UV- AND VISUAL SPECTROSCOPY OF NINE EXTREMELY HELIUM RICH SUBLUMINOUS-O-STARS

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ABSTRACT. Nine helium rich sdO stars are found to show no trace of hydrogen on high resolution visual spectra. Effective temperatures derived from UV fluxes range from 42500 K to 80000 K. A dichotomy with respect to the C/N ratio is found which is reminiscent of the OBN and OBC stars near the main sequence. It is estimated that about 20% of the sdO stars are extremely helium rich. This fraction compares nicely with those of the (helium rich) DB white dwarfs (20%) and the helium rich central stars of planetary nebulae (less than 35%).

1. INTRODUCTION

Hydrogen deficiency is an outstanding feature of most of the sdO stars. Previous spectroscopic analyses revealed that the helium to hydrogen ratio (by number) is typically close to unity (see Hunger et al., 1981). However, a few sdO stars are known which are extremely hydrogen deficient and do not show any trace of hydrogen in their spectra.

The sdO stars are immediate progenitors of the white dwarfs. Since about 20% of the white dwarfs are also helium rich (spectral type DB), it would be interesting to compare the properties of these two groups of stars.

Presented here are ultraviolet and visual spectra obtained with the IUE Satellite and the ESO Cassegrain Echelle spectrograph (CASPEC). We concentrated on low galactic latitude sdO's (listed in Table I), mainly from the complete and homogenous survey of Drilling (1983).

2.OBSERVATIONS

High resolution visual spectra of nine helium rich sdO stars have been obtained at La Silla using the ESO-CASPEC attached to the 3.6m telescope. These spectra covered the spectral range from 3900 Å to 4800 Å and were reduced as described by Heber, Jonas and Drilling (these proceedings). A spectral resolution of 0.25Å was achieved.

K. Hunger et al. (eds.), Hydrogen Deficient Stars and Related Objects, 345–349.

Table I. V-magnitudes and galactic coordinates of the programmme stars

star	V	l^{II}	b^{II}	reference
LS IV+10°009	11.99	56	-19	Drilling (1983)
UV 0904-02	11.5	227	21	Berger and Fringant (1981)
UV 0832-01	12.0	232	28	Berger and Fringant (1981)
CPD-31°1701	10.54	246	-5	Garrison and Hiltner (1973)
LSS 1274	12.4	277	-5	this paper
LSE 153	11.35	314	15	Drilling (1983)
JL 9	13.37	323	-27	this paper
LSE 259	12.6	332	-8	Drilling (1983)
LSE 263	11.8	345	-23	Drilling (1983)

Most of the programme stars have been observed with the IUE satellite in the low and high resolution mode.

3. EFFECTIVE TEMPERATURES AND INTERSTELLAR REDDENING

Absolutely calibrated IUE low resolution spectra are well suited to derive effective temperatures of hot stars since the main flux is carried in the UV. For the large temperatures in question, however, the flux maxima shift towards unobservably small wavelengths and the IUE fluxes become less sensitive to T_{eff}. Moreover, since the programme stars lie at low galactic latitudes, interstellar extinction is non-negligible. The "UV-colour index" R, which is defined as the ratio of the integrated SWP fluxes to the integrated LWR fluxes has been calibrated empirically in terms of $T_{eff}(R)$ for hot subdwarfs (Schönberner and Drilling, 1984). R is shown to be almost insensitive to interstellar reddening. Schönberner and Drilling (1984) derived effective temperatures of twelve hot subdwarfs ($T_{eff} > 60000$ K) using their $T_{eff}(R)$ calibration. Subsequently, NLTE analyses of visual high resolution spectra for some of these sdO stars have been carried out (Husfeld et al., these proceedings and unpublished work by the authors). These spectroscopic results agreed within 27% with the UV-effective temperatures, in the worst case. Therefore, the R index allows the effective temperatures of our programme stars to be determined to an accuracy of some 20%. Since four programme stars have already been analyzed by means of NLTE analyses (CPD-31°1701, Giddings, 1980; LSE 153, LSE 259 and LSE 263, Husfeld et al., these proceedings), we can use these (completely independent) results to recalibrate R in terms of T_{eff} for extremely helium rich sdOs. (LSE 259 was neglected in the calibration since it is known to show P-Cygni profiles produced by a stellar wind, which affects the R index.) The resulting effective temperatures are given in Table II. According to their R indices, JL 9 is the hottest and CPD-31°1701 is the coolest star in our sample, while four stars have nearly identical T_{eff}s of some 50000 K. Interstellar reddening is determined by removing the λ 2200 Å bump.

