ASTRONOMY & ASTROPHYSICS
SUPPLEMENT SERIES

Astron. Astrophys. Suppl. Ser. **132**, 281–289 (1998)

A spectrographic study of the symbiotic system Hen 1761*

E. Brandi[1,2], R. Barbá[1,3], L.G. García[1], and N. Beltrán[1]

[1] Facultad de Ciencias Astronómicas y Geofísicas, Universidad Nacional de La Plata, 1900 La Plata, Argentina
e-mails: ebrandi@fcaglp.fcaglp.unlp.edu.ar; rbarba@fcaglp.fcaglp.unlp.edu.ar; lia@fcaglp.fcaglp.unlp.edu.ar
[2] Member of the Carrera del Investigador Científico, Comisión de Investigaciones Científicas de la Provincia de Buenos Aires (CIC), Argentina
[3] Member of the Carrera del Investigador Científico, Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET), Argentina

Received August 14, 1997; accepted April 24, 1998

Abstract. This work presents the results of a spectroscopic study in the optical and near infrared region of the symbiotic star Hen 1761. Relative fluxes and radial velocities of emission and absorption lines are obtained on the basis of low, intermediate and high resolution spectra. Our observations show that this scarcely studied object underwent very important spectroscopic variations in the interval 1990-1995. The observed variations are quite similar to those of symbiotic stars where accretion events on a hot dwarf are responsible for an eruptive behavior. Some of the physical parameters of the system are derived.

Key words: stars: emission-lines — symbiotic stars — stars: variable stars — stars: individual: Hen 1761

1. Introduction

Hen 1761 [$\alpha(2000.0) = 19^{\rm h}42^{\rm m}25\overset{\rm s}{.}9$; $\delta(2000.0) = -68°\ 07'41''$] is a symbiotic star about which several papers have been published although the knowledge of this system is still very poor indeed. The star was mentioned for the first time by Mayall (1951), as a new peculiar object and Thackeray (1954) classified it as a symbiotic star. He detected emission lines of H I, He I, He II λ4686, C II, C III, N III, [O III]; the presence of Fe II being uncertain. The continuum, stronger in the red, showed moderate TiO molecular bands but the presence of atomic absorption lines was very doubtful. According to Glass & Webster (1973), the infra-red energy distribution of Hen 1761 corresponded to that of an M star. Allen (1980), classified the late-type component as M3 on the basis of infra-red spectroscopy at 2 μm and a distance of 1.4 kpc was estimated. The first published optical spectra of Hen 1761 was shown by Allen (1984) in his Catalogue of Symbiotic Stars. Allen (1982) discards the presence of circumstellar dust because of the colour indices $J-K$ and $H-K$ and considers the object as a S-type symbiotic. Hen 1761 was found to have undergone very important photometric (Munari et al. 1992) and spectroscopic (van Winckel et al. 1993) variations. Since Thackeray's report, written more than forty years ago, the above mentioned authors and Wright & Allen (1978); Lund & Tuvikene (1987); Kenyon (1986); Kenyon et al. (1988); Schulte-Ladbeck et al. (1990) and Whitelock & Munari (1992), have included Hen 1761 together with other symbiotic stars in different researches but the present paper is devoted in particular to this object with the aim of presenting and discussing recent spectroscopic data.

2. Observations

The spectroscopic observations were carried out with the 2.15 m telescope at the Complejo Astronómico El Leoncito, CASLEO (San Juan, Argentina). Medium-low resolution spectrograms were obtained with a Boller & Chivens spectrograph using a photon-counting Reticon, called Z-Machine, during 1990 and 1991 and a Thompson CCD (500×592 pixels) in 1992. Since 1994 high resolution spectrograms were obtained with a REOSC echelle spectrograph using a Tek CCD (1024×1024 pixels). A log of the observations is shown in Table 1.

Details about the Z-Machine observations and data reduction procedures were given by Barbá et al. (1992).

Send offprint requests to: E. Brandi

* Based on observations taken at Complejo Astronómico El Leoncito (CASLEO), operated under an agreement between the Consejo Nacional de Investigaciones Científicas y Técnicas de la República Argentina, the Secretaría de Ciencia y Tecnología de la Nación and the National Universities of La Plata, Córdoba and San Juan.

Table 1. Log of the spectroscopic observations of Hen 1761

Date	$JD_{\odot}$ 244+	Resolution	Range (Å)	T_{exp} (s)
6/7/90	8078.8	2700	5650−7000	600
9/8/90	8112.8	4100	4400−5062	840
11/8/90	8114.8	2700	5830−7100	360
4/11/90	8199.6	2700	5830−7100	480
4/11/90	8199.6	2700	5830−7100	240
9/11/90	8204.6	4100	4400−5062	480
7/4/91	8353.9	4100	4400−5062	720
8/7/92	8811.8	3400	4725−5080	1200
9/7/92	8812.7	2300	6340−7080	300
8/8/92	8842.7	2600	8300−9000	600
9/8/92	8843.7	2100	5730−6475	300
9/8/92	8843.7	2900	6450−7200	240
9/8/92	8843.7	2900	8300−9000	300
9/8/92	8843.8	2900	7680−8400	240
9/8/92	8843.8	2600	7130−7800	240
14/8/92	8848.8	800	3750−5170	300
26/10/94	9651.5	15000	3500−5900	1200
26/10/94	9651.6	15000	3500−5900	1200
27/10/94	9652.5	15000	4900−8150	1800
28/10/94	9653.5	15000	4900−8150	1200
15/8/95	9944.7	15000	4200−7200	2400
15/8/95	9944.8	15000	4200−7200	2400

