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IUE observations of high galactic latitude F supergiants HD 161796 and HD 187885

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Summary. Low resolution (6 Å) IUE ultraviolet spectra of the high galactic latitude F supergiants HD 161796 (F3 Ib) and HD 187885 (F2–3I) are analysed. The UV spectrum (1250 Å to 3250 Å) of HD 161796 shows no excess UV flux attributable to a hot degenerate companion. From the UV spectrum the temperature is found to be 6300 K. There is no evidence for significant metal deficiency. Except for the N IV] 1487 Å line the rest of the transition region emission lines are weak. In spite of the large IR (IRAS) excess the 2200 Å region shows no evidence for circumstellar reddening.

The UV spectrum (1250 Å to 1900 Å) of HD 187885 is peculiar. A broad emission feature with emission peak centered around 1580 Å is present. A broad absorption feature nearly 100 Å wide centered around 1657 Å appears to be present. This absorption feature may be due to C I or due to quasimolecular absorption of the H_2.

Key words: planetary general – stars: abundances – supergiant – UV radiation

1. Introduction

HD 161796 and HD 187885 are high galactic latitude F supergiants which were found to show strong far-infrared (IRAS) excesses due to large amounts of dust around them (Parthasarathy and Pottasch, 1986; Pottasch and Parthasarathy, 1988). The masses and sizes of the dust envelopes around HD 161796 and HD 187885 suggests that these stars suffered extensive mass loss. If the ratio of gas to dust mass is about 100, as it is in the interstellar medium, the total shell masses are of the order of $0.3\,M_{\odot}$. This is very similar to that found in planetary nebulae (Pottasch et al., 1984). However, the most striking is the higher luminosity of the F supergiants by about 1 or 2 orders of magnitude compared to planetary nebulae. These stars are very far from any star-forming regions and are definitely at very large distances above the galactic plane. For HD 161796 Abt (1960) found the s-process elements to be underabundant, similar to that of population II stars. These results suggest that the high galactic latitude F supergiants originated from low mass population II stars and suffered extensive mass loss and are now in high luminosity AGB or post-AGB phase of evolution. It is likely that these objects are a small part of hitherto unseen phase of stellar evolution. Lamers et al. (1986) and recently Waelkens et al. (1987) also found the high galactic latitude A supergiants HR 4049 and HD 213985 to have far-infrared (IRAS) excess due to dust shells around these stars. The evolutionary stage of these two stars also appear to be similar to that of HD 161796.

The far-infrared flux emitted by the dust shells around HD 161796 and HD 187885 is nearly or slightly more than equal to the flux emitted in the blue visual region by these stars. The dust must absorb the optical radiation of the F supergiants and re-emit it in the far-IR region. There is no noticeable reddening for HD 161796 (Humphreys and Ney, 1974; Parthasarathy and Pottasch, 1986). The size of the dust particles in the dust shells of HD 161796 and HD 187885 appears to be larger than 3 μm.

We have observed HD 161796 and HD 187885 with the International Ultraviolet Explorer (IUE) to study the UV spectra of these stars. In this paper we report an analysis of the IUE low resolution (6 Å) spectra of HD 161796 and HD 187885.

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2. Observations

We obtained short-wavelength (1150 Å < λ < 2000 Å) and long-wavelength (1900 Å < λ < 3200 Å) low-resolution (6 Å) spectra of HD 161796 and HD 187885 (only short wavelength spectrum) with the IUE satellite. Details of the IUE spectra are given in Table 1. The spectra are well exposed and have high signal to noise ratio.

