the large error reduces the reliability of this distance estimate. However, the new edition of the HIPPARCOS catalogue (van Leeuwen 2007) gives a parallax value of 1.09 ± 2.04 mas, which is unable to provide any information about the distance owing to the very uncertain parallax. Individual parallax measurements of the A and B components are not available.

2.3. Magnitudes and photometry

The first reliable magnitude values ($V_A = 6.07$, $V_B = 6.44$) were published by Cannon (1912b). She also gives the combined AB magnitude as 5.49. Maybe that only the combined magnitude value was given in her earlier spectral classification (Cannon 1912a) and in the HD catalogue (Cannon & Pickering 1918) caused its being incorrectly but often quoted as the magnitude of the A component until now. A similar value is also listed in the Bright Star Catalogue ($V = 5.46$, Hoffleit & Jaschek 1991).

The photometry of HR 1847 was measured by several authors always during observing runs devoted to large sample of stars. Eggen (1977) measured *uvby* β photometry of early type stars and derived values $V_A = 6.1$ and $V_B = 6.5$. Lindroos (1983) measured *uvby* β photometry of visual binaries including HR 1847. He derived corresponding V magnitudes of both components from the y filter values as $V_A = 6.091 \pm 0.019$ and $V_B = 6.510 \pm 0.023$. *BVR* observations of visual binaries at Mount Maidanak were performed by Shatskii (1998), and he obtained $V_A = 6.09 \pm 0.02$ and $V_B = 6.51 \pm 0.02$. The EXPORT *UBVRi* photometry (observed by the Nordic Optical Telescope, Oudmaijer et al. 2001) gave values $V_A = 6.09 \pm 0.10$ and $V_B = 6.49 \pm 0.07$. Recent determinations of magnitudes were derived from HIPPARCOS photometry (see Perryman et al. 1997). With the HIPPARCOS V_T and B_T magnitudes, Kharchenko (2001) derived the magnitudes $V_A = 6.056 \pm 0.008$ and $V_B = 6.451 \pm 0.004$, which do not differ too much from the first values of Cannon. A more complete list of photometric magnitudes of both components of HR 1847 is given in Table 1.

2.4. Polarization

Oudmaijer et al. (2001) found the value of V band polarization $P_V = 0.0063 \pm 0.0004$ for the A component, and $P_V = 0.0063 \pm 0.0002$ for the B component.

2.5. Spectral types and luminosity classes

The early classification of both components was “*egregie alba*” (very white) by Struve (1837). Later, (Cannon 1912b) classified both stars as B9.

Using his own observations in the period from April 1954 to March 1955 at the Yerkes Observatory, Osawa (1959) determined the spectral type of component A as B7IV and of component B as B8IV. From his own observations with the Perkins telescope, Slettebak (1963) determined spectral types B7III for component A and B7IV for component B. Cowley et al. (1969) determined spectral types B8III and B8V for components A and B, respectively, using spectra from MacDonald and Yerkes Observatories. Levato (1975) observed both components at Cerro Tololo Inter-American Observatory and obtained spectral type B7III for component A and B8IV for B. Finally, Mora et al. (2001) changed the Bright Star Catalogue classification of HR 1847A from B7IIIe to B5V.

2.5.1. Emission

Andrews (1968) found that component B shows $H\alpha$ emission using $H\alpha$ photometry, which was later spectroscopically confirmed by Wackerling (1970). The emission sign, which appeared at the spectral type of component A in both the Bright Star Catalogue and the Simbad database, is incorrect, as $H\alpha$ emission was never reported for HR 1847A.

2.6. Rotation

Rotational velocities of both components were first determined by Slettebak (1963). The projected rotational velocity of component A was measured as $(v \sin i)_A = 50 \text{ km s}^{-1}$, while component B was found to be rotating rapidly, $(v \sin i)_B = 300 \text{ km s}^{-1}$. Levato (1975) determined $(v \sin i)_A = 60 \text{ km s}^{-1}$ and $(v \sin i)_B = 300 \text{ km s}^{-1}$. Abt et al. (2002) refined the values of the rotational velocities to $(v \sin i)_A = 45 \text{ km s}^{-1}$ and $(v \sin i)_B = 200 \text{ km s}^{-1}$ using coude spectra obtained at the Kitt Peak 0.9-m telescope.

2.7. Variability

Slightly different values of magnitude obtained at different times using different instruments, which are listed in the Sect. 2.3, cannot be considered as firm proof of variability. The only available homogeneous set of observations was obtained by the HIPPARCOS satellite. Using HIPPARCOS photometry, Percy et al. (2004) determined the characteristic time scale of variability for HR 1847 as 0.9 days. They conclude that it is a classical Be star, but it is not clear which component they are referring to, since both components A and B have HIPPARCOS photometry available. In addition, data for both components also include several values that correspond to the combined magnitude of both components. Since it is not clear that they excluded the apparently wrong values (those corresponding to combined A+B magnitude), their result is questionable. We performed an independent search for variability and could not confirm the variability time scale found by Percy et al. (2004).

