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The SARG very high resolution spectrum of P Cygni

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Abstract. We present here the results of a preliminary analysis of the very-high-resolution spectrograms (R=86 000) of P Cyg obtained with the new SARG spectrograph attached to the Italian National Telescope (TNG). A marked change in the Hα profile is noticed with respect to the May 1996 observations of Gäng (2000). We also analyse the effect of the telluric lines on the spectral appearence by comparison with lower-resolution observations, and find that it can simulate weak-line variability.

1. SARG observations of P Cyg

The spectrum of P Cyg was observed the first time on 10th June 2000, during the commissioning time of the high resolution spectrograph (SARG) attached to the Italian Telescopio Nazionale Galileo (TNG) which is sited on La Palma, Canary Islands (Gratton et al. 2000). The resolution was R=86 000 and the useful spectral range 4950–7340 Å; only a S/N of about 60 for the yellow continuum was achieved due to rather poor weather conditions. A new observation was made in July with the same resolution and a S/N of 300 was achieved with a 5

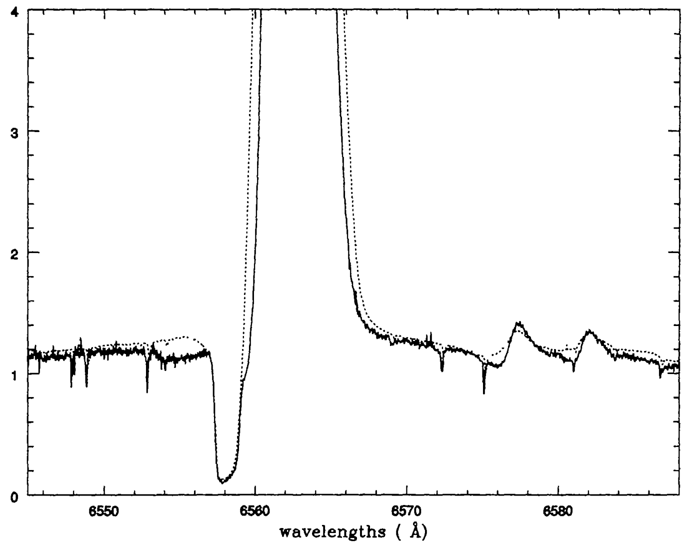

Figure 1. $H\alpha$-profile variation at very high resolution. The June 2000 SARG spectrum (solid line) is compared with that of May 1996 (from Gäng 2000, dotted line).

minute exposure. A complete description of the spectrograph can be found in the web site: `http://www.tng.iac.es/instruments/sarg/sarg.html`.

2. The very high resolution optical spectrum of P Cyg

In Figure 1 we show the high-resolution profile of Hα in June 2000. The P Cygni absorption component reaches zero flux, and has a rather steep edge at its violet side (at -250 km s^{-1}), that is identical to the one observed in the R=100 000 spectra of the star obtained at KPNO on 1996, May 20-22 and reported by Gäng (2000, see also these proceedings).

A marked difference can be detected at the continuum level, where the SARG spectrum shows a kind of 'step' starting at -165 km s^{-1}, and marking the transition between the absorption and emission components. The feature is present with exactly the same profile in two echelle orders. This feature has not been observed previously, but it might be related to the line–splitting features observed in the higher Balmer lines as reported by Kolka (1999). Similar line-profile inhomogeneities have been observed in other LBVs as well, and might be common features not observable at all times because of the strongly-variable conditions in their atmospheres (e.g. Gäng 2000, Ch. 4). This indicates changed atmospheric conditions in P Cyg that could be due to its LBV variablity pattern, as well as to its slightly changing evolutionary status (see Lamers & de Groot 1992). The line shape is also affected by telluric lines which, at lower resolution, may simulate 'wiggles' in the profile. Actually, successive observations made with different zenithal distances and water-vapour contents, might simulate time variability of these features. To our future observations we intend to apply the observing technique of Gäng (2000) to get reference spectra of telluric and interstellar lines, so that the effects of stellar and non–stellar variablility can be