3. Analysis

3.1. *HD 161796*

The short wavelength (1150 Å < λ < 2000 Å) spectrum of HD 161796 is shown in Fig. 1. For A and F stars the most important spectral class criterion in the UV is the slope of the continuum towards shorter wavelengths. The features that are also spectral type dependent are $\lambda\lambda$ 1850, 1933, 2670, 2755, 2800 Mg II and 2852 Mg I. The λ1850 feature which is mostly due to Fe II, Fe III, Cr II, and Al II is also sensitive to luminosity. From a

Table 1. IUE observations

Star HD	V	Sp	Camera image No.	Exposure start time (UT)	Exposure time (min)
161796	7.04	F3 Ib	SWP 29556	1986 Oct 30.5791	200
			LWP 9442	1986 Oct 30.5689	8
			LWP 9443	1986 Oct 30.6844	7
			LWP 9444	1986 Oct 30.7373	32
187885	8.56	F2–3 I	SWP 29557	1986 Oct 30.7835	120

comparison of the SWP and LWP spectrum of HD 161796 with the spectra of standard stars given in IUE low dispersion spectra reference atlas (Heck et al., 1984; Wu et al., 1983) we find that the spectral type and luminosity class to be F2–3I which is in very good agreement with that determined by Bidelman (1951) and Fernie and Garrison (1984). The spectral features sensitive to temperature, luminosity and chemical composition in the UV spectra of A and F stars are discussed by Böhm-Vitense (1982) and Böhm-Vitense and Proffitt (1984). The discontinuity at 1700 Å due to Si I is strongly temperature dependent. The discontinuity at 2600 Å is mostly due to an absorption edge of Mg I and Fe. It is sensitive to Mg + Fe abundance and is also temperature dependent. In Fig. 2 we show the theoretical flux ratios $\log[f_\lambda(2662\,\text{Å})/f_\lambda(2537\,\text{Å})]$ from the models of Kurucz (1979). This ratio is a measure of the 2600 Å discontinuity and is shown in Fig. 2 as a function of surface gravity $\log g$ for $T_{\text{eff}} = 6000$ K and 6500 K and [Fe/H] = 0.0, −1.0, and −2.0. Kurucz (1979) models do not extend for F supergiants with $\log g < 2$. The observed flux ratio $\log[f_\lambda(2662\,\text{Å}/f_\lambda(2537\,\text{Å})] = 0.44$ is close to the theoretical flux ratio derived from the model atmosphere $T_{\text{eff}} = 6500$ K, $\log g = 1$ and [Fe/H] = 0.0. The observed and theoretical flux distributions from 1250 Å to 3200 Å are shown in Fig. 3. The flux ratio $\log[f_\lambda(5500\,\text{Å})/f_\lambda(1900\,\text{Å})]$ is sensitive to temperature. The calibration of Böhm-Vitense (1982) yields a temperature of 6300 K which is in good agreement with the value determined by Fernie and Garrison (1984). The 2400 Å absorption feature is also a indicator of Fe abundance. Our analysis suggests that HD 161796 is not significantly metal poor. Metal deficiency of