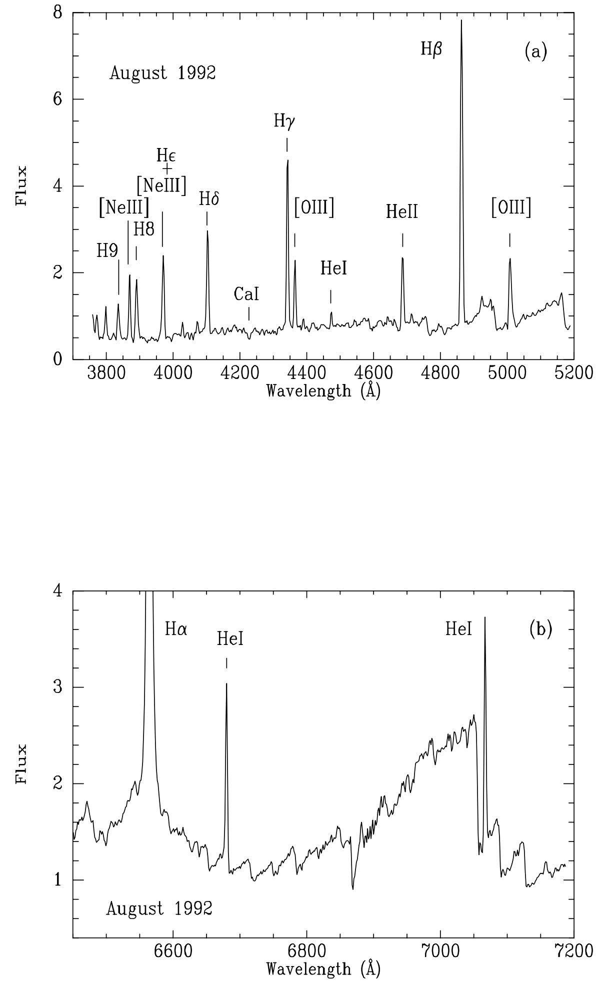

Fig. 1. Low resolution optical spectra for Hen 1761. Spectral regions **a)** between $\lambda\lambda$ 3750 − 5200 Å and **b)** $\lambda\lambda$ 6200 − 7200 Å. Numerous TiO molecular bands are present in the red region. The Raman scattered O VI emission lines at λ 6825 Å and λ 7082 Å are absent. Fluxes are indicated in unit of 10^{-13} erg cm^{-2} s^{-1} $Å^{-1}$

The CCD data were reduced with standard IRAF[1] packages, CCDRED and ONEDSPEC and all the spectra were measured using the SPLOT task within IRAF.

To obtain the flux calibration, standard stars from Stone & Baldwin's (1983) and Baldwin & Stone's (1984) lists, were observed each night. An analysis of the flux calibration errors, by flux comparisons of the standard stars, shows that they may be estimated at about 15% for the Z-Machine images, 5% for the Thomson CCD images and 20% in the central part of each order for the REOSC echelle images. However, it must be kept in mind that true flux errors are largely dependent on the tracing of the continuum and the emission line strengths.

3. Analysis

3.1. Spectral variations

In the spectra of Hen 1761 we confirm the presence of emission lines of H I, He I, He II, C III, N III, [O III] and Fe II and detect O I, Mg II, Ti II, [Fe II], [S II], [Ne III], [Fe IV], [Fe VI], [Fe VII] and [Ca V]. Some members of the Paschen Series are also present as very weak emission lines. A Balmer jump in emission is observed in the images of October 1994. The Figs. 1a and b show two spectral regions between $\lambda\lambda$ 3750 − 5170 Å and $\lambda\lambda$ 6200 − 7200 Å with the fluxes indicated in units of 10^{-13} erg cm^{-2} s^{-1} $Å^{-1}$. As seen in Fig. 1a, numerous TiO molecular bands are present in the red region and the Raman scattered O VI emission lines at λ 6825 Å and λ 7082 Å (Schmid 1989) are not detected in Hen 1761. The flux ratios of the most important emission lines for the different observing runs, scaled with respect to $H\beta = 100$, are given in Table 2. The estimated error in the determination of the integrated emission line fluxes is in the order of ±10% for strong emission lines and ±25% for weaker lines. The fluxes are not corrected for reddening.

We can see in Table 2 that during 1990-95 Hen 1761 shows variations, in the line intensities of He I, He II, N III and [O III] in the same sense, reaching in general their minimal values in April 1991, and then increasing until

[1] IRAF is distributed by the National Optical Astronomy Observatories, which is operated by the association of Universities for Research in Astronomy, INC., under contract to the National Science Foundation.

Table 2. Line fluxes in the spectrum of Hen 1761 scaled to Hβ = 100

Ion	λ (Å)	Z-Machine 8/90	Z-Machine 11/90	Z-Machine 4/91	CCD 500×592 7/92	CCD 500×592 8/92	CCD 1024×1024 10/94	CCD 1024×1024 8/95
HeI	4471	4	3	3	-	3	2	7
	5015	6	7	3	3	bl	2	8
	5876	-	-	-	-	21	15	35
	6678	-	-	-	-	15	10	41
	7065	-	-	-	-	21	14	59
HeII	4685	19	19	8	-	20	23	64
NIII	4634	3	1	1	-	w	1	3
NIII	4640	4	4	2	-	w	3	5
[OIII]	4363	-	-	-	-	15	13	20
	4959	11	6	4	13	10	9	14
	5007	33	21	11	38	26	27	49
[CaV]	5309	nd	nd	nd	nd	nd	2	8
FeII	4629	3	3	2	-	nd	1	w
	5018	5	4	4	1	bl	1	w
[FeVI]	4967	nd	nd	nd	nd	nd	w	3
	4972	nd	nd	nd	nd	nd	w	3
	5176	nd	nd	nd	nd	nd	2	8
[FeVII]	5721	nd	nd	nd	nd	nd	nd	3
	6087	nd	nd	nd	nd	nd	nd	5
Hβ flux$^{(*)}$		2.51	3.52	5.07	2.90	5.60	5.24	1.59

Notes:
- : the line is either outside of the observed spectral range or the image does not include Hβ.
nd: undetected line
w: very weak line.
bl: blended line.
(*): The mean absolute fluxes in units of 10^{-12} erg cm^{-2} s^{-1}.

