SPECTROPHOTOMETRY OF HOT WHITE DWARFS FROM THE PALOMAR-GREEN SURVEY

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The Palomar-Green Survey (1977) contains a list of some 3000 spectroscopically classified stellar objects, chosen on the basis of ultraviolet excess. The survey covers 10,000 square degrees of the sky above $|b|=30^{\circ}$ with $\delta \geq -10^{\circ}$ down to an average limiting B=16.2. A significant subset of this sample is a new catalogue of over 700 newly discovered hot degenerates (Green 1979). The combination of selection by color only without regard to motion and the large area covered resulted in the discovery of some rare, luminous degenerates and pre-degenerate objects. We report here on the first observations in a program of more detailed spectroscopic study of these objects, and display representative groups of common spectral or physical properties. These scans at 1.5-2.5 Å resolution were obtained with either the KPNO 2.1-m and intensified image dissector scanner or the Palomar 1.5-m with SIT spectrograph.

While the great majority of hot degenerates are of DA spectral type, we are primarily interested in studying those stars showing evidence for atmospheric helium. The hottest of these are traditionally classified DO. The prototype of this rare group is HZ 21, the spectrum of which is shown in Fig. 1. He II λ4686 is the strongest line in the spectrum, with He I λ4471, He I λ4713, and Hγ also present, with possible weak He II λ4540. An atmospheric analysis (Koester, Liebert and Hege 1979) indicates a temperature of ∿46000 K, with log n(He)/n(H) = +0.8; this intermediate abundance requires that He II contribute to the Hγ line. PG 2201+145 shows a spectrum quite similar to that of HZ21, while the PG objects 1034-001, 0109+111, and 0108+101 contain broad He II λ4686, decreasing in strength with increasing temperature as He I disappears. He II λ4540 is weak in these stars, and there is little evidence for atmospheric hydrogen.

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The only other previously established DO star in Greenstein and Sargent's (1974,GS) compilation is HZ34, the spectrum of which is shown in Fig. 2. As with the very hot DAwk star G191-B2B, broad and weak H lines dominate the spectrum; however, HZ 34 and especially PG 1210+533 have surprisingly sharp He II λ4686. Other helium lines are not clearly seen. The GS (their Fig. 3) D(0.2) model calibrations suggest that all objects in our Figs. 1 and 2 have log g > 7. Since the Koester et al. analysis confirms that HZ 34 has a hydrogen-dominated atmosphere, it might be appropriate to classify it and PG 1210+533 as DAO stars.

Some very hot, helium-rich objects with lower surface gravities are shown in Fig. 3. Feige 46 and Ton 803 are analyzed in GS as sdO stars of relatively high log g $\gtrsim$ 6. We may speculate that these are the immediate precursors of the DO degenerates. However, more detailed determinations of their atmospheric parameters require the calculation of hot, helium-rich models for a variety of gravities and temperatures. We can then determine whether their luminosity function is consistent with stars in a gravitational contraction phase.

A complication to this evolutionary picture is the existence of cooler (T $\lesssim$ 30,000 K) stars with apparently comparable gravities, some with helium-rich atmospheres (see Fig. 4). The high (log g $\gtrsim$ 6) gravities may be derived from GS using the D(0.2) values in Table 1, and may be seen by comparison with the strikingly similar line profiles of the 7000 K DA white dwarf, Ross 627. DA's of temperature comparable to the subdwarf stars would have much broader lines, however. The evolutionary status of these stars is unknown, since they are too cool to be fit by tracks for gravitationally contracting stars.

Recently, some cooler fully degenerate stars with mixed He/H compositions have been discovered. The DBA stars LDS 785A and G 200-39 are believed to have n(H)/n(He) of order 10^{-4} (Wickramasinghe and Whelan 1977, Liebert et al. 1979). The contribution of additional continuum opacity by the hydrogen helps produce rather narrow He I and H lines, leading to some possibility of confusing them with subdwarfs from low resolution or low quality spectra. In Fig. 5, the spectra of G 200-39, a normal DB star (Ton 10), and a new DBA object LP 497-114 = PG 1311+129 are shown. The ratio of the triplet λ4471 line strength to the singlet λ4388 strength is very large in both DBA objects in accordance with predictions for log g $\geq$ 8 (e.g. Shipman, Greenstein and Boksenberg 1977); for cooler sdO stars with strong He I, such as PG0902 +057 in Fig. 3, this ratio is moderate. Furthermore, the helium-rich subdwarfs having broader He I lines may all be hotter objects than the DBA's, so that He II λ4686 is also detected. Thus, the DBA's may be distinguished spectroscopically from lower surface gravity, helium-rich stars.

