CHAPTER III

SPECTROSCOPIC STUDIES OF MASSIVE X–RAY BINAIRES

Hα profile of HD 77581 around phase 0.8
(cf. Zuiderwijk et al., 1974; plate G3857)
Spectroscopic observations of the early type B-supergiant Wray 977 (4U1223-62): Description of the spectrum and Classification.

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* based on observations collected at the European Southern Observatory, La Silla, Chile
Summary

Spectroscopic observations of the emission-line star Wray 977 are presented. Drastic variations are observed in the P-Cygni profiles of $H_B$ and $H_\gamma$. The classification of Wray 977 as a B1I supergiant is supported by our spectra.

Key words: X-ray binaries - supergiants - spectral variations - interstellar lines

1 Introduction

The B-type supergiant Wray 977 has been proposed as the optical counterpart of the X-ray source 3U1223-62 (Vidal, 1973; Hammerschlag-Hensberge et al., 1976). Since the publication of the third Uhuru catalog (Giacconi et al., 1974), the X-ray error box has been considerably improved by SAS-3 observations (Bradt et al., 1977), which have confirmed beyond doubt that Wray 977 coincides with the X-ray source 4U1223-62. The X-ray source shows irregular variations on time scales of days and hours. White et al. (1976) discovered periodic X-ray pulsations with a period of 699 seconds. Recently White et al. (1978) mentioned a 41 day periodicity which they discovered in X-rays through time delay of the pulses. However, this period may be an artifact of the reduction method used (Takens, 1978).

Wray 977 has been studied photometrically by several authors (van Genderen, 1973, 1977; Hammerschlag-Hensberge et al., 1976; Mauder, 1974, 1976; Bord et al., 1976). Hammerschlag-Hensberge et al. (1976) found a periodic variation in the uvby photometry of $23 \pm 1$ days.

A first description of the spectrum of Wray 977 has been given by Vidal (1973). As this study was rather coarse due to the low dispersion of his plate material we give here the first results of our spectroscopic investigation of this star.

2 Description of the Spectrum

Table 1 lists our observational material, obtained with the Coudé and Echellec spectrographs attached to the 1.5 m telescope of the ESO, La Silla,
Chile. The Coudé plates have a higher dispersion but they are more noisy due to bad weather conditions combined with the long exposure times needed for this faint object \((m_V = 10.8, m_B = 12.5)\). Therefore, in 1977 and 1978 we decided to obtain Echellec first order spectra with a dispersion of 62 A/mm. These spectra cover the wavelength region 4050 A - 4900 A. In figure 1a-c an intensity tracing of the spectrum of Wray 977 in this region is shown. To reduce the noise we added 4 to 6 spectra; this method results in a much better signal to noise ratio than for a single spectrum and makes the identification of spectral lines more certain. The strength of the interstellar lines (indicated by IS in the figures) is most striking in these figures. The central depth of each of the interstellar features in Wray 977 is larger than observed in any of the stars studied by Herbig (1975). From his relation between the strength of the interstellar lines and the color excess \(E(B-V)\), we derive for Wray 977: \(E(B-V) = 1.8\) mag. in good agreement with our previous estimates (Hammerschlag-Hensberge et al., 1976).

An inspection of the individual spectra reveals that all the observed P-Cygni lines and emission lines show very striking variations. For this reason, \(H_B\) is not included in the addition of the spectra. Figure 1b indicates that even \(HeI \lambda 4471\) has a weak emission component. Figure 2 shows the variations in \(H_\gamma\) and \(H_\beta\). On the 4 plates of 1977 (P791-800) the P-Cygni profile of \(H_\gamma\) remains constant. On P1000-1001 the \(H_\gamma\) profile looks similar to the one on P791-800. However, two days later (P1022) the emission has weakened considerably, whereas still one to three days later the emission has disappeared completely. The \(H_\beta\) emission changes in the same way as the \(H_\gamma\) emission. We note that Vidal (1973) mentions that the \(H_\gamma\) absorption is filled in by emission on all his plates; also \(H_\beta\) changes drastically on his plates. The \(H_\gamma\) variations on our plates suggest that the variations could be periodically and that monitoring of this star during several days to one month would be extremely desirable.