August 1995. He II λ4686 Å and the forbidden line [O III] λ5007 Å display the most significant intensity variations, but the He I and N III intensities change with a much lower amplitude (see Fig. 2a). In contrast, the Fe II line emissions show a systematic decrease of intensities until 1995. The Fig. 3a shows a spectral region where the variations in the He I, [O III] and Fe II lines are displayed.

Van Winckel et al. (1993) already found dramatic changes in the [O III] λ5007 Å and Fe II λ5018 Å lines in time scales of several months. In our spectra Hα is slightly asymmetric on the blue side and a weak central absorption is more noticeable in August 1995. Otherwise, the shape of the Hβ profile undergo important changes along the time (see Fig. 4). In August 1990 the profile has a symmetrical appearance but a double-peaked profile can be observed in the image of November 1990, being the radial velocity of the central absorption of 49 km s^{-1}. Hβ becomes a single emission with an asymmetry on the blue wing, few months later, in April 1991. An incipient central absorption is observed in August 1995.

In the blue region of the spectra the Ti II lines are in absorption in August 1990, then they practically disappear in November 1990, and in April 1991, are visible as weak emissions. Later, up to the last observations, these lines are present as absorptions. Figure 3b shows the dramatic variations when the absorptions are filled by emissions.

In 1994 double peak profiles of [Fe VI] λ4967 Å λ4972 Å and λ5176 Å as well as [Ca V] λ5309 Å appear in the spectrum. Then, in 1995 these lines become stronger and other forbidden lines of higher ionization, like [Fe VII] λ5721 Å and λ6087 Å can be detected.

In order to establish the behavior of the continuum as function of a time, we have chosen to measure fluxes in 50 Å bands centered at 4895 and 6975 Å since these spectral ranges are free of important emission lines. The respective fluxes have been converted into a color index $CI = m_{4895} - m_{6975} = -2.5 \log F_{4895}/F_{6975}$ listed in Table 4. In Fig. 2b we can see that the system is much bluer during August-November 1990 and later, in July 1992 the red continuum becomes stronger.

From 1990 to 1992 the spectra are dominated by many narrow absorption lines which were identified more frequently as Fe I and Ti I. Moreover, other absorption lines of neutral and once ionized metals, e.g. Ca I λ4227 Å Ni I, Cr I, Na I, O I, V I, Ca II and Ni II are also present.

