THE H-R DIAGRAM OF O-TYPE SUBDWARFS

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A spectroscopic survey by Drilling (1983) of non-emission OB+ stars in the Case-Hamburg survey and its extension to b = ±30° for l = ±60° has turned up 12 hot, relatively bright O-type subdwarfs (V<13). Drilling's survey covers more than 13 times the area of the south galactic polar survey of Slettebak and Brundage (1971), but has revealed only the hottest and/or hydrogen-poor objects because only the weakest-lined O- and B-type stars were observed. We have observed all of these stars in the large-aperture, low-resolution mode of the IUE satellite. A full description of their spectral appearance is given elsewhere (Schönberner and Drilling, 1984). The spectra were corrected for interstellar absorption using the Seaton (1979) reddening law to nullify the 2200 Å interstellar feature, and in all cases $E_{B-V} < 0.25$.

We determined the temperatures using R, the ratio of the total flux between 1240 and 1945 Å to that between 1945 and 3120 Å. This quantity is dependent on effective temperature and nearly independent of the color excess: ΔE(B-V) = 0.1 corresponds to only a 5% change in R! In order to calibrate R against temperature, we chose four hot stars from the IUE data center with reasonably well known temperatures, gravities and compositions (see Table 1). Unfortunately two of them are helium rich, whereas the others are helium poor. Because the UV flux also depends on the composition (see Schönberner and Drilling 1984), we calibrated R against the color temperature, T_{BB}. This is the temperature of the black body which best matches the flux between 1200 and 3100 Å of the model atmosphere corresponding to the published values of temperature, gravity and composition. These black body temperatures, T_{BB}, are also listed in Table 1, together with the measured values of R.

Our subdwarf O stars have R in the range 2.5 to 3.9, indicating color temperatures from 60,000 K to over 100,000 K according to Table

A. Maeder and A. Renzini (eds.), Observational Tests of the Stellar Evolution Theory, 219–222.

1. We estimated the compositions from visual spectra (Drilling, 1983) and assigned to each star the effective temperature of a model whose UV flux matches that of a black body with temperature T_{BB}. We derived distances from the color excesses as described by Schönberner and Drilling (1984). The resulting absolute magnitudes cover the range from 1.5 to 8.

Fig. 1 shows the loci of our objects in the H-R diagram together with those of previously analyzed sdO's. Obviously our new hot subdwarfs occupy a previously empty region in the H-R diagram, filling the luminosity range from central stars to white dwarfs. This spread in luminosity is in agreement with their spectral appearance (see Schönberner and Drilling 1984) and indicates differences in their origin. Fig. 1 suggests that the less luminous sdO's are post-EHB

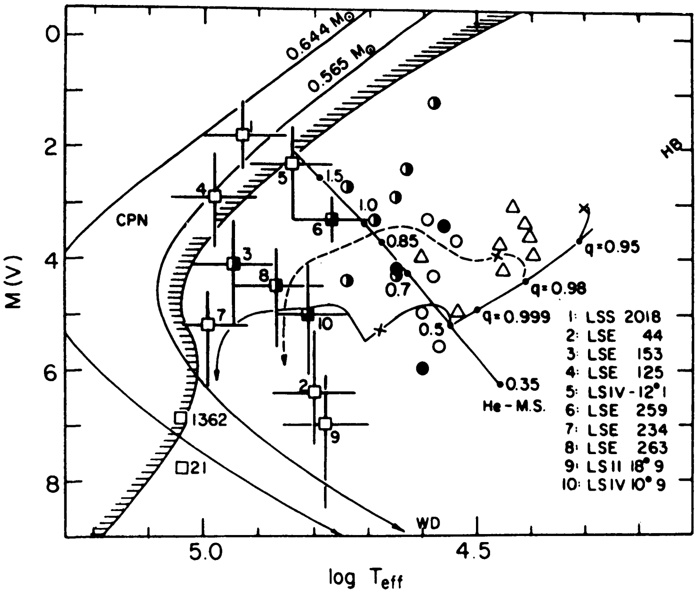

Figure 1. H-R diagram with the central star region (CPN) to the left of the shaded line, the helium main sequence (Paczynski, 1971), the extended horizontal branch (q), and the loci of our objects (squares). The evolutionary paths of post-AGB models of 0.565 and 0.644 M_0 are from Schönberner (1979, 1983), and that of a 0.5 M_0 pure helium star is from Paczynski (1971). The central helium-burning phase of an EHB model with M = 0.5 M_0 and q = 0.95 (Sweigart and Gross, 1976) is also shown. The (estimated) evolution of a 0.5 M_0 EHB star with q = 0.98 is marked by a dashed line. The crosses indicate the termination of central helium burning. The sdO's (circles) from Hunger et al. (1981) and sdB's (triangles) from Heber et al. (1983) are also displayed. The n(He)/n(H) ratios are indicated as follows: open symbols: normal or helium poor; half filled: helium rich; three-quarters filled: probably extremely helium rich; filled: extremely helium rich.

