Kinematics of Subclusters in Star Cluster Complexes: Imprint of their Parental Molecular Clouds

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ABSTRACT
Star cluster complexes such as the Carina Nebula can have formed in turbulent giant molecular clouds. We perform a series of \( N \)-body simulations starting from subclustering initial conditions based on hydrodynamic simulations of turbulent molecular clouds. These simulations finally result in the formation of star cluster complexes consisting of several subclusters (clumps). We obtain the inter-clump velocity distribution, the size of the region, and the mass of the most massive cluster in our simulated complex and compare the results with observed ones (the Carina Nebula and NGC 2264). The one-dimensional inter-clump velocity dispersion obtained from our simulations is \( 2.9 \pm 0.3 \) and \( 1.4 \pm 0.4 \) \( \text{km s}^{-1} \) for the Carina- and NGC 2264-like models, respectively, which are consistent with those obtained from Gaia Data Release 2: \( 2.35 \) and \( 0.99 \) \( \text{km s}^{-1} \) for the Carina Nebula and NGC 2264, respectively. We estimate that the masses of the parental molecular clouds for the Carina Nebula and the NGC 2264 are \( 4 \times 10^5 \) and \( 4 \times 10^4 \) \( \text{M}_\odot \), respectively.

Key words: methods: numerical — galaxies: star clusters: general — Galaxy: open clusters and associations: general — Galaxy: open clusters and associations: individual: Carina, NGC 2264

1 INTRODUCTION

Star clusters are often born in a hierarchical structure which consists of several subclusters (hereafter clumps). One of the biggest systems is the Carina Nebula, which include several star clusters and smaller clumps (Feigelson et al. 2011; Kuhn et al. 2014). Such “star cluster complexes” are considered to have formed via the gravitational collapse of giant molecular clouds with turbulence (McKee & Ostriker 2007, and references therein). The formation of stars and star clusters in turbulent molecular clouds have been tested using numerical simulations (Bonnell et al. 2008; Bate 2012; Krumholz et al. 2012b; Federrath & Klessen 2012; Fujii & Portegies Zwart 2015; Fujii 2015; Fujii & Portegies Zwart 2016). In these studies, hierarchical structure formation has been confirmed.

Star clusters are initially embedded in their parental molecular clouds (Lada & Lada 2003), but once massive stars formed, the gas is expelled by gas expulsion such as ionization, stellar winds, and supernovae explosions. As a result, the embedded clusters are expected to expand. This expansion has also been studied using numerical simulations (Pfalzner 2009; Pelupessy & Portegies Zwart 2012) and also by observations (Gouliermis 2018; Kuhn et al. 2018).

Not only star clusters, star cluster complexes have also been suggested to expand by numerical simulations. Fujii & Portegies Zwart (2015) performed a series of simulations of star cluster complexes forming in turbulent molecular clouds. They suggested that star cluster complexes also expand although some subclusters (hereafter, clumps) merge and evolve to more massive clusters within a few Myr (see also Fujii 2015; Fujii & Portegies Zwart 2016). However, the relative velocity among clumps in star cluster complexes was not studied in their work.

Observational studies on the kinematics of star cluster complexes require an accurate velocity measurement. Thanks to Gaia Data Release 2 (Gaia Collaboration et al. 2018), the proper motions of individual stars in young star clusters and associations are now available. This data allows us to study the kinematics of star cluster complexes. Kuhn et al. (2018) measured inter clump velocities for some star cluster complexes such as the Carina Nebula. They reported an expansion of star cluster complexes as well as that of young star clusters.

In this paper, we measure the velocity structure among clumps in star cluster complexes using the results of our numerical simulations (Fujii 2015; Fujii & Portegies Zwart 2016).
local gas density

a local star formation efficiency (SFE), which depends on the
to stellar particles using the following procedure. We assume
of the potential energy (\(E_p\)). With this setting, the sys-
set the kinetic energy (\(E_k\)) with a power spectrum
\(|\delta v|^2 \propto k^{-4}\) (Ostriker et al. 2001; Bonnell et al. 2003). The spectral index of \(-4\) appears in the case of compressive
turbulence (Burgers turbulence), and recent observations of
molecular clouds (Heyer & Brunt 2004), and numerical sim-
ulations (Federrath et al. 2010; Roman-Duval et al. 2011; Federrath 2013a) also suggested values similar to \(-4\). We adopt the mass and density of the molecular clouds as pa-
rameters.