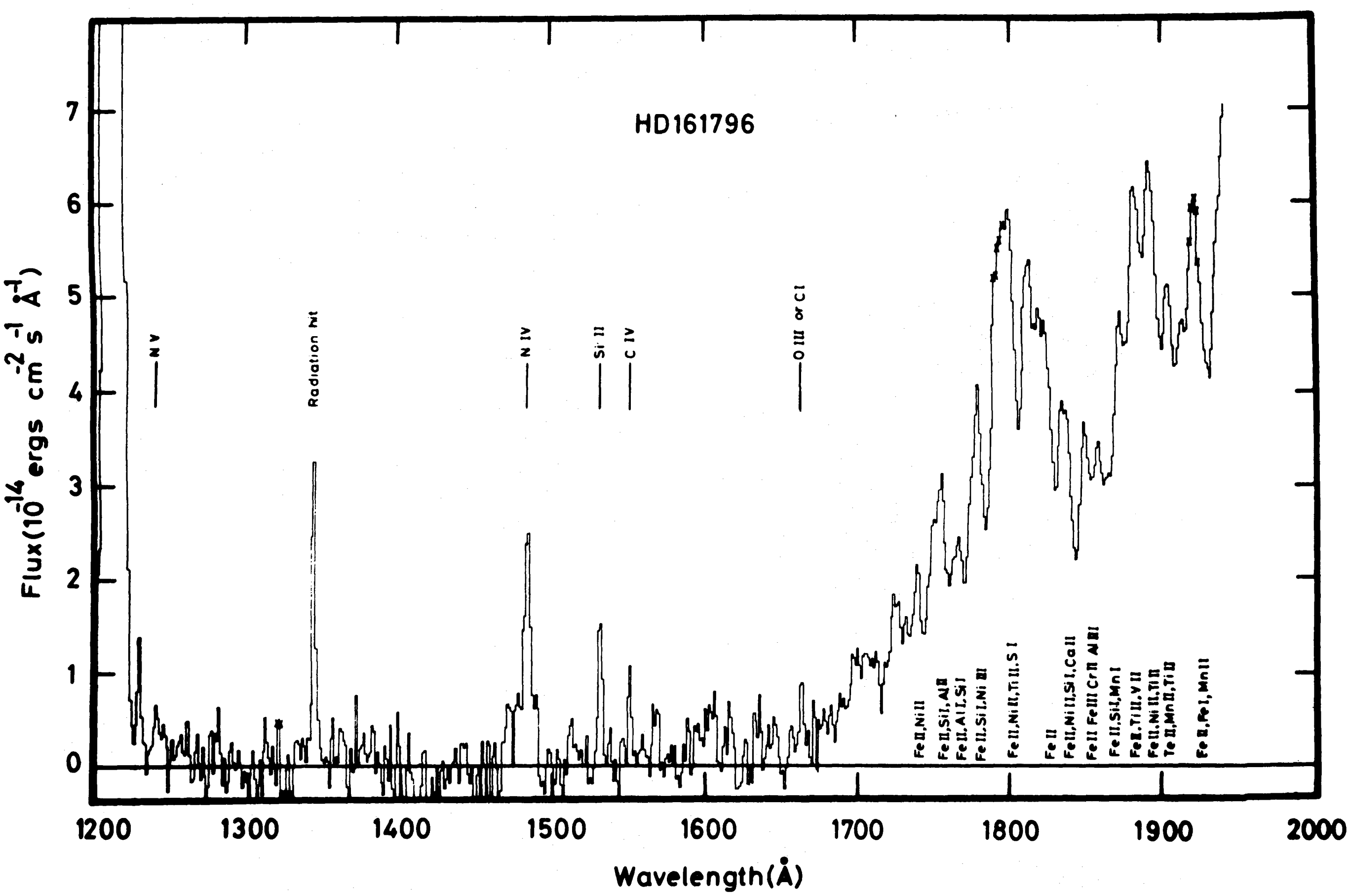

Fig. 1. IUE short-wavelength low resolution (6 Å) spectrum of HD 161796. (X: Reseau)

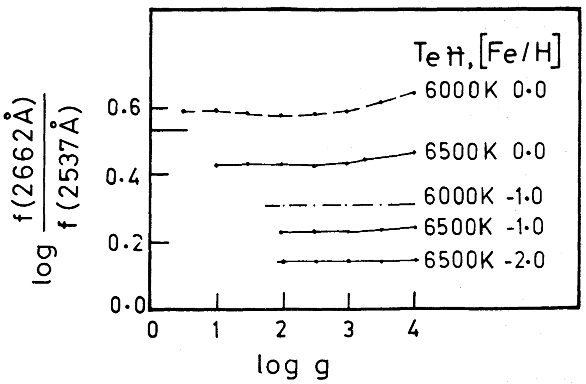

Fig. 2. The theoretical ratio of the fluxes at 2662 Å and 2537 Å is shown as a function of the surface gravity log g for different $T_{\rm eff}$ and [Fe/H]. The observed flux ratio is marked on the Y-axis

