H-ALPHA EMISSION IN HOT DEGENERATES AND OB SUBDWARFS

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Based on observations obtained using the 60-inch telescope at Palomar Observatory which is jointly owned by the California Institute of Technology and the Carnegie Institution of Washington and on observations obtained with the 200-inch Hale telescope which is owned by the California Institute of Technology.

1. *Introduction*

The intial observations of white dwarf stars and their immediate precursors, the hot subdwarfs, suggested that these stars possess the simplest (and, aesthetically, the most pleasing) spectra of any astronomical object. The high gravity leads to the spectrum being dominated, in the most stars, by broad lines of either hydrogen or helium, depending on the composition of the photospheric layers, with a few stars exhibiting lines from both species. However, the more detailed observations of recent years have revealed a higher degree of complexity. In particular, absorption lines of high excitation species (N V, C IV, etc.) have been detected in the ultraviolet spectra of several hot white dwarfs (Bruhweiler & Kondo, 1982) and, most recently, high resolution optical spectra have shown that one of the latter stars, the hottest known DA, G191-B2B, exhibits significant emission in the core of the H-alpha absorption line (Reid & Wegner, 1988). Following up the latter observation, we have obtained high resolution spectra of a number of hot subdwarfs, with temperatures ranging from $\sim 20,000K$ to more than 60,000 K. Most of these stars also exhibit Balmer emission, at $H\beta$ as well as $H\alpha$ in at least one case. We suggest the temperature reversal in the stellar atmosphere may be a function of the He/H ratio at the level of the photosphere.

2. G 191-B2B

Before describing our observations of hot subdwarfs, we briefly summarise the conclusions drawn from our spectroscopy of the DA white dwarf G191-B2B (see Reid & Wegner, 1988, for further details). Figure 1 shows the H-alpha profile, with the emission clearly evident. This star is the common proper motion companion of a main sequence K-dwarf. The trigonometric parallax measurement of the white dwarf leads to a distance of 45 parsecs, implying a separation of 2200 astronomical units between the two stars. Thus there is no question of an interaction between the two stars. Infrared photometry rules out an optically undetected close M-dwarf companion, while time-resolved spectroscopy argues against G191-B2B being a white-dwarf - white-dwarf binary, such as L870-2 (Saffer, Liebert & Olszewski, 1988). Finally, there is no evidence for spatially extended emission (or forbidden

O [IÍI] emission), as one might expect if the the white dwarf were ionising the surrounding remnants of a planetary nebula.

Since G191-B2B is in a wide binary, the main sequence companion can be used to estimate the space velocity. Our observations show that the $H\alpha$ emission is centrally situated within the absorption core, and the observed wavelength corresponds to a redshift of about 18 km/sec. The same redshift is observed for the ultraviolet lines of C IV, N V and Si IV that are observed in this star. On this basis we have suggested that both sets of lines have their origin close to the photospheric surface and that the velocity difference we observe is the Einstein or gravitational redshift. As a corollary of this hypothesis, we require a temperature inversion in the white dwarf atmosphere to permit these lines to exist.

3. Observations

We have obtained intermediate dispersion spectroscopy of a further sample of OB subdwarfs, mainly selected from the preliminary catalogue produced by Kilkenny, Heber & Drilling (1988). The stars cover a range in effective temperatures from $\sim 24,000K$ to $\sim 65,000K$ (Table 1). Most of these observations were obtained with the echelle spectrograph on the 60-inch telescope at Palomar Observatory (McCarthy, 1987). This spectrograph uses a TI 800 × 800 format CCD as the detector, gives a spectral coverage from $\sim 4000Å$ to $\sim 8000Å$ and a velocity resolution (2 pixels) of $\sim 15 km/sec$ at $H\alpha$. The spectra were reduced using the same techniques employed in our analysis of the spectroscopic observations of G 191-B2B (Reid & Wegner, 1988).

In addition to these observations, we also obtained spectra of two stars, Feige 67 and BD +28 4211, using the double spectrograph on the 200-inch Hale telescope. These spectra have a resolution of 1.6$Å$ (2 pixels) at $H\alpha$ and 1.0$Å$ at $H\beta$ and are therefore less sensitive to the presence of weak emission. Nonetheless, emission is detected at $H\alpha$ in both stars, while BD +28 4211 is the only star in our sample with convincing emission at $H\beta$. Figure 2 presents examples of our spectroscopic observations. The large-scale undulations in the spectra reflect residual effects of the echelle blaze function - these data have not been flux calibrated - while the narrow absorption lines are terrestial atmospheric features.