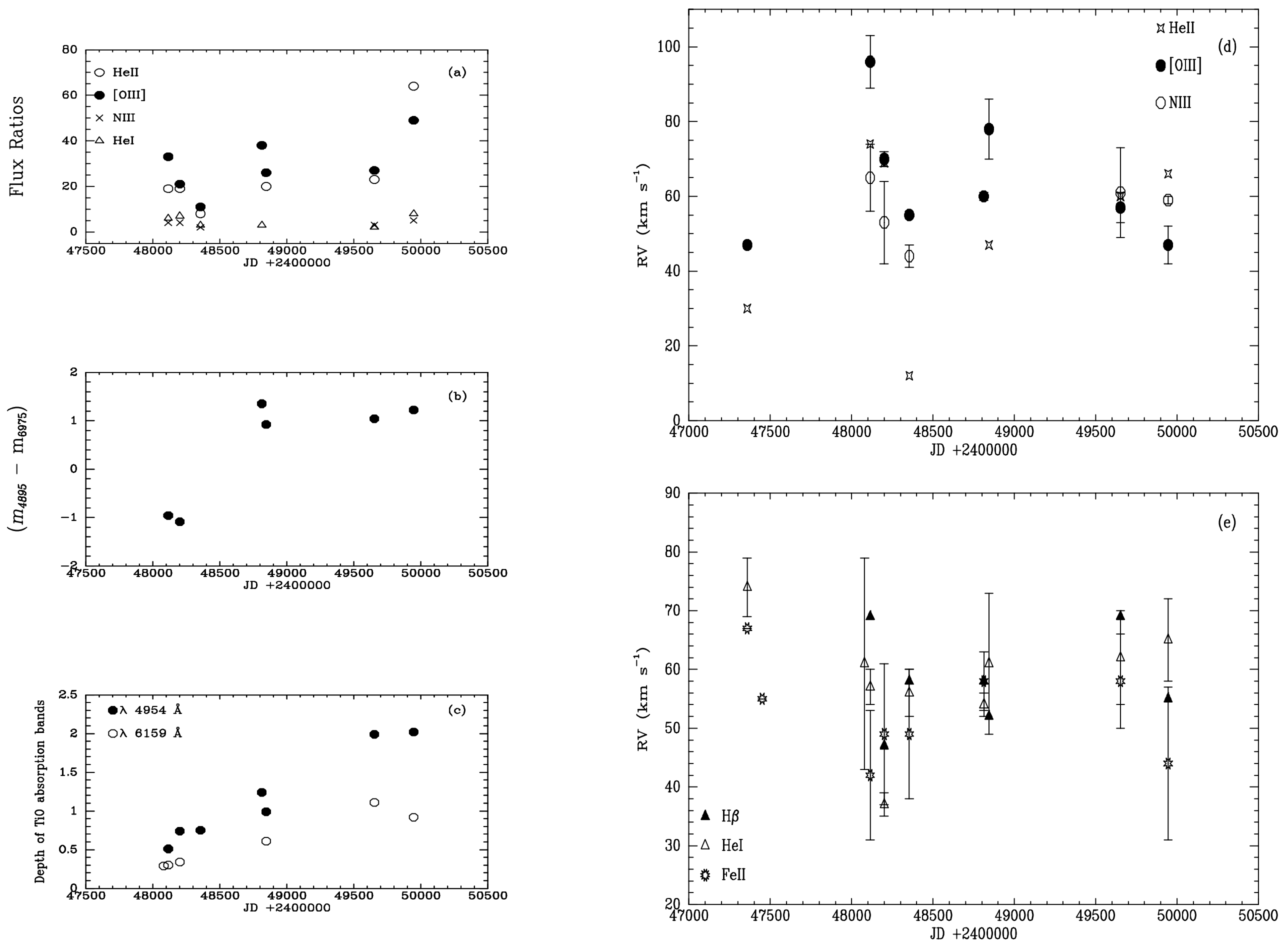

Fig. 2. a) Intensity ratio variations of He I, He II, N III and [O III] observed in Hen 1761. **b)** "color index" $(m_{4895} - m_{6975})$. **c)** depth of TiO absorption bands at λ 4954 Å and λ 6159 Å. **d)** and **e)** Radial velocities obtained from different ions. Radial velocity values published by van Winckel et al. (1993), were included in the plots between HJD 2 447 360 and 2 447 790

3.2. Radial velocities

A complete summary of the heliocentric radial velocities of Hen 1761 are given in Table 3. The individual emission and absorption lines have been measured by fitting a Gauss function to the profiles. The average values of the radial velocities, the corresponding mean errors and the measured line number within brackets are indicated for differents epochs.

The radial velocities have also a variable behavior with time. The Fig. 2d shows the radial velocity curves corresponding to the high ionization potential ions, He II and [O III], while the Fig. 2e shows those of the low ionization potential ions H, He I and Fe II separetely. The largest amplitudes of the radial velocity curves and a systematic decrease from August 1990 to April 1991 is observed in the first figure.

Radial velocities of several Balmer lines, Hα to H9, can be measured in two epochs, 1992 and 1994, except for H8 since it is affected by blending with the He I λ3888 Å. A regression of the Balmer series radial velocities increasing towards the first members of the series may be an evidence that the lines are emitted in an expanding region with a finite optical thickness in these lines.

The singlet and triplet series of the He I lines are shown separately in Table 3. Their radial velocities show differences which are more noticeable in the Echelle spectra, 17 km s^{-1} in October 1994 and 14 km s^{-1} in August 1995, the triplet emission lines being redshifted with respect to the singlet ones.

In the case of [Fe VI], three double peaked lines λ4967 Å, λ4972 Å and λ5176 Å are measured in August 1995. The mean radial velocities of each peak are 68 ± 8 km s^{-1} and 109 ± 4 km s^{-1} respectively.

3.3. Classification of the cool component

The spectral classification of the cool component was based on the TiO optical molecular-band strengths at $\lambda\lambda$ 6180 and 7100 Å as proposed by Kenyon & Fernández-Castro (1987). We adopted the calibration of the [TiO]

Table 3. Heliocentric radial velocities of the absorption and emission lines in Hen 1761 in km s^{-1}

Ion		Z-Machine				CCD 500×592		CCD 1024×1024	
		7/90	8/90	11/90	4/91	7/92	8/92	10/94	8/95
Hα	E	72	42	58		65	63	83	62
Hβ	E		69	47	58	58	52	69	55
Hγ	E						54	45	
Hδ	E						42	41	
H8	E						69	39	
H9	E						39	37	
He I (S)	E	43(1)	$60 \pm 8(3)$	$35 \pm 1(2)$	$52 \pm 4(2)$	$56 \pm 2(3)$	49(1)	$54 \pm 5(4)$	$58 \pm 1(4)$
He I (T)	E	79(1)	55(1)	$38 \pm 7(2)$	59(1)	52(1)	$73 \pm 6(4)$	$71 \pm 3(3)$	$72 \pm 4(3)$
He IIλ4685	E		74	69	12		47	60	66
N III	E		$65 \pm 6(2)$	$53 \pm 8(2)$	$44 \pm 2(2)$			$61 \pm 5(5)$	54 ± 1
[O III]	E		$96 \pm 5(2)$	$70 \pm 1(2)$	$55 \pm 0(2)$	$60 \pm 1(2)$	$78 \pm 6(2)$	$57 \pm 2(3)$	$47 \pm 3(3)$
Na I (D)	A	$64 \pm 5(2)$	$25 : \pm 4(2)$	$88 \pm 13(2)$			$80 \pm 22(2)$	$55 \pm 1(2)$	$59 \pm 0(2)$
[Ca V]	E							63 (1)	
Fe II	E		$42 \pm 4(7)$	$49 \pm 4(7)$	$49 \pm 4(7)$	$58 \pm 3(3)$		$59 \pm 3(8)$	$44 \pm 6(5)$
Ti II	A		$65 \pm 4(9)$		$72 \pm 9(3)$(E)			$89 \pm 5(12)$	$56 \pm 4(19)$
[Fe VI]	E							$71 \pm 6(3)$	$94 \pm 5(3)$
[Fe VII]	E								$62 \pm 7(2)$

Notes:
(S)= singlet; (T)= triplet; (D)= doublet; E= emission line; A= absorption line
(n)= number of measured lines
: dubious value.

indices with the spectral types of M giants given by these authors and both indices, $[\mathrm{TiO}]_1$ and $[\mathrm{TiO}]_2$, were calculated with the observations of August 1992 and October 1994. The spectral type obtained from the first index $[\mathrm{ST}]_1$, is earlier than that given by the second one $[\mathrm{ST}]_2$, indicating that the first index is more affected by the contribution of the hot component. In the case of the 1992–1995 observations, the fluxes were measured separately in each spectra to obtain, for each epoch, the mean indices with their respective internal mean errors.