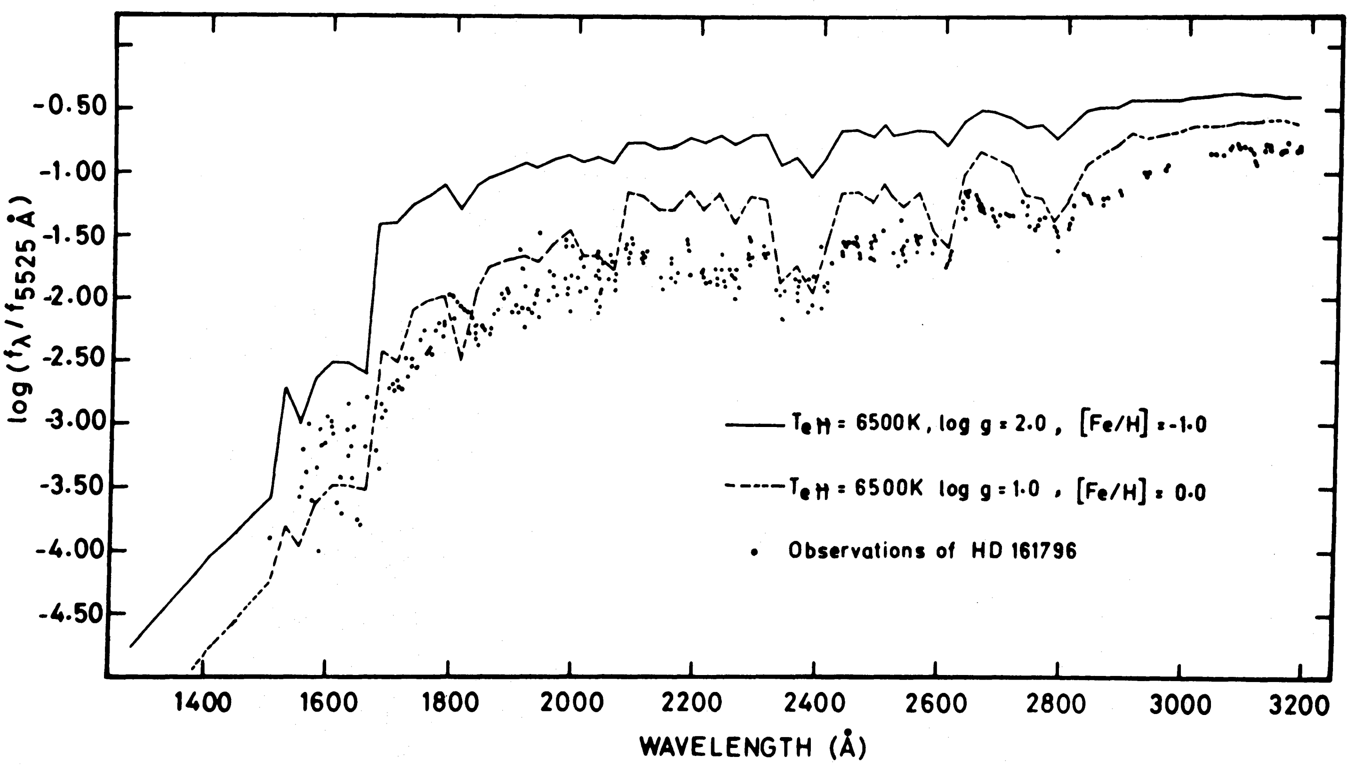

Fig. 3. Observed energy distribution log $[f_\lambda/f_\lambda(5525\,\text{Å})]$ for HD 161796. For comparison energy distributions from the model atmospheres of Kurucz are shown

[Fe/H] = −0.3 cannot be ruled out; which is in agreement with the [Fe/H] value derived by Abt (1960), Fernie (1986) and Bond and Luck (1987). We carried out similar analysis of the low resolution (6 Å) IUE spectra of 89 Her (SWP 15555 and LWR 12038, Ref. Wu et al., 1983) and find no evidence for significant metal deficiency. Metal deficiency of the order of [Fe/H] = −0.3 is possible.

The flux distribution of HD 161796 shows no interstellar or circumstellar reddening (Humphreys and Ney, 1974; Parthasarathy and Pottasch, 1986). The 2200 Å absorption feature in the LWP spectrum of HD 161796 shows no evidence for interstellar or circumstellar reddening. The flux distribution in the 2200 Å region is in reasonable agreement with the theoretical fluxes (Kurucz, 1979) for $T_{\rm eff} = 6300$ K; [Fe/H] = −0.3. The flux distribution of HD 161796 from 1600 Å to 3 μm shows no evidence for circumstellar reddening. This result suggest that the dust shell around HD 161796 has neutral extinction properties and the size of the dust particles may be of the order of 3 μm.