4. Discussion

Table 1 summarises the results of our observations so far. All save one of the subdwarfs with photospheric effective temperatures of 38,000 K or more have detectable emission in the core of the $H\alpha$ line, although only BD +28 4211, as we noted above, has convincing emission at $H\beta$. Unfortunately this last star has not been analysed using models atmospheres, but the He I and Balmer line strengths are very similar to those observed in Feige 67, and we have adopted an effective temperature of 40,000 K. in both this star and the (perhaps) slightly hotter BD +25 4655 the peak of the $H\alpha$ emission reaches close to the level of the neighbouring continuum. The hotter subdwarf LS IV-12, with a temperature comparable to that of G191-B2B, has a broad core to the absorption at $H\beta$, which may arise from emission filling in the central part of the absorption. We suggested that there is marginal evidence for similar low-level emission in G191-B2B.

The full-width half-maximum estimates made for the several stars with emission cores are all comparable, particularly allowing for the uncertainties involved in the measurement. None show evidence for extended emission and, as we noted in

Table 1

star	$H\alpha$	EW mÅ	FWHM Å	$H\beta$	EW mÅ	FWHM Å	T_{eff}	type
HD 4539	no	-	-	no	-	-	24,500	sdB
Feige 108	no	-	-	no	-	-	31,600	sdB
Feige 67	yes	120	1.5	no	-	-	38,900	sdO
Feige 110	yes	100	1.1	no	-	-	40,000	sdO
BD +28 4211	yes	400	1.5	yes	25	0.9	40,000	sdO
BD +25 4655	yes	145	1.2	no	-	-	42,200	sdO
Feige 34	yes	-	-	no	-	-	>50,000	sdO
LS IV-12	yes	140	1.2	?	-	-	60,200	sdO
G191-B2B	yes	90	1.5	?	-	-	62,250	DA