TABLE II. R indices, effective temperatures and interstelar reddening

star	R	T_{eff}	E(B-V)
CPD-31°1701	2.40	42500[a]	0.00
LS IV+10°009	2.52	50000	0.07
LSS 1274	2.55	52000	0.15
UV 0832-01	2.55	52000	0.02
UV 0904-02	2.63	59000	0.02
LSE 263	2.66	70000[b]	0.10
LSE 153	2.85	70000[b]	0.09
JL 9	2.88	80000	0.07

[a] NLTE analysis, Giddings (1980)
[b] NLTE analysis, Husfeld et al., these proceedings

4. THE HELIUM LINE SPECTRUM

The CASPEC spectra are dominated by strong Stark broadened He II lines. Hydrogen is not detected, since the He II line profiles in question (λ 4340 Å and λ 4100 Å) do not show any distortion by corresponding hydrogen Balmer lines. Pronounced He I line spectra are present in five stars (CPD-31°1701, LSS 1274, LS IV+10°009, UV 0832-01, UV 0904-02), the He I lines being strongest for CPD-31°1701 and weakest for UV0904-02 among these five stars. Since the He I line strength is expected to decrease with increasing T_{eff}, this confirms the temperature sequence derived from the UV fluxes (see Table II).

For the hotter stars, He I lines are either very weak (only He I, λ 4471 Å is detected in LSE 153 and LSE 263, $W_{\lambda} \approx$ 100mÅ) or absent (LSE 259 and JL 9) which confirms the high effective temperatures deduced from the UV measurements.

5. CARBON AND NITROGEN LINE SPECTRA

The C/N ratios can give important clues as to the origin of the hydrogen deficiency. The "cool" stars ($T_{eff} \leq$ 60000 K) display C III, C IV, N III and N IV lines while the hotter stars display only the higher ionized species C IV, N IV and N V.

5.1 The "cool" stars

LS IV+10°009, LSS 1274, UV 0832-01 and UV 0904-02 show strong carbon and nitrogen line spectra, whereas CPD-31°1701 is carbon weak lined. This can be seen from Figure 1 where the spectrum of UV 0832-01 is compared to that of CPD-31°1701. The most striking difference to be noted is the strength of C III and C IV lines which are strong in the former but weak or even absent in the latter. This difference becomes even more apparent when we compare the C IV resonance lines in the UV (see Figure 2).

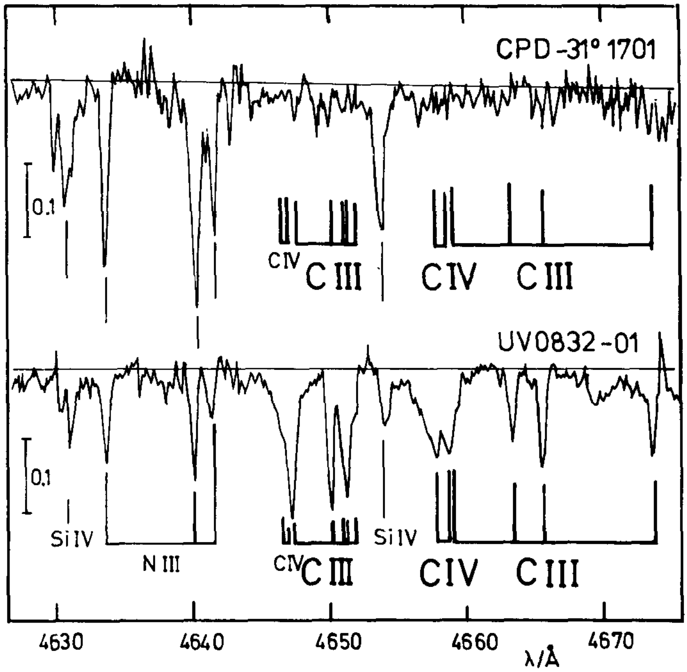

Figure 1: Comparison of the CASPEC spectra of CPD-31°1701 (top) and UV 0832-01 (bottom). 10% continuum height is marked by a vertical bar.