Finally, we show in Fig. 6 two peculiar objects of high temperature - PG1707+427 and PG1159-035. (A third star, PG 0948+534, illustrates a very hot, lower surface gravity object with a hydrogen atmosphere.) The peculiar objects appear to have sharp, weak features which we identify with He II, C III, C IV and possibly ions of N and O as well. A number of these features may blend together over the 4650-4686 A region. There is little evidence for H in the atmosphere. These objects appear spectroscopically similar to hot, helium- and carbon-rich stars of high luminosity (e.g., Hunger 1975), and they may be contracting to the white dwarf stage (Schönberner 1977). PG1159-035 is of special interest since it is a variable star with $5\text{-}8^m$ periodicities, as will be discussed by J.T. McGraw at this meeting.

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TABLE 1

Absorption Line Data

Object	Type	Equivalent Widths (A) Hγ	λ4471	λ4540	λ4686	log D(0.2)
HZ 21	DO	1.3	4.0		4.5	1.43
PG1034-001	DO	0.8	0	1.2	3.1	1.09
HZ 34	DAO	3.2			1.0	1.46
PG1210+533	DAO	7.4			1.5	1.63
G191-B2B	DAwk	5.1				1.65
PG0956+359	sdO	2.0	1.8	3.1	2.5	1.23
F 36	sdB					1.41
PG1112+339	sdB					1.44

