ON THE MIXING OF THE MATTER IN SEMICONVECTIVE REGIONS OF MASSIVE STARS

(Abstract)

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There are two possibilities concerning the problem of convective stability of the region of varying molecular weight μ. Schwarzschild and Härm (1958) assumed that in semiconvective zones of massive stars the radiative temperature gradient is equal to the adiabatic one:

$$\nabla_r = \nabla_a.$$

Sakashita and Hayaski (1961) suggested the use of the Ledoux criterion for the convective stability:

$$\nabla_r < \nabla_a + \nabla_\mu, \tag{2}$$

where: $\nabla_\mu = (\beta/4 - 3\beta)\,(\mathrm{d}\ln\mu/\mathrm{d}\ln P)$.

Kato (1966) showed that the zone where the conditions

$$\nabla_a < \nabla_r < \nabla_a + \nabla_\mu \tag{3}$$

is satisfied is vibrationally unstable. This instability leads to the partial mixing of matter.

Dudorov and Tutukov (1972) investigated the mixing problem solving the linearized equation of motion of an element in a medium with varying molecular weight and with a radiative temperature gradient ∇_r satisfying conditions (3). The roots of the characteristic equation and rates of growth of perturbations of different size elements were found analytically for $\nabla_r - \nabla_a \ll \nabla_\mu$.

It appeared, that elements with the size $\sim 10^7$ cm have the largest increment of perturbation growth under conditions typical for semiconvective zones of massive stars. The amplitude of vibration is limited by the turbulent friction. The turbulence starts when the amplitude becomes $\sim 10^6$ cm or about 10^{-5} of the radial dimension of the semiconvective zone. The turbulence leads to a partial mixing of the matter. The necessary mixing velocity is secured during the hydrogen-burning stage if $\nabla_r - \nabla_a$ is about 10^{-5}.

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