Model atmospheres and SEDs of chemically peculiar stars.

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Abstract.
Procedure and results of computations of stellar model atmospheres and spectral energy distributions are discussed. Model atmospheres of some chemically peculiar stars are computed taking into account detailed information about their abundances:
— R CrB-like stars of $T_{\text{eff}} \sim 7000 \, \text{K}$,
— Sakurai’s object (V4334 Sgr) of $4000 < T_{\text{eff}} < 7000 \, \text{K}$
— Przybylski’s star of $T_{\text{eff}} \sim 6500 \, \text{K}$.

We show that our self-consistent approach provides a unique possibility to investigate the temporal changes of physical parameters of chemically peculiar stars.

Some issues of computation of model atmospheres of M and C-giants are also considered.

1. Introduction

In many aspects, the existence of the irregular hydrogen-deficient (Hd) variables remains puzzling so far. R CrB is the most known member of the post-AGB group. Sakurai’s object (SO, V4334 Sgr) provides another, extreme case of stellar evolution.

It has been firmly established that the most abundant elements in atmospheres of R CrB-like stars are helium and carbon. Determination of abundances in their atmospheres is possible only in the frame of self-consistent approach (Asplund et al. 1998). Still even in the case of the “normal” red giants that approach should be used. Otherwise, abundance determination results might be affected by significant errors ($> 0.2$-$0.3$ dex, see Pavlenko & Yakovina 1994 for more details).

HD 101065 (V816 Cen) presents another case of the peculiar stellar spectrum (see Cowley et al. 2000) — the strongest spectral lines in the spectrum of HD 101065 generally belong to lanthanides.

2. Ionization-dissociation equilibrium

In comparatively cool ($T_{\text{eff}} < 6500 \, \text{K}$) atmospheres of Hd stars densities of carbon containing molecules increase (Pavlenko 2002b). Strong molecular bands
of CO, CN, C$_2$ appear in optical and IR spectra of Sakurai’s object (Pavlenko 2002b, Pavlenko & Geballe 2002).

3. Opacities

At photospheric levels of hotter Hd stars ($T_{\text{eff}} > 7000$ K), the continuum opacity is governed mainly by a bound-free absorption of C atoms (Fig. 1, see also Pavlenko 1999). To compute opacities due to bf absorption of C, N, O atoms we used TOPBASE (Seaton 1982) crossections (Pavlenko & Zhukovska 2002). At the same time, opacity above the photosphere of Hd stars with $T_{\text{eff}} < 6500$ K is determined, to a large extent, by absorption of molecules contained C, N, O atoms (Pavlenko, Yakovina & Duerbeck 2000). Naturally, this severely limits the use of ODF-like methods for the computation of blanketing effects (see discussion in Mihalas 1978). We used JOLA and “line by line” models of absorption by molecules to compute opacities in atmospheres of late-type stars for Kurucz (1993), Partridge and Schwenke (1998), Goorvitch (1994) and Harris (2002) lists.

4. Dependence $\tau_{\text{ross}} = f(T, P)$

Due to drop of H$^-$ absorption the mean opacity $\kappa_{\text{ross}}$ is reduced in photospheres of Hd stars. As result, they are shifted downwards higher pressure regions (Fig.2).

5. Model atmospheres

We computed a grid of stellar model atmospheres of $T_{\text{eff}} = 7000$-4000 K, log g = 0 - 1 by SAM12 program (Pavlenko 2002, 2002a). SAM12 is a modification of ATLAS12 (Kurucz 1999). Opacity sampling treatment was used to account atomic and molecular absorption.

6. Sakurai’s object

Fits of theoretical SEDs to observed in 1997 - 1998 ones allow us to determine $T_{\text{eff}}$ and $E_{B-V}$ of Sakurai’s object at the latest stages of its evolution (Fig. 3 in the frame of self-consistent approach(Pavlenko et al. 2000, Pavlenko & Duerbeck 2001, Pavlenko & Geballe 2002). Fits to IR spectra allows to clearly determine an infrared excess due to emission of hot ($T > 1000$ K) dust (Fig.4, see Pavlenko & Geballe 2002 for more details).

7. Przybylski’s star

Model atmospheres with $T_{\text{eff}} = 6400$-6800 K, log $g =$4.0 and abundances from Cowley et al. (2000) were computed using the opacity sampling method using VALD (Kupka et al. 1999) and DREAM (DREAM 2002) line lists. Atomic lines are the main source of opacity in Paczinsky’s star (Fig. 5). We found, however, that a contribution of the bound-bound r-elements into opacity is rather low.
in comparison with other elements. The most probably, it is a consequence of incompleteness of the used line lists of r-elements. Computation of complete line lists of r-elements is of crucial importance for now.

8. **C-giants**

Two grids of model atmospheres of different $^{12}$C/$^{13}$C and C/O ratios were computed by SAM12 program for opacities provided by diatomic molecules (Kurucz 1993) lists and HCN (Harris 2002). Our model atmospheres of C-giants (see Pavlenko 2002a) depend on input parameters, therefore fits to observed spectra are not good enough in some cases (Fig. 6).

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Figure 1. Continuum absorption coefficients computed for solar (top) and R CrB (bottom) model atmospheres. Computations were carried out for $T = 5900$ K (Pavlenko 1999). The most important distinction in Hd atmospheres is a substantial decrease of $H^-$ absorption and, accordingly, an increase of the importance of bound-free absorption by neutral carbon atoms proved to be substantial over large frequency intervals.
Figure 2. Top: absorption coefficients $\kappa_{\text{ross}}$ as a function of gas pressure computed for solar (blue lines) and R CrB (blue lines) abundances. Computations were carried out for $T_e = 6000$ K. Thin and thick lines indicate the computations with continuum absorption alone and with continuum + atomic lines, respectively. Bottom: temperature structures of model atmospheres 5000/0.0 computed for solar and Sakurai’s abundances, respectively.
Figure 3. Fits to optical SEDs of V4334 Sgr in 1997-1998.
Figure 4. Fits to IR SEDs of V4334 Sgr in 1997.
Figure 5. Impact of ree absorption on SEDs of Przybylski’s star (top). Temperature of a few model atmospheres computed for different input parameters.
Figure 6. Top: dependence of the temperature structure of model atmosphere of C-giant 3000/0 on input parameters. Bottom: fit to the observed SED of WX Cyg (Barnbaum et al. 1996).