In Table 1, the initial conditions of molecular clouds are
summarized. The model names represent the initial mass and density; for example, m100k-d100, m40k-d100, and m100k-d10. We adopt isother-
al (30K) homogeneous spheres and give a divergence-free random Gaussian velocity field \(\delta v\) with a power spectrum
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2.1 Numerical Simulations

We use the results of Fujii & Portegies Zwart (2016) and also perform additional simulations for some models. Here, we briefly summarize the methods used in this study (see also Fujii 2015; Fujii & Portegies Zwart 2016). First, we perform hydrodynamic simulations for molecular clouds using a smoothed-particles hydrodynamics (SPH) code, Fi (Hernquist & Katz 1989; Gerritsen & Icke 1997; Pelupessy et al. 2004; Pelupessy 2005) with the Astronomical Multipurpose Software Environment (AMUSE) (Portegies Zwart et al. 2009, 2013; Pelupessy et al. 2013). We set-up the initial conditions of the molecular clouds using AMUSE following Bonnell et al. (2003). We adopt isothermal (30K) homogeneous spheres and give a divergence-free random Gaussian velocity field \(\delta v\) with a power spectrum
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Table 1. Initial Conditions of Molecular Clouds

| Model       | N_{\text{run}} | M_{\text{MC}}(10^5 M_\odot) | R_{\text{MC}} (pc) | σ_{\text{MC}} (km s^{-1}) |
|-------------|----------------|-------------------------------|---------------------|-----------------------------|
| m1M-d100    | 1              | 1000                          | 13.3                | 19.6                        |
| m400k-d100  | 3              | 400                           | 10.0                | 14.4                        |
| m100k-d100(-vir) | 5         | 100                           | 6.2                 | 9.12                        |
| 40k-d100    | 10             | 40                            | 4.6                 | 6.70                        |
| m400k-d10   | 3              | 400                           | 21.0                | 9.92                        |
| m100k-d10   | 6              | 100                           | 13.3                | 6.23                        |

The first column indicates the name of the model. The second column gives the number of runs. Column 3–5 are give the mass, radius, and velocity dispersion (\(\sigma_{\text{MC}}^2 = 2E_k/M_{\text{MC}}\) and \(E_k\) is the kinetic energy) of the molecular cloud. For all models we set \(E_k/|E_p| = 1.0\), but for m100k-d100-vir \(E_k/|E_p| = 0.5\).

The entire system of this model is distributed in 100\(s_{\text{out}}\), we repeat the same procedure for the clump, because the clump may consist of some sub-clumps. We set the minimum number of stars for a clump to be 50, but for models m40k-d10 and m100k-d10, it reduce to 32 because their total mass is smaller than the other models, and as a result, the number of clumps are also small. The detected clumps have a mass-radius relation similar to that of observed clusters. We confirmed it in our previous papers (Fujii 2015; Fujii & Portegies Zwart 2010).

3 RESULTS

We measure the center-of-mass velocity of the detected clumps with respect to the center-of-mass velocity of the all detected clumps. In the top panel of Fig. 1, we present the spacial distribution of stars and detected clumps for one of model m400k-d110 at 0.5 Myr. The initial mass and density of this model are \(4 \times 10^5 M_\odot\) and \(10 M_\odot\)pc\(^{-3}\), respectively. We also show the velocity vector of each clump in the figure.

The averaged size (three-dimensional root-mean-square radius from the center-of mass position) and one-dimensional velocity dispersion among clumps of this model are \(r_{\text{rms}} = 14 \pm 1\) (pc) and \(\sigma_{\text{1D}} = 2.9 \pm 0.3\) (km s\(^{-1}\)), respectively. These values are similar to those of the Carina Nebula; the two-dimensional root-mean-square radius and the one-dimensional velocity dispersion are 9.15 pc and 2.35 km s\(^{-1}\), respectively (Kuhn et al. 2018). Considering the root-mean-square radius in our simulations is calculated in three dimension, the observed radius is scaled to be 11.2pc. The entire system of this model is distributed in \(\pm 20\)pc (see the top panel of Fig. 1). The Carina Nebula is also distributed on similar scale (see Fig. 13 in Kuhn et al. 2018).

