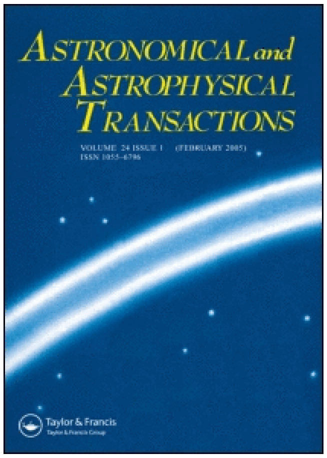

Astronomical & Astrophysical Transactions
The Journal of the Eurasian Astronomical Society
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713453505

Shortening of core collapse time in star clusters with two mass components

E. Khalisi [a]
[a] Astronomisches Rechen-Institut, Heidelberg, Germany

Online Publication Date: 01 June 2001
To cite this Article: Khalisi, E. (2001) 'Shortening of core collapse time in star clusters with two mass components', Astronomical & Astrophysical Transactions, 20:1, 51 - 54
To link to this article: DOI: 10.1080/10556790108208184
URL: http://dx.doi.org/10.1080/10556790108208184

Astronomical and Astrophysical Transactions, 2001, Vol. 20, pp. 51–54
Reprints available directly from the publisher
Photocopying permitted by license only

SHORTENING OF CORE COLLAPSE TIME IN STAR CLUSTERS WITH TWO MASS COMPONENTS

E. KHALISI

Astronomisches Rechen-Institut, Mönchhofstr. 12–14, 69121 Heidelberg, Germany
E-mail khalisi@ari.uni-heidelberg.de

(Received October 15, 2000)

We present high-accuracy N-body simulations of isolated star clusters consisting of two distinct mass components, m_1 and m_2, and vary their relative ratio $\mu = m_2/m_1$. The mass fraction of the more massive component relative to the total mass, $q = M_2/M_{\text{tot}}$, is set equal to 0.1 in all cases. We determine the average star mass within a fixed 'Lagrangian shell'. It is found that the time of first core collapse is reduced by the ratio μ with respect to a cluster with uniform masses.

KEY WORDS Methods: numerical, galaxies: star clusters

1 INTRODUCTION, SIMULATION TOOLS, INITIAL CONDITIONS

Stars are usually formed in a community of clusters, which may range from small associations of some tens of stars (Hillenbrand and Hartmann, 1998) to very dense and rich ones containing some thousand stars such as the Trapezium in the Orion Nebula Cloud (McCaughrean and Stauffer, 1994). The most massive stars are often found near the cluster centres, indicating a process of mass segregation. This could be explained either by stellar dynamical mass segregation (Spitzer, 1969) or as an inherent consequence of the fragmentation and star formation in a gas cloud (Bonnell and Davies, 1998). Dynamical models are challenged to answer this question by comparison with models of star formation. We choose the simple case of a cluster consisting of only two different stellar masses as an approximation to a mass spectrum. The heavy stars of individual masses m_2 were chosen five times heavier than the light ones, m_1, and they made up a fraction $q = M_2/M_{\text{tot}}$ of 10% of the total cluster mass. Inagaki and Wiyanto (1984) varied this fraction q and found that the evolution is delayed for different values: for higher fractions, the massive stars play a more dominant role in the dynamics, and for smaller fractions their total number becomes too small to make significant contributions.

In this paper, we fix q throughout all models to Inagaki and Wiyanto's value, and examine the evolutionary differences for various ratios of individual masses