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Figure 1 - DO white dwarfs

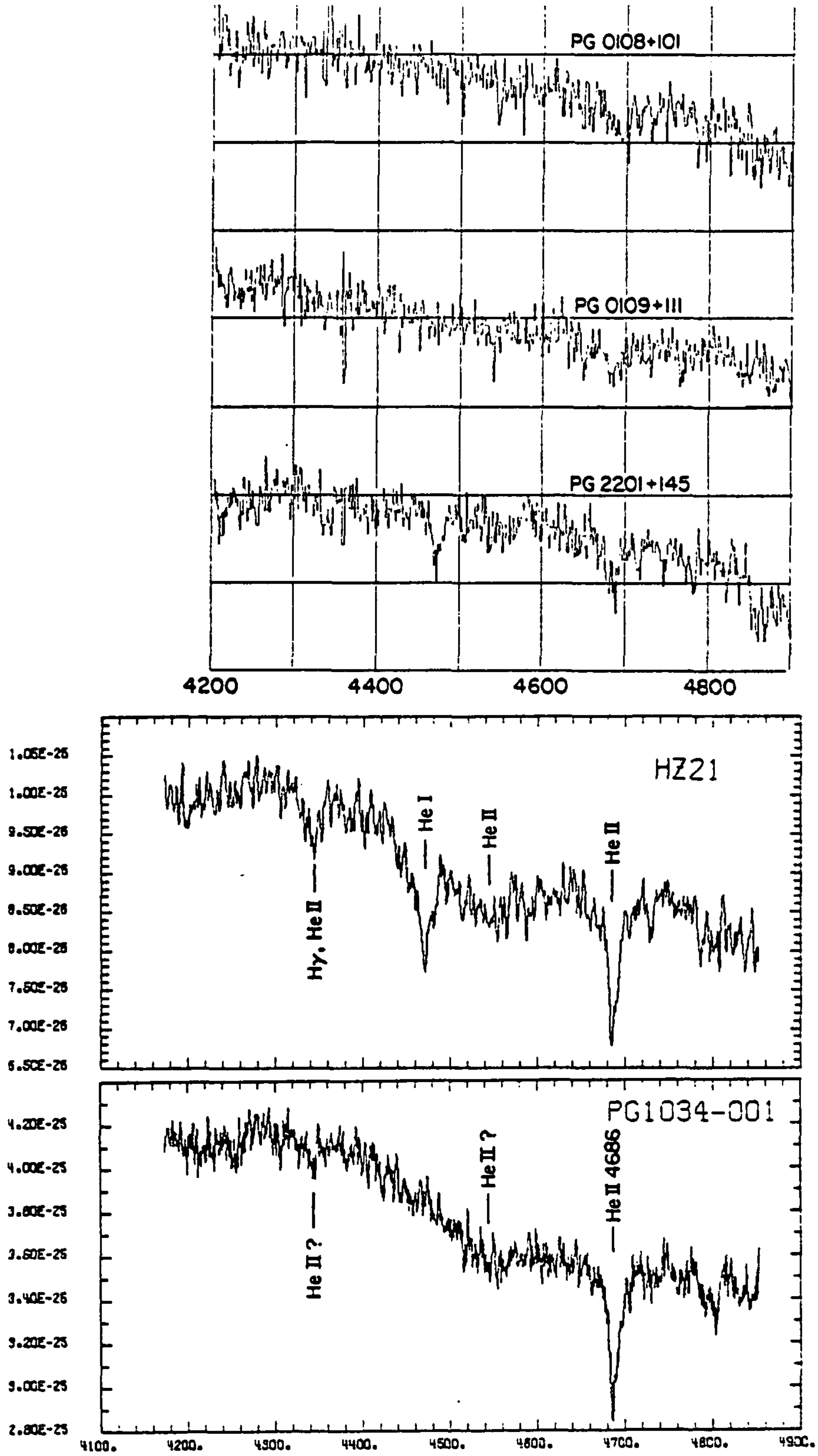

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Figure 2 - DAO and DAwk white dwarfs

