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CAN MASSIVE STARS FLY OUT OF OPEN CLUSTERS AND EVOLVE OUTSIDE THEM?

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It is traditionally believed that blue hypergiants such as LBV should be concentrated in young massive clusters, such as early OB-type stars. But according to the observations of Smith & Tombleson [5] they are often located far from the OB associations. We performed a numerical simulation how the LBVs can be ejected from the parent stellar cluster. As it was established the evolution in binary systems can lead to the ejection of LBV or pre-LBV stars.

Keywords: star – LBV stars – Cluster dynamic

1. INTRODUCTION

Most massive stars are believed to be formed in the central region of the clusters. However, some of them such as LBVs are detected later outside the parent cluster [1]. These bright blue supergiants are characterized by the irregular variability and strong stellar wind. The lifetime of such stars does not exceed several million years and it is unknown up to date why such short-lived stars can appear outside of the parent OB. The solution of this problem can shed light on the scenario of the LBVs formation.

In the present paper we study the mechanisms for a massive star to be ejected from the cluster due to of the close interactions with other massive stars and in a result of a kick after supernova explosion in a binary system. We use numerical simulation of the dynamic evolution of the cluster and follow the motion of the LBVs candidates in this system. The parameters of our model of the cluster are discussed in Section 2.

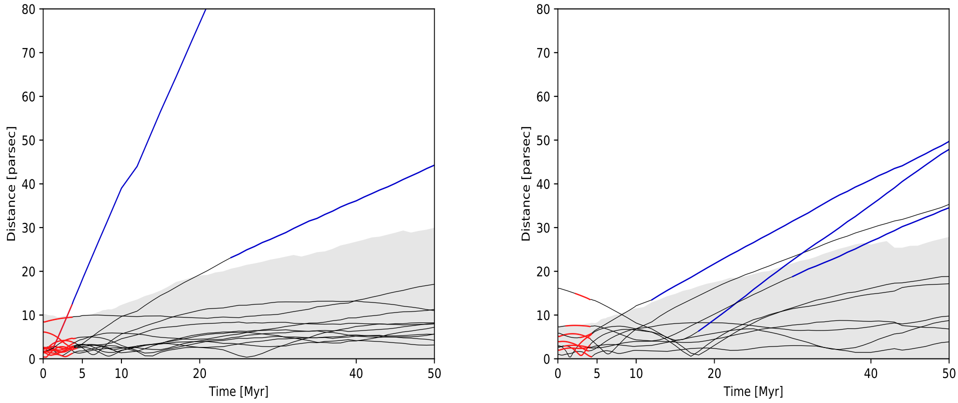

Fig. 1. Left panel. The dependence of the distance of the outgoing stars (black lines) to the cluster center of mass for the stellar masses larger than 5 $M_{\odot}$) . The stars at LBV stage are marked by red color. The gray region limits the cluster size at the current time. **Right panel**. The same as in the left panel, but for more massive cluster with masses $M > 6M_{\odot}$.

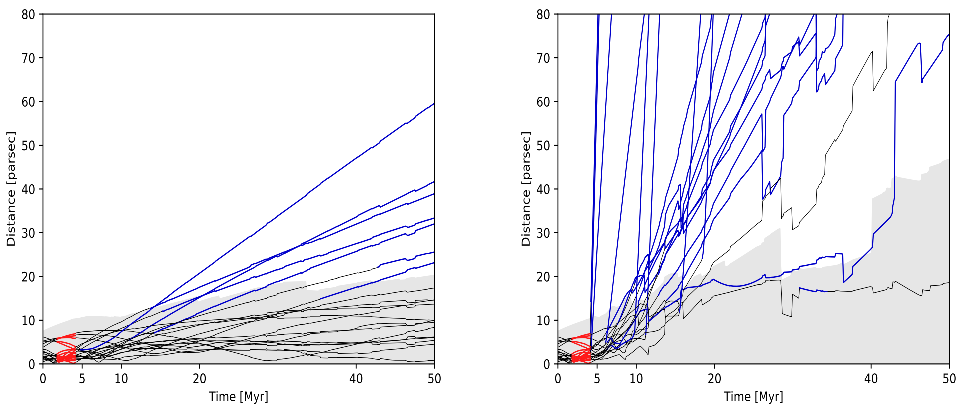

Fig. 2. figure
Left panel Cluster evolution without supernova explosions. **Right panel** Evolution of the same cluster taking into account the influence of supernovae.

2. MODELING

For modeling the stellar evolution we use the SSE code by Hurley et al. [3]. Simulation starts when the virial equilibrium is established and finishes when all massive stars became the supernovas. The initial function of the masses is taken from the paper by Kroupa [4]:

$$f(M) \propto M^{-\beta}, \tag{1}$$

where $\beta = 2.3$. The minimal stellar mass in cluster is limited by $5M_{\odot}$.

We suppose that stars with $\dot{M} > 10^{-5}\, M_{\odot}\, \mathrm{yr}^{-1}$ which are close to the Humphreys-Davidson limit [2] are LBV candidates. They are stars with a mass $M > 40M_{\odot}$ and an average lifetime of less than 5 Myr. The escape velocity depends of cluster parameters. For our cluster model it is about of 15 km/s. As it can be seen from Fig. 1 (left panel) no stars leave the cluster during the LBV stage. In several simulations, LBVs could be located at the periphery of the cluster as it seen in Fig. 1 (right panel).

We also examine the impact of of the supernova explosion on the ejection of LBVs. We use a simplified model of this scenario when at the time of the outburst the speed of the star closest to the supernova increases by a random value corresponding to a normally distributed random value with the mean velocity 50 km/s. The first ejections in Fig. 1 (right panel) correspond to most massive SN progenitors collapsed to a black hole. Now with the current model of stellar evolution, supernovae eject the future LBV a little later than it is necessary to see the LBS far from the cluster. However it can be seen that the acquired velocities allow to massive stars move away at large distances from their parent cluster in a short time.

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