THE PECULIAR SPECTRUM OF THE EXTREME HELIUM STAR BD-9°4395

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ABSTRACT. The spectrum of the extreme helium star BD-9°4395 has already been noted for emission lines of HeI 3889Å and CII 4267Å. Further anomalies in the HeI and CII spectra have been observed, including the identification of additional emission lines, asymmetry in the He I line profiles and variability in all features. It is suggested that these features may be associated with other evidence for non-radial pulsations in BD-9°4395.

1. INTRODUCTION

The extreme helium star BD-9°4395 has an effective temperature of 23 000 K (Drilling et al. 1984) and a surface gravity log g=2.6 (Kaufmann & Schönberner 1977). With helium and carbon abundances n_{He}=0.994, n_C=0.006, it resembles other hot carbon-rich extreme helium stars (e.g. HD124448, BD+10°2179: Heber 1983) and appears to be the remnant of a post-asymptotic giant-branch star evolving to become a white dwarf (Schönberner 1977). Some spectroscopic anomalies, notably emission in CII 4267Å and HeI 3889Å, were reported in early high resolution spectra.

Jeffery et al. (1985) have interpreted multiperiodic photometric and spectroscopic variability in BD-9°4395 as evidence for non-radial pulsations, identifying periods of 3.5 and 11.2 day. They confirmed the presence of variable emisiion lines, interpreting the behaviour of CII 4267Å as evidence for variable mass-loss. Indeed this line was observed on one occasion with a P Cygni profile. A comparison with theoretical subordinate-line profiles in stellar winds (Olson 1981) provided an upper limit of 10^{-7} $M_\odot$ yr^{-1} to the instantaneous mass-loss rate. This is appreciably larger than that obtained from the UV resonance-line profiles by Hamann et al (1981) (10^{-8} $M_\odot$ yr^{-1}). In order to investigate the time-scale of the spectroscopic variability, as well as to examine the behaviour of other HeI and CII lines, new

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high-resolution spectra have been obtained with the Anglo-Australian Telescope. These spectra show several interesting anomalies and suggest a more detailed interpretation is required.

2. OBSERVATIONS

Spectra of BD-9°4395 were obtained in 1985 March at the AAT with the IPCS and the 82cm camera of the RGO spectrograph at reciprocal dispersions of 10, 5 and 2.5 Å mm^{-1}. Repeated observations in the vicinity of CII 4267Å, HeI 3889Å and HeI 4144Å were made, as well as around HeI 5876Å and other strong CII lines. The data were reduced in the manner described by Jeffery et al. (1985).

Comparisons of the line profiles of CII 4267Å and HeI 4121Å/4144Å on several nights are shown in Figs. 1 and 2, which include AAT spectrograms already reported (Jeffery et al. 1985). Whilst CII 4267Å showed a P Cygni profile in 1979 February and was apparently absent in 1979 July and 1980 May, its apparent development from 1985 March 11 to March 13 gives a better idea of the time-scale of the variation. On 1985 March 11 the blue wing of the CII 4267Å line is steeper than the red wing, with a hint of emission, resembling a reverse P Cygni profile. Indeed a pronounced reverse P Cygni profile was observed on an ESO echelle spectrogram (Heber, private communication). On March 12 the blueward emission is replaced by an additional blue-shifted absorption component, and on March 13 CII 4267Å appears to have a nearly normal profile. An unidentified absorption feature with a blue-shift of 350 km s^{-1} may be related to CII 4267Å since it has no counterpart in the 'quiet' spectrum.

The sequence of spectrograms of HeI 4121Å/4144Å (Fig. 2) presents a new dimension to the variations already documented in BD-9°4395. Although the data are of variable quality and resolution, and the three day sequence available for CII 4267Å is absent, we note significant changes in the HeI line profile. In 1979 February, HeI 4121Å and OII 4119Å were fully resolved, but in later years and at higher spectral resolutions these lines have been increasingly blended. The increasing width of HeI 4144Å is documented in table I, but an extended blue wing observed in 1985 March consistent with the blending of HeI 4121Å and OII 4119Å suggests that the line symmetry is also variable.

In the cases of other lines in the spectrum of BD-9°4395, the number of repeated observations is insufficient for detailed comparisons. However two members of CII multiplet 1 appear in emission, while another is in absorption: all may be variable. Since HeI 3888Å is seen in emission HeI 5876Å was also examined. Both lines are often found to be peculiar in Be stars (Underhill 1966). In the one spectrogram available (1985 March 13), HeI 5876Å shows an emission component, but it is not clear whether the line profile is a P Cygni type or a normal atmospheric absorption line with a superimposed emission core.