The relation between the mass of the parental molecular clouds (\(M_{\text{MC}}\)) and the most massive star cluster (\(M_{\text{cl, max}}\)) was discussed in our previous study (Fujii & Portegies Zwart 2015), and found that it follows:

\[
\frac{M_{\text{cl, max}}}{1 M_\odot} = 0.2 \left( \frac{M_{\text{MC}}}{1 M_\odot} \right)^{0.76}.
\]

A similar relation is also found using radiation-hydrodynamic simulations with sink particles (Howard et al. 2018). Our results are roughly consistent with this relation. The mass of the most massive cluster (clump) would be an important parameter to discuss the parental molecular clouds. The mass of the most massive clump of model m400k-d10 is \(3.3 \pm 1.9 \times 10^3 M_\odot\). The most massive cluster in the Carina Nebula is Trumpler 14, which has a mass of \(4.3^{+3.3}_{-1.5} \times 10^3 M_\odot\) (Sana et al. 2010). The total stellar mass and gas + dust mass of the Carina Nebula are estimated to be \(2.8 \times 10^3 M_\odot\) (Preibisch et al. 2011b) and \(2 \times 10^3 M_\odot\), respectively, which are similar to those of model m400k-d10; \(2.5 \pm 0.8 \times 10^3 M_\odot\) and \(4 \times 10^3 M_\odot\), respectively (see Tables 2 and 3).

In the bottom panel of Fig. 1, we present the position vs. velocity plot of individual stars in the detected clumps for this model. The clumps distribute within \(v_z \lesssim |10|\) km s\(^{-1}\), and this is consistent with that of the Carina Nebula (see Fig. 12 in Kuhn et al. 2018). Here, we see the entire system is expanding.

At 0.5 and 2 Myr for each model, we calculate the average and standard deviation of the number (\(N_{\text{cl}}\)), one-dimensional velocity dispersion (\(\sigma_{\text{1D}}\)), root-mean-square radius (\(r_{\text{rms}}\)), and maximum mass (\(M_{\text{cl, max}}\)) of the detected clumps among the same models with different random seeds, and these results are summarized in Table 2. We, for comparison, summarize these values for Carina Nebula and NGC 2264 in Table 3. We here note that the inter-clump velocity dispersion measured in our simulations does not strongly depend on clump finding algorithms, because it is comparable to the velocity dispersion of all individual stars in the same region (see Appendix A).

While the velocity dispersion did not change much, the root-mean-square radius increased. This expansion is due to the gas expulsion. After we removed all gas particles, the virial ratio of this system is larger than 0.5 (Fujii & Portegies Zwart 2015; Fujii 2015; Fujii & Portegies Zwart 2016). The velocity dispersion among clumps depends on the initial condition of the molecular clouds. Higher mass or density result in a larger velocity dispersion. We found no
clear differences even if we change the initial virial ratio of the molecular clouds (see models m100k-d100 and m100k-d100-vir). We discuss this point in Section 4.

In the top panel of Fig. 2, we present the spacial distribution of clumps with their velocity vectors for one of model m40k-d100, which has a size similar to NGC 2264 region. In order to compare with the results of Kuhn et al. (2018), we also present the position vs. velocity plots for these models in the bottom panels of this figure. In this case, we see a clear velocity gradient, which shows an expansion.

Since the age of NGC 2264 is estimated to be $\sim 3$ Myr (Venuti et al. 2017), we compare the results of this model at 2 Myr. The 1D velocity dispersion and root-mean-square radius at 2 Myr is $1.4 \pm 0.4 \, \text{km s}^{-1}$, which is consistent with that of the NGC 2264 region ($0.99 \, \text{km s}^{-1}$) (Kuhn et al. 2018). The size ($r_{\text{rms}}$) of this model is $3.2 \pm 1.5 \, \text{pc}$ at 2 Myr, which is similar to that of NGC 2264 ($2.53 \, \text{pc}$) (see Table 3 and Figure 13 of Kuhn et al. 2018). Model m100k-d10 also has a velocity dispersion comparable with model m40k-d100, but the size of model m100k-d10 is $6.9 \pm 4.9 \, \text{pc}$ at 2 Myr, which is twice as large as that of model m40k-d100.