The SWP spectrum of HD 161796 shows few emission lines due to N V, N IV], Si II, C IV. Except N IV] line at 1487 Å the rest of the transition region lines are very weak. In early F supergiants the transition region lines are very weak or absent. The strength of the N IV] line (Fig. 1) and the large flux ratio of N IV/C IV = 3.6 suggests an overabundance of N in the atmosphere of HD 161796. However from N IV] 1487 Å line alone one cannot conclude an overabundance of nitrogen in HD 161796. The flux of the N IV semiforbidden line depends sensitively on the density. However from photospheric absorption lines Bond and Luck (1987) find

[C/Fe] = +0.0; [N/Fe] = +0.8 and [O/Fe] = +0.6. The CNO abundances clearly suggests the presence of hydrogen – burning products on the surface of HD 161796.

3.2. *HD 187885*

In the HD catalogue the spectral type of HD 187885 is given as F8. In Fig. 4 we show a 3 Å resolution 3500 Å to 7400 Å Reticon spectrum of HD 187885 obtained by Dr. Menzies with the Reticon spectrograph on the 1.9 m reflector at Sutherland. From a comparison of the spectrum of HD 187885 (Fig. 4) with "An atlas of low-dispersion grating stellar spectra" (Abt et al., 1968), with an "Atlas of representative stellar spectra" (Yamashita et al., 1977) and with the Library of stellar spectra (Jacoby et al., 1984) we estimate the spectral type to be F2–3I. The steep Balmer discontinuity also suggests the luminosity class to be I.

The Hα line is rather peculiar and appears to have an emission in the wings or it may be partially filled in by emission. The Hα profile of HD 187885 may be similar to that of HD 161796 (Arellano Ferro, 1985). The strength of the G-band in the spectrum of HD 187885 is relatively stronger probably due to an overabundance of carbon.

In Fig. 5 we show the SWP spectrum of HD 187885. The spectrum is rather peculiar. In the spectra of F supergiants the flux in the wavelength region $\lambda < 1700$ Å is very low and the flux ratio $f_\lambda(1800\,\text{Å})/f_\lambda(1700\,\text{Å})$ is of the order of 6. However this flux ratio in the spectrum of HD 187885 is equal to 2. From the IUE FES data we estimate the visual magnitude $V = 8\overset{m}{.}56$. In the HD catalogue the V magnitude is given as $9\overset{m}{.}0$. The difference in brightness suggests that HD 187885 may be variable similar to other high galactic latitude F supergiants.

The interstellar reddening in the direction of HD 187885 is estimated to be $E(B-V) = 0.1$ (Pottasch and Parthasarathy, 1987). The UV fluxes of HD 187885 are corrected for reddening using the Seaton's (1979) UV extinction curve. The integrated flux from 1400 Å–1900 Å is found to be 3.74 10^{-11} erg cm^{-2} s^{-1}, which is in reasonable agreement with that expected from an early F supergiant. In late A and early F stars the flux in the wavelength region $\lambda < 1700$ Å is very low. The fluxes from the model atmospheres of Kurucz (1979) also show similar result. However the UV spectrum of HD 187885 (Fig. 5) shows significant flux in the wavelength region 1400 Å–1700 Å. The flux ratio log $[F_\lambda(1900\,\text{Å})/F_\lambda(1420\,\text{Å})]$ using the calibration of Böhm-Vitense (1982) suggests a temperature of 8500 K. Further observations in the ultraviolet (1900 Å < λ < 3200 Å), blue, visual, and near-IR regions of the spectrum are needed to study the energy distribution. The UV spectrum of HD 187885 is peculiar because of the broad absorption feature around 1657 Å and also because of the low value of the flux ratio $f_\lambda(1800\,\text{Å})/f_\lambda(1700\,\text{Å})$. The broad absorption centered around 1657 Å is 100 Å wide and shows violet edge at 1580 Å. The flux at 1580 Å (Fig. 5) cannot be explained as due to [Ne v] which is observed in the UV spectra of high excitation planetary nebulae. There are only two possible weak emission lines (1487 Å, N iv] and 1453 Å, unidentified) in the UV spectrum of HD 187885 (Fig. 5). If the broad absorption feature at 1657 Å is due to the violet shifted stellar wind profile of the resonance line of Al ii then the edge velocity is of the order of 16000 km s^{-1}. However there are no other violet shifted absorption