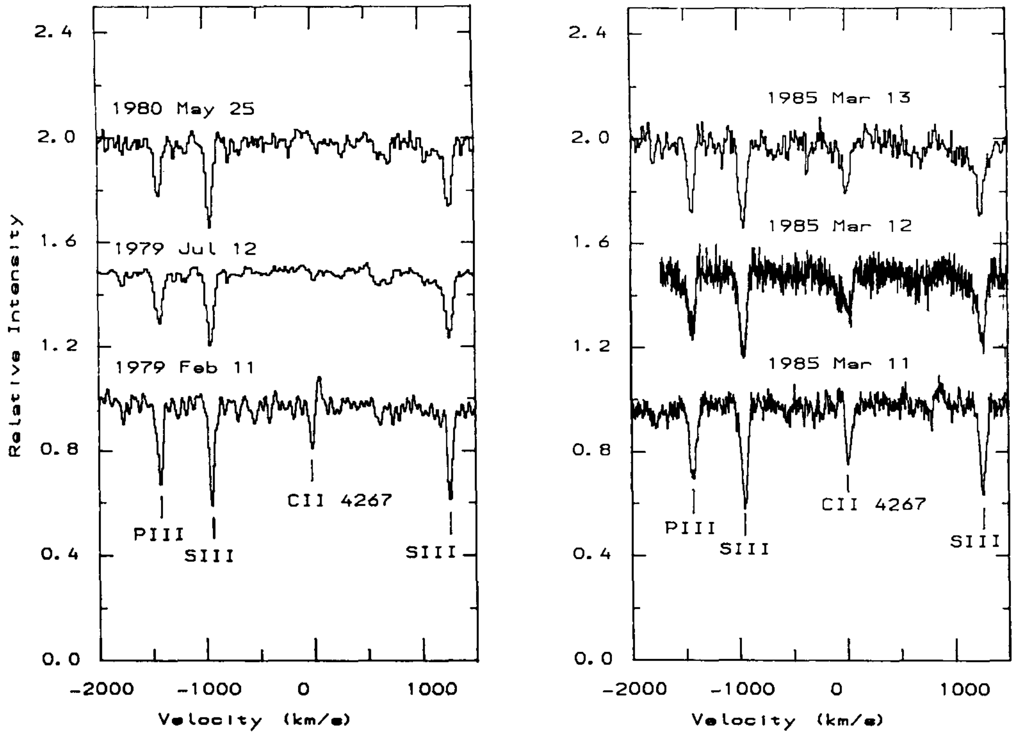

Figure 1. Variations in the line profile of CII 4267Å in BD-9°4395. Spectral dispersions (in Å mm^{-1}) were 8 (1979 Feb), 16 (1979 Jul & 1980 May), 5 (1985 Mar 11), 2.5 (1985 Mar 12) and 10 (1985 Mar 13).

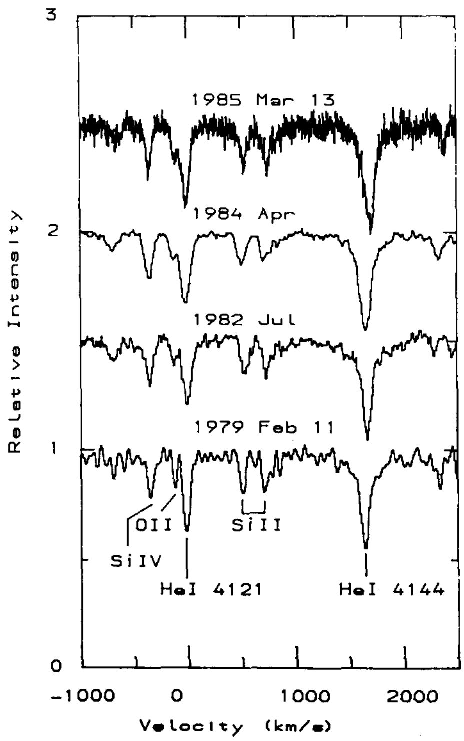

Figure 2. Variations in the line profiles of HeI 4121Å and HeI 4144Å in BD-9°4395. Spectral dispersions (in Å mm^{-1}) were 8 (1979 Feb), 10 (1982 Jul & 1984 Apr) and 2.5 (1985 Mar).

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Table I. Width of HeI 4143Å

Date	FWHM (Å)	W (Å)
1979 February	1.36	0.873
1982 July	1.39	0.853
1984 April	1.76	0.970
1985 March	1.61	0.963

3. DISCUSSION

It has been established that BD-9°4395 has an emission spectrum which is variable on a time-scale of days. The emission spectrum provides ample evidence for the presence of circumstellar material. The time-scale of the variations is comparable with that of the light variations which are believed to arise in non-radial pulsations (Jeffery et al. 1985).

It is necessary to determine whether the circumstellar material takes the form of an envelope as in the classical Be stars, or clouds of C-rich material as in the R CrB stars, or a stellar wind. The emission spectrum shows many properties normally found in Be stars, but the low rotational velocity ($v \sin i < 30$ km s^{-1}) and short period variations of BD-9°4395 appear to preclude this interpretation. A spherically symmetric uniform stellar wind is precluded by the observation of both reversed and normal P Cygni profiles at different times. Feast's (1979) description of the R CrB phenomenon being caused by the ejection of C-rich clouds into the line of sight gives some satisfaction since emission lines could be formed in clumps of circumstellar material with different temperatures and velocities. However the hot R CrB star MV Sgr shows emission lines of H, FeII and CaII (Herbig 1975) which are absent in BD-9°4395. Moreover BD-9°4395 shows no infra-red excess (Walker 1985) characteristic of the R CrB stars.

It is proposed that the emission spectrum in BD-9°4395 is related to g-mode non-radial pulsations. Amongst the extreme helium stars and like the emission spectrum, these have so far only been observed in BD-9°4395. It has been known for some time that moving shells are seen in the radial β Cephei pulsators (Smith 1983). Typically an optically thick shell appears with a radial velocity of some 30 to 50 km s^{-1} which decelerates, becoming transparent as it moves out to some 25% of the stellar radius. It eventually returns, but some 1% of the shell may be lost to the star (Burger et al. 1982). Penrod & Smith (1984) suggest that similar phenomena occur in nearly all B stars as a result of non-radial pulsations. Some evidence to support this theory exists in the cases of ρ Leo (Smith & Ebbetts 1981) and λ Eri (Penrod & Smith 1984).

This conjecture must be tested with a more homogeneous set of high resolution spectra whilst the behaviour of CII 4267Å must be related to UV observations of the stellar wind.

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