MODEL ATMOSPHERES OF PECULAR CARBON GIANTS

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ABSTRACT. We calculated 240 model atmospheres of carbon giants of high carbon abundances (2800 $\leq$ T$_{\rm eff}$ $\leq$ 3400 K, 0.06 $\leq$ log(C/O) $\leq$ 2.7). The set of models was calculated in process of analysis by spectral synthesis of spectral energy distribution of the evolved carbon star DY Per shown photometric features of R CrB type stars. The majority of these models are metal deficient (-3.5 $\leq$ [Fe/H] $<$ 0), part of them are calculated with hydrogen deficiency (1/9 $\leq$ H/He $<$ 9/1). Model atmosphere calculations were carried out in the framework of classical approaches with account of the relevant opacity sources in carbon stars. The opacity sampling method was used to calculate the opacity due to atomic and molecular line absorption.

Introduction

Recently Yakovina et al. (2009) using spectral synthesis technique determined the atmosphere parameters of DY Per - carbon giant shown some photometric features of R CrB type stars. We fit computed fluxes calculated with high carbon abundances, metal deficient and hydrogen deficient model atmospheres to the observed SED of DY Per. Our model atmospheres are outside the known and accessible grids of model atmospheres for carbon stars (Johnson, 1982; Eriksson et al., 1984; Harris et al., 2003). Model atmospheres of carbon giants with such high values C/O, [N/Fe], low [Fe/H] and with the deficiency of H were not calculated by other authors at all. We consider that they can be useful to other researchers of carbon stars for the similar studies.

Model atmosphere calculations

We calculated model atmospheres of carbon giants in the classic assumptions by the program SAM12 (Pavlenko, 2003) which is a modification of the ATLAS12 (Kurucz, 1999). SAM12 allows to calculate model atmospheres for stars with the peculiar chemical compositions. Bound-free absorption by CI, NI and OI (Pavlenko & Zhukovskaya, 2003) is added to the sources of continuous absorption included in ATLAS12. We account CIA (Collisional-Induced Absorption) - the absorption by the molecular complexes He-H_2 and H_2-H_2 induced by collisions. It becomes the important source of opacity in the atmospheres of cool metal deficient stars (Borysow et al., 1997). The opacity sampling method was used to calculate the opacity due to atomic and molecular line absorption.

For most models we set “non solar” abundances not only of C but of H, He and N too. We vary parameters C/O, H/He and [N/Fe]. We set solar abundances from (Gurtovenko & Kostik, 1998) for other elements and adopt the microturbulent velocity V_t =3 km/s.

Results

We present 240 model atmospheres of carbon-rich red giants of the effective temperatures 2800 $\leq$ T$_{\rm eff}$ $\leq$ 3400 K and carbon abundances 0.06 $\leq$ log(C/O) $\leq$ 2.7. Majority of model atmospheres were computed for log g = 0.0, but 32 models were calculated for log g= -1, -0.5, 0.5 or 1. Some calculated model atmospheres are metal deficient (-3.5 $\leq$ [Fe/H] $<$ 0), 83 models are hydrogen deficient (1/9 $\leq$ H/He $<$ 9/1). All our model atmospheres are given in the ATLAS12-like format. Models and short description are available on the web:

ftp://ftp.mao.kiev.ua/pub/users/yp/Cmod/cmod.pdf (description),
ftp://ftp.mao.kiev.ua/pub/users/yp/Cmod/hsol.htm (models of ”solar” H/He),
ftp://ftp.mao.kiev.ua/pub/users/yp/Cmod/hdef.htm (models of ”not solar” H/He).

The model columns contain the next parameters:

RHOX - $\rho_x = \int_0^x \rho(z) * dz$ (g/cm^2) is mass of matter above 1 cm^2 of atmosphere on the geometrical depth z, $\rho(z)$ is a density of matter on the depth z;

T - T_e, electronic temperature of level (K);

P - P_g, gas pressure (dyne/cm^2);

XNE - n_e, electronic density (1/cm^3);

ABROSS - $\kappa_{\rm ross}$, rosseland opacity (cm^2/g);

ACCRAD - $a_{\rm rad}$, acceleration due to radial pressure (cm/s^2);

VTURB - $V_{\rm turb}$, turbulent velocity (km/s);

FLXCNV - $F_{\rm conv}$, energy flux that bear a convection (erg/cm^2/s);

VCONV - $V_{\rm conv}$, convective velocity (km/s);

Tauross - $\tau_{\rm ross}$, rosseland optical depth;

FluxErr - ΔF, difference of fluxes in two last iterations (in percents from a flux in last but one iteration);

DELTAT - ΔT, correction to the temperature after last iteration;

DeltaRx - $\Delta \rho_x$, correction to ρ_x after last iteration;

FluxRatio - $F_{\rm conv}/F_{\rm total}$, relation of convective flux to the total one.

The convergence of models can be seen in the column FluxErr. For most our models FluxErr < 1 % at all depth levels. It is evidence of good convergence. Sometimes we assumed the small exceeding above 1 % in the deepest layers of model and consider it possible because these layers show very little impact on the calculated stellar spectra.

As a example, we show a fit of the computed spectrum for model atmosphere with T$_{\rm eff}$/log g/[Fe/H] = 3000/0/-1.5, H/He=5/5, log(C/O) =0.8, [N/Fe]=0.5 to the observed fluxes of DY Per. We computed synthetic spectrum by the program WITA6 (Pavlenko, 1997). The same continuum opacity sources and V_t were used as in model atmosphere calculations. We account atomic lines from VALD (Kupka et al., 1999) and molecular lines from database (Kurucz, 1993-1994), CD-ROM N18.

Discussion and conclusions

Our model atmospheres of C-giants were computed in the framework of the classical assumptions. We believe that they are suitable for qualitative and quantitative analysis of the spectra of C-giants. Moreover, we obtain a good fit of the theoretical spectra computed with our subgrid of model atmospheres to observed SED of the peculiar C-giant DY Per.

At one hand, our models can be used at least for investigation of the peculiar DY Per-like stars.

On the second hand, they can be used as a starting model atmospheres to be improved in the future. No doubt, we need more sophisticated procedures accounting more complete sets of opacity sources, 3D convection, stellar wind and dusty phenomena, etc.

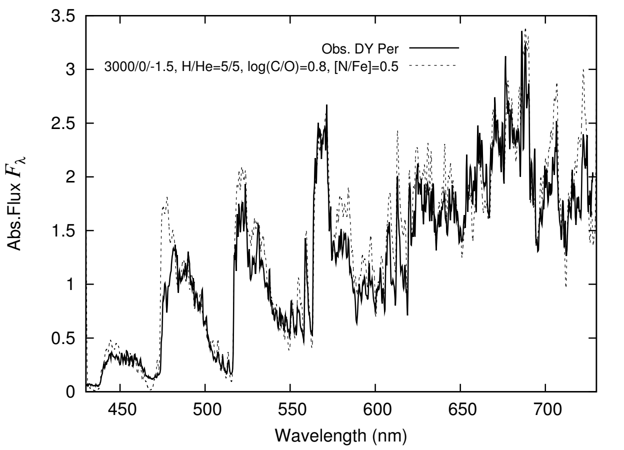

Figure 1: Fit of the theoretical spectral energy distribution of DY Per to the observed one for the model atmosphere {3000/0/-1.5, H/He=5/5, log(C/O) =0.8, [N/Fe]=0.5}.

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