GRAPE-SPH SIMULATIONS OF GLOBULAR CLUSTER FORMATION

N. NAKASATO[1], M. MORI[1], T. TUJIMOTO[2], G. MATHEWS[3], AND N. NOMOTO[1]
[1] Univ. Tokyo , [2] National Astronomical Observatory, Japan and [3] Univ. Notre Dame

Abstract. We examine two globular cluster formation scenarios with SPH simulations, using GRAPE-3AF. First model is the spontaneous collapse, which is found to induce a disruption of the system. However, the system can survive when sufficiently high external pressure exists. Second model is the collision of the two proto-cluster clouds, which can form a bound stellar system due to efficient cooling and a burst of star formation.

1. Scenario

At the formation of globular clusters, the star formation history is important in two respects (e.g., Murray et al. 1993). First, the metallicity of globular clusters is quite homogeneous. This property suggests that many of the member stars of the cluster formed in a very short period. Second, massive stars, which formed in proto-cluster clouds, evolve quickly and emit UV radiation. Such radiation heats the surrounding gas to cause its expansion. If the star formation rates (SFR) is low, most of the remaining gas will be brown off due to this heating before the gravitationally bound stellar system is formed. If there is external pressure, however, the expanding gas is decelerated and thus additional star formation may occur.

Proto-cluster clouds can be divided into two types depending on their masses. The clouds whose mass exceed the Jeans mass are gravitationally unstable, thus spontaneously collapsing to form stars. The clouds which are less massive than the Jeans mass are stable until some instabilities are introduced. A cloud-cloud collision or cloud-disk collision can trigger such an instability. When such collisions occur, clouds would become thermally unstable by efficient cooling. This cooling would lead to a burst of star formation because of the formation of a very dense region.

P. Hut and J. Makino (eds.), Dynamical Evolution of Star Clusters, 397–398.

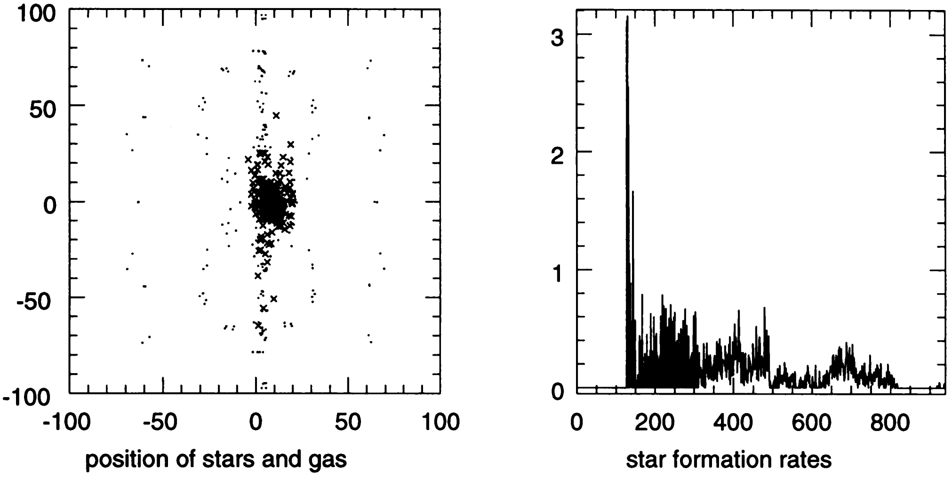

Figure 1. Left: positions of stars(cross) and gases(dot),(x, y both in pc). Right:star formation rates(x:10^4yr, y:$M_\odot yr^{-1}$).

2. Result

We calculate three simple cases using GRAPE-3AF (Sugimoto et al. 1990). The initial conditions are as follows.

- case I : spontaneous collapse for $M = 10^6 M_\odot$ and R = 50 pc
- case II : same as case I but with external pressure
- case III : collision of the two clouds in case I with $V_{\rm collision} = 100$ km/s

In case I, most gases are driven out of the system due to heating and the resulting stellar mass fraction is only $\sim$ 10%. In case II, the SFR is higher than in case I, so that the stellar mass fraction amounts to $\sim$ 50%. For case III, the position of the formed star particles at $\sim$ 10 Myr and star formation history are shown in Figure 1. A violent star formation occurs in a short period and the bound stellar system forms. This short period is consistent with the observational properties. In case II and III the stellar mass fraction exceeds 50% so that the system will survive(Lada et al. 1984).

This work has been supported by grants # 05242102, 06233101, 07CE200.

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https://doi.org/10.1017/S007418090000200X Published online by Cambridge University Press