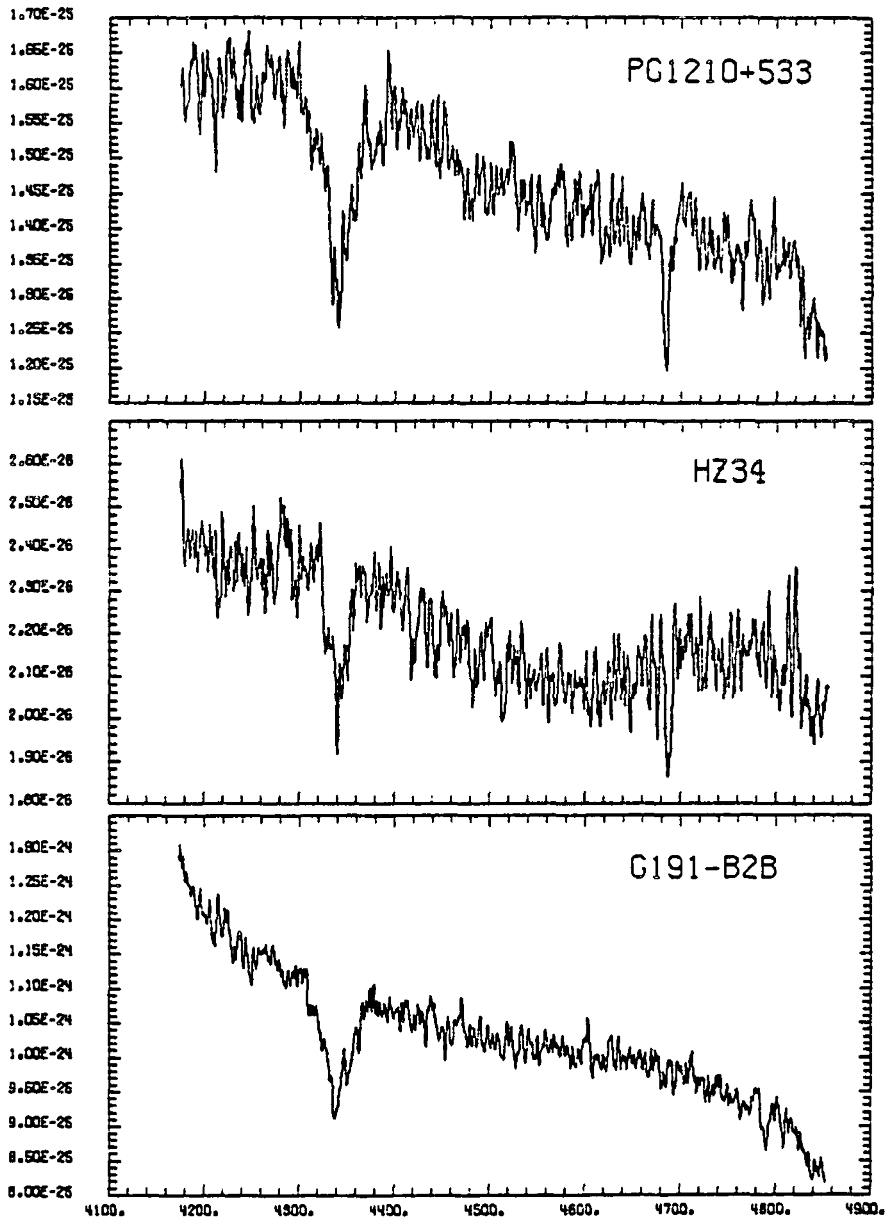

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Figure 3 - (Left) Hot, high gravity subdwarf O stars