2.8. X-rays

HR 1847 has also been identified as an X-ray source by ROSAT (Berghöfer et al. 1996) with an X-ray luminosity $\log L_X = 29.64$ (in the paper version). In the online version of the same catalogue (their Table 2), this value is slightly different, $\log L_X = 29.79$. Both corresponding values of $\log(L_X/L_{\text{bol}}) = -6.82$ (or -6.79 in the online version) correspond to a typical $\log(L_X/L_{\text{bol}})$ relation for B-type X-ray emitters (cf. Berghöfer et al. 1997). It is, of course, a question of which star of the pair is the X-ray source, if not both. The position of the ROSAT source 1RXS J053214.9+170319 suggests it is more probably coincident with the star TYC 1301-1942-1 = HR 1847B (Flesch & Hardcastle 2004); however, the positional error is $18''$ (Voges et al. 2000), so HR 1847A also lies within the error circle.

2.9. IR excess

In their study of IR excess of 101 Be stars Coté & Waters (1987) found IRAS magnitudes $[12] = 4.95$, $[25] = 2.22$, $[60] = -0.92$, which places HR 1847 in the $[12]-[25]/[12]-[60]$ colour-colour diagram far away from the region where almost all Be stars are located. Coté & Waters suggest there is a reflection nebula close to HR 1847. Whitelock et al. (1989) associate HR 1847 with the IRAS SSSC source X0501+589. Magnier et al. (1999) suggest that HR 1847 is a good candidate for a Herbig Ae/Be star with a very large or a very cool circumstellar disk, but Iwata et al. (1999) did not find any CO emission for this star.

Again, it is not clear which star has IR excess, but most likely it is component B, which was found to be a Be star. There is also a small possibility that both stars are Be stars, with component A not in emission at that moment. Further observations may shed a light on it. Coté & Waters (1987) attributed the spectral type B7IIIe to HR 1847, which corresponds to component B, and $v \sin i = 55 \text{ km s}^{-1}$, which corresponds to component A.

2.10. Cluster membership

Although HR 1847 is located in the same region as the open cluster Collinder 65 (A component is #771, B component #772, according to the WEBDA¹ database), its membership is improbable mainly because to the different proper motion (Kharchenko et al. 2004).

3. Observations and data reduction

The data available for this study consist of several data sets of electronic spectra mostly centred on the $H\alpha$ region:

Component A

- 68 spectra in the spectral range 6250–6770 Å obtained with a CCD SiTe ST-005 800 × 2000 pix camera attached to the coude spectrograph of the 2 m-telescope in Ondřejov (Czech Republic). The spectra were obtained between 18 October 2003 and 25 February 2008. Spectra were reduced using IRAF².

¹ The Galactic and Magellanic Clouds open cluster database WEBDA is available at <http://obswww.unige.ch/webda/>

² IRAF is distributed by the National Optical Astronomy Observatories, which are operated by the Association of Universities for Research in Astronomy, Inc., under cooperative agreement with the National Science Foundation.

- One spectrum obtained on 22 March 2003 with the red (5850–8450 Å) and blue (3800–5650 Å) channels of the fiber-fed echelle spectrograph HEROS (resolving power $\sim 20\,000$, for its brief description see Kaufer 1998). The spectrograph was attached to the Cassegrain focus of the 2 m-telescope at the Ondřejov Observatory. All the basic data reduction processing was done using the HEROS pipeline written by Otmar Stahl and Andreas Kaufer as an extension of the basic MIDAS echelle context (see Stahl et al. 1995, also Škoda & Šlechta 2002).
- 14 spectra obtained in the spectral range (6510–6608 Å) at Rozhen Observatory (Bulgaria) using the coude-spectrograph of the 2 m RCC telescope. The CCD camera Photometrics AT200 with an SiTe SI003AB 1024 × 1024 CCD chip ($24 \times 24 \mu\text{m}$ pixel size) was used in the f/9.5 camera of the spectrograph to provide spectra with a spectral resolution of 36 000 in the $H\alpha$ region. Spectra were obtained between 24 October 2004 and 30 August 2007 and reduced with the MIDAS package.
- One spectrum in the spectral range 6290–6745 Å obtained at Observatório do Pico dos Dias (OPD, Brasil) and published by Vieira et al. (2004). For details and information about the reduction process, see the reference above.

In addition to the electronic spectra, we also used the radial velocity measurements of Plaskett & Young (1919). For comparison purposes, several values of published radial velocities were used from the works of Frost et al. (1926) and Duflot et al. (1992).

Component B spectra came from the same instruments as mentioned in the preceding part describing spectra of component A.

- 38 spectra obtained using the Ondřejov coude spectrograph between 17 October 2003 and 22 March 2008.
- One HEROS spectrum obtained at the Ondřejov Observatory, one night after the HR 1847A spectrum, on 23 March 2003.
- Three spectra between 28 August 2007 and 30 August 2007 obtained at the Rozhen Observatory.

3.1. Radial velocity measurements

Radial velocities were measured using the code SPEFO, which was developed by the late Dr. Jiří Horn (see also Škoda 1996). The FITS files obtained from IRAF and MIDAS were transformed to the SPEFO format, and then the radial velocities (RVs) were obtained interactively by means of the best match of the line profile with its mirror. The RVs were obtained for hydrogen $H\alpha$, He I 6678 Å, Si II 6347 Å and 6371 Å lines. RV data for individual components are described later in this paper in Sects. 4.2 and 5.1.