objects with 0.5 M_o and a helium burning shell as their energy source. The evolution could then proceed as indicated in Fig. 1 by the dashed line, thereby providing the low mass tail of the white dwarf mass distribution. The peculiar helium-to-hydrogen ratios then have to be explained by diffusion and convective mixing in surface layers (Michaud et al. 1983; Wesemael et al. 1982). Another possibility is that some of these stars are descendants of HB stars which were more massive than 0.5 M_o, but not massive enough to climb the AGB ($M < 0.57\ M_o$). Such stars also have a hydrogen burning shell which contributes significantly to their luminosity.

This work was supported in part by the National Science Foundation (Grant Nos. AST-8018766 and INT-8219240) and the National Aeronautics and Space Administration (Grant No. NAG 5-71).

TABLE 1

Star	T_{eff}	n(He)/n(H)	T_{BB}	R	Ref.
HD 49798	47,500	1.0	58,000	2.30	Kudritzki and Simon, 1978
BD+75°325	55,000	1.5	63,000	2.50	Kudritzki, et al. 1980
HZ 43	62,500	<0.001	97,000	3.10	Auer and Shipman, 1977
NGC 7293	105,000	0.01	145,000	4.00	Bohlin, et al. 1982; Mendez, et al. 1983

REFERENCES

Auer, L. H., and Shipman, L. H. 1977, *Ap. J. (Letters)*, **211**, L103.
Bohlin, R. C., Harrington, J. P., and Stecher, T. P. 1982, *Ap. J.*, **252**, 635.
Drilling, J. S., 1983, *Ap. J. (Letters)*, **270**, L13.
Heber, U., Hunger, K., Jonas, G., and Kudritzki, R. P., 1983, *Astr. Ap.*, in press.
Hunger, K., Gruschinske, J., Kudritzki, R. P., and Simon, K. P., 1981, *Astr. Ap.* **95**, 244.
Kudritzki, R. P., and Simon, K. P., 1978, *Astr. and Ap.*, **70**, 653.
Kudritzki, R. P., Gruschinske, J., Hunger, K., and Simon, K., 1980, Proc. 2nd-year IUE Conference, Tubingen.
Mendez, R. H., Kudritzki, R. P., and Simon, K. P., 1983, *IAU Symp. No. 103*, 343.
Michaud, G., Vauclair, G., and Vauclair, S., 1983, *Ap. J.*, **267**, 256.
Paczynski, B., 1971, *Acta. Astr.*, **21**, 1.
Schönberner, D., 1979, *Astr. and Ap.*, **79**, 108.
Schönberner, D., 1983, *Ap. J.*, in press.
Schönberner, D., and Drilling, J. S., 1984, *Ap. J.*, in press.
Seaton, M. J., 1979, *Mon. Not. Roy. Astron. Soc.*, **187**, 73P.
Sweigert, A. V., and Gross, P. G., 1976, *Ap. J. Suppl.*, **32**, 387.
Slettebak, A., and Brundage, R. K., 1971, *Astr. J.*, **76**, 338.
Wesemael, F., Winget, D. E., and Cabot, W., 1982, *Ap. J.*, **254**, 221.

DISCUSSION

Lub: Would you please care to indicate the errors in effective temperature and absolute magnitude in your diagram as these two are correlated!

Schönberner: The quantity R is nearly independent of the assumed colour excess. The reason is that the λ2200 bump compensates for the increasing absorption below 1900 Å. The main error in temperature stems from the somewhat uncertain surface composition. We estimate it to be around 20 %. The error in absolute magnitude is somewhat around 1 magnitude.

Cannon: Could you explain how your sample of new sdO stars was selected, i.e. what was the discovery technique?

Schönberner: These sdO stars are contained in the Case-Hamburg survey of luminous stars and in its extension made by J. Drilling. They are classified as OB+ stars.