In Table 4 we can see that the spectral type of the cool star gets increasingly later during the period of our observations. This behavior could be interpreted either as a heating suffered by the giant during the first observations or as the result of variations in the blue continuum. Figure 2c shows variations of the depth of TiO absorption bands in connection with the local continuum level. Two strong absorption bands at λ4954 and λ6159 have been measured (see Table 4), and we notice that the relative depth of each band increases at the time the spectral type of the giant becomes later, but the amplitude of these variations seems to be more important toward the shorter wavelengths. Besides, if we consider the behavior of the color index $CI = (m_{4895} - m_{6975})$ (Fig. 2b) we may conclude that the observed changes in the spectral type of the giant are the result of a dilution effect of an additional blue continuum, coming from the hot source and veiling the M spectrum. The influence of the blue continuum was decreasing in time, as it is shown in the Figs. 2b and c. Consequently we might consider that the spectral type of the cool component in Hen 1761 is as later as M5 III and according to the published near-infrared data from 1972 (Glass & Webster 1973) and 1990 (Munari et al. 1992), no change is registered in the IR colors, specially in the K and L bands.

3.4. Reddening and distance

Before deriving the physical parameters of Hen 1761, it is important to determine the interstellar extinction and distance of the system. We present several ways to determine the reddening, adopting in all the cases, the interstellar extinction curve given by Savage & Mathis (1997).

The Balmer decrement provides a good reddening diagnostic considering that the optical H I recombination lines are formed under case B conditions. But this is not the case in the majority of the S-type symbiotic stars, which show significant departures from case B in the lower Balmer series members, due to self-absorption effects. Netzer (1975) has computed the self-absorption effects on hydrogen line intensities in dense nebulae, as functions of Ly-α and Hα optical depths (τ_α, $\tau_{\mathrm{H}\alpha}$). By using his results and comparing them with the mean values of our intensity ratios observed in August 1992, October 1994 and August 1995, $I(\mathrm{H}\alpha)/I(\mathrm{H}\beta) = 5.4 \pm 1.0$; $I(\mathrm{H}\gamma)/I(\mathrm{H}\beta) = 0.37 \pm 0.05$; $I(\mathrm{H}\delta)/I(\mathrm{H}\beta) = 0.22 \pm 0.07$; we can derive $E(B-V) = 0.26 \pm 0.04$, corresponding to $\tau_{\mathrm{H}\alpha} \sim 20$ and $\tau_\alpha = 10^4$, and densities of $n_\mathrm{e} = 10^9$ cm^{-3}. The upper Balmer series members have nearly constant intensity

Table 4. Spectral type of the cool component, color index CI = $(m_{4895} - m_{6975})$ and TiO relative depths

Epoch	$[TiO]_1$	$[ST]_1$	$[TiO]_2$	$[ST]_2$	CI	$\lambda4954$	$\lambda6159$
July'90	0.29	M1.0					0.29
August'90	0.34	M1.4			− 0.96	0.51	0.30
November'90	0.33	M1.3			− 1.09	0.74	0.34
April'91						0.75	
July'92					+1.35	1.24	
August'92	0.52 ± 0.01	M3.1 ± 0.1	0.78 ± 0.06	M4.3 ± 0.3	+0.92	0.99	0.61
October'94	0.47 ± 0.02	M2.6 ± 0.2	0.95 ± 0.02	M5.1 ± 0.8	+1.04	1.99	1.11
August'95	0.76 ± 0.01	M5.3 ± 0.1			+1.34	2.02	0.92

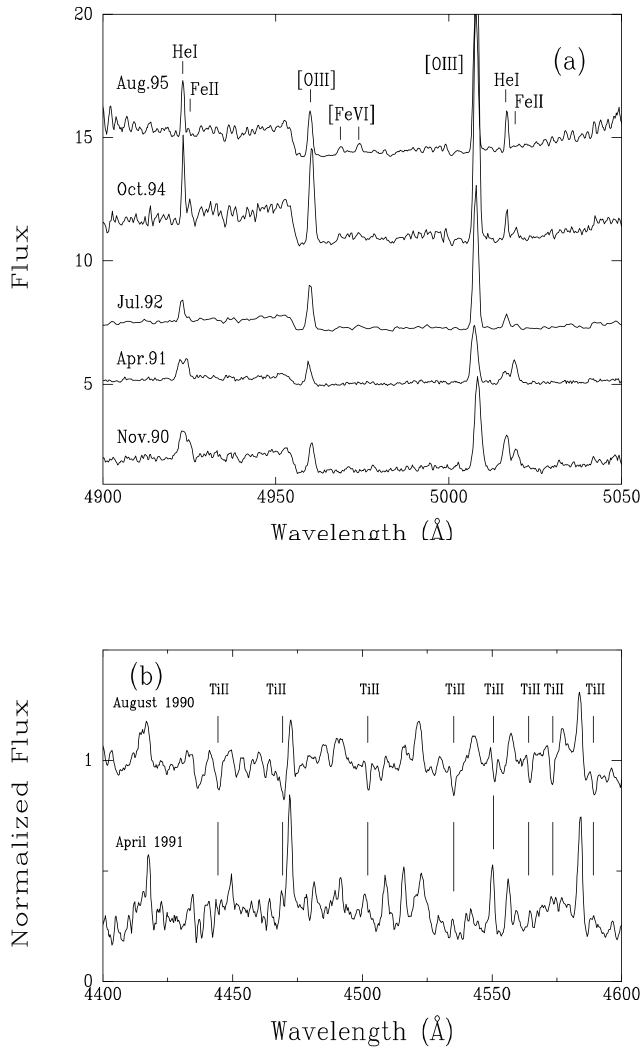

Fig. 3. The spectrograms show intensity variations in the lines of He I, Fe II and Ti II. **a)** In August 1995, Fe II is very weak and the spectrum develops forbidden lines of high ionization such as [Fe VI]. **b)** In August 1990, there is a greater number of absorptions in the blue region, particularly Ti II absorption lines, which disappear in April 1991 or are visible as weak emissions

