THE HARD LIFE OF CLUMPS IN ATMOSPHERES OF EARLY-TYPE STARS

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Abstract. As has been recently established, the atmospheres of early-type stars are strongly disheveled. These atmospheres consist of dense clumps and a more rarefied interclump medium. We consider the forces that determine the motion of the clumps. We show that the main force is gravitational attraction of the clumps to the star. For stars with a high effective temperature ($T_{eff} \geq 6 \cdot 10^4$ K) it appears that the clump/interclump gas number density ratio is ≥ 30. In this case we can conclude that the clumps are formed by shock waves. Some evidence as to the existence of gas jets in the atmospheres of Wolf-Rayet stars have recently been presented. We propose that such jets may be a common feature of all early-type stars. Profiles of HeI lines in spectra of clumped atmospheres with jets have been calculated.

There is now much evidence (both theoretical and observational) that inhomogeneities exist in the atmospheres (envelopes) of early-type stars (Antokhin et al. 1988, hereafter AKC; Andrillat and Vreux 1988; Floquet et al. 1992, Lamers et al. 1988). These inhomogeneities can be described in the framework of the Clump model. In the Clump model (see, for example, AKC, Cherepaschuck 1990) stellar atmospheres are presented as consisting of numerous dense clumps embedded in a rarefied interclump medium. Ions of low and moderate ionization stages are found only in clumps while the interclump medium is strongly ionized.

In the case of early-type stars the prime reason for the formation of clumps seems to be the instability of the radiation driven stellar wind (see, for example, Owocki et al. 1990). After the initial perturbations are formed they can be compressed by shock waves to provide a ratio of the clump/interclump number densities as large as $30 - 100$, which is needed to keep the ions of the low and intermediate ionization stages in the deeper layers of the clumps (Kholtygin 1988). A special case is presented by the clumps in shells of Herbig Ae/Be stars. They have huge, dense and extremely cold clumps with comet like orbits. The formation of clumps in Herbig Ae/Be star shells are probably connected with the gravitational collapse of primordial molecular clouds (Grinin 1988, Voschinnikov and Grinin 1991).

We have considered the forces that determine the motion of clumps in an atmosphere and concluded that the main force is gravitational attraction to the core and that the clumps should therefore be decelerated in the atmosphere. However, the cluster of clumps seems to be accelerated (e.g., Lamers et al. 1988). So we must conclude that either the clumps are formed in the whole atmosphere, or that the cluster of clumps, which form the profile

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bump, include clumps with very different velocities.

The Clump model has been used as the base for line profiles calculations. We have considered lines of ions in lower ionization stages (HeI, CII, NII, etc.) which are disposed only in clumps.

In spectra of some WR stars the profiles of the HeI λ10830 lines have bumps with a constant shape and velocity displacement (Eenens 1991). Similar bumps have been observed in optical HeI lines (Robert et al. 1992). For this reason we have proposed that there are only one or two jets or streams consisting of both rarefied gas and clumps. To evaluate the line profiles we proposed that the ratio of the clump number densities in the jets and in the remaining atmosphere is constant. The calculated profiles of the HeI λ 10830 line in the spectra of the star WR 134 are in a good accordance with the observed ones (Eenens 1991). The jet-like structures also exist in the atmospheres of Herbig Ae/Be stars. They seems to be connected with the existence of a strong magnetic field (Pogodin 1990). We propose that jets are a common feature in all early-type stars.

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