We also compare the maximum mass of the most massive cluster (S Mon) in NGC 2264 with the model. In order to obtain the mass of S Mon, we use the fraction of the number of samples summarized in Table 4 in Kuhn et al. (2018). According to the table, the number of samples for S Mon is 67, and the number of all samples in NGC 2264 is 516. If we assume that the fraction in the number of samples is the same as the mass fraction of S Mon, we estimate...
the mass of S Mon is 150 $M_\odot$ from the total mass of NGC 2264 (1100$M_\odot$) (Piskunov et al. 2008). On the other hand, the mass of the most massive clump for model m40k-d100 is 340 ± 240$M_\odot$. The minimum value is comparable to the observation. We, therefore, estimate that NGC 2264 formed in a dense molecular cloud (100$M_\odot$ pc$^{-3}$ i.e., 1700 pc$^{-3}$) with a mass of a few $10^4$ $M_\odot$.

In our method, we assumed an instantaneous gas expulsion. In observed star cluster complexes, however, the gas mass is comparable to or larger than stellar mass. In the Carina Nebula, for example, the estimated gas mass including dust is 2 $\times$ 10$^4$ $M_\odot$ (Preibisch et al. 2011a), which is an order of magnitude larger than that of stellar mass, 2.8 $\times$ 10$^3$ $M_\odot$ (Preibisch et al. 2011b). We, therefore, may overestimate the inter-cluster velocity dispersion in our simulations.

4 DISCUSSION

Which initial parameter decides the inter-cluster velocity dispersion? In our simulations, the velocity dispersion depends on the potential energy of the initial molecular cloud. In Fig. 3, we present the relation between the potential energy of our initial molecular clouds and the inter-cluster velocity dispersion at 0.5 Myr. Since the velocity dispersion does not change much at 2 Myr, we fit a power-law function to this relation using a least-mean-square method and obtain $\sigma_{1D,0.5Myr} = 1.66(E_p/E_{p,\text{min}})^{0.21}$ (km s$^{-1}$), where $E_{p,\text{min}}$ is the minimum $E_p$ among our models; specifically, $E_p$ for model m400k-d10.

In Fig. 4, we plot the relation between the initial size of the molecular cloud and the size of the resulting star cluster complexes at 0.5 and 2 Myr. At 0.5 Myr, the sizes of the complexes are correlated with those of the initial molecular cloud, but not in later time. This is because the expansion velocity of the complexes depends on the potential energy of the initial molecular cloud. Even if the initial size of the molecular cloud is the same, the expansion velocity can be different comparing models with different densities (see models m1M-d100 and m100k-d10).

In our study, we tested only initially spherical models. In the Orion A molecular cloud, however, stellar and proto-stellar clumps including the Orion Nebula Cluster is associated with a 50-pc scale filament (Megeath et al. 2016; Kounkel et al. 2018). In such a region, the initial molecular cloud might have been cylindrical (Bonnell et al. 2008), or a cloud-cloud collision might have triggered the star cluster formation (Fukui et al. 2018). In a large velocity dispersion of stars around the Integral Shaped Filament (Bally et al. 1987) associated with the Orion Nebula Cluster (Stutz & Gould 2016), a magnetic field may play an important role to eject stars from the filament by the “slingshot” mechanism (Boekholt et al. 2017; Stutz 2018).

5 SUMMARY

We performed a series of $N$-body simulations for the formation of star cluster complexes. Following the method in Fujii & Portegies Zwart (2015), we first performed SPH simulations of turbulent molecular clouds and then used the last snapshots to generate initial conditions for the $N$-body simulations, in which stars are distributed in clumpy and filamental structures.

The one-dimensional inter-clump velocity dispersion obtained from our simulations is 2.9 ± 0.3 and 1.4 ± 0.4 km s$^{-1}$ for the Carina- and NGC 2264-like models, respectively, which are consistent with those obtained from Gaia Data Release 2, which are 2.35 and 0.99 km s$^{-1}$ for the Carina Nebula and NGC 2264. The simulated complexes expand with time. We also confirmed the size and the mass of the most massive clump in these models are consistent with the observations.