4. Component A

4.1. The effective temperature and gravity

The spectral region observed by HEROS covered the range 3800–8620 Å (see Figs. A.1 and A.2) and was used to determine the spectroscopic effective temperature and surface gravity. The line spectrum of the star is quite poor. Balmer lines up to H10 and some infrared lines are seen. No emission is present in the Balmer lines and in the lines of other metal ions.

The effective temperature and surface gravity were determined by comparing the observed spectra to model spectra. We used the ATLAS9 LTE line blanketed model atmospheres, which were calculated by Kurucz (1993) assuming solar metallicity and microturbulent velocity 2 km s^{-1} . All synthetic spectra were convolved (using the code ROTIN3 by I. Hubeny) with the Gaussian function having $FWHM = 0.25$ to reduce the resolution of the synthetic spectra to the observed resolution. We used a χ^2 -fitting routine to compare the whole observed spectra with the synthetic ones, and we obtained a best fit of $T_{\text{eff}} = (12\,500 \pm 500) \text{ K}$ and $\log g = 3.5 \pm 0.5$. Following the temperature scale of Theodossiou & Danezis (1991), these values correspond to spectral type B7–B8, and from the value of the surface gravity, we estimate the luminosity class as IV–V. The quoted error bars correspond to the adopted steps of our model grid, which are 500 K in temperature and 0.5 in $\log g$.

Using the code ROTIN3, we calculated a grid of rotationally broadened spectra for $5 \text{ km s}^{-1} \leq v \sin i \leq 500 \text{ km s}^{-1}$ with a step of 5 km s^{-1} . Then we applied the χ^2 fitting routine again to determine the best rotational velocity for this star. To do this, we used the spectral line Mg II 4481 Å (recommended by Gray 1976, as a line free of pressure broadening) in the fitting process. We determined the projected rotational velocity of HR 1847A as $v \sin i = (40 \pm 3) \text{ km s}^{-1}$, which differs by 5 km s^{-1} from the value of Abt et al. (2002). The error of our value of the rotational velocity was calculated employing a $1-\sigma$ error algorithm of Zhang et al. (1986).

4.2. Radial velocities

Tables A.1 and A.2 display the line radial velocity measurements that were derived using the methods described in Sect. 3.1. Columns 1–3 represent the file identification, HJD, and the heliocentric RVs, respectively. Column 4 lists the RV measurements for the H α line. Columns 5–7 list the RVs measurements for He I 6678 Å, Si II 6347 Å, and Si II 6371 Å (which are weak) absorption lines, respectively. The measured RVs were shifted to the zero-point using a set of sharp telluric absorption lines by means of the technique described in Horn et al. (1996).

The RVs of HR 1847A vary between 8 km s^{-1} to 27 km s^{-1} with a mean velocity around 13 km s^{-1} . Figure 1 displays the measured RVs for hydrogen H α and He I 6678 Å as a function of time. The plots indicate that our RV measurement started with one value just before the RV maximum, then after the maximum, a clear decrease in the RV values is recorded until the RV values reach their minimum around HJD 2 453 620 with RV values of $9\text{--}10 \text{ km s}^{-1}$. Then they quickly reached the next maximum value of 27 km s^{-1} around HJD 2 453 670. Although only two cycles are covered by our observations, fortunately we successfully recorded two epochs of rapid rise to the maximum, which happened during a very short time (nearly 35 days) of the long cycle. Rozhen observations confirmed the present distribution of RVs. Such a relatively short event could easily be missed.

The RV measurements that were obtained with different lines in the H α region show the same distribution with time, and only a small difference in the maximum height can be recognized, as illustrated for the He I 6678 Å line (lower panel of Fig. 1).

4.3. Period determination

One of the most fundamental parameters of binary systems is the orbital period. The present RVs span an interval of 1801 days.

Fig. 1. The radial velocity variations for hydrogen H α (upper panel) and He I 6678 Å (lower panel) lines measured from the Ondřejov and Rozhen spectrograms as a function of HJD. The He I 6678 Å line is only present in the Ondřejov spectra. Full symbols represent Ondřejov data, and open symbols stand for Rozhen data. All values are from Tables A.1 and A.2.

From the inspection of the time plot one can conclude that

1. the present RV measurements of H α and of some other metallic lines show clear evidence of long-term cyclic variability; and
2. the relatively large scatter between individual measurements on successive nights indicates that shorter period variability could be present in the data distribution.

No period search of the RV measurements has been carried out so far for HR 1847A. Improper data distribution, gaps, and timing of the observations are the most common problems in the period search process. The period search was carried out separately for several sets of measurements, and two independent numerical period searching routines were used. The first one is based on the phase dispersion minimization (PDM) technique (Stellingwerf 1978), the other one, PERIOD (Breger 1990), is based on a Fourier analysis.

