SEMICONVECTION MIXING AND ITS INFLUENCE ON CASE B MASS EXCHANGE IN MASSIVE BINARIES

E.I. STARITSIN
Astronomical Observatory of the Ural State University
Lenin Street 51, 620083 Ekaterinburgh, Russia
eugene@astro.urgu.e-burg.su

Abstract. In case of moderate matter mixing in the semi-convective zone the primary loses part of its mass on a nuclear time-scale. It looks like a CNO-supergiant during the first part of the helium burning stage. Another part of the mass is lost on the thermal time-scale. The primary looks like a WR star during the second part of the helium burning stage.

Key words: stars: Wolf-Rayet – CNO stars – binaries – mass exchange – semi-convection

After termination of the main sequence evolution a massive star may convert into a blue or red supergiant. It depends on the matter mixing intensity in the semi-convective zone (SCZ) during the stage of the gravitational compression (Massevitch & Tutukov 1988). The hydrogen content in any shell of the SCZ can be defined in the diffusion approximation (Staritsin 1987) as:

$$X = \frac{X_0 + X_a \cdot \alpha \cdot X''_{r2} \cdot \Delta t}{1 + \alpha \cdot X''_{r2} \cdot \Delta t}$$

$$\alpha = \frac{1}{160\pi CG} \cdot (\lambda Re)^2 \cdot \nu_{rad} \cdot \frac{4-3\beta}{(1-\beta)\beta^2} \cdot \left(\frac{C_s}{C}\right)^2 \cdot \frac{1}{\nabla_\mu} \cdot \frac{L_r}{M_r}$$

with X_0 is the hydrogen content without matter mixing; X_a is the hydrogen content in case of S–criterion (Schwarzschild *et al.* 1958); X''_{r2} is the space derivative of the hydrogen content; Δt is the time step between two successive evolutionary models;, G is the gravitational constant; C is the light speed; C_s is the local sound speed; L_r is the luminousity at radius r; M_r is the mass at radius r; β is the gas-to-full pressure ratio; ∇_μ is the mean molecular weight gradient; ν_{rad} is the radiation viscousity; $\lambda - 1$ is the turbulence-to-radiation viscousity ratio; and Re is the critical value of the Reynolds number.

In case of $\lambda Re = 10^5$ the matter doesn't mix in the SCZ. The temperature gradient in the SCZ is equal to the radiative one. This case corresponds to L-criterion for semi-convection (Sakashita *et al.* 1961). In case of $\lambda Re = 10^9$ the radiative temperature gradient decreases to the adiabatical one. This case corresponds to the S-criterion for semi-convection. In case of $10^5 < \lambda Re < 10^9$ there is the moderate matter mixing in the SCZ. The temperature gradient takes a value between radiative and adiabatical ones. The shell source luminousity decreases during the helium burning stage. The star is a blue supergiant if the shell source luminousity is more than some critical

K. A. van der Hucht and P. M. Williams (eds.), Wolf-Rayet Stars: Binaries, Colliding Winds, Evolution, 324–325.

value. When the shell source luminousity reaches this critical value the star's envelope begins to expand on the thermal time-scale. The star converts into the red supergiant. During blue-red transition in the HR-diagram, the helium content in the convective core of 32 $M_\odot$ star is equal to 0.40 and 0.20 for $\lambda Re = 10^6$ and 10^9, respectively (Staritsin 1989) .

In the case B of mass-exchange in binary systems the primary component fills the Roche-lobe after the main sequence evolution. The primary loses mass in the thermal time-scale if the mixing of matter in the SCZ wasn't taken into account. It converts into a WR star (Paczynski 1967). In this case the primary evolves according to the scenario OB-WR. If the mixing of matter in the SCZ is taken into account according to the S-criterion, the the primary fills its Roche-lobe during all of the helium burning stage. It looks like a CNO-supergiant. In this case the primary evolves according to scenario OB-CNO-supergiant (Kraitcheva 1978).

In the case of the moderate matter mixing in the SCZ the primary loses mass at first on a thermal time-scale, then on a nuclear time-scale. The shell source luminousity decreases sharply during mass loss on the thermal time-scale and gradually during mass loss on the nuclear time-scale. When the shell source luminousity reaches the critical value the primary component envelope begins to expand on the thermal time-scale. The primary component loses mass in the thermal time-scale again and detaches from the Roche lobe. In a binary system of 32+30 $M_\odot$ with an initial period of $P^o = 11^d.3$ detachment off occurs when the helium content in the convective core decreases to $Y_c = 0.50$. If the primary loses mass according observated rates (*e.g.,* de Jager *et al.* 1988), it converts into a CNO sypergiant and then into WR star (Staritsin 1991a). In the case of the moderate matter mixing in the SCZ the primary component evolves according to scenario OB-CNO-WR. The primaries with initial mass from range $20 < M/M_\odot < 100$ follow this scenario. In case of smaller mass the time-scale doesn't depend of matter mixing in the SCZ (Massevitch & Tutukov 1988). The more massive primaries produce large helium cores and lose mass on the thermal time-scale (Staritsin 1991b).

References

de Jager, C., Nieuwenhuijzen, H., van der Hucht, K.A. 1988, *A&A Suppl.* **72**, 295

Kraitcheva Z.T. 1978, *Nauchnye Informacii* **41**, 37

Massevitch, A.G., Tutukov, A.V. 1988, in: Evolution of stars: theory and observation (Moscow: Nayka), p. 280

Paczynski, B. 1967, in: J. Dommanget (ed.), On the Evolution of Double Stars, *Proc. IAU Coll. No. 111*

Sakashita, S., Hayashi, C. 1961, *Prog. Theor. Phys.* **26**, 942

Schwarzschild, M., Harm, R. 1958, *ApJ* **128**, 248

Staritsin E. 1987, *Nauchnye Informacii* **63**, 97

Staritsin E. 1989, *Nauchnye Informacii* **67**, 117

Staritsin E. 1991a, *Astron. Zh.* **68**, 306

Staritsin E. 1991b, *Nauchnye Informacii* **70**, 21