NLTE ANALYSIS OF SDO STARS

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Among the faint blue halo stars the sdO's form a group whose evolutionary status is still not fully understood. Phenomenologically they appear to be related to the horizontal branch. The knowledge of stellar parameters and abundances may give a clue for understanding their evolutionary status. As the sdO's are hot ($T_{eff} \gtrsim 35000K$), the assumption of LTE leads to substantial errors. Hence detailed NLTE analyses are inevitable.

THE METHOD OF ANALYSIS

High (or medium) resolution visual and UV spectra are analysed by means of complete NLTE techniques in the following way:
In the first step a grid of NLTE model atmospheres is constructed which is then used for additional line formation calculations for hydrogen, He II and He I. A fit of the observed profiles of hydrogen and helium lines then yields simultaneously effective temperature, gravity and helium abundance. From the finally adopted model multi-level (or two-level) calculations are carried out for different metal ions to determine metal abundances. An illustrative example for the procedure of model fitting is given by Kudritzki and Simon (1978).

ATMOSPHERIC PARAMETERS

26 sdO's up to now have been analyzed for atmospheric parameters. The results are summarized in Table 1 and plotted in Fig.1. Most strikingly there is a subdivision of the group with respect to the helium content. We find three groups:
1) 5 stars are extremely helium rich. Their photospheres consist almost entirely of helium (helium number fraction $y = 1.0$).
2) 10 stars have intermediate helium rich photospheres ($y \approx 0.5$).
3) 11 stars are helium poor ($0.0007 \lesssim y \leq 0.12$).
Moreover, there is a clear borderline which separates helium rich objects from the helium poor ones, the critical temperature being 40000K. The helium rich sdO's are hotter, the helium poor ones cooler then this. The helium poor sdO's are intermediate in T_{eff} to the sdB stars (see Fig.1) which are also helium poor and are better called sdOB stars.

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Table 1: Atmospheric parameters of sdO stars (for a list of references see Heber et al., 1983b)

star	T_{eff}/K	log g	y	star	T_{eff}/K	log g	y
CD-31°4800	42500	5.5	1.0	BD-3°2179	>55000	4.5	0.3
BD+39°3226	45000	5.5	1.0	LB 1566	42600	5.0	0.2
BD+37° 442	55000	4.0	1.0	SB 884	40000	6.1	0.12
TONS 103	40000:	6.5:	1.0	SB 169	37000	6.3	0.04
SB 21	36300	5.4	1.0	HD 149382	35000	5.5	0.04
SB 58	38000	4.5	0.7	Feige 110	40000	5.0	0.03
HD 127493	42500	5.25	0.6	SB 38	39000	5.4	0.03
BD+75° 325	55000	5.3	0.6	EG 55	38000	5.8	0.02
HD 49798	47500	4.25	0.5	Feige 66	36000	6.0	0.02
SB 705	44700	5.8	0.5	SN 1006	38500:	6.5:	0.015
LS 630	55000	6.0	0.5	LB 3241	41000	5.7	≲ 0.005
SB 933	49000	5.5	0.4	LB 3459	40000	5.3	0.003
HD 128220	{45000 40000	4.75 4.25	0.37 0.17	SB 707	34000	6.0	≲ 0.0007

: uncertain due to low quality observations

METAL ABUNDANCES

Abundances of C,N and Si have been obtained for 3 helium rich sdO's and 3 sdOB's. The results are listed in Table 2. For the helium rich sdO's the data given in Table 2 indicate that the material in their atmospheres has been processed in the CNO cycle. For the sdOB's the abundances are considerably different (see Table 2). Silicon is deficient in all analyzed stars by large factors. Nitrogen is approximately solar. Carbon is moderately deficient in HD 149382 and Feige 66 while it is strongly deficient in Feige 110 (by more than a factor of 300000).These strange abundance patterns of the sdOB stars can be explained by diffusion. Due to the high gravity helium, carbon and silicon settle downwards out of the photosphere. The prerequisite for gravitational settling is an atmosphere that is quiet. For effective temperatures near 40000K a helium convection zone occurs, which may impede diffusion.