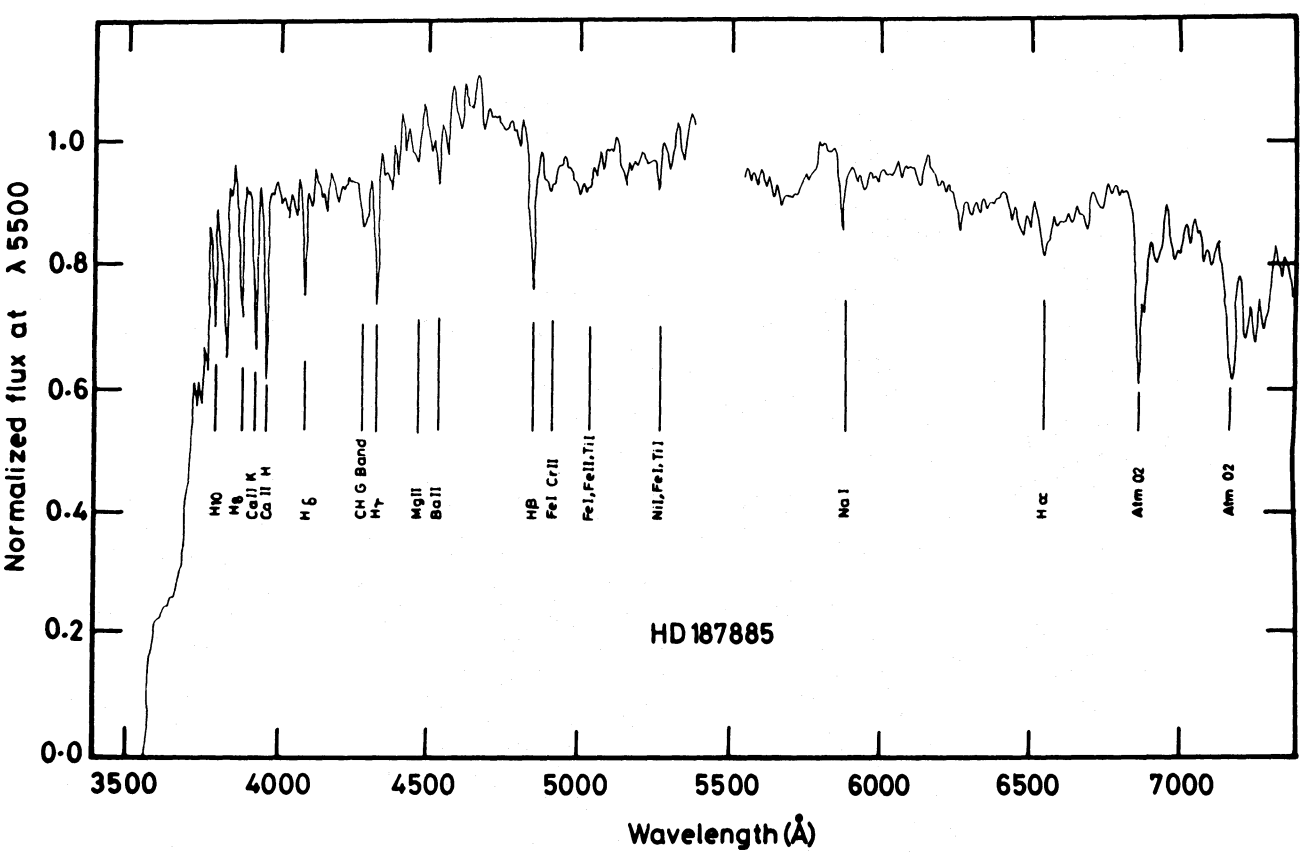

Fig. 4. Low resolution (3 Å) Reticon Spectrum of HD 187885

