Surviving Gas Expulsion with Substructure

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Abstract

We simulate the effects of gas expulsion from each of 2,5, or 10 sub-clusters within a larger cluster. Each sub-cluster is a super-virial Plummer sphere placed within a virialised Plummer sphere cluster. We find that the more sub-clusters we have, the greater the fraction of stars that remain bound within the cluster. For an effective star formation efficiency of 25% we find that 70% of the initial mass remains bound when we have 10 sub-clusters, compared to complete destruction for a sub-cluster in isolation.

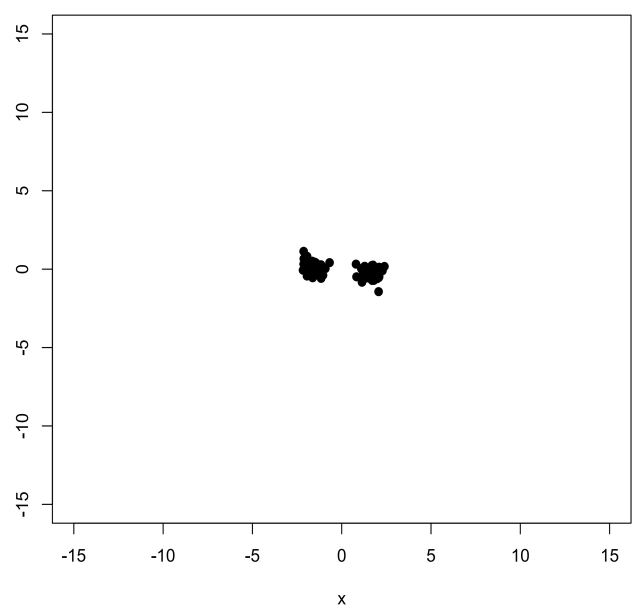
Introduction

Observations show that $\sim$10% of stars end up in bound clusters by $\sim$10 Myr (Lada & Lada 2003). It is often argued that most stars *form* in clusters, but most of those clusters are destroyed by gas expulsion (e.g. Goodwin & Bastian 2006; Baumgardt & Kroupa 2007). Gas expulsion has mostly been studied in single, isolated clusters. In this poster we present simulations of 'popping' sub-clusters within a larger (virialised) cluster to investigate the effects of gas expulsion in a deeper global potential well.

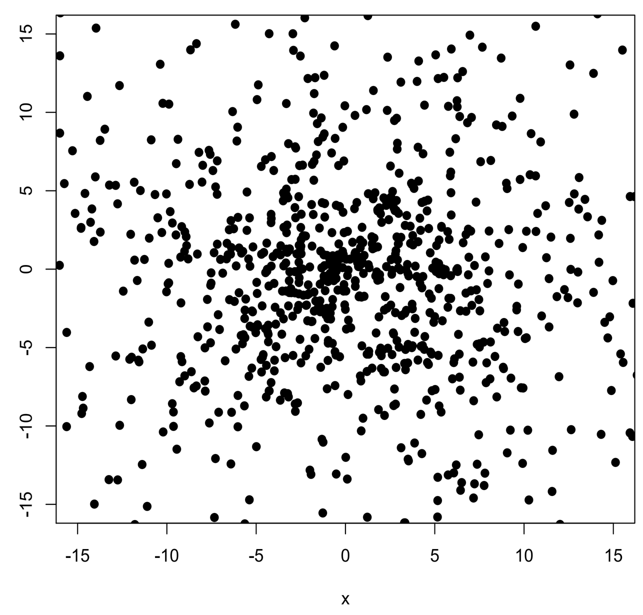
Initial Conditions

Using nbody6 (Aarseth 2001) we simulate systems with N=1000 equal mass stars. Sub-clusters are 0.1 pc Plummer spheres embedded in a larger (R_{plum}=1 pc) cluster. The larger cluster is always in virial equilibrium.
We use N=2, 5, and 10 sub-clusters (with N=500, 200, and 100 stars). These sub-clusters have *internal* virial ratios of 0.5, 1.0, 1.5, 2.0, and 4.0 - corresponding to effective star formation efficiencies (eSFEs) of 100%, 50%, 33%, 25%, and 13%.
We then simulate several realisations of each system for 10 Myr. At 10 Myr we determine the fraction of stars still bound.
For single clusters there is a critical eSFE of 30% above which a bound core can remain, below which the cluster is completely destroyed.