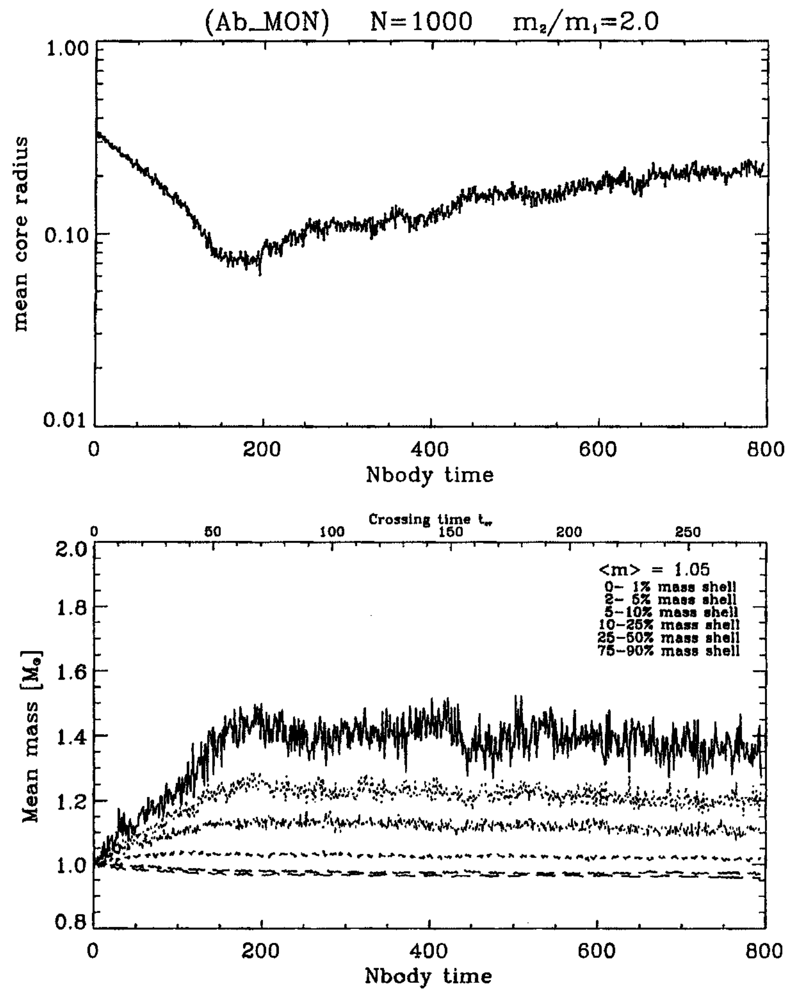

Figure 1 The time evolution of the core radius (upper panel), and the stratification of masses (lower panel) for a model with $N = 1000$ and $\mu = 2$. A conversion from N-body time units to crossing times t_{cr} is given on the upper axis.

$\mu = m_2/m_1$ ranging from 2 to 15. We use the most accurate method in order to follow the evolution of a two-mass component cluster, the direct force integration with N-body6 (Aarseth, 1999a, b) in its special version N-body6++ for massively parallel computers (Spurzem, 1999). Moreover, we deal with point masses without softening or merging of close particles. The scaling is done to standard N-body-units (Heggie and Mathieu 1986). In these units the crossing time of a particle is $t_{cr} = t_{NBU}/(2\sqrt{2})$, and the virial radius is 1.

The simulations were performed with various particle numbers ($N = 500$, 1000, 2500, and 5000). Initially, all particles are distributed randomly according to a

Table 1. Times of first core collapse (in N-body–time units).

$\mu = m_2/m_1 =$	*1*	*2*	*3*	*5*	*10*	*15*
$N = 500$ (40×)	189 ± 36	103 ± 26	59 ± 18	31 ± 11	23 ± 9	17 ± 5
$N = 1000$ (20×)	336 ± 36	173 ± 21	88 ± 17	48 ± 13	25 ± 6	21 ± 6
$N = 2500$ (8×)	683 ± 27	378 ± 24	202 ± 22	100 ± 16	50 ± 16	31 ± 7
$N = 5000$	–	$648 \pm 32^*$	$294 \pm 2^*$	$142 \pm 6^*$	$60 \pm 6^\dagger$	$53 \pm 4^\dagger$

*, Based on 2 simulations; †, based on 3 simulations.

Plummer sphere, and the system is in a global virial equilibrium. Moreover, we neglect any kind of stellar evolution, external galactic field, and primordial binaries.

2 RESULTS

Our simulations are summarized in Table 1. Each model, depending on N and μ, is averaged over the number of particular runs given in brackets in the first column. The particular runs differ in the initial seed only, which leads to a randomized setup. Giersz and Heggie (1994) pointed out that the statistical value of such ensemble averages are well balanced: for example, a set of 40 runs containing 500 particles is statistically comparable with a single run containing 20000 particles. Because of the large calculation efforts only a few simulations for $N = 5000$ are available.