Due to the bad signal to noise ratio of our Coudé plates we only picked out the most important lines which are shown in figures 3 and 4. Figure 3 shows the \(H_\alpha\) emission on plate F3118. The P-Cygni profile of \(HeI \lambda 6678\) is plotted in figure 4. \(HeI \lambda 5876\), which is not shown, also has a P-Cygni type profile. The emission components of these lines appear to be weaker on plate F3118, compared with the plates F3138 and F3143.
3 Classification

We compared the line strength ratios of SiIV/HeI, MgII/HeI and OII/HeI measured on the intensity tracings of our added Echellec spectra with those given by Sinnerstad (1961) for different spectral types. This comparison supports a spectral type Bl, which is slightly earlier than Bl.5 suggested by Vidal (1973), based on the comparison of an underexposed spectrum of Wray 977 with that of a B0.5Ia supergiant. The strength of the OII lines and the Balmer lines indicates a supergiant type rather than a main sequence star or a (bright) giant.

4 Conclusions

The spectrum of Wray 977 shows drastic changes with time. Especially the $H_\gamma$ profile could be used to search for periodic variations. The spectra show that the OII, SiIII and HeI absorption lines are suited for radial velocity studies. It may be difficult to measure radial velocities of these lines from individual spectra, because the lines are very weak. A good approach would be to take several spectra during each night (4 or more) and to add these spectra to improve the signal to noise ratio before calculating the radial velocities.
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Table 1: Observational material. \( F \) numbers are Coudé plates with a dispersion of 31 \( \AA/mm \), \( P \) numbers are Echelle plates with a dispersion of 62 \( \AA/mm \).

<table>
<thead>
<tr>
<th>Plate number</th>
<th>Date</th>
<th>Emulsion</th>
<th>Observer</th>
</tr>
</thead>
<tbody>
<tr>
<td>F 3118</td>
<td>27 May 1975</td>
<td>098-02</td>
<td>GHH</td>
</tr>
<tr>
<td>F 3138</td>
<td>6 June 1975</td>
<td>098-02</td>
<td>GHH</td>
</tr>
<tr>
<td>F 3143</td>
<td>7 June 1975</td>
<td>IIaD</td>
<td>GHH</td>
</tr>
<tr>
<td>P 791</td>
<td>7 July 1977</td>
<td>nuclear</td>
<td>EH</td>
</tr>
<tr>
<td>P 792</td>
<td>7 July 1977</td>
<td>nuclear</td>
<td>EH</td>
</tr>
<tr>
<td>P 799</td>
<td>8 July 1977</td>
<td>nuclear</td>
<td>EH</td>
</tr>
<tr>
<td>P 800</td>
<td>8 July 1977</td>
<td>nuclear</td>
<td>EH</td>
</tr>
<tr>
<td>P 1000</td>
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<tr>
<td>P 1001</td>
<td>28 Febr 1978</td>
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<td>P 1028</td>
<td>3 March 1978</td>
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<td>CdL</td>
</tr>
<tr>
<td>P 1068</td>
<td>6 March 1978</td>
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<td>CdL</td>
</tr>
<tr>
<td>P 1069</td>
<td>6 March 1978</td>
<td>nuclear</td>
<td>CdL</td>
</tr>
</tbody>
</table>
Captions of the Figures

**Figure 1:** Intensity spectrum of Wray 977 for the wavelength regions (a) \( \lambda 4075 - 4300 \), (b) \( \lambda 4300 - 4525 \), (c) \( \lambda 4525 - 4750 \).

The continuum level is normalized to 1.0 and some of the most important spectral features are identified.

**Figure 2:** Intensity variations in \( H_\alpha \) and \( H_\beta \).

The plate numbers are indicated in the figure.

The dates on which the plates were taken can be found in Table 1.