For PERIOD, starting values for the frequencies need to be given, and frequency values are improved within the limits given by the window function. We used this program to search for periodicities in both H α and He I 6678 Å RV data sets in the range between 1 to 1000 days, with an expected frequency resolution of 0.00055 d^{-1} . The upper panel of Fig. 2 displays the periodogram of the detected frequencies in this period range. It shows three candidate frequencies (indicated by arrows in the upper panel of Fig. 2), namely 0.0069 d^{-1} , 0.0014 d^{-1} , and 0.1077 d^{-1} . The frequency 0.0069 d^{-1} has power 61, and is dominant. The middle panel of Fig. 2 shows the spectral window. In the lower panel of Fig. 2 we show the power spectrum

Fig. 2. *Upper panel:* power spectrum of measured RVs of H α and He I 6678 Å in the frequency range from 0.001 d⁻¹ to 1 d⁻¹, *middle panel:* spectral window, and *lower panel:* power spectrum of the prewhitened residual with 0.0014 d⁻¹. In all panels frequencies at the x-axis are given in d⁻¹.

Table 2. Candidate frequencies resulting from the PDM period search.

Frequency (d ⁻¹)	Period (days)	θ
0.0069	144.92753	0.3841
0.0014	714.28571	0.4092
0.1077	9.28505	0.4668

of the residual periodogram prewhitened for 0.0014 d⁻¹ (using PERIOD), which clearly shows the disappearance of all peaks related to all three candidate frequencies.

Using the PDM technique we searched for periodicity in intervals 1–10 days, 1–100 days, and 1–1000 days. The results are summarized in Table 2 and agree with the ones obtained with PERIOD. Figure 3 illustrates the phase diagrams of measured RVs for the H α line folded with the 0.1077 d⁻¹, 0.0069 d⁻¹ and 0.0014 d⁻¹ frequencies.

Although the frequency 0.0069 d⁻¹ has the highest power (cf. Fig. 2 and Table 2), we suspect that this frequency is not a real one. First, the historical observations of Plaskett & Young (1919) are out of phase by about half of the period (open squares in the middle panel of Fig. 3). Second, the corresponding RV curve predicts a maximum of RVs near HJD 2453 350, which was not confirmed by our observations. Values around ~15 km s⁻¹ appear instead of maximum ones. In addition, the interval of 145 days (or approximately five months) roughly corresponds to the gap between the end of one season in March/April and the next start of observations in

Fig. 3. Phase diagram of measured RVs for H α lines folded with different frequencies displayed from top to bottom, 0.1077 d⁻¹ (9^d28505), 0.0069 d⁻¹ (144^d9275), and 0.0014 d⁻¹ (714^d2857). Filled circles (●) and open circles (○) denote data obtained from our observations at Ondřejov and Rozhen, respectively. Open squares (□) and open triangles (▽) represent data from Plaskett & Young (1919) and Vieira et al. (2004), respectively.

August/September. Third, the candidate frequency 0.0069 d⁻¹ is almost exactly equal to 5×0.0014 d⁻¹. The relative scatter of individual RV values folded with the 0.1077 d⁻¹ frequency is quite large. Following these arguments, we propose the frequency at 0.0014 d⁻¹ as the dominant frequency.

4.4. Orbital solution

The variability of the radial velocities with frequency 0.0014 d⁻¹ can most likely be explained by binarity, and it supports the earlier idea of Plaskett & Young (1919) that the star is a spectroscopic binary.

Starting from the frequency 0.0014 d⁻¹, we performed 4 different orbital solutions using the program FOTEL developed by Hadrava (1990, 2004). For the solutions denoted as I, II, and III

Table 3. Orbital elements of HR 1847A with FOTEL.

Element	Solution I	Solution II	Solution III	Solution IV
P[d]	715.03 ± 1.06	713.83 ± 1.49	719.79 ± 0.17	710.49 ± 0.98
$T_{\text{periast.}}$	51501.61 ± 4.26	51504.34 ± 5.93	51480.31 ± 3.88	51503.67 ± 3.09
$K(\text{km s}^{-1})$	7.89 ± 0.53	7.58 ± 0.55	7.73 ± 0.44	8.23 ± 0.23
e	0.79 ± 0.02	0.72 ± 0.03	0.70 ± 0.02	0.73 ± 0.01
$\omega[\text{deg}]$	306 ± 5.87	310 ± 6.99	304 ± 7.03	286 ± 3.70
$\gamma_1(\text{km s}^{-1})$	13.47	13.39	13.44	—
$\gamma_2(\text{km s}^{-1})$	—	9.54	9.88	—
$\gamma_3(\text{km s}^{-1})$	—	—	10.63	—
$\gamma_4(\text{km s}^{-1})$	—	—	10.52	—
$\gamma_5(\text{km s}^{-1})$	—	—	—	13.23
$\gamma_6(\text{km s}^{-1})$	—	—	—	13.36
$\gamma_7(\text{km s}^{-1})$	—	—	—	10.97
$\gamma_8(\text{km s}^{-1})$	—	—	—	13.10
$f(m)$	0.0095	0.0104	0.0126	0.0132
No. of RVs	64	76	83	246
$rms(\text{km s}^{-1})$	1.76	2.08	2.22	1.94

Notes. The velocity γ_1 is based on Ondřejov data, γ_2 on Rozhen data, γ_3 on OPD data (Vieira et al. 2004), and γ_4 on historical data of Plaskett & Young (1919). In solution IV γ_5 , γ_6 , γ_7 , and γ_8 stand for $H\alpha$, He I 6678 Å, Si II 6347 Å, and Si II 6371 Å, respectively.

