The HD 5980 binary system: Components and Spectral Types

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Abstract. We present a radial velocity study of the optical spectral lines of the eclipsing binary HD 5980, which recently underwent a major luminous blue variable (LBV)-type outburst. From our data we confirm that both binary components appear as stars with emission line spectra of Wolf-Rayet type. The binary component which is in front of the system during the primary eclipse, is the more massive one, and the one which produced the outburst. Absorption lines present in the pre-outburst spectrum of HD 5980 seem not to follow the orbital motion of the binary, but show variations from epoch to epoch.

1. Introduction

HD 5980 is an eclipsing binary with Wolf-Rayet (WR) type spectrum in the Small Magellanic Cloud, which surprisingly entered into a LBV like outburst in 1994 (cf. Barbá et al. 1995). The pre-outburst spectrum of HD 5980, dominated in the blue optical region by the very strong emission line of HeII 4686Å, is known to be variable since the spectral observations by Feast et al. (1960). Breysacher and Perrier (1980) derived an eccentric light curve and a period of 19.266 days for this binary.

A radial velocity study of the emission line of HeII 4686Å and absorption lines present in the spectrum (Breysacher et al. 1982), did not reveal the high amplitude orbital motion that one would expect to find in an eclipsing binary of $M_V \sim -7.5$. Only small amplitude variations were observed instead. Those variations, if interpreted as orbital motion, would correspond to component stars of a few solar masses, which seemed improbable for a system as luminous as HD 5980. In order to explain the diminished amplitude of the radial velocity variations

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The HD 5980 binary system

Table 1. Orbital Elements of HD 5980 from NIV and NV emissions

<table>
<thead>
<tr>
<th>N IV em</th>
<th>NV em</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a \sin i \ [R_\odot]$</td>
<td>81</td>
</tr>
<tr>
<td>$K \ [\text{km s}^{-1}]$</td>
<td>226</td>
</tr>
<tr>
<td>$M \sin^3 i \ [M_\odot]$</td>
<td>28</td>
</tr>
<tr>
<td>$e$</td>
<td>0.28</td>
</tr>
<tr>
<td>$\omega \ [\text{deg}]$</td>
<td>160</td>
</tr>
<tr>
<td>$P \ [\text{d}]$</td>
<td>19.2655</td>
</tr>
</tbody>
</table>

variations, Breysacher et al. (1982) suggested that both components of the binary were contributing to the observed HeII 4686Å emission.

A further radial velocity study of the fainter emission lines of NIV 4058Å and NV 4603Å and absorptions of H9 and HeI 4471Å (Niemela 1988) in the spectrum of HD 5980, revealed relatively large amplitude antiphased orbital motions for NIV and NV emissions. This was interpreted as indicating that the binary is composed by two WR type stars, one with stronger NIV emission and the other with stronger NV emission, corresponding approximately to component stars of spectral types WN3 and WN4. No orbital motion was found for the absorption lines, which were therefore assumed to arise in a line-of-sight close companion.

Here we re-examine the pre-outburst radial velocity variations in the spectrum of HD 5980, and derive radial velocity curves for selected emission lines observed in the post-outburst spectrum.

2. Observations

The observations upon which this paper is based, consist of photographic spectrograms obtained between 1980 and 1983, and digital spectra obtained between 1985 and 1988, at Cerro Tololo Interamerican Observatory (CTIO), Chile; and digital spectrograms obtained between 1992 and 1996 at the Complejo Astronómico El Leoncito (CASLEO), San Juan, Argentina. The CTIO data were secured with the Cassegrain Image Tube spectrograph attached to the 1-m Yale telescope; and the CASLEO data were obtained with the Cassegrain and REOSC-echelle CCD spectrographs attached to the 2.1-m telescope.

The photographic spectrograms were digitized with a Grant microphotometer at La Plata Observatory. All calibrations and data reductions were performed using IRAF routines.

3. Results and their Discussion

3.1. Pre-outburst orbital motion

Our newly determined radial velocities for the lines in the spectrum of HD 5980 confirm the previous results (Niemela 1988), namely that the NIV 4058Å and NV 4603Å emissions show antiphased variations, and that the absorption lines vary in an apparently random way. An orbital solution based on the radial velocity variations of NIV and NV emissions is listed in Table 1.
Figure 1. Left: Radial Velocity variations of NIV 4058Å (filled circles) and NV 4603Å (open circles) emissions in the spectrum of HD 5980, as function of the orbital phase. The lines represent the orbital solution from Table 1. Right: Radial velocity behaviour of the upper Balmer absorption lines in the 1980-83 spectra of HD 5980. Different symbols correspond to different observing runs.

In Figure 1 we show the radial velocity behaviour of NIV 4058Å and NV 4603Å emissions, and of the upper Balmer hydrogen absorption lines from our digitized photographic spectra. The continuous line in the figure corresponds to the orbital solution from Table 1. The phases in all figures have been calculated with the recent ephemeris by Breysacher & Perrier (1997, these Proceedings).

The fact that NIV and NV emissions present antiphased radial velocity variations with the eclipsing binary period, clearly indicates that both components of the HD 5980 binary system have emission lines typical of WNE type stars in their spectra. However, as already noted by Niemela (1988), the high visual absolute magnitudes and high values of the masses of the binary components, are more alike galactic late type WN stars found in open clusters. The higher ionization seen in the spectrum of HD 5980 may reflect the lower metallicty of the Small Magellanic Cloud.

In Figure 2 we show blue optical spectra of HD 5980, obtained in August 1983, during the orbital phases of eclipses. Note that the spectrum corresponding to the primary eclipse shows stronger NV, and the one corresponding to the secondary eclipse, shows stronger NIV emission.

The orbital elements in Table 1 should be considered only as indicative, since they are based on radial velocities determined for just one faint emission line each, and therefore may be subject to considerable uncertainties.

Remarkably, beginning 1985, the radial velocity variations of the NIV 4058Å emission disappeared. This is illustrated in Figure 3 where we show the radial velocities measured for this emission line between 1985 and 1992. Also the absorption lines seem to have disappeared at about the same time from the spectrum. In 1985 HD 5980 had probably already started to increase its brightness on the way to the 1994 outburst.

In 1992 the spectrum of HD 5980 already exhibited somewhat lower ionization state and NIII 4634-40Å emission appeared. This emission followed the
Figure 2. Spectra of HD 5980 in 1983, August, corresponding to the primary and secondary eclipses.

orbital motion of the star which is in front of the system during the primary eclipse, called component A (Barbá et al. 1996). Therefore this component is considered to be the one which was cooling and brightening, the same that later produced the LBV-type outburst.

3.2. Post-outburst orbital motion

Shortly after the 1994 outburst, the radial velocity variations corresponding to component A reappeared (Barbá et al. 1996). We show in Figure 4 our radial velocity measurements corresponding to NIII 4634-40Å and NIV 4058Å emissions as observed during several observing runs in 1996. Note that now the NIV 4058Å emission shows similar radial velocity behaviour than NIII 4634-40Å in coincidence with the motion of component A. No radial velocity variations of lines corresponding to component B have yet been detected. However, on recent high resolution echelle spectrograms the emission lines seem to show double profiles (cf. Barbá et al. 1997, these Proceedings).

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Figure 3. Radial velocities of NIV 4058Å emission in the 1985-92 spectra of HD 5980 as function of the orbital phase. Different symbols correspond to different observing runs.

Figure 4. Radial velocity variations of NIII 4634-40Å (left) and NIV 4058Å (right) emissions in the 1996 spectra of HD 5980 as function of the orbital phase.

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