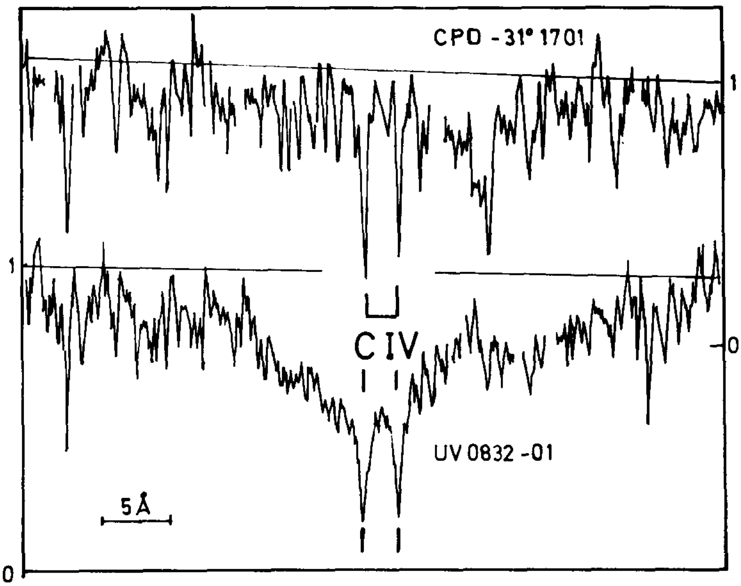

Figure 2: Comparison of C IV resonance lines of CPD-31°1701 (top) and UV 0832-01 (bottom).

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5.2. The hotter stars

Nitrogen lines are present in the hotter stars in similar strength. As in the case of the "cool" stars, the carbon line spectra vary considerably. LSE 153 and LSE 259 are carbon strong lined while LSE 263 and JL 9 are carbon weak lined.

5.3. The C/N dichotomy

In conclusion, the high resolution spectra reveal strong evidence for a dichotomy of the group of extremely helium rich sdO stars with respect to the C/N ratio. Six of our programme stars have large C/N ratios while the other three must have much smaller C/N. This is reminiscent of the chemically peculiar OB stars near the main sequence (OBN and OBC stars).

Among the "cool" stars, the well known Garrison and Hiltner star CPD-31°1701 (the brightest star in our sample) is the only carbon weak lined star and, therefore, is probably not an archetypal extremely helium rich sdO but appears to be an exceptional case.

6. FREQUENCY OF HELIUM RICH SDO STARS

The sdO stars as well as the central stars of planetary nebulae (CPN) are immediate progenitors of the white dwarfs. About one fifth of the white dwarfs are helium rich (Liebert, these proceedings). Among the CPNs, less than 35% are helium rich (Méndez et al., these proceedings). It would, therefore, be interesting to know what fraction of the sdO stars is extremely helium rich. Two complete and homogeneous surveys have been studied in order to answer this question:
(i) The Slettebak-Brundage (1971) survey at the south galactic pole contains five sdOs out of which only one is extremely helium rich (Heber, 1986).
(ii) The Drilling (1983) survey at low galactic latitudes contains twelve sdOs out of which three stars are extremely helium rich.
Since there is no obvious bias against the extremely helium rich subdwarfs, we conclude that extreme hydrogen deficiency occurs as frequently among subluminous O stars as among the white dwarfs and the CPNs.

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DISCUSSION

LYNAS-GRAY: Did you use the standard Kudritzki's non-LTE code or did you include CNO levels following Husfeld et al.?

HEBER: I did not use any model atmospheres analysis here.

LYNAS-GRAY: You must have used some menas for the temperature analysis.

HEBER: The temperature determinations are purely empirical. We calibrated the R-indes in terms of T_{eff} by using CPD -31°1701 and LSE 153/LSE 263 as calibration standards. These stars have been analyzed from line profiles by means of NLTE model atmosphere techniques (Giddings, 1980, Husfeld, 1985).