**Figure 3:** \( H_\alpha \) profile of Wray 977.

**Figure 4:** HeI 6678 has a clear P-Cygni profile.
Figure 1a
Figure 1b
Figure 1c
Figure 2
Figure 3

Figure 4
THE SPECTRUM OF HD 77581 (VELA X-1)

VARIATIONS IN THE PROFILES OF H$_B$ AND HE II $\lambda$4686

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Summary

The blue spectrum of the B0.5Ib supergiant HD77581, optical counterpart of the X-ray source 4U0900-40, is described. The profile of Hβ is phase dependent and consists of two absorption components, superimposed on one another. One of these is variable in both strength and velocity, the other is the steady photospheric profile. The profile of HeII λ 4686 Å is of P-Cygni type around phase 0.7, whereas the line is in absorption with variable strength between phase 0.9 and phase 0.5. These observations indicate the presence of a gaseous stream in the system, and an asymmetrically expanding atmosphere of HD77581.

Key words: X-ray Binaries - Supergiants - Spectrum Variations
Introduction

The massive X-ray binary HD77581/4U0900-40 is one of the most extensively studied systems of this type. The compact object is an X-ray pulsar with a period of $283^s$, for which the slightly eccentric orbit has been determined accurately (Rappaport et al., 1976). The primary shows the well-known ellipsoidal brightness variations with an amplitude of about $0.10^m$ and a period of 8.966 days (Jones and Liller, 1973; Zuiderwijk et al., 1977).

Spectroscopic studies were presented by Wickramasinghe et al. (1974), Hutchings (1974), Wallerstein (1974), and Zuiderwijk et al. (1974). The spectrum of the primary is very similar that of the B0.5Ia supergiant ε Ori. The periodic variation of the $H_\alpha$ emission line profile is commonly interpreted as being due to gaseous streams in the system. Evidence for variations in the profiles of $H_\beta$ and some HeI lines was given by Zuiderwijk et al. (1974). The presence and variability of the HeII line $\lambda 4686\AA$ was reported by Hutchings (1974); the absorption and emission components are very weak and Hutchings (1974) stated that observations with a high signal to noise ratio would be required for a decent study of this line.

Radial velocity variations of the primary were discussed by various observers (Hiltner et al., 1972; Wallerstein, 1974; Hutchings, 1974 and Zuiderwijk et al., 1974). In the most recent study, van Paradijs et al. (1977a) give an accurate mass determination for both the neutron star and the primary, i.e. $1.74 M_\odot$ and $21.3 M_\odot$, respectively ($q=0.076$). For a review of further observations of this X-ray binary system we refer to Bahcall (1978) and references therein.

Since the bolometric luminosity of the X-ray source is fairly low — about $10^{-4}$ of the luminosity of the primary — the secondary contributes virtually nothing to the optical spectrum. The spectrum of HD77581 is "clean": no conspicuous peculiarities, like strong emission features, are present, except in $H_\alpha$. Therefore, this X-ray binary system constitutes an ideal test case to study the influence of geometrical distortions, due to the secondary, on the photometric and spectroscopic properties of the primary.

Theoretical studies of the effects of tidal and rotational deformation
on the apparent radial velocity of the primary - of obvious importance for a reliable mass determination - were made by Wilson and Sofia (1976) and by van Paradijs et al. (1977b). The latter authors predict significant deviations between the "true" orbital velocity of the primary and the apparent radial velocity derived from absorption lines of several ions (HeI, OII and SiIV). These predicted discrepancies would be due to the phase dependent shape of the theoretically computed line profiles.

The evidence for the presence of these predicted distortion effects is not very strong (van Paradijs et al., 1977a). This may be due to the fact that HD77581 is not rotating with the orbital angular velocity (Conti, 1978; Wallerstein, 1974), while corotating was assumed in the theoretical computations. It is desirable in any case to study the shape of several important spectral lines which were used in the determination of the radial velocities; only in this way it is possible to set an upper limit on non-orbital contributions to the radial velocity curve.

The first results of such a study are reported in this paper. The observational material consists of averaged intensity tracings obtained from the spectrograms used by van Paradijs et al. (1977a) for their radial velocity study. The next section describes the reduction of the density tracings and the construction of the averaged spectra. An atlas of the spectrum, in which line identifications are indicated is presented in section 3, and in the last section the variations in the profiles of H\(_\beta\) and HeII\(\lambda\) 4686\(\AA\) are discussed. A list of equivalent widths and a comparison of line profiles with profiles derived from theoretical model computations will be presented elsewhere.