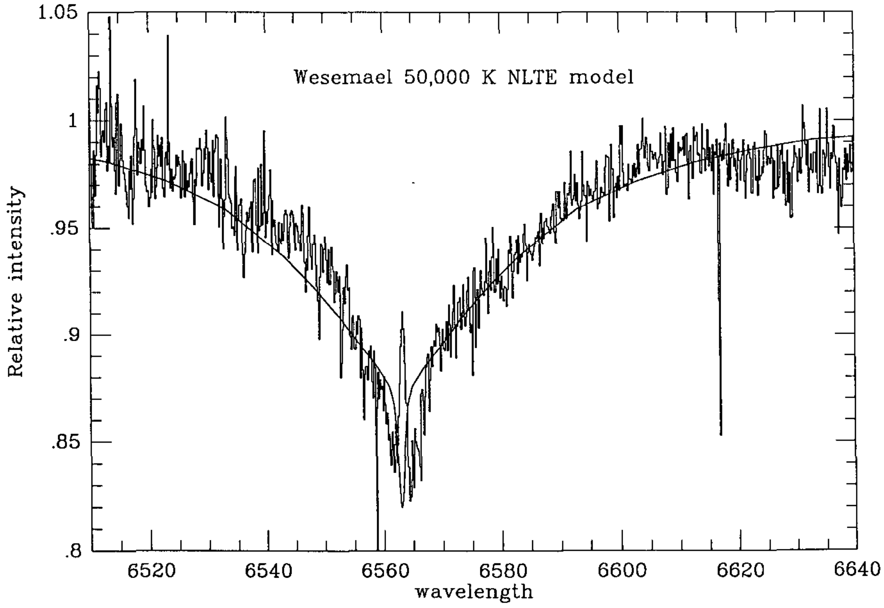

Figure 1. The $H\alpha$ profile of the hot white dwarf G191-B2B

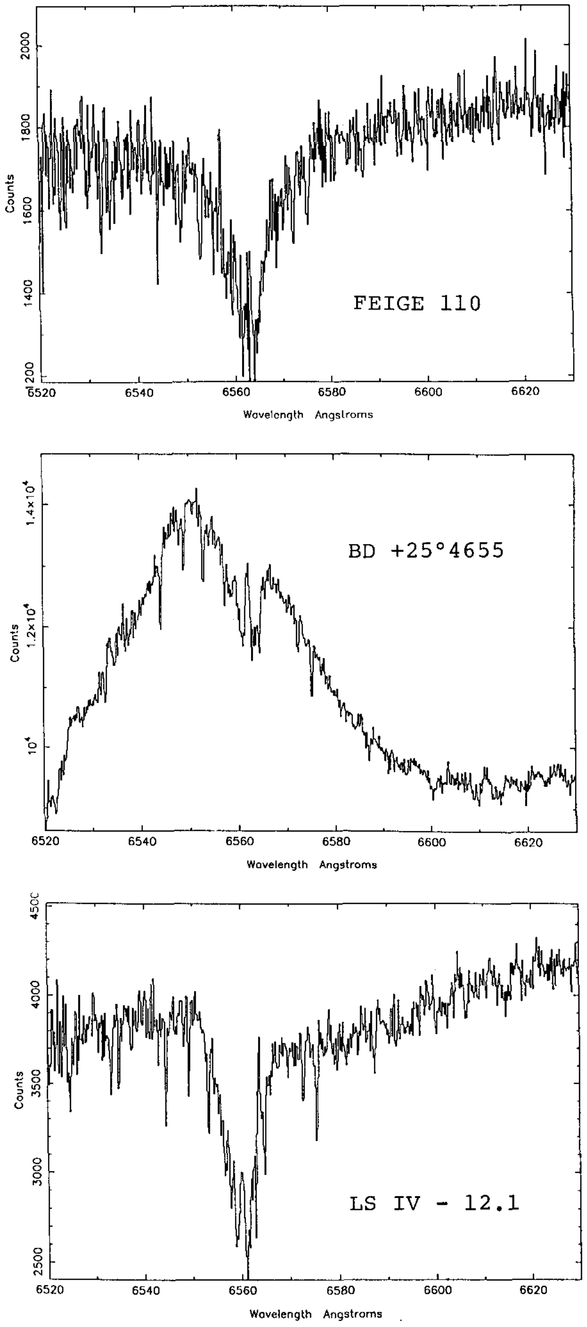

Figure 2. Balmer line profiles for a selection of the hot subdwarfs listed in Table 1.

the case of G191-B2B, the observed line widths are consistent with the Stark broadening expected near the top of the stellar photosphere. The only hot subdwarf in which there is no clear evidence of emission is Feige 34, where we have obtained only a relatively low signal-to-noise spectrum (figure 2).

The presence of Balmer emission requires the existence of a temperature inversion in the stellar atmosphere. We are currently investigating the stability of chromospheres and coronae in white dwarfs (Reid & Collier Cameron, in prep.), but such temperature inversions have already been predicted in some atmosphere models. Wesemael's (1981) calculation of the temperature distribution in an NLTE, pure-He white dwarf model with effective temperature 70,000 K predicts a temperature minimum at the point where He II becomes transparent, with the overpopulation of the He II ground state leading to heating of the upper layers. Jordan & Koester (1986) find that a similar temperature structure can occur in stratified H/He white dwarf models which possess a thin outer shell of hydrogen. Vennes et al. (1988) have shown that optical and soft X-ray observations imply a trend of decreasing He/H ratio with decreasing photospheric temperature amongst white dwarf stars. This they interpret as partly due to cooling effects and partly due to an increase in the mass and thickness of the outer layer of hydrogen. While only one of the stars in our sample is a white dwarf, it may be significant that, as the hottest known DA, it has a high He/H ratio. Similarly, the hotter sdO stars are generally regarded as He-rich, while the sdB and sdOB stars have He-poor atmospheres, and the lower He/H abundances in the latter stars may account for the absence of Balmer emission.

Further observations and more detailed models are required to determine the range of effective temperature, surface gravity and photospheric abundances of those stars exhibiting Balmer emission, and we are currently embarking on such a project. However, it seems likely that the characteristics of these emission cores can furnish information on the atmosphere structure in hot white dwarfs and subluminous OB stars.

This work was partially supported by the National Science Foundation through Grant AST85-15219.

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