Figure 4 - (Right) Cooler, high gravity subdwarfs

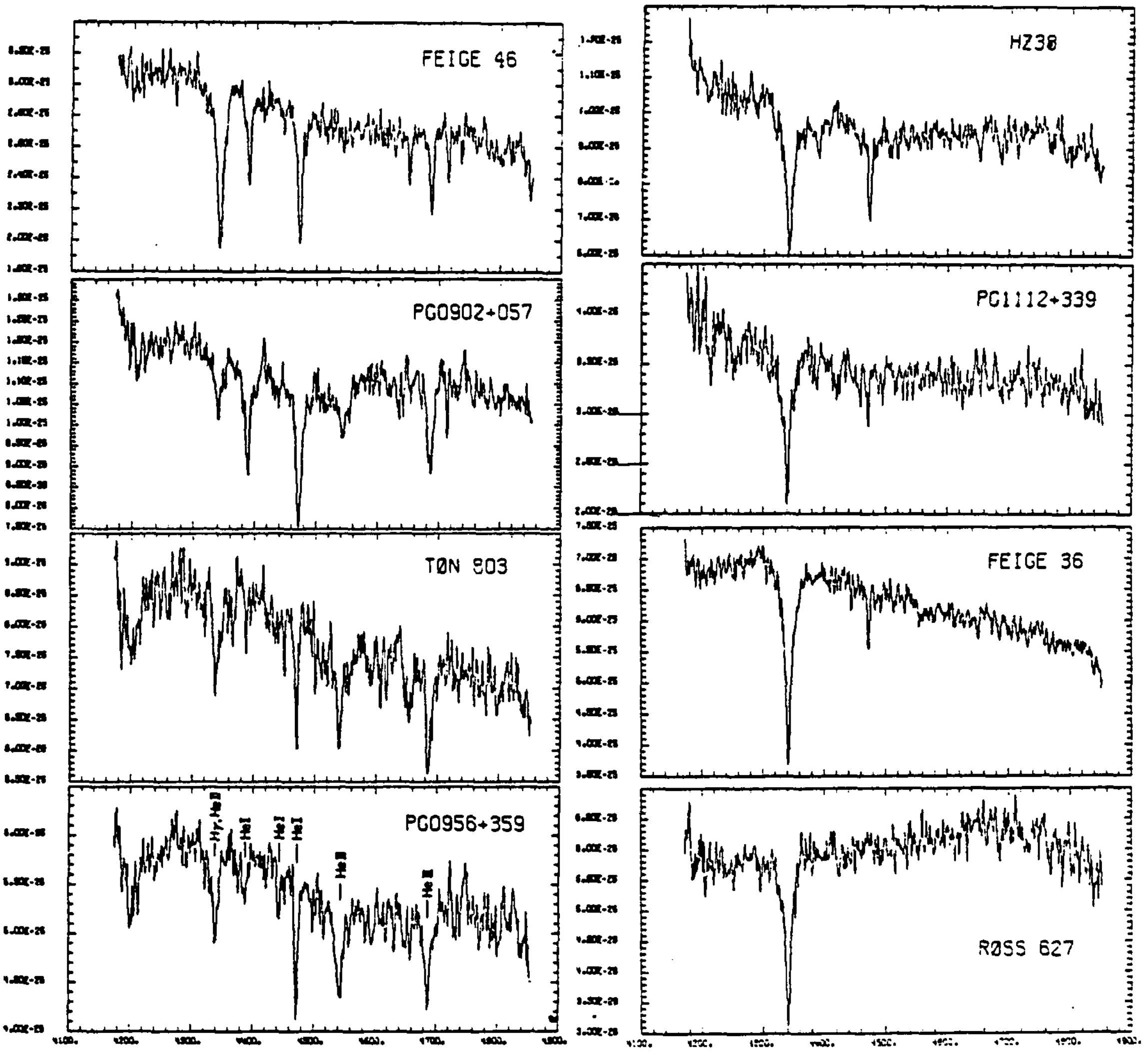

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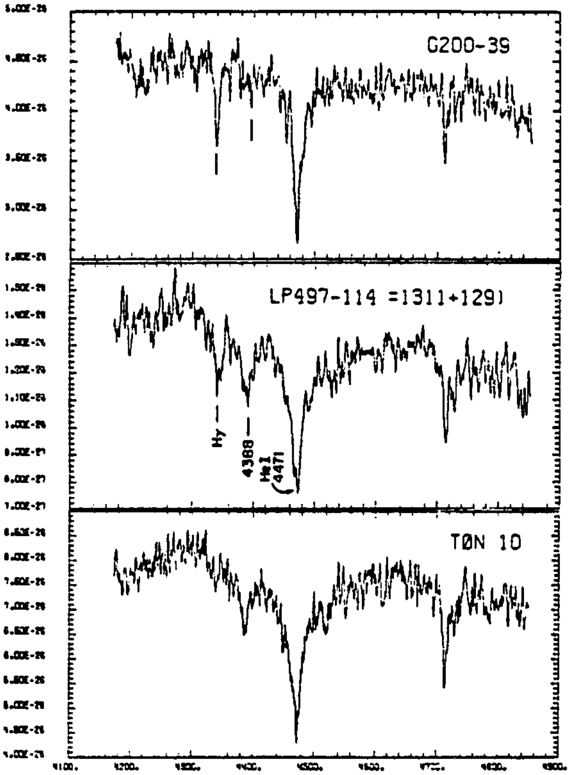
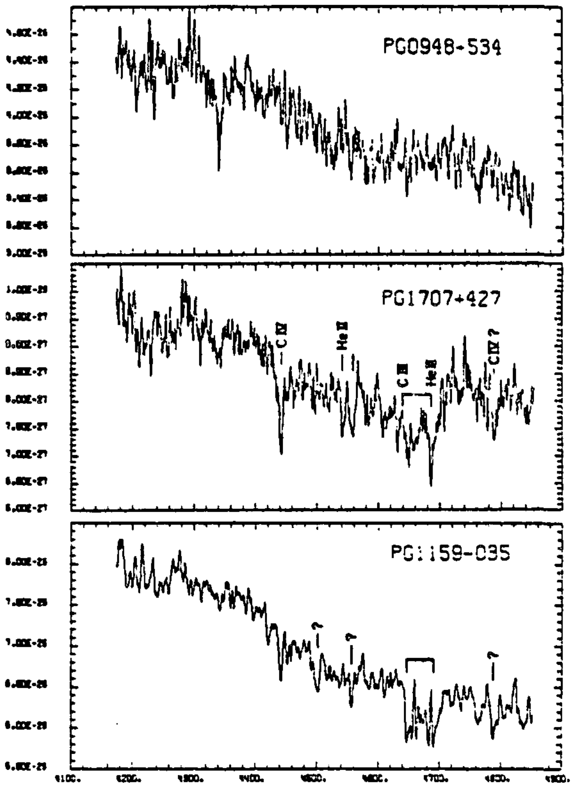
Figure 5 - (Left) DBA and DB white dwarfs

Figure 6 - (Right) Some peculiar, very hot stars





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