THE SHOCK WAVE HEATING MECHANISM OF PULSATING STAR CHROMOSPHERES

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Abstract. A mechanism is suggested which explains the origin and variability of chromospheric emission in the centres of the MgII h and k lines in the spectra of pulsating stars. According to the model the emission originates from gas heated by a shock wave passing through the outer layers of the star’s atmosphere.

Keywords: Star: Pulsating star

Introduction. The chromospheric emission in the resonance doublet lines of MgII, CaII and in some lines of CI, CIV, SiIV with high excitation potentials are observed in Cepheids β Dor, ε Gem and δ Cep. The emission flux in these lines is on the average less than that of stationary stars. At maximum chromospheric activity of the pulsating stars, the emission flux amounts to the values characteristic of nonvariable stars. Such an emission testifies to the existence of a high temperature plasma in the chromosphere and transition zone (Parsons, 1980, Schmidt and Parsons, 1984a, schmidt and Parsons, 1984b).

Of extreme importance were investigations of chromospheric activity of pulsating stars of A-F spectral types carried out by Fracassini and Pasinetti (1982) and Fracassini et al. (1983). The authors detected emission in the MgII h and k lines in δ Sc type stars: τ Cyg, β Cas, ρ Pup. (The most detailed investigations made for ρ Pup has shown that the emission flux varies with the pulsation phase). In τ Peg, χ Boo, α Eri the emission can be suspected. According to Ulmschneider (1979) nonvariable A-type stars show no emission in the MgII h and k lines. Thus, the chromospheric emission originating in pulsating stars, and its variability with the phase of pulsation, can be interpreted as a result of periodic inflow of energy into the outer star’s layers. A shock wave (SW) generated by pulsation is a carrier of such an energy in pulsating stars.

This paper considers the heating mechanism of layers radiating chromospheric lines of Sc t-type stars. The main problem is, whether the radiation of the outer atmospheric layers, heated as a result of the SW passing, can provide values of fluxes which are consistent with the fluxes observed in the lines and with their variability.

Calculation and results. The SW motion is associated with regions of high electron temperature and ionization degree in the atmosphere. The boundary of this region coincides with the SW front whereas its extension is determined by the SW velocity and the efficiency of the radiative cooling of the gas. Physical conditions behind the SW front and their time dependencies can be determined by solving the equation of state of the hydrogen ionization and the energy balance of the gas. A complete description of the system of differential equations is given in the work by Garbuzov and Andrievsky (1986). It should be noted here that the system determines the variation of concentration of electrons $n_e$ with time, the concentration of $L_a$ quanta $n_a$, the electron temperature $T_e$ and the temperature of the ions $T_i$.

A case of a hydrogen plasma with an admixture of metals ($n_m = 10^{-4} n$) is considered. The system of equations has been solved for the interval $n = 3 \times 10^{10} - 5 \times 10^{12}$ cm$^{-3}$ under the following initial conditions: $t_0 = 0$ (the moment of passing the front of SW through a point with a present value $n$), $n_e 0 = 10^{-3} n$, $n_m 0 = 0$, $T_e 0 = 10^4$ K, $T_i 0 = 5 \times 10^4$ K. For the SW velocity we adopt $D = const = 30$ km s$^{-1}$. In Fig.1 the electron temperature is shown varying behind the SW front for two different values of the density in the star’s envelope. If the relations $T_e(t)$ and $n_e(t)$ behind the front of a SW are known, one is able to construct a space distribution of electronic temperature and electronic density in outer layers of the envelope of a pulsating star. Here we assume that the distribution of the hydrogen number density in the envelope of the δ Sc t-type star determined by $T_e$ and is characteristic of the star ρ Pup. The $T_e$-distribution for three different subsequent positions of the

![Graph](image)

Fig. 1. The electron temperature as a function of time for $n = 10^{11}$ cm$^{-3}$ (1) and $n = 10^{10}$ cm$^{-3}$ (2).
SW front in the star's envelope is given in Fig.2. Taking into account the distribution and found and allowing for the shock character of the transition into the excitation level of ion MgII, it is easy to calculate the emission flux in the MgII h and k lines generated by the heated region. The parameter R(MgII) determined by the relation of emission flux in the MgII h and k lines to the bolometric luminosity of the star for ρ Pup varies from a value $10^{-5}$ (when the SW front is at the point with $n = 3 \times 10^{12} \text{ cm}^{-3}$) to $10^{-6}$ (when the front is shifted to the point with $n = 5 \times 10^{9} \text{ cm}^{-3}$). According to the data by Fracassini et al. (1983) we can determine that the value R(MgII) observed for ρ Pup varies from $10^{-5}$ to $5 \times 10^{-6}$ which is in good agreement with the theoretical estimations.

Thus we can make a conclusion that the chromospheric emission observed in the MgII h and k lines in pulsating stars are to a great extent determined by the radiation of a gas heated by a pulsating shock wave.

References