2 Observational Material and Reduction

Several data of the spectrograms used for this study are listed in Table 1. These plates were selected from the file obtained by van Paradijs et al. (1977a) with the 152 cm telescope and Coudé spectrograph of the European Southern Observatory in Chile. The selection criteria were twofold: a photographic calibration of reasonable quality should be available, and several other spectrograms recorded at about the same binary phase must be available. In practice this resulted in the use of
six sets, consisting of 6 to 8 plates each, each set being obtained during one night, supplemented with two similar sets, consisting of 3 plates each.

Spectrograms obtained in the same night were developed under standard conditions together with 3 to 5 calibration plates. The spectra are recorded on sensitised IIaO emulsion. Exposure times and widening of the individual spectra were typically 15 minutes and 0.4–0.5 millimeter respectively. On each spectrogram an Iron-arc comparison spectrum was recorded, both before and after the exposure of the stellar spectrum. All spectra cover the wavelength region between λ3800 Å and λ4900 Å; therefore Balmer lines from H_n on, were not included in the study. (These lines are still usable for radial velocity determinations, as the distortions due to astigmatism are perpendicular to the dispersion direction.) The continuum density of the spectra ranges from 0.7 to 0.9. Unfortunately, beyond λ4700 Å the sensitivity of the emulsion decreases, which results in a lower density level (about 0.3) around H_α; this makes the photographic calibration less reliable for this line.

All spectrograms were scanned in the same way with the Faul Coradi digitized Micro Densitometer of the Astronomical Institute at Utrecht. This scanning device is described by Heintze et al. (1975). The accuracy of the positioning of the scanner slit is better than 0.4 μm. For each spectrogram four scans were performed: one of the stellar spectrum, two of the comparison spectrum on both sides, at equal distances from the stellar spectrum, and one scan of the neutral plate density as close to the stellar spectrum as possible. Each scan consists of some 20000 to 25000 density measurements recorded with a step size of 4 μm. The digitized tracings are stored on magnetic tape and were analyzed by means of a set reduction programs written and developed by the author, using the CDC7300 computer system of the SARA at Amsterdam, and the CDC7700 system of CERN in Geneva. Several features of the reduction software are described in the following paragraphs.
Wavelength Calibration

Some 45 Iron-arc comparison lines were used to establish the wavelength calibration. They were taken from a list given by Edlén (1960) and were chosen because of their selected location in the spectrum and their virtually undisturbed symmetric shape. The method used to identify the lines in the comparison spectrum and to measure their positions is straightforward, as follows.

First a list of approximate positions of all stronger lines present in the spectrum is stored in core memory. In a properly exposed spectrum up to 400 individual lines can be distinguished.

Subsequently a small number of lines - typically 3 to 5 - which define a group characteristic for the wavelength region covered by the spectrogram, is traced. This is performed by means of a simple "pattern recognition" algorithm that looks for coincidences of the relative positions of these few comparison lines with relative positions of the reference lines in the list. Once this group of lines has been located, the other comparison lines to be measured are easily found by means of linear or quadratic extrapolation, based on the position of comparison lines already identified and the wavelength of the next line to be found. This method functions well in the case of Coudé spectra over wavelength intervals as large as 200 Å. The only information which the program requires, apart from the wavelength of the spectral lines to be identified, is the dispersion of the spectrogram.

Finally the run of the density is analyzed near the preliminary positions of the identified comparison lines by means of a subroutine which simulates the well known "Grant" comparator method of position determination by "eye estimate". Typically 20 to 25 density points are used in the determination of the precise position of a line; for some weaker lines 10 to 15 points are used. Before determining the accurate positions of the lines, their profiles are submitted to a symmetry test. Asymmetric and blended lines are properly recognized and, if too much distorted, omitted from the list. It appeared that when a line was rejected in this way, always a clear reason (such as bad focus or misidentification) for this rejection could be indicated a posteriori.
The positions of the reference lines in the two comparison spectra are transformed to the location of the stellar spectrum by means of linear interpolation. The wavelength calibration is represented by two polynomials of third degree. One polynomial represents the relation between wavelength \( \lambda \) and position \( p \) in the spectrum:

\[
\lambda = a_1 + a_2 p + a_3 p^2 + a_4 p^3 \tag{1a}
\]