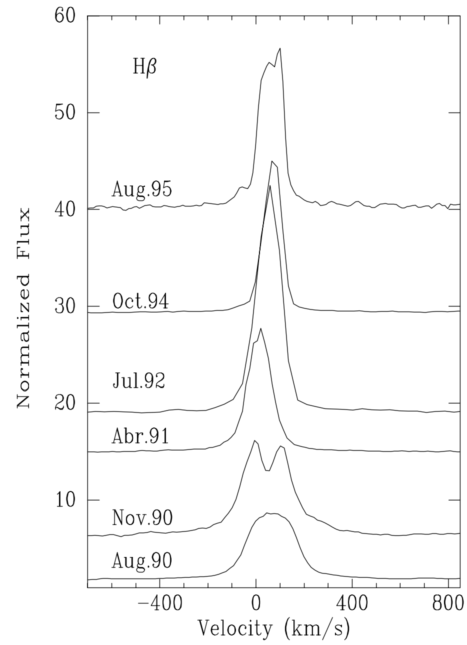

Fig. 4. Variations in the shape of the Hβ profile along the time. The double-peaked profile observed in November 1990, becomes a single asymmetric emission. Later, in 1995, the Hβ profile shows an incipient central absorption

ratios in August 1992 and October 1994, with mean values $I(\mathrm{H}\epsilon)/I(\mathrm{H}\beta) = 0.13$; $I(\mathrm{H9})/I(\mathrm{H}\beta) = 0.07 \pm 0.03$ and $I(\mathrm{H10})/I(\mathrm{H}\beta) = 0.05 \pm 0.02$. The lines showing severe blending were not considered, such as Hϵ on the lower resolution spectrum of August 1992, which was blended with [Ne III] and H8 with He I λ3888 Å. In this case a value of $E(B-V) = 0.21 \pm 0.12$ is obtained by comparison with theoretical values of case B-recombination taken from Brocklehurst (1971) for $T_{\mathrm{e}} = 10\,000$ K and $n_{\mathrm{e}} = 10^6$ cm^{-3}.

Since the near infrared colors of the M star have remained virtually constant in Hen 1761, reddening migh also be obtained from the JK photometry and the spectral type of the cool component. By combining the observed $(J-K)$ colour index (Munari et al. 1992), with intrinsic colors given by Bessell & Brett (1988), and considering that the cool component is a normal M5 giant, we obtain $E(B-V) = 0.20$. Then a distance of $d \sim 2.2$ kpc is

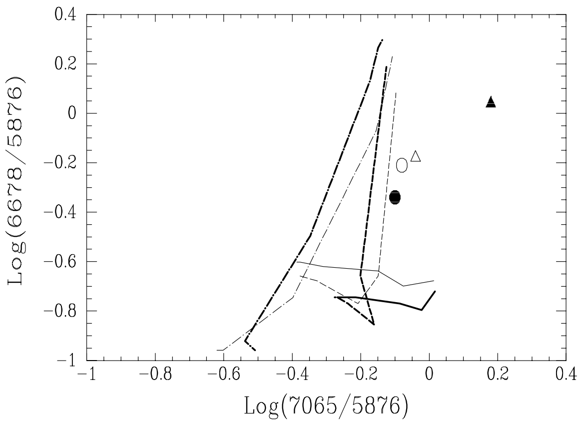

Fig. 5. The He I intensity ratios measured on logarithmic scale in Hen 1761. A comparison with theoretical models taken from Proga et al. is shown for $n_e = 10^{12}\,\mathrm{cm}^{-3}$ (dot-dashed lines), $n_e = 10^{10}\,\mathrm{cm}^{-3}$ (dashed lines), $n_e = 10^{8}\,\mathrm{cm}^{-3}$ (solid lines), T_e of 10 000 K (light lines) and 20 000 K (heavy lines). The observed intensity ratios in Hen 1761 are indicated with symbols for different epochs: 1990 (solid circle), 1992 (open triangle), 1994 (open circle) and 1995 (solid triangle)

obtained by means of the absolute magnitude $M_K = -6.26$ calculated from the $M_V \sim -0.3$ (Schmidt-Kaler 1982) and $A_K = 0.08$.

Whitelock & Munari (1992) found that many of S-type symbiotics have IR characteristics very similar to those of nonsymbiotics M-giants of the Galactic bulge. Tacking into acount this considerations, a color excess $E(B-V) = 0.73$ was obtained by comparing the observed $(J-K)$ colour index with the intrinsic colors given by Frogel & Whitford (1987) for a bulge M5-giant. Considering the distance modulus to the galactic center, 14.43 mag (Tiede et al. 1995) and the K magnitude given by Frogel & Whitford (1987), we estimate $M_K = -5.2$ and $A_K = 0.28$. A distance of $d \sim 1.3$ kpc is obtained in this case. The reddening resulting when we consider the giant of the Hen 1761 as belonging to the galactic bulge, $E(B-V) = 0.73$, conduces to a high reddening, $A_V = 2.3$ mag. Consequently the intrinsic colors $(H-K)$ would be correlated with earlier spectral type $\sim$ M0 $-$ M2 (see Figs. 7a and 7b Whitelock & Munari 1992), and this is inconsistent with our considerations about the spectral type of the cool star. While the reddening estimated for the H I line emissions is very similar than that derived by comparing the $J-K$ colors observed in Hen 1761 with those for normal giants. This means that the cool component is as reddened as the nebular region of the system. Circumstellar dust around the giant is not important, as usual in S-type symbiotic systems. In this sense, the *IRAS* data for S-type symbiotic stars (Kenyon et al. 1988), indicated that Hen 1761 has flux ratios, [25/12] $\sim$ 0.2 and [60/25] $\sim$ 1.0, similar to those of normal M giant stars.

Table 5. Physical parameters of the hot component

Epoch	T_h K	L_h $L_\odot$	R_h $R_\odot$
August'90	112000	90	0.02
November'90	112000	120	0.03
April'91	90000	160	0.05
August'92	114000	200	0.04
October'94	120000	200	0.03
August'95	160000	70	0.01

In the next sections we will correct the line fluxes for interstellar reddening adopting the values: $E(B-V) = 0.20$ and $A_V = 0.6$.