(see Table 3), the orbital elements were derived for $H\alpha$ radial velocity variations with data observed from different sites. Solution I is only performed with Ondřejov data, Solution II is obtained using $H\alpha$ measurements from both Ondřejov and Rozhen observations, Solution III is obtained using all of the available data, namely Ondřejov and Rozhen observations, one spectrum from OPD, and including the historical measurements. Solution IV was obtained using radial velocities of all available spectral lines in the $H\alpha$ region ($H\alpha$, He I 6678 Å, Si II 6347 Å, and Si II 6371 Å).

In our calculations we allowed the period, eccentricity, periastron longitude, and semiamplitude to converge. For each data set FOTEL also allows individual γ -velocities to be determined. Figure 4 illustrates the FOTEL Solution III with its O–C residuals. We searched for additional periodicities in the residuals but did not find any significant periods.

We adopt the Solution III ($P = 719^{\text{d}}.79 \pm 0^{\text{d}}.17$, $e = 0.70 \pm 0.02$) as an orbital solution of HR 1847A.

5. Component B

The B component is a Be star with a relatively weak emission in $H\alpha$ and almost negligible one in $H\beta$. Since 2003, the weak emission in $H\alpha$ further weakened, indicating an approaching end of the Be phase. No time scale may be given for this apparently long-term variability, since only 4 years of observations are available. Long term variability (strengthening and weakening of emission) is typical of Be stars on time scales from years to tens of years (for a review see Hubert 2007). For example, κ Dra has quite a well-established long term time scale, and its most recent determination is 22.11 years (see Kubát et al. 2010, and references therein). The $H\alpha$ profiles obtained by our observations are plotted in Fig. 5. We fitted the spectrum of component B using the same methods as for component A. We found $T_{\text{eff}} = (12\,500 \pm 500)$ K, $\log g = (3.5 \pm 0.5)$, and $v \sin i = (230 \pm 5)$ km s $^{-1}$.

Fig. 4. Upper panel: radial velocity curve of the primary component corresponding to the FOTEL orbital solution III ($P = 719^{\text{d}}.79$), which was based on $H\alpha$ RV measurements of Ondřejov, Rozhen, and OPD spectra and on RV values from Plaskett & Young (1919). RV values are displayed in the centre-of-mass reference system. Lower panel: phase plot of O–C deviation from the RV curve for Solution III.

5.1. Radial velocities

Owing to the high rotational broadening of lines in the component B spectrum, the helium and silicon lines, which were used for RV measurement of component A, are too shallow in component B, and therefore unusable for RV measurement. Consequently, we measured the RVs of component B only from the $H\alpha$ line. RVs were measured with the profile inversion technique. However, the rapid rotation of the component B and relatively low S/N made it impossible to arrive at precise RV values. Cross-correlation techniques, such as least-square deconvolution (LSD, Donati et al. 1997) would not improve the RV accuracy as too few line profiles are available in our spectra. Also,

Fig. 5. The evolution of the H α profile of HR 1847B.

the bisector method does not give more accurate results because of the limited quality and not high enough S/N of our spectra.

The H α line in the B component is characterized by a double-peak emission with peaks of equal strength. We measured the RVs of three different features at the H α line, namely of the line wings, of the emission part, and of the central absorption. The results are listed in Tables A.3 and A.4 and plotted in Fig. 6.

Although the RVs are evidently variable, a period search did not give any reasonable result. That is why we cannot make any conclusions about the possible binarity of HR 1847B until a more complete set of more accurate data has been obtained.

6. The possible A+B system

There is a question as to whether the components of this visual pair are physically bound. However, there is not enough data to help to resolve this question. The history of all relative position measurements of HR 1847 in the sky (see Sect. 2.1.1) do not allow any conclusion about their relative motion. Slightly different values can be attributed to errors in individual measurements.

Unfortunately, only a common parallax measurement from HIPPARCOS is available. Since individual measurements are missing, we cannot easily say whether the A and B components are at the same distance. However, study of visual binaries by Shatskii (1998) suggests that HR 1847 could be a physical system (with a period shorter than 1 Myr), since both components have similar proper motion and corresponding photometric parallaxes, which agree with the hypothetical parallax.

In case the visual components of HR 1847 are physically bound, their similar spectral type suggests that they are of similar age. Then there is the question of why one of these stars developed an envelope that causes H α emission and the other does not. The emission could not be caused by mutual interaction between components A and B, simply because the distance

Fig. 6. Time evolution of the H α radial velocities of HR 1847B. Measurements of line wings are denoted by w, measurements of emission are denoted by e, and measurement of the central absorption are denoted by a. Capital letters denote the observatory, R stands for Rožhen, O stands for Ondřejov.

Table 4. Summary of parameters of both components of HR 1847.

	HR 1847A	HR 1847B
$\alpha(J2000)$	05 32 14.14	05 32 14.56
$\delta(J2000)$	+17 03 29.3	+17 03 21.8
V	6.09	6.51
T_{eff}	$12\,500 \pm 500$	$12\,500 \pm 500$
$\log g$	3.5 ± 0.5	3.5 ± 0.5
$v \sin i$ (km s $^{-1}$)	40 ± 3	230 ± 5
Be star	no	yes
binary	SB1*	SB1?