The other represents the inverse relation:

\[
p = b_1 + b_2 \lambda + b_3 \lambda^2 + b_4 \lambda^3 \tag{1b}
\]

This representation is sufficiently accurate over a wavelength range of at least 1000 \( \text{Å} \) in the Coudé spectrograms. The coefficients \( a_i \) and \( b_i \) are determined from the wavelengths and positions of the reference lines by using a least squares fitting algorithm which also analyses the distribution of the residuals. The possible presence of a "bad line" results in an abnormal distribution and is properly recognized. For all spectrograms the standard deviations of the residuals with respect to the fitted polynomials are in the range 0.010 - 0.015 \( \text{Å} \) for wavelength, and in the range 0.8 - 1.2 \( \mu \text{m} \) for position. This result is as good as, or even better than, the "eye estimated" results obtained with a Grant comparator for the same spectrograms by van Paradijs et al. (1977a).

b Photometric Calibration

The calibration spectra consist of the usual spectra of a continuum source; a rotating step sector with 13 transmission steps was placed before the entrance slit of the calibration spectrograph. Density tracings of the plates, recorded in the direction perpendicular to the dispersion, were all analyzed in the same way by using a sub-program that properly recognizes the "steps" and determines the density of each of them. The finally used calibration curves for all plates obtained in one night were determined by taking together several (4 to 5) individual curves from different calibration plates, followed by a least squares fit to the
analytical expression:

\[ \log I = c_1 \log (1 - T) + c_2 \log (T) \]

where \( T \) denotes the transmission of the photographic plate. The coefficients \( c_1 \) and \( c_2 \) are computed with a least squares fitting algorithm.

This representation of the intensity calibration appears to be at least as accurate as a free-hand determination (Underhill, 1966) for the density range from 0.2 to 2.5, which is the part of the curve of our interest. A typical example is shown in Figure 1 to illustrate the quality of the representation.

The analytical function (2) is stored in tabular form for equidistant density values. To cover a range in densities from 0 to 2.0 one hundred points turned out to be sufficient. The transformation into intensity of each density measurement (after correction for the neutral density) is performed by means of linear interpolation in this table. This method is sufficiently accurate and much less time consuming than evaluating equation (2) for each point.

C Averaged Intensity Tracings

The registration of IIaO spectrograms are quite noisy (Underhill, 1966). Therefore, several averaged intensity tracings were constructed to improve the signal to noise ratio. If one wishes to detect small distortions of the line profiles or weak lines, the application of this technique is absolutely required. Since the expected distortions are phase dependent, only plates obtained during the same night were used to construct the averaged spectra. The range in binary phase is typically 0.01 to 0.02 in each set of plates (cf. Table 1).

In principle, two different methods can be applied to construct averaged spectra:

One might obtain rectified intensity tracings for each individual spectrogram, followed by the computation of the mean of several of these tracings. This approach may give rise to some difficulties when dealing with spectra of substantially different exposure and with different
photographic calibrations. In that case one has to assign a weight to each individual rectified tracing in the computation of the mean spectrum, in order to compensate for differences in the continuum densities. Individual tracings with the poorest signal to noise ratio should be given the lowest weights.

This difficulty is not encountered when we are dealing with a homogeneous set of spectrographs which all have the same calibration, such as those used in this study. It is then sufficient to construct individual non-rectified intensity tracings and simply add them. The rectified spectrum is obtained later from the composite intensity tracing constructed in this way.

Irrespective of which of these methods is chosen, the original density vs. position tracings have to be transformed into intensity vs. wavelength tracings; the intensity in each individual spectrogram has to be computed at equidistant wavelength values ($\Delta \lambda$ is 0.05 Å in our case). This is performed by estimating for every wavelength value the corresponding position in the original tracing, followed by the computation of the density by means of a four-point Lagrangian interpolation between the original density measurements, which are sampled at equidistant positions. The thus computed density is transformed into intensity by applying the photometric calibration. In the computation of the position in the original tracing a correction for the motion of the earth is included. Therefore the finally computed averaged tracings are obtained in the solar-centric reference frame.