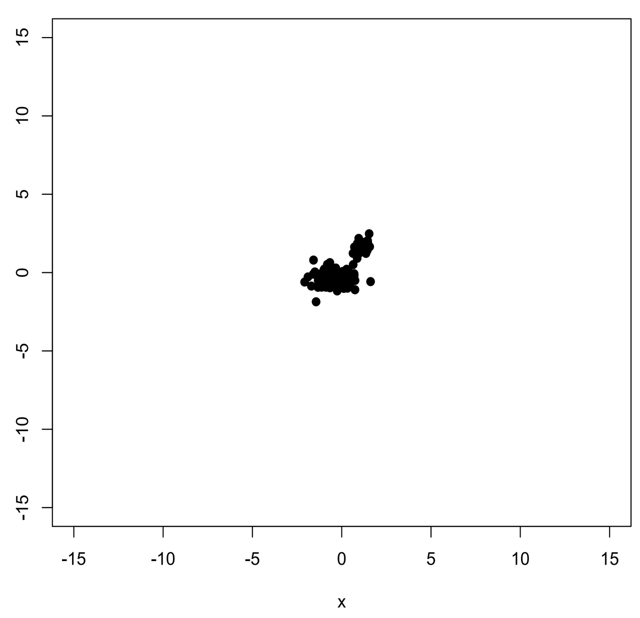
Fig. 1 (below) shows the initial and final distributions of stars for example clusters with N=2, 5, and 10 sub-clusters with Q=1.5 (eSFE=33%) seen in 30-by-30 pc boxes.



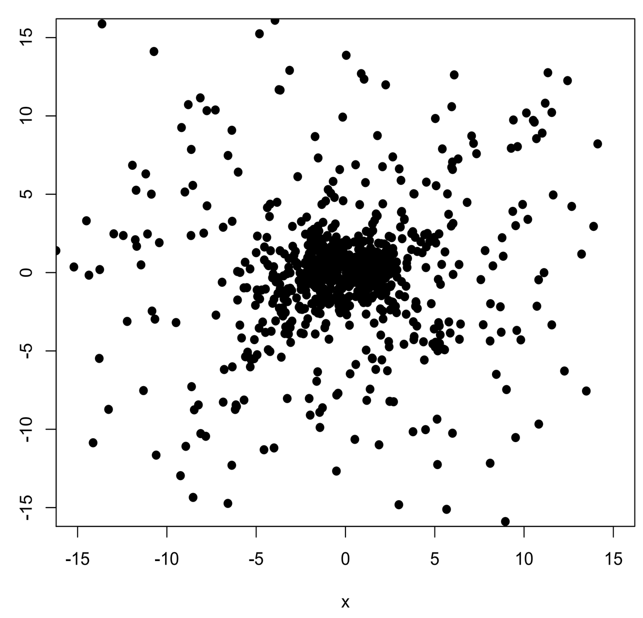
(a) N=2, t=0Myr



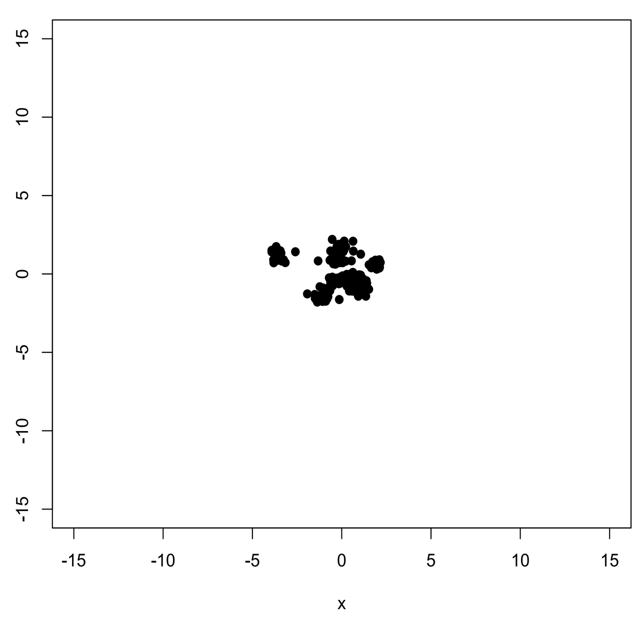
(b) N=2, t=10Myr



