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 though the outer layers of the star's atmosphere.

Key words: Star: Pulsing star

Introduction. The chomospheric emission in the resonance doublet lines of MgII, CaII and in some lines of CI, CIV, SiIV with higt excitation potentials are observed in Cepheids β Dor, ξ 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 chomosphere 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 Sct 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^2 Boo, o^1 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 oroginating in pulsating stars, and its variability with the phase of pulsation, can be interpreted as a result of periodic inflow of enegy into the outer star's layers. A shock wave (SW) generated by pilsation is a carrier of such an enegy in pulsating stars.

This paper considers the heating mechanism of layers radiating chromospheric lines of Sct-type stars. The main problem is, whether the radiation of the outer atmospheric layers, heated sa 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 dependences 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_α-quanta n_α, the electron temperature T_e and the temperature of the ions T_i.

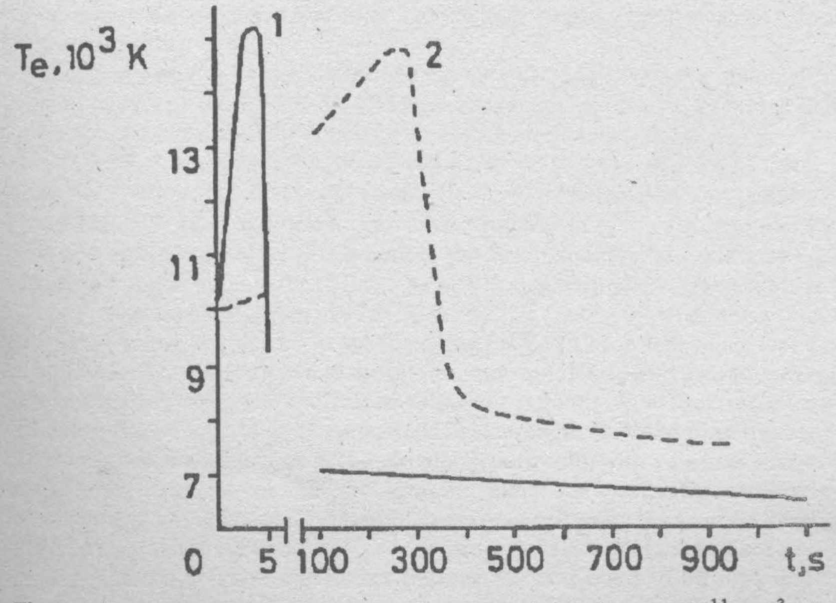

Fig. 1 The electron temperature sa a function of time for $n = 10^{11}$cm^{-3} (1) and $n = 10^{10}$cm^{-3} (2).

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 $n = 3\times10^{12} - 5\times10^{9}\ cm^{-3}$ under the following initial conditions: $t_0 = 0$ (the moment of passing the front of SW through a point with a present value n), $n_{e0} = 10^{-3} n, n_{\alpha 0} = 0$, $T_{e0} = 10^4$ K. $T_{i0} = 5\times 10^4$ K. For the SW velocity we adopt $D = const = 30$ kms^{-1}. In Fig.1 the electon 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 Sct-type star determined by T_{ef} and is characteristic of the star ρ Pup. The T_e-distribution for three diferent subsequent positions of the

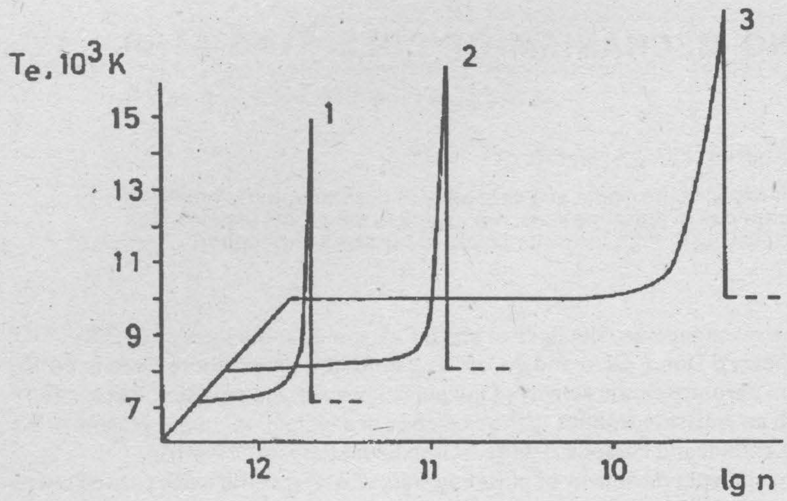

Fig. 2 The electron temperature distributions sa a function of the height of the shock wave front:

1 - the front is at the point with $n = 8 \cdot 10^{11}\mathrm{cm}^{-3}$,

2 - at $n = 2 \cdot 10^{11}\mathrm{cm}^{-3}$,

3 - at $n = 1.6 \cdot 10^{11}\mathrm{cm}^{-3}$.

SW front in the star's envelope is given in Fig.2.

Taking into account the distribution of 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 $n = 3\times10^{12}$ cm^{-3}) to 10^{-6} (when the front is shifted to the point with $n = 5\times10^{9}$ 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 5×10^{-6} which is in good agreement with the theoretical estimations.

Thus we can make a conclusoin 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

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