Table 2: Abundances of sdO stars (log of mass fraction)

star	H	He	C	N	Si	
HD 49798	-0.70	-0.10	-3.7	-1.6	-3.0	
HD 127493	-0.85	-0.07	-4.1	-2.1	-3.0	
BD+ 75°325	-0.85	-0.07	-3.7	-1.9	-3.1	
CNO cycle	-0.85	-0.07	-4.1	-1.9		(with $T_6 = 2 \cdot 10^7$K)
sdOB stars:						
HD 149382	-0.07	-0.85	-4.4	-2.9	< -7.7	
Feige 66	-0.03	-1.12	-4.5	-2.7	< -7.8	
Feige 100	-0.05	-0.96	< -7.9	-3.1	< -6.8	
sun	-0.152	-0.55	-2.4	-3.0	-3.16	

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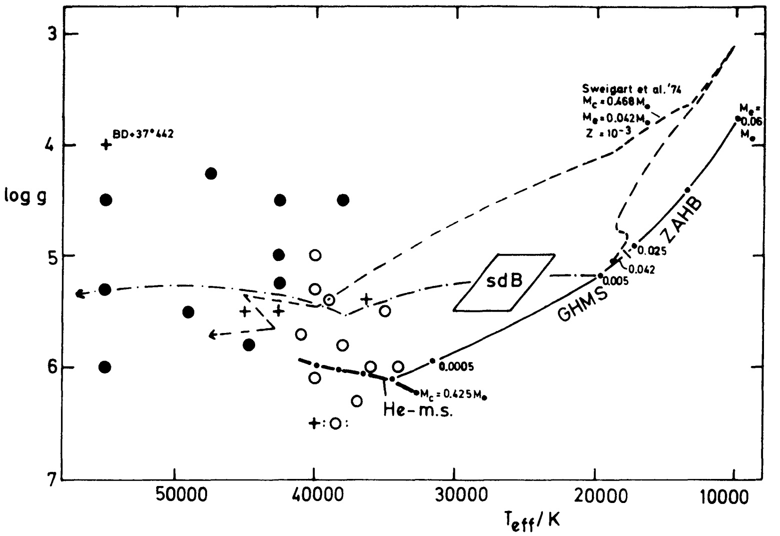
Fig.1:Position of sdO stars in the log g-Teff-plane:
+ = extremely helium rich
● = intermediate helium rich
o = sdOB



THE EVOLUTIONARY STATUS OF THE SDO STARS

In Fig.1(the log g-T_{eff}-plane) zero age horizontal branch models (Gross, 1973) are plotted.The models are labelled with their envelope masses M_e. For $M_e < 0.02\ M_\odot$ the hydrogen rich envelope is inert.These models may be called generalized helium main sequence models (GHMS, see Heber et al., 1983a). The true helium main sequence is also shown. The sdO's lie to the left of the ZAHB and GHMS but above the helium main sequence. We can reach the position of the subdwarfs in the log-T_{eff}-plane when evolution is considered. Two relevant evolutionary tracks are shown in Fig.1. The dashed curve represents evolution of a ZAHB-star (Sweigart et al., 1974), while a GHMS star proabably evolves similar to a pure helium star along the dashed dotted curve. From Fig.1 we conclude that there are essentially two ways sdO's can form: either by evolution from horizontal branch B stars and/or from sdB stars. The latter are slightly evolved GHMS stars ($M_e < 0.02\ M_\odot$). Some of the high gravity sdOB's are located at the helium main sequence, which means that their hydrogen rich envelope masses are even smaller ($M_e < 10^{-3} M_\odot$). This situation is reminiscent of DA white dwarfs which are known to have very little hydrogen floating atop the helium rich layers. Some (low gravity) stars (e.g. BD+37°442) are probably remnants of the asymptotic giant branch.

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DISCUSSION

Renzini: How can an HB star be turned into an extreme He star?

Heber: No idea.

Cox: What are the luminosities above which there is convection to prevent the He settling?

Heber: The onset of convection in the photosphere is not very sensitive to luminosity. Instead it is more sensitive to the effective temperature of the star.

Mould: Isn't it possible that an extremely large mass loss could have completely stripped the hydrogen envelope from these stars?

Heber: Yes. In order to account for the very low envelope masses M_e of the subdwarfs ($M_e \lesssim 0.05\ M_\odot$) we have to consider mass loss both on the red giant branch and during the core helium flash. At present nobody is able to tell you what is going on during the core helium flash.

Schatzman: Is there any information on the rotational velocities of these objects?

Heber: From our spectra we conclude that they must be very low (below the detection limit).

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