Notes. (*) Binary parameters are listed in Table 3.

between the components is too large. A different mechanism for the origin of the Be phenomenon in HR 1847B has to be found (see, e.g., the review by Porter & Rivinius 2003). The emission in the component B is most probably connected with its rapid rotation. Projected rotational velocity of component A is lower, and this star also has no emission. On the other hand, since the inclination angles are unknown, we can not exclude the possibility that the component A is also rapidly rotating, as there is apparently no correlation between directions of spin axes for wide binaries (Howe & Clarke 2009).

6.1. Comparison with other visual binaries

HR 1847 is not the only example of a visual multiple system with similar components, with some of them also showing the Be phenomenon. The visual triple system β Mon consists of three Be stars (see Marañón di Leo et al. 1994, and references therein), and all these three stars are rapidly rotating (Abt et al. 2002). The projected rotational velocities of β Mon A and β Mon C was reported as 260 km s^{-1} and 250 km s^{-1} , respectively, while β Mon B is rotating more slowly (140 km s^{-1}) and, interestingly, also has weakest emission (Cowley & Gugula 1973). This supports the connection between rapid rotation and the Be phenomenon. More visual binaries with Be-components may be found in Abt & Cardona (1984).

Investigation of such multiple systems with resolved visual components (like HR 1847 or β Mon) may help when studying multiple partially resolved or unresolved systems with Be stars like α And (see Olević & Cvetković 2006, and references therein) or β Cep (see Wheelwright et al. 2009, and references

therein), where light from all stars is mixed, making the analysis extremely difficult. The physical parameters and system characteristics derived from resolved systems will put constraints on stellar structure and binary evolution models, such that the unresolved systems can be modelled in a better way with the improved models. Careful study of resolved systems and careful determination of their parameters are very important feedback on models.

7. Conclusions

This paper is the first attempt to collect all available information about the stars in the visual binary system HR 1847 and to correct errors that appear in the SIMBAD database and Bright Star Catalogue. We have presented results of our spectroscopic analysis. HR 1847A ($V = 6.09$, Shatskii 1998) is a B type single-lined, eccentric, ($e = 0.70 \pm 0.02$), spectroscopic binary with a period of 719.79 ± 0.17 days. Model atmosphere analysis of this star yielded $T_{\text{eff}} = 12\,500$ K, $\log g = 3.5$, and $(v \sin i)_A = 40$ km s $^{-1}$. HR 1847B ($V = 6.51$, Shatskii 1998) is a Be star with variable radial velocities, however, no reasonable orbital solution could be found based on the available data. Model atmosphere analysis of this star yielded the same effective temperature and surface gravity as for the A component, but with a rotational velocity of $(v \sin i)_B = 230$ km s $^{-1}$. A decrease in the H α emission was recorded during the last 4.5 years of observations. In addition, positions of X-ray (1RXS J053214.9+170319, see Sect. 2.8) and infrared (X0501+589, see Sect. 2.9) sources indicate that HR 1847B is more likely an X-ray and IR source than HR 1847A.

Several other issues, such as the short term variability of HR 1847A or the reliable period determination of HR 1847B, could not be addressed by this paper owing to the lack of necessary data. Consequently, further long-term observations of these stars are desirable. Future work should also include a detailed abundance analysis using high S/N spectra and NLTE model atmospheres.

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Appendix A: Visual spectra of HR 1847A and HR 1847B

Fig. A.1. Line identification of the spectrum of HR 1847A obtained with the blue channel of the *HEROS* spectrograph (dots) and comparison with the synthetic spectrum calculated from the Kurucz (1993) LTE model atmosphere $T_{\text{eff}} = 12\,500$ K, $\log g = 3.5$, rotationally broadened with $(v \sin i)_A = 40 \text{ km s}^{-1}$ (full line).

Fig. A.1. continued.

Fig. A.2. Line identification of the spectrum of HR 1847A obtained with the red channel of the *HEROS* spectrograph (dots) and comparison with the synthetic spectrum calculated from the Kurucz (1993) LTE model atmosphere $T_{\text{eff}} = 12\,500$ K, $\log g = 3.5$, rotationally broadened with $(v \sin i)_A = 40 \text{ km s}^{-1}$ (full line). Note the presence of telluric lines and bands near 6280 Å , $H\alpha$, 6870 Å , 7250 Å , and 7590 Å .

Fig. A.3. Line identification of the spectrum of HR 1847B obtained with the blue channel of the *HEROS* spectrograph (dots) and comparison with a synthetic spectrum calculated from the Kurucz (1993) LTE model atmosphere $T_{\text{eff}} = 12\,500$ K, $\log g = 3.5$, rotationally broadened with $(v \sin i)_{\text{B}} = 230$ km s⁻¹ (full line).

Fig. A.3. continued.

Fig. A.4. Line identification of the spectrum of HR 1847B obtained with the red channel of the *HEROS* spectrograph (dots), and comparison with a synthetic spectrum calculated from the Kurucz (1993) LTE model atmosphere $T_{\text{eff}} = 12\,500\text{ K}$, $\log g = 3.5$, rotationally broadened with $(v \sin i)_{\text{B}} = 230\text{ km s}^{-1}$ (full line). Note the presence of telluric lines and bands near 6280 Å , $\text{H}\alpha$, 6870 Å , 7250 Å , and 7590 Å .