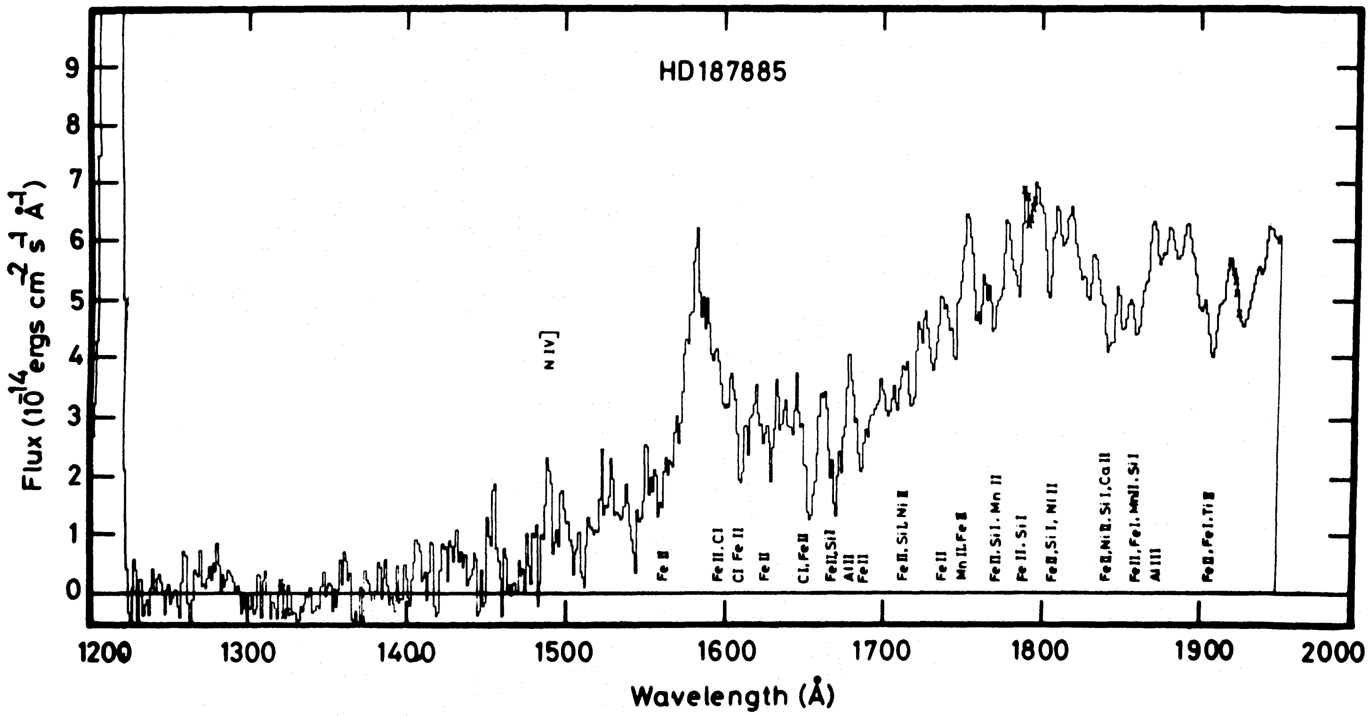

Fig. 5. IUE short-wavelength low resolution (6 Å) spectrum of HD 187885. (X: Reseau)