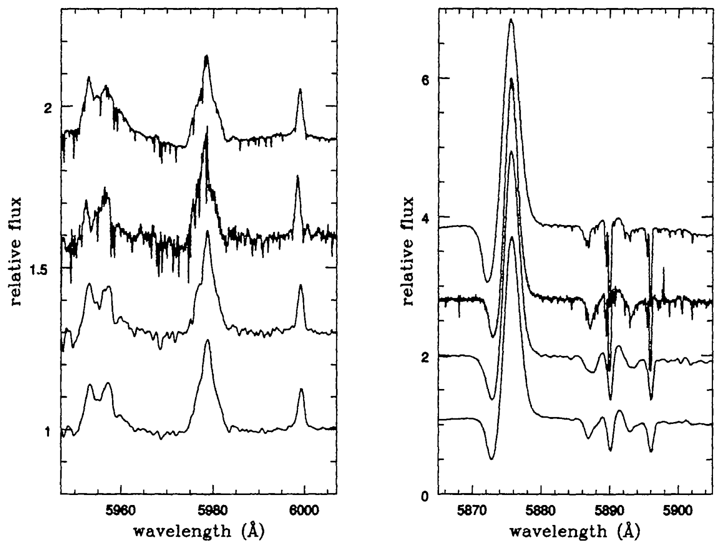

Figure 2. Comparison of spectra of P Cyg at different resolutions. From top to bottom: May 1996: CFT/KPNO; June 2000: SARG/TNG; 1989-1992: Stahl et al. (1993); July 1998: AURELIE/OHP. Left: Fe III and Si II lines near 5930-6010 Å. Right: The He I 5876 Å and Na I D lines.

separated. Future observations will also expand the covered wavelength range to include higher Balmer lines so that the 'step' contribution to the line profiles can be analyzed quantitatively.

The effect of telluric lines on the stellar line profiles is better illustrated in Figures 2 and 3. The left panel of Figure 2 shows P Cyg's spectrum near 5930–6010 Å as it appears at different resolutions: Gäng's observations of 1996, the SARG spectrum, Stahl et al.'s (1993) *Atlas of P Cygni* (R=12 000), and the R=10 000 spectrum taken at OHP with AURELIE in July 1998. It is evident in the figure that many absorption features in the two lower spectrograms are resolved in the upper ones into groups of telluric lines.

In the right panel of Figure 2 we compare the different resolution spectra in the region near the 5876 Å helium line and the sodium D–doublet. Many telluric lines are present longward of the helium line, and their presence makes it difficult to identify and measure the multicomponent structure of the interstellar absorption components of the Na I lines. This is better shown in the top-left panel of Figure 3, which is an expanded view of the high-resolution KPNO and SARG spectra near the Na I lines. The effect of the telluric lines is more dramatic near the He I 7281 Å line (Figure 3, bottom left). The comparison with the SARG spectrum degraded to a resolution of 10 000 illustrates how many *pseudo–absorptions* are coming out when an intermediate resolution is used.

Another fundamental point is the intrinsic variability of the star. Variations in the profiles up to 30% have been reported by Stahl et al. (1993). For the 5876 Å line plotted in Figure 2, we see that, while the position and intensity of the emission component are the same in the two high-resolution spectra, the FWHM are 131 and 111 km s^{-1} in 1996 and 2000, respectively; to detect this

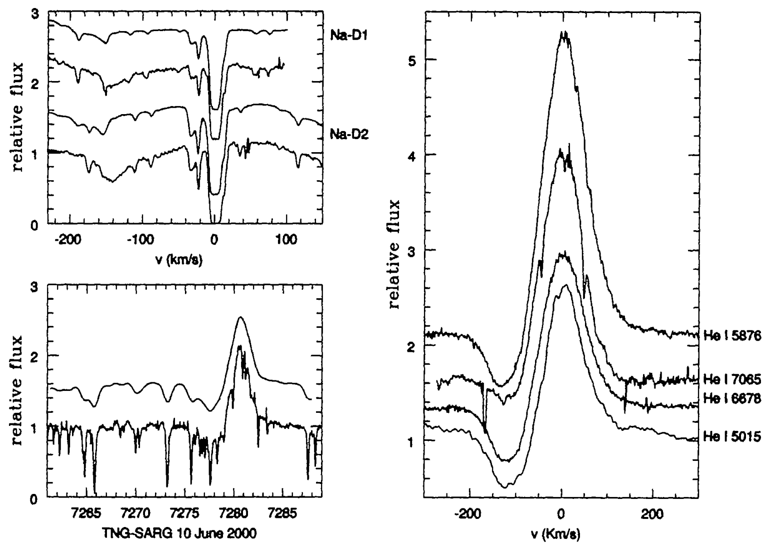

Figure 3. Top left: Expanded velocity plot of the regions near the sodium lines. From top to bottom: Na I λ5896 (D1), KPNO and SARG, Na I λ5890 (D2), KPNO and SARG. Bottom left: The SARG spectrum near the He I λ7281 largely affected by telluric lines. The degraded spectrum as discussed in the text is also shown (upward displaced thin line). Right: SARG velocity profiles of selected He I lines.

difference a resolving power of at least 15 000 is necessary. In addition, one can see that in the SARG spectrum the absorption component is redshifted by about 40 km s^{-1}. Similar variations appear to have occurred in all the helium lines which are common to the two spectra, as one can see by comparing the profiles shown in the right panel of Figure 3, with the 1996 spectrum (see Gäng, these proceedings).

At lower resolution this could have affected the position and intensity of the emission component. These low-excitation lines are of the greatest importance for testing wind models; again, this is an important reason why, at least for the study of line profiles, resolutions larger than ~40 000 are absolutely needed, and an accurate correction for telluric lines is a must.

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