THE DYNAMICAL EVOLUTION OF EXPANDING HI SHELLS AND INITIAL MASS FUNCTION OF OB ASSOCIATIONS

S.A.Silich
Main Astronomical Observatory Academy of Sciences of the Ukrainian SSR
252127 Kiev-127, Goloseevo
USSR

ABSTRACT. The evolution of expanding supershells produced by SN explosion in OB associations is considered. The expansion velocities of the shells and OB associations IMF spectral index are obtained. The results agree well with observational data.

The distribution of the Galactic HI column density in small velocity ranges shows the existence of many curved HI filaments. In some cases filaments change their sizes with velocity as expading shells. Some shells are huge. Their radii vary between 0.1kpc - 1kpc approximately and their masses reach $10^6 M_\odot - 10^7 M_\odot$. But their expansion velocities vary within narrow velocity range $10 km\ s^{-1} \lesssim U \lesssim 24 km\ s^{-1}$ (Heiles, 1979).Hence, it follows that expansion velocities of these shells are almost costant (at least for the late evolutionary stage).

We consider the evolution of OB association within HI supercloud (Elmegreen and Elmegreen, 1983) accompanied by supernovae explosions and expanding HI shell origin. It is shown that the shell expansion velocity will be constant as the total supershell energy will increase with a rate $\mathcal{E}_0(t) \sim t^2$. Then by assuming that supernovae explosions are the main energy source in OB associations one can find OB association stars initial mass function and shell expansion velocity U_0.

We have studied the propagation of a strong radiative shock wave in infinitely thin layer approximation. It have been assumed that all swept-up interstellar gas collapses in a thin shell radius R and the gas pressure is uniform within cavity. The motion of the shell is described by equation

$$\ddot{R} + \frac{3(\gamma + 1)}{2} R^{-1}\dot{R}^2 = \frac{9(\gamma - 1)}{4\pi \rho R^4} E(t) \quad , \qquad (1)$$

where E(t) is the total shell energy, γ is adiabatic index, ρ is the gas density. From equation (1) it follows that the shell expansion velocity is constant as the supernovae add energy to cavity at a rate

$$\mathcal{E}_{SN} = 4\pi\gamma(\gamma - 1)^{-1}\rho\, U^5 t^2 \ . \qquad (2)$$

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Taking into account the analytical expression by Bisincehi et al.(1983) for the massive stars main sequence lifetime $t = Am^{-\alpha}$, where $A = 5.3 \cdot 10^7$ yr $\alpha \simeq 0.6$, it is easy found that in OB association with IMF $n(m) = dN/dm = Cm^{\delta}$ supernovae release energy at a rate

$$\mathcal{E}_{SN} = CE_0 \alpha^{-1} A^{\frac{\delta+1}{\alpha}} t^{-\frac{\delta+\alpha+1}{\alpha}}, \qquad (3)$$

where E_0 is the supernova explosion energy. Equating the right-hand parts (2) and (3) we get the IMF spectral index $\delta = -1-3\alpha \simeq -2.8$ and the value of the shell expansion velocity :

$$U_0 = \left[\frac{3(\gamma-1)NE_0 m_1^{3\alpha}}{4\pi\gamma\rho A^3}\right]^{0.2}, \qquad (4)$$

where N is the total number of massive stars in association, m_1 is minimum mass of stars exploding as supernovae. From (4) it follows that U_0 depends weakly on parameters of OB association and superclouds. Substituting into (4) $\gamma = 5/3$, $E_0 = 10^{51}$ erg, N = 100, m_1 = 9 and $\rho = 10^{-23}$ g cm^{-3} we have $U_0 = 16$ km s^{-1}, for the same values N, E_0, m_1 and $\rho = 10^{-24}$ g cm^{-3} we have $U_0 = 25$ km s^{-1}.

The expansion velocity of the shell will be constant up to the time $t_c = Am_1^{-\alpha} \simeq 1.5 \cdot 10^7$ yr, when the last sufficiently massive star becomes supernova. When $t = t_c$ the shell radius reaches $R_c = U_0 t_c$ = 250pc - 400pc . After such a time the energy pumping stops and shell decelerates up to the random velocity of the interstellar clouds $U_c \simeq$ 10 km s^{-1}. The maximum radius of the shell is higher by a factor 2 - 3 than R_c and can reach 0.5 kpc - 1.0 kpc.

Our calculations show that for undestanding dynamics of expanding HI shells it is necessary to take into account that supernovae release energy continuously up to the time t_c. The present modification of the theory by Bruhweiler et al. (1980) and Tomisaka et al. (1981) provides a natural explanation of the fact that expansion velocities of the Heiles shells vary within the narrow velocity range and is also confirmed by a good agreement of the obtained values of shell expansion velocities and IMF spectral index with the observational data.

We believe that the self-consistent theory including entire history of star formation regions can be analyzed now. Superclouds formation in unstable galactic disk, origin of the molecular clouds, massive stars and OB associations within superclouds, the interaction of stellar winds and supernovae with the surrounding interstellar medium, formation of HI shells, theirs development and destruction seem to be the main elements of such theory.

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