Without further precautions the four-points interpolation procedure may become unstable, due to the noise in the original density measurements; the interpolated values then deviate unrealistically strong from the original data. We can avoid this difficulty by smoothing the original density tracings slightly, before computing the interpolated values. This was performed by applying a Fourier Filtering technique - based on a fast Fourier Transform algorithm given by Singleton (1969), - to remove the highest frequencies from the data. An extensive discussion of this smoothing technique was given by Brault and White (1971). From these authors we adopted the data manipulation procedures preceding the filtering process itself, i.e. systematic trends were removed from the data and end region masking was applied to the individual data segments - consisting of 2000 densities each- into which the scans were divided. (Removal of a systematic trend from the data
is basically equivalent to compensating for the slope of the continuum. The continuum level, here in terms of density, was estimated automatically and subtracted from the data. Afterwards, the smoothed data are restored by again adding the continuum level).

The filter function was adopted from Brault and White (1971); the "cut-off" frequency was estimated empirically such that the profile of the interstellar CaII K line remained unaffected. Therefore, the improvement of the signal to noise ratio in the averaged spectra is completely due to the near-cancelation of the noise contributions from the individual tracings. The filtering procedure has no influence on the final results as it was only applied to stabilize the interpolation in the original density measurements.

3 Preliminary Investigation of the Spectrum of HD77581

The averaged spectrum of HD77581, obtained from 8 spectrograms recorded during one night around phase 0.42 (1975, nov. 07; cf. van Paradijs et al., 1977) is shown in Figure 2. The spectrum closely resembles that of εOri, a B0.5Ia supergiant. All of the stronger spectral features found in the identification list of εOri (Lamers, 1972) are present in this spectrum of HD77581. Especially interesting is the presence of several of the weaker interstellar absorption lines, such as: CH 4300 Å, CH<sup>+</sup>43958 Å and CH<sup>+</sup>4232 Å; the equivalent width of the CH line is about 20 mA.

From the width of the interstellar lines the spectral resolution can be estimated, which is approximately 0.4 Å. This is not much different from the resolution of about 0.3 Å, which would be expected for these Coudé plates; the difference may easily be due to some smearing introduced by the averaging process.

A modified version of a method given by Peast et al. (1970) was used to establish the continuum level and rectify the intensity tracings. This method is based on the analysis of the distribution of densities in the tracing. If one assumes that this distribution is a composite one, consisting of a Gaussian distributed continuum population and a line population, then the continuum level can be estimated quite easily from determining the centroid of the Gaussian distribution. The original version of the method (Peast et al., 1970) was extended in order to not only determine the level but also the slope of the continuum. This method works very well in the case of spectra with a relatively small number of absorp-
tion lines; the results are completely consistent with the "eye-estimated" continuum determination. Only very broad spectral features, such as the diffuse interstellar absorption band near 4430 Å, are not recognized by this procedure.

A detailed study of the spectrum and an analysis of the line profiles is presently being carried out; the results will be given in a separate paper. Here we only consider the broadening mechanisms of the lines.

Inspection of the line profiles reveals that the width of the hydrogen lines is systemetically larger by about 40 percent than those of the lines of HeI, SiIV and NIII. The shape of the lines suggests that macroturbulence might be an important broadening mechanism. A velocity gradient in the atmosphere, however, has a similar effect on line profiles as macroturbulence. Since HD77581 certainly has an outflowing atmosphere (Zuiderwijk et al., 1974), and the hydrogen lines are formed further outwards than the lines of other elements, one expects them to show the outflow effects most clearly (cf. Underhill, 1966). However, the absence of a Balmer progression (van Paradijs et al., 1977a) makes an explanation in terms of real macroturbulence more likely. If we assume that this macroturbulence is absent in the profiles of the HeI lines, the rotational velocity of HD77581 can be estimated roughly from the width of these lines. A value $v \sin i = 120 \text{ km/s}$ was obtained as an upperlimit. Given the corotation velocity $v \sin i = 175 \text{ km/s}$ (Avni, 1976), we see that the corotation factor for the primary is about 0.7 or smaller. This fact is of importance for the calculation of theoretical light curves (this thesis Chapter I).