Table A.1. Heliocentric radial velocities (RV) of HR 1847A – spectra from Ondřejov Observatory, where V_{hel} is the heliocentric velocity.

File	HJD (JD–2 400 000)	V_{hel} (km s ⁻¹)	RV (H α) (km s ⁻¹)	RV (He I 6678 Å) (km s ⁻¹)	RV (Si II 6347 Å) (km s ⁻¹)	RV (Si II 6371 Å) (km s ⁻¹)
ra5788	52 721.3728	–29.71				
mj170023	52 930.5671	25.36	21.45	21.11	18.65	20.07
mj170025	52 930.6315	25.23	21.03	20.75	17.80	18.98
mk120038	52 956.5608	16.02	21.45	21.67	17.67	20.76
ml090033	52 983.4198	3.03	20.12	18.98	16.15	18.86
na050019	53 010.4552	–11.13	13.55	15.33	14.84	16.80
na050021	53 010.5053	–11.23	16.48	15.82	13.41	16.43
nd210018	53 117.2973	–23.56	13.44	16.89	15.73	16.70
nd210019	53 117.3210	–23.57	15.78	17.09	13.39	12.61
nd220014	53 118.3330	–23.35	15.06	18.36	13.79	16.32
nd300002	53 126.3175	–20.47	12.67	13.76	14.90	18.87
ng300048	53 217.5797	21.00	18.70	10.85	15.09	18.95
ng300049	53 217.5864	21.01	16.35	12.35	12.79	17.14
nh220044	53 240.5571	27.37	15.60	13.35	14.20	13.74
nh220045	53 240.5649	27.36	14.43	13.58	13.35	15.67
nh220049	53 240.5862	27.35	15.00	14.95	12.49	14.69
nh220053	53 240.6052	26.32	14.99	10.90	13.32	15.52
nh230063	53 241.5625	27.55	12.98	14.95	13.63	17.10
ni020057	53 251.6021	28.97	15.21	15.56	11.75	15.84
ni060034	53 255.6179	28.14	11.90	11.14	9.90	14.66
ni080043	53 257.5953	29.47	14.39	–	14.39	–
nj240062	53 303.5864	23.00	11.76	10.54	9.57	12.05
nk240049	53 334.5637	10.01	8.79	–	–	–
nl100020	53 350.2773	2.36	13.55	11.30	9.52	11.50
oa160018	53 387.3315	–16.40	12.44	12.31	10.18	11.89
oc220010	53 452.3157	–29.61	10.35	10.01	6.21	5.04
oc310022	53 462.2998	–28.42	11.33	9.78	6.25	11.64
od010016	53 461.3659	–28.62	10.47	10.03	6.91	10.42
od010015	53 462.2998	–28.42	11.33	9.78	6.25	11.64
od010016	53 462.3100	–28.41	10.15	10.12	5.51	10.18
oi060036	53 620.5833	29.34	9.90	9.15	7.15	4.46
oi060037	53 620.5954	29.33	9.30	11.79	8.23	10.97
oj070018	53 651.4465	27.84	23.89	21.65	20.52	20.50
oj070028	53 651.4953	27.79	23.28	21.63	21.83	23.74
oj070034	53 651.5630	27.69	24.35	21.76	20.64	22.79
oj070040	53 651.6182	27.58	23.69	21.45	19.95	21.99
oj070042	53 651.6418	27.54	23.05	23.36	20.76	21.94
oj070044	53 651.6703	27.48	25.93	24.46	21.79	23.70
oj080058	53 652.4732	27.62	25.34	26.92	25.08	25.40
oj080062	53 652.5220	27.56	23.91	23.42	21.44	23.02
oj080069	53 652.5815	27.46	21.98	23.37	20.87	22.44
oj080073	53 652.6229	27.38	24.64	28.68	25.40	23.28
oj080079	53 652.6823	27.26	27.72	25.32	23.06	27.61
oj260033	53 670.4313	21.60	26.45	24.66	19.67	23.76
oj260035	53 670.4447	21.58	24.58	22.92	21.83	22.17
oj290036	53 673.4859	20.51	25.52	22.75	20.12	21.90
oj290037	53 673.5018	20.48	21.98	22.49	20.33	22.87
pa080032	53 744.3096	–12.56	16.11	16.95	14.12	14.79
pj110024	54 020.6019	26.67	11.60	11.71	9.29	12.49
qc160019	54 176.2664	–29.87	9.03	10.00	5.16	8.53
qc160037	54 176.3253	–29.98	8.83	10.50	6.73	7.65
qc160046	54 176.4145	–30.04	9.94	9.52	6.06	8.80
qc270011	54 187.3995	–29.25	8.95	10.44	5.00	7.82
qd020010	54 193.3620	–28.37	7.03	10.44	4.54	7.95
qd070002	54 198.3054	–27.40	9.50	10.71	6.31	8.86
qd130019	54 204.2939	–26.03	8.63	9.98	3.03	7.47
qd130023	54 204.3337	–26.05	9.20	9.15	5.43	4.80
qd140022	54 205.3262	–25.79	9.31	9.81	5.81	8.30
qe020011	54 223.3037	–20.03	13.92	–	–	–
qe020012	54 223.3097	–20.03	11.02	12.46	2.89	6.97
qh240029	54 337.5997	27.59	11.53	13.34	12.39	15.14
qh250033	54 338.6177	27.71	11.84	11.91	9.87	13.95
qi150036	54 359.5365	29.70	20.28	22.21	18.66	20.35
qi160031	54 360.5360	29.70	20.50	22.06	19.61	23.03
qi160039	54 360.6371	29.57	21.48	20.63	17.17	21.79
qj130036	54 387.4787	26.51	21.26	18.68	21.17	20.95
qj130040	54 387.5534	26.39	22.08	20.12	20.21	21.70
qj130046	54 387.6826	26.13	23.03	21.13	19.13	21.96
rb250029	54 522.3202	–28.60	17.53	16.29	15.33	17.04