3.5. Hot component

The temperature of the hot component has been estimated from the intensity ratios of the H I, He I and He II recombination lines under certain assumptions (Kenyon (1986) and references therein). We give in Table 5, the temperatures of the hot component T_h for each epoch of observation, by using Iijima's method and the de-reddened flux ratios of (He IIλ4686)/Hβ and (He Iλ4471)/Hβ.

The T_h in turn leads to a crude estimation of the black-body luminosity and radius of the hot star from H I, He I and He II recombination line fluxes assuming theoretical emissivities of case B (Harman & Seaton 1966), adopting $T_e = 10\,000$ K and our estimation of distance $d \sim 2.2$ kpc.

3.6. Nebulae

We are constrained to estimate physical conditions in the nebulae of Hen 1761 with the emission lines observed in the optical region. The most popular line ratio that has been used for the determination of T_e and n_e is [O III] $[I(4959)+I(5007)]/I(4363)$. When it was possible to measure the three [O III] emission lines in our spectra, the dereddened intensity ratio increased slightly from 2.2 in August 1992 to 2.5 in October 1994 and to 2.9 in August 1995, which corresponds to $T_e = 10\,000$ K, using the Kafatos & Lynch (1980) diagnostic diagram and the corresponding densities between $n_e = 6\,10^7 - 3\,10^7\,\mathrm{cm}^{-3}$ have been calculated on the basis of Seaton's (1975) relation.

In a large sample of galactic symbiotic stars, Proga et al. (1994) found that, besides distinguishing between S and D type symbiotics, the He I $\lambda6678/\lambda5876$ ratio provides an useful tool for approximating the physical conditions within the nebulae. The $I(\lambda6678)/I(\lambda5876)$ ratio in Hen 1761 is $\gtrsim 0.5$ which corresponds to a S-type symbiotic. Some comments on the position of our object in the $I(\lambda6678)/I(\lambda5876)$ vs. $I(\lambda7065)/I(\lambda5876)$ diagram may be worthwhile. In Fig. 5 we can see that the positions of the points fall near Proga et al.'s models for $n_e \sim 10^{10}\,\mathrm{cm}^{-3}$ and temperature 10 000 K. The figure shows also that the line ratios appear to be variable, increasing with decreasing n_e since 1990 to 1995. Proga et al. found that the $I(\lambda 6678)/I(\lambda 5876)$ ratio variations are, in most systems, correlated with V, in the sense that lower intensity ratios seem to be associated with optical maxima, either during an eruption when the system changes from quiescence to an outburst stage (i.e. RS Oph) or as a function of the photometric phases along an orbital motion (i.e. V443 Her, AG Peg). It is not clear at the moment which is the case of Hen 1761, and it would be necessary to ascertain the origin of the observed variations first.

The [Fe VII] lines at $\lambda\lambda$ 4942, 4989, 5159, 5721 and 6087 Å, are the higher ionization forbidden lines found in Hen 1761 in the spectra of 1995. Nussbaumer & Storey (1982) give relative intensities of [Fe VII] lines as a function of the electron density and electron temperature in the region where these lines are formed. Our dereddened values of the optical line ratios 5159/6087 and 4942/6087 are 0.63 and 0.20 respectively. The first one is larger than the maximum theoretical values presented by Nussbaumer & Storey but the second line ratio suggests that the [Fe VII] lines are emitted in a region where the electron temperature is very high, $T_e \gtrsim 60\,000$ K and the density is in the order of $n_e = 10^7$ cm^{-3}.

Some considerations about the observed variations in the physical conditions in the nebulae of Hen 1761 will be made in the next sections.

4. Discussion

The timescale of some of the variations is probably very short, one month at least (July and August 1990) according to our observations. Moreover, taking into account Munari's et al. photoelectric observations performed two weeks before our spectroscopic observations of July/90, variations of $\Delta U = 0.17$ mag, $\Delta B = 0.09$ mag, $\Delta V = 0.05$ mag, $\Delta R = 0.02$ mag and $\Delta I = 0.01$ mag occur from one night to the next one, tending to increase the photometric gradient with decreasing wavelength and can thus be associated with the hot component. These rapid photometric variations or "flickering" effect are observed in other symbiotic systems with low hot component luminosities and it is usually interpreted as some measure of fluctuations in the accretion rate (Dobrzycka et al. 1996).

On the other hand, there are variations that seem to take place in Hen 1761 in a longer timescale. [O III]λ5007 Å was present on the spectra obtained in 1988, it disappeared in 1989 and later since 1990, together with the other high-excitation emission line He IIλ4686 Å, displayed important changes in the relative fluxes, reaching a minimun in 1991 and then, increasing until 1995. If we assume that the [O III] lines arise from an homogeneous nebula with $T_e = 10\,000$ K and electron density of $n_e = 10^7 - 10^8$ cm^{-3}, the size of the [O III] emitting region can be calculated (Mikolajewska 1985). For a mean unreddened flux of the λ5007 line, $F(5007) = 1.85\,10^{-12}$ erg cm^{-2} s^{-1}, and adopting the distance $d = 2.2$ kpc, we obtain a range for the radius of the nebula of 4 to 7 AU. If a typical binary separation of 2 AU for S-type symbiotic stars (Kenyon 1986; Schmid 1995) is considered, the [O III] lines are not produced close to the hot component and consequently, their radial velocity variations would hardly correspond to the orbital motion.