Our results suggest that the parental molecular cloud of NGC 2264 has a mass of $\sim$ 4 $\times$ 10$^4$ $M_\odot$ and that Carina Nebula formed from a giant molecular cloud with a mass of $\sim$ 4 $\times$ 10$^5$ $M_\odot$, but the cloud density for NGC 2264 is estimated to be higher than that of the Carina Nebula. The inter-cluster velocity dispersion in our simulations, however, tends to be larger than that of observed star cluster complexes. This may be because we assumed an instantaneous gas expulsion, while observed star cluster complexes are still surrounded by molecular gas comparable or more massive than the total stellar mass.

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For the density, there are three parameters; peak density \( \delta_{\text{peak}} \), saddle density \( \delta_{\text{saddle}} \), and outer density \( \delta_{\text{outer}} \) thresholds. Density peaks higher than \( \delta_{\text{peak}} \) are detected as individual clumps. On the other hand, particles with a density lower than \( \delta_{\text{saddle}} \) are excluded from clumps. Particles with a local density higher than \( \delta_{\text{outer}} \) are clump candidates.

In regions with a density higher than \( \delta_{\text{outer}} \), several clumps can be included. In order to detect such clumps, \( N_{\text{merge}} \) is used. For a star in a density peak, if one of its \( N_{\text{merge}} \) nearest particles belongs to another density peak, then the averaged density of the two density peaks is calculated. If the averaged density is less than saddle density \( \delta_{\text{saddle}} \), these two density peaks are detected as two clump. If not, they are treated as one clump. The recommended value for \( N_{\text{merge}} \) is 4.

The peak density \( \delta_{\text{peak}} \) and saddle density \( \delta_{\text{saddle}} \) are determined depending on \( \delta_{\text{outer}} \). In Eisenhauer et al. (1998), \( \delta_{\text{peak}} = 3\delta_{\text{outer}} \) and \( \delta_{\text{saddle}} = 2.5\delta_{\text{outer}} \) are recommended. The outer density threshold \( \delta_{\text{outer}} \) should be chosen for each system, and can significantly change the result. In our study, we adopt three times of the half-mass density of the system (the density within a radius in which the half of the total mass is included) as \( \delta_{\text{outer}} \). The half-mass density in our models was typically \( 10^{-10} M_\odot \) pc\(^{-3}\) at 0.5 Myr and 1–10 M\(_\odot\) pc\(^{-3}\) at 2 Myr. For \( \delta_{\text{peak}} \) and \( \delta_{\text{saddle}} \), we adopt \( \delta_{\text{peak}} = 8\delta_{\text{outer}} \) and \( \delta_{\text{saddle}} = 10\delta_{\text{outer}} \), which values are higher than those recommended in Eisenhauer et al. (1998). In Eisenhauer et al. (1998), they applied this method to a cosmological \( N \)-body simulations and chose the parameters. In our simulations, however, the density contrast in star cluster complexes would be higher than that of dark matter halos. We, therefore, chose a higher values for \( \delta_{\text{peak}} \) and \( \delta_{\text{saddle}} \). Even if we adopt density thresholds same as those adopted in Eisenhauer et al. (1998), the results did not change significantly (see Table A1).

We also tested a fixed value for \( \delta_{\text{outer}} \). If we adopted \( \delta = 10 M_\odot \) pc\(^{-3}\) for both 0.5 and 2 Myr, the number of clumps at 0.5 Myr was twice as large as that obtained using our standard setting. However, the velocity dispersion among the detected clumps was not much different from that obtained using the standard setting. In Figure A1, we present the positions and velocities of detected clumps with our standard setting (left) and \( \delta = 10 M_\odot \) pc\(^{-3}\) (right). In the right panel, we see that a larger number of clumps with lower densities are identified because of the lower density threshold compared with our standard setting. We also find that some of the detected clumps in the right panel would not be identified as clumps by eye. Thus, a fixed outer density threshold for all models and all time does not work well, and we therefore adopt the mean density of the entire system as the outer density threshold rather than a fixed one.

For relatively large clumps, however, the determined velocities are consistent with those obtained from our standard settings. We also confirmed that the inter-clump velocity dispersion does not largely change even if we change the detection criteria. This is because the inter-clump velocity dispersion is similar to the velocity dispersion of all individual stars in the same region. We calculated the velocity dispersion within the \( r_{\text{rms}} \), where we set it to be 3 pc.