Table A.2. Heliocentric radial velocities (RV) of HR 1847A – spectra from Rozhen Observatory.

File	HJD (JD–2 400 000)	V_{hel} (km s ^{–1})	RV (H α) (km s ^{–1})
04j119	53 303.4455	23.17	10.52
04j120	53 303.4563	23.16	9.14
04j303	53 306.5530	21.99	11.16
04j304	53 306.5638	21.97	12.06
04k109	53 333.3218	10.99	8.39
05c062	53 452.6889	–29.64	4.76
05c163	53 453.3861	–29.56	7.58
05c235	53 454.4102	–29.47	4.93
07h050	54 341.5910	28.25	11.92
07h129	54 342.5379	28.43	12.12
07h135	54 342.6011	28.36	12.05
07h215	54 343.5844	28.52	12.19

Table A.3. Heliocentric radial velocities (RV) of HR 1847B – spectra from Ondřejov Observatory.

File	HJD (JD–2 400 000)	V_{hel} (km s ⁻¹)	RV (H α)		
			(km s ⁻¹) wings	(km s ⁻¹) emission	(km s ⁻¹) absorption
ra5806	52 721.8197	-29.59	11.10	9.73	14.30
mj170025	52 930.6315	25.23	15.40	12.47	18.92
mk120038	52 956.5608	16.02	15.05	12.71	19.70
nc290015	53 094.3765	-28.89	14.39	13.21	17.90
nd300001	53 126.3043	-20.50	18.17	16.41	18.17
nh220047	53 240.5755	27.33	27.44	16.00	12.75
ni020058	53 251.6217	27.36	7.47	6.88	9.22
ni130036	53 262.5828	29.65	10.24	9.06	10.82
nj240060	53 303.5565	23.02	3.83	-0.19	2.16
nj240061	53 303.5692	22.99	8.58	7.40	7.99
oa160016	53 387.3113	-16.39	19.80	8.08	18.92
od010017	53 462.3213	-28.44	10.92	9.16	10.92
oi060038	53 620.6195	29.30	21.00	18.06	24.51
oi220034	53 636.6211	29.34	23.59	24.17	24.76
oi220035	53 636.6365	29.31	17.11	20.04	23.52
oj070034	53 651.5630	27.69	19.70	17.94	29.08
oj070040	53 651.6182	27.58	12.55	-2.11	13.14
oj070042	53 651.6418	27.54	21.86	30.69	21.89
oj070044	53 651.6703	27.48	21.25	14.80	27.70
oj080060	53 652.4977	27.60	–	37.52	24.62
oj280042	53 672.5077	21.87	12.90	16.42	19.94
oj290035	53 673.4623	21.60	11.50	7.39	–
pj110026	54 020.6245	26.62	7.44	19.17	13.31
qc160019	54 176.2664	-29.87	8.43	7.26	10.78
qc160039	54 176.3427	-29.98	7.94	5.60	11.46
qc160048	54 176.4353	-30.05	8.46	7.87	11.39
qc270010	54 187.3763	-29.24	2.51	7.78	11.30
qd020011	54 193.3770	-28.37	5.14	22.14	3.97
qd130021	54 204.3139	-26.05	8.04	3.93	11.56
qd140024	54 205.3461	-25.80	4.30	8.99	7.23
qh240030	54 337.6245	27.57	20.89	32.61	23.23
qi150038	54 359.5627	29.68	22.60	22.02	21.43
qi160033	54 360.5562	29.68	23.68	37.17	24.27
qi160039	54 360.6371	29.57	20.12	37.13	20.12
qj130046	54 387.6826	26.13	22.66	32.04	23.25
rb250027	54 522.2805	-28.54	8.89		
rb250033	54 522.3822	-28.73	8.21		
rb250035	54 522.4158	-28.77	7.35		
rc220012	54 548.3622	-29.65	21.58		

Table A.4. Heliocentric radial velocities (RV) of HR 1847B – spectra from Rozhen Observatory.

File	HJD (JD–2 400 000)	V_{hel} (km s ⁻¹)	RV (H α)		
			(km s ⁻¹) wings	(km s ⁻¹) emission	(km s ⁻¹) absorption
07h049	54 341.5732	28.25	21.98	35.69	23.52
07h136	54 342.6176	28.33	21.19	28.47	26.19
07h216	54 343.5993	28.50	21.33	25.90	21.33