When the cool component displays the earlier spectral type, M1.0, an additional blue continuum, coming from the hot source is veiling the M spectrum. In the blue region, metallic lines are in absorption; the forbidden lines are weaker; the high ionization emission lines are absent and the Fe II emission lines are stronger. A considerable weakening in the blue continuum is observed since July 1992. The TiO absorption band depths became greater and consequently the spectral type of the giant gets increasingly later than the former observations. During the latest observations the forbidden lines requiring still higher excitation conditions (e.g. [Fe VI], [Fe VII] and [Ca V]) are detected for first time in Hen 1761, some of them with a double-peaked profile as has been observed in other symbiotic stars. The Fe II emission lines show a systematic decrease of intensities and almost disappear in 1995.

Strong central absorptions are visible in the H lines particularly Hα and Hβ with variations in time. Many authors have suggested that these profiles are originated in an accretion disc which surrounds the hot component of the system.

The absence of the Raman scattered O VI emission lines $\lambda\lambda$ 6825, 7082 Å deserves to be mentioned. These lines are almost always present in symbiotic systems with high excitation lines, such as [Fe VII] or [Ne V] (Schmid 1996) but according to Kenyon (1986) the symbiotics that have noticeable [Fe VII] emissions and no trace of $\lambda\lambda$ 6825, 7082 Å, are likely candidates for an accreting main sequence star as the hot source.

5. Conclusions

We summarize our study by saying that Hen 1761 is an S-type symbiotic star with important spectral variations. Some of the spectral changes can be explained if we consider that Hen 1761 has to go through outburst and quiescence stages, in the case that the system contains a red giant star M5 and a hot white dwarf with an accretion disk, which powers the activity of the system. Unfortunately, it is not possible to specify both stages due to the lack of a light curve following the spectral changes. During the activity in 1990-91 the spectrum shows the characteristic outburst properties as is somtimes observed in symbiotic stars: the presence of H I, He I, He II, N III and Fe II emission lines and forbidden lines of [Fe II], [Ne III] and [O III]. Absorption lines like the doublet Na I and Ca I λ4226 Å are also present in this phase. On the other hand, a blue continuum veils the giant's features and an earlier spectral type for the cool component is inferred from the optical spectrum. The quiescence phase may have started in 1992, when the Fe II emission lines decreased, the forbidden lines of low-excitation [Fe II] and [Ne III] disappeared and forbidden lines requiring still higher excitation conditions (e.g. [Fe VI], [Fe VII] and [Ca V]) are observed. At the same time, the veiling of the absorption bands on the blue continuum decreases substantially. The [O III] emission lines are present as much as the He II ones, during both phases but their intensities are increasingly noticeable on our quiescent observations. The variability of the He I intensity ratios presented in Fig. 5 suggests that the outburst produces changes in the density of the nebula where these lines are formed.

Other spectral variations are observed in Hen 1761 due perhaps to orbital motion or associated with the flickering activity. In order to separate the causes of the variations, a series of photometric and spectroscopic observations are necessary. Thus, it would be very important to analyse the UV spectrum of Hen 1761 with the aim of learning more about the nature of the hot component and confirming the existence of an accretion disk.

Acknowledgements. The authors wish to thank Prof. J. Sahade for careful reading of the manuscript. The authors also acknowledge the use of the CCD and data acquisition system supported under U.S. National Science Foundation grant AST-90-15827 to R.M. Rich.

References

Allen D.A., 1980, MNRAS 192, 521
Allen D.A., 1982, in The Nature of Symbiotic Stars, IAU Coll. 70, Friedjung M., Viotti R., (eds.). Reidel, Dordrecht, p. 27
Allen D.A., 1984, Proc. Astron. Soc. Aust. 5, 367
Baldwin J.A., Stone R.P.S., 1984, MNRAS 206, 241
Barbá R., Brandi E., García L., Ferrer O., 1992, PASP 104, 33
Bessell M.S., Brett J.M., 1988, PASP 100, 1134
Brocklehurst M., 1971, MNRAS 153, 471
Dobrzycka D., Kenyon S.J., Milone A.A., 1996, AJ 111, 414
Frogel J.A., Whitford A.E., 1987, ApJ 320, 199
Glass I.S., Webster B.L., 1973, MNRAS 165, 77
Harman R.J., Seaton M.J., 1966, MNRAS 132, 15
Kafatos M., Lynch J.P., 1980, ApJS 42, 611
Kenyon S.J., 1986, The Symbiotic Stars. Cambridge Univ. Press. Cambridge
Kenyon S.J., Fernández Castro T., 1987, AJ 93, 938
Kenyon S.J., Fernández Castro T., Stencel R.E., 1988, AJ 95, 1817
Lund L., Tuvikene T., 1987, Afz 26, 457
Mayall M., 1951, Bull. Harvard College Obs. 920, 32
Mikolajewska J., 1985, Acta Astron. 35, Nos. 1-2
Munari U., Yudin B.F., Taranova O.G., et al., 1992, A&AS 93, 383
Netzer H., 1975, MNRAS 171, 395
Nussbaumer H., Storey P.J., 1982, A&A 113, 21
Proga D., Mikolajewska J., Kenyon S.J., 1994, MNRAS 268, 213
Savage B.D., Mathis J.S., 1979, ARA&A 17, 73
Schmid H.M., 1989, A&A 211, L31
Schmid H.M., 1995, MNRAS 275, 227
Schmid H.M., 1996, MNRAS 282, 511
Schmidt-Kaler Th., 1982, in Landolt-Börnstein, New Series. Berlin Springer Vol. VI/2, p. 18
Schulte-Ladbeck R.E., Aspin C., Magalhães A.M., Schwarz H.E., 1990, A&AS 86, 227
Seaton M.J., 1975, MNRAS 170, 475
Stone R.P.S., Baldwin J.A., 1983, MNRAS 204, 347
Thackeray A.D., 1954, Observatory 74, 258
Tiede G.P., Frogel J.A., Terndrup D.M., 1995, AJ 110, 2788
van Winckel H., Duerbeck H., Schwarz E., 1993, A&AS 102, 2
Whitelock P.A., Munari U., 1992, A&A 255, 171
Wright A.E., Allen D.A., 1978, MNRAS 184, 893