4 Line Profile Variations

The most pronounced variations in line profiles occur in Hβ and in HeII 4686 Å. They are shown in figures 3 and 4, respectively. It is clear that the disturbance of the Hβ profile is the strongest around phase 0.4 (with respect to X-ray eclipse), while the disturbances in the HeII line are most pronounced around phase 0.7. The profile of Hβ clearly consists of two components: an underlying steady absorption profile on which an extra absorption component with variable velocity is superimposed. The following velocity differences between the two components are observed:

$\phi = 0.55$: 120 km/s; $\phi = 0.7$: 200 km/s; $\phi = 0.9$: 300 km/s. This behaviour is remarkable similar to that of the Hα profile (cf. Zuiderwijk et al., 1974; Wallerstein, 1974) and has been interpreted as due to a gaseous stream
in the system. The striking similarity of the profiles around phase 0.53 and phase 0.58, derived from two sets of plates obtained one year apart, strongly indicates that this gaseous stream is a stationary phenomenon on longer time scales. It should be noticed that the P-Cygni type of the H\textsubscript{\beta} profile reported by Hutchings (1974) has not been found here, except perhaps around phase 0.42 where a minor emission component might be present.

A puzzling aspect of the gaseous stream seen in H\textsubscript{\beta} is that the stream is most strongly visible around phase 0.4. This may indicate that the region of the surface of the primary preceding the X-ray source is the most perturbed.

The small emission in HeII 4686 Å around phase 0.7 may be due to a density increase in the stellar wind around this phase. Also in other X-ray binaries, such as HD153919, lines of HeII are drastically varying (Hammerschlag-Hensberge, 1978), which is interpreted as being due to an asymmetrically outflowing atmosphere.

Preliminary Discussion

The differences in width between lines of different ions is a well known phenomenon in early-type stars (Underhill, 1966). They indicate an increase in the turbulence with increasing height in the atmosphere. In the case of HD77581 this may be caused by the non-synchronous rotation of the primary. The fact that the orbit is eccentric and that the star is not corotating, strongly suggests that HD77581/4U0900-40 is very young as an X-ray source, and that HD77581 is at present in the stage of rapid envelope expansion following the depletion of hydrogen in the core of this star. Even if the primary was corotating during its main-sequence life, then, because of the conservation of angular momentum, the star will rotate slower than synchronous, as the time scale for tidal synchronisation is expected to be much longer than the $10^4$ yr timescale of envelope expansion (cf. Savonye and van den Heuvel, 1977). The fact that the orbit of the secondary is still eccentric indicates that dissipation processes, which synchronize the rotation and circularize the orbit were not important in the recent history of the system.

This is in good agreement with theoretical expectations for systems with a main-sequence primary and with an orbital period longer than 5 days (Lecar et al., 1976), as was the configuration of this binary system longer than some $10^4$ years ago.
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Wickramasinghe, D.T., Vidal, N.V., Bessel, M.S., Peterson, B.A.,
Astron. & Astrophys. 35, 353
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Notes to table 1: *) Phase calculated according to (JD-2441446.54)/8.9681
+: Observers: P = J. van Paradijs, L = C. de Loore (cf. van Paradijs et al., 1977a)
Figure 1: Intensity calibration for the spectrograms G7158 to G7164. The solid line represents the analytical function discussed in the text.
Figure 2: Averaged spectrum of HD77581, computed from 8 spectrograms - G7180 to G7187 - around phase 0.42 (with respect to X-ray eclipse). The continuum level was estimated automatically, except for the spectral region around 4430 Å. The "line" near 4162 Å is due to a disturbance ("spike") in the tracing of spectrogram G7186.
Figure 3: Variations in the profile of $H_\beta$ as a function of orbital phase (X-ray eclipse is phase 0). The variations in the central depth of the line may be not real, because of an unreliable calibration for some of the spectrograms.
Figure 4: Variations in the profile of HeII λ4686 Å as a function of orbital phase.