In the table the mean time of core collapse and its standard deviation is given. Figure 1 demonstrates the time evolution of the mean mass in the inner shells for a model with $N = 1000$ and $\mu = 2$. As one sees we start with an equal distribution of all masses. In the course of the dynamical evolution the innermost shell (solid line) gathers a large number of heavier particles, and its average mass increases at the expense of the outer shells (dashed lines). Core collapse occurs at 170 N-body–time units when the mass segregation has been largely completed. After that, a binary-driven post-collapse follows. The results of all simulations are shown in Figure 2. It illustrates the gradual shrinking of the core collapse time with increasing μ. For all particles numbers investigated, the slope is -0.98 ± 0.06.

3 SUMMARY

Our results can be summarized as follows:

1. The process of mass segregation is governed by the ratio of the individual particles $\mu = m_2/m_1$.

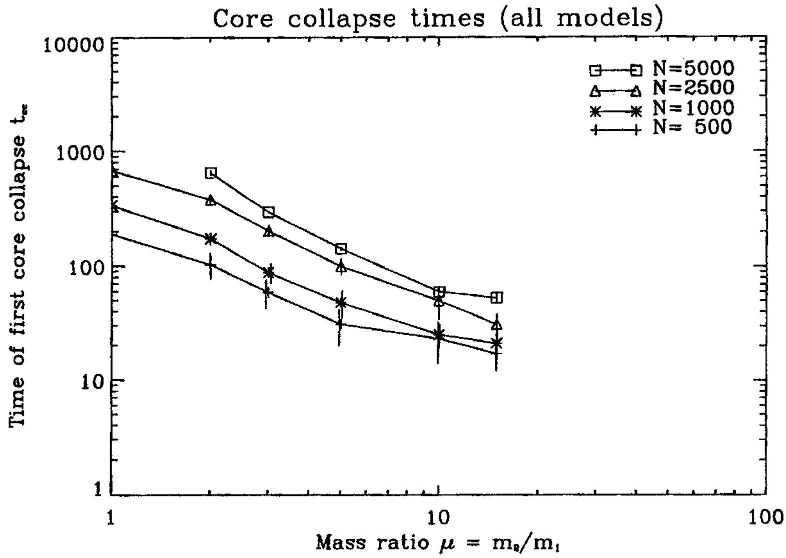

Figure 2 Shortening of the core collapse time in two-component star clusters.

2. The time of core collapse is reduced by μ in comparison to the core collapse time of a cluster with uniform masses ($\mu = 1$):

$$t_{cc,\mu} \propto \frac{1}{\mu} t_{cc,1}.$$

This result is not a big surprise for experts in the field, but it has never been directly and quantitatively proven in ensemble averaged N-body models with two mass components, as in the present work. Further studies are in preparation (Khalisi and Spurzem, 2001).

References

Aarseth, S. J. (1999a) *Celest. Mech. Dyn. Astron.* **73**, 127.
Aarseth, S. J. (1999b) *Publ. Astron. Soc. Pac.* **111**, 1333.
Bonnell, I. A. and Davies, M. B. (1998) *Mon. Not. R. Astron. Soc.* **295**, 691.
Giersz, M. and Heggie, D. C. (1994) *Mon. Not. R. Astron. Soc.* **268**, 257.
Heggie, D. C. and Mathieu, R. D. (1986) In: P. Hut and S.L.W. McMillan (eds.) *The Use of Supercomputers in Stellar Dynamics.* p. 233, Springer Verlag Berlin.
Hillenbrand, L. A. and Hartmann, L. W. (1998) *Astrophys. J.* **492**, 540.
Inagaki, S. and Wiyanto, P. (1984) *Publ. Astron. Soc. Japan* **36**, 391.
Khalisi, E. and Spurzem, R. (2001) in prep.
McCaughrean, M. J. and Stauffer, J. R. (1994) *Astron. J.* **108**, 1382.
Spitzer, L. jr. (1969) *Astrophys. J.* **158**, L139.
Spurzem, R. (1999) *J. Comput. Appl. Math.* **109**, 407.