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THE NEED FOR VERY HIGH RESOLUTION SPECTROSCOPY FOR THE STUDY OF HOT SUBDWARFS

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Science with the GTC 10-m Telescope (Granada, España, 5-8 febrero 2002)
Editors: José Miguel Rodríguez Espinosa, Francisco Garzón López & Verónica Melo Martín

Hot subdwarf stars (hot sds) are blue subluminous objects at high galactic latitudes. They split into two well-separated spectroscopic sequences: the O (sdOs) and B-type (sdBs), according to composition and effective temperature. As they are immediate progenitors of white dwarfs (WDs), this resembles the spectroscopic H (DA)/He (DB) distinction between these. Among the various theories for the origin and final fate of hot sds, both single and close binary evolution have been suggested but the issue is still debated. Only a few determinations are available to date regarding the study of such aspects as rotation and microturbulent velocities (Heber et al. 2000) or the magnetic nature of these objects (Elkin 1996).

sdBs (and the subclass of the sdOBs) are H-rich with temperatures not exceeding about 35 000–40 000 K (Greenstein & Sargent 1974; Heber 1986). They have a canonical mass of 0.55 $M_\odot$, with thin H-rich envelopes of less than 0.02 $M_\odot$, and a distribution in surface gravities ($\log g$) around 5.25–6.5 (Ulla & Thejll 1998, hereafter UT98). These objects are proposed as descendants of blue horizontal branch stars or asymptotic giant branch (AGB) stars (Saffer et al. 1998). They are also proposed to be responsible for the UV upturn flux observed in early-type galaxies (Bica et al. 1996). Enough evidence has been accumulated to date in favor of a binary nature for at least 40% of the field hot B subdwarf stars (e.g., Allard et al. 1994; Jeffery & Pollacco 1998; UT98; Heber et al. 2002), with the detected companions ranging broadly in spectral type and physical parameters. sdBs/sdOBs, despite generally displaying few and weak lines, spectroscopically form a homogeneous group. About 25 rapid sdB oscillators have been detected since 1997 (see Heber et al. 2000).

sdOs exhibit a wide range of atmospheric properties and form, moreover, a much more inhomogeneous group. They have effective temperatures ranging from 40 000 to 90 000 K and surface gravities from about $\log g = 4.0$ to $\log g = 6.5$. Besides, both H and He abundances show large variations, as well as their line strengths, from object to object (Heber 1998). Here, owing to the high temperatures involved, LTE atmospheric models are inappropriate for detailed quantitative analysis. As for their evolutionary status, the situation is also much less clear than for sdBs: luminous sdOs of low surface gravity can be found close to the post-AGB tracks while stars of higher gravities can be found close to the post-extreme horizontal branch (EHB) tracks.

As derived from high resolution spectroscopy, the chemical abundances observed in hot subdwarfs are very peculiar. While some species are highly deficient (He [in the sdBs], C, O, Ne, Mg, Al, and Si), other elements (N and Fe) can be normal or even enriched, but with a broad range of values from star to star. Competing explanations propose that this could be indicative of different gravitational settling and/or radiative levitation (or diffusion), nuclear evolution, or dust/mass-loss phenomena acting in each object—or a mixture of these processes.

Some of the questions that still remain open regarding the spectroscopic nature of hot subdwarfs can be addressed with larger telescopes, such as the Keck or the GTC, provided they are furnished with the right instrumentation (see, for example, Heber et al. 2000). It then becomes attractive to consider doing spectroscopy with much greater resolution, and better signal to noise than is possible today with most existing equipment. As as example, Figure 1 shows the simultaneous line fitting for the sdO PG0208+016. For spectroscopic analysis of sdBs (H lines) and sdOs (H and He I + II lines) the problem

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has been to resolve the core of the spectral lines well enough to utilize the sensitivity to gravity. The line wings are not strongly broadened, so all parts of the line profile must be analyzed spectroscopically, notably the line cores. Thejll et al. (1994) used spectra with an FWHM resolution of about 5 Å, a choice that proved marginal in that unsatisfactory separation of the mixed lines of H and He II occurred, leading to ambiguous results in separating the effects of gravity from composition. With better resolution the slight difference in position of the Balmer lines of H and the Bracket series of He II can be utilized to separate the two opacity contributions. The γ and β line-complexes are separated by 1.8 and 2.0 Å, respectively, and a better resolution than this is required to satisfactorily separate gravity and composition effects for lines where the H and He II opacities are of similar magnitude in the mixed lines. Being able to separate these has an impact on several questions—notably the spectroscopic determination of distances, in that the population membership of sdOs can be determined better if their distances are unambiguous, which they are not when the best possible spectroscopic gravity estimates are no better than several tenths, in $\log g$. Determination of metal abundances in hot subdwarfs helps constrain evolution theories, and models for distributions of elements in stellar atmospheres where radiative pressures may be important.

We have selected fifteen sdO and fifteen sdB objects from the Palomar Green (PG) catalogue (Green et al. 1986) for a detailed study, in preparation for the availability of the GTC after 2003. Our study comprises photometry, spectroscopy, spectropolarimetry, oscillations, and magnetism, both from an observational and a theoretical point of view. In particular, from the spectroscopic investigations we expect to obtain accurate effective temperature ($T_{\rm eff}$), surface gravity ($\log g$) and He content (Y) values for our sample. The more accurate thsse are, the more precisely can we compute stellar models—using MacDonald's code (Jimenez & MacDonald 1986), to be fed into Christensen-Dalsgaard's pulsational code (Christensen-Dalsgaard & Bertomieu 1991) for the theoretical study of the possible oscillatory nature of our targets. So far, we are able to provide new results for the 21 sdO objects. Details of the original fitting procedure can be found in Thejll et al. (1994).

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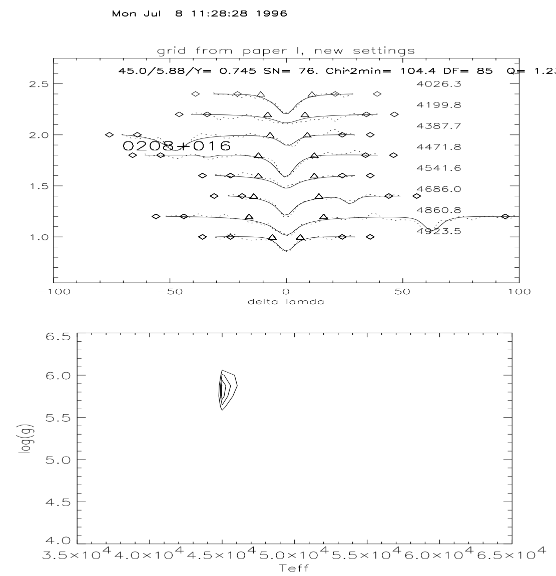

Fig. 1. Simultaneous line fitting for the sdO PG0208+016 with NLTE atmospheric models. Best fit parameters are: $T_{\rm eff} = 45\,000$ K; $\log g = 5.88$; $Y = 0.745$. Details of the fitting procedure can be found in Thejll et al. (1994).

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