The velocity dispersion of all stars within 3 pc from the center of mass position of the complex is \( 3.4 \pm 0.4 \) km s\(^{-1}\) at
$t = 0.5 \text{ Myr}$. At $t = 2 \text{ Myr}$, the velocity dispersion of all stars within $r_{\text{rms}}(\equiv 6 \text{ pc})$ is $2.0 \pm 0.4 \text{ km s}^{-1}$. Thus, inter-clump velocity dispersion is an index relatively independent of clump finding algorithms.

We also changed the values of $N_{\text{dens}} = 32$ and $N_{\text{hop}} = 32$ from the recommended values in Eisenhauer et al. (1998). In our standard setting, we reduced the value of $N_{\text{dens}}$ in order to detect clumps consisting of less than 50 particles. On the other hand, we increased $N_{\text{hop}}$ to 32 in order to search peaks in slightly wider range of particles. However, the choice of $N_{\text{hop}}$ and $N_{\text{dens}}$ does not affect the results. In Table A1, we summarize the results using different values for HOP parameters.
Figure A1. Snapshots at 0.5 Myr for one of m100k-d100-vir. Each color indicate each detected clump. Gray dots indicate stars which do not belong to clumps. Arrows show the center-of-mass velocity of the detected clumps. Left: with our standard parameter set for HOP. Right: with outer density threshold ($\delta_{\text{outer}}$) of $10M_\odot$ pc$^{-3}$, but standard values for the other parameters.

Table A1. Results of m100k-d100 using different HOP parameters

| Changed parameters | $N_{\text{clump}}$ | $\sigma_{1D}$ (km s$^{-1}$) | $\tau_{\text{rms}}$ (pc) | $M_{\text{cl, max}} (10^3M_\odot)$ |
|--------------------|---------------------|-----------------------------|--------------------------|-----------------------------------|
| 0.5 Myr            |                     |                             |                          |                                   |
| Standard           | 13 ± 4              | 2.6 ± 0.3                   | 2.5 ± 0.7                | 1.1 ± 0.9                         |
| $\delta_{\text{peak}} = 3\delta_{\text{outer}}$ | 11 ± 3.2            | 2.7 ± 0.31                  | 2.7 ± 1                  | 0.78 ± 0.38                       |
| $\delta_{\text{outer}} = 10M_\odot$ pc$^{-3}$ | 22 ± 4              | 2.9 ± 0.21                  | 3.3 ± 0.66               | 1.9 ± 1.5                         |
| $N_{\text{hop}} = 8$ | 12 ± 4.5            | 2.6 ± 0.23                  | 2.6 ± 0.68               | 1.1 ± 0.87                        |
| $N_{\text{hop}} = 64$ | 13 ± 4.5            | 2.6 ± 0.24                  | 2.6 ± 0.8                | 1.2 ± 0.88                        |
| $N_{\text{dens}} = 16$ | 14 ± 5.2            | 2.7 ± 0.18                  | 2.6 ± 0.8                | 1.2 ± 0.89                        |
| $N_{\text{dens}} = 64$ | 12 ± 3.5            | 2.6 ± 0.18                  | 2.4 ± 0.35               | 1.1 ± 0.87                        |
| 2 Myr              |                     |                             |                          |                                   |
| Standard           | 13 ± 5              | 2.3 ± 0.5                   | 7.7 ± 1.8                | 2.3 ± 2.2                         |
| $\delta_{\text{peak}} = 3\delta_{\text{outer}}$ | 12 ± 4              | 2.2 ± 0.38                  | 7.5 ± 1.6                | 1.6 ± 0.97                        |
| $\delta_{\text{outer}} = 10M_\odot$ pc$^{-3}$ | 10 ± 3              | 2.2 ± 0.52                  | 7.5 ± 2                  | 1.1 ± 0.58                        |
| $N_{\text{hop}} = 8$ | 13 ± 4.8            | 2.2 ± 0.46                  | 6.4 ± 2.5                | 1.3 ± 0.84                        |
| $N_{\text{hop}} = 64$ | 13 ± 5.4            | 2.3 ± 0.51                  | 7.8 ± 2                  | 2.4 ± 2.2                         |
| $N_{\text{dens}} = 16$ | 13 ± 3.8            | 2.3 ± 0.53                  | 6.5 ± 2.9                | 2.3 ± 2.1                         |
| $N_{\text{dens}} = 64$ | 11 ± 4.3            | 2.3 ± 0.46                  | 7.6 ± 1.8                | 2.4 ± 2.2                         |