lines and the emission lines are very weak or absent therefore the broad absorption feature at 1657 Å may not be explained as due to the violet shifted stellar wind profile of the resonance line of Al II. A broad absorption feature centered around 1600 Å has also been observed in λ Boo stars (Baschek et al., 1984) in field horizontal branch stars (Jaschek et al., 1985) and in cool DA white dwarfs (Nelan and Wegner, 1985 and references therein; Koester et al., 1985). In λ Boo stars the 1657 Å feature is due to C I and 1600 Å absorption feature is about 80 Å wide and not resolved into lines in the high resolution spectra (Baschek et al., 1984). Wegner (1984) suggested that the 1600 Å feature is due to an edge like appearance of a strong flux drop below 1600 Å which he observed in the IUE spectra of two cool DA white dwarfs. However Koester et al. (1985) and Nelan and Wegner (1985) explained the 1600 Å absorption feature in cool DA white dwarfs as due to quasimolecular absorption of the H_2. However the center of the broad absorption feature in HD 187885 is not at 1600 Å. Instead, at 1580 Å we find a strong emission peak (Fig. 5). The low value of the flux ratio $f_\lambda(1800\,\text{Å})/f_\lambda(1700\,\text{Å})$ appears to be due to an additional broad absorption in the 1800–1900 Å region. The strength of the absorption lines in the 1850 Å region is low compared to normal late A and early F supergiants. These features and the strong emission peak at 1580 Å makes the UV spectrum of HD 187885 very peculiar. Comparison with the UV spectra of λ Boo stars, field horizontal branch stars, cool DA white dwarfs and normal A–F stars has not yielded satisfactory explanation. The strong and broad (1560 Å to 1610 Å) emission at 1580 Å may be due to Si I lines. There is a crowding of Si I lines in this wavelength region (Kelly and Palumbo, 1973). These lines can be in emission if for some reason, the temperature at the surface would not drop as steeply as in normal A and F supergiants or there is an outward increase of temperature. This also makes the discontinuity at 1700 Å due to Si I less steep which seems to explain the observed discontinuity at 1700 Å (not so steep, Fig. 5). If we can obtain high resolution ultraviolet spectrum of HD 187885, we may be able to find a satisfactory explanation for the observed spectral peculiarities.

4. Conclusions

The ultraviolet spectrum of HD 161796 (Fig. 1) is consistent with it being a F 3 I star. There is no excess UV flux attributable to a hot degenerate companion. The discontinuity at 1700 Å due to Si I and the flux ratio log $[f_\lambda(5500\,\text{Å})/f_\lambda(1900\,\text{Å})]$ using the calibration of Böhm-Vitense (1982) yields a temperature of 6300 K for HD 161796, which is in good agreement with the value determined by Fernie and Garrison (1984). From a similar analysis of IUE low resolution (6 Å) ultraviolet spectra of 89 Her we find its temperature to be 6250 K. Humphreys and Ney (1974) suggested that 89 Her is a binary system. Our results suggest that high galactic latitude F supergiants are not binary systems. The UV spectra of HD 161796 and 89 Her when compared with the fluxes from the model atmospheres of Kurucz (1979) suggests that these two stars are not very metal poor. To make them metal poor $[(\text{Fe/H})] = -1.0$) the effective temperature has to be lowered to 5500 K. There is no evidence for significant metal deficiency. Metal deficiency of $[\text{Fe/H}] = -0.3$ cannot be ruled out. Fernie (1986) and Bond and Luck (1987) also find that HD 161796 and 89 Her are moderately metal deficient ($[\text{Fe/H}] = -0.3$) which is in agreement with the Fe peak abundance derived by Abt (1960).

The 2200 Å absorption feature in the spectrum of HD 161796 shows no evidence for circumstellar or interstellar reddening. HD 161796 shows no reddening from 1600 Å to 3.5 μm which suggests that grain size in the dust shell around the star is relatively larger. Joshi et al. (1987) from polarimetric observations also suggest for the presence of relatively large dust grains.

The blue visual region spectrum of HD 187885 (Fig. 4) suggests that it is a F2–3 I star. However the 1250 Å to 1900 Å low resolution (6 Å) spectrum of HD 187885 (Fig. 5) is very peculiar. High resolution ultraviolet spectra may provide answers to the observed peculiarities.

The size and mass of the dust shells (Parthasarathy and Pottasch, 1986), detection of CO $J = 1 \rightarrow 0$ emission (Likkel et al., 1987) and overabundance of N (Bond and Luck, 1987) clearly suggests that HD 161796 and related stars are evolved population II stars which are now in the luminous post-AGB stage of evolution.

For HD 161796 Fernie and Garrison (1984) derived the logarithmic surface gravity $\log g = 0.1 \pm 0.5$. The spectrum and the steep Balmer decrement of HD 187885 suggests the surface gravity $\log g < 1.0$. We found several more stars which appear to be similar to HD 161796 (Pottasch and Parthasarathy, 1987). In order to do detailed abundance analysis and to compare the observed spectra and fluxes with the theoretical spectra and fluxes we need a grid of model atmospheres with surface gravity $\log g = 0$ and $T_{\rm eff} = 6000$ K to 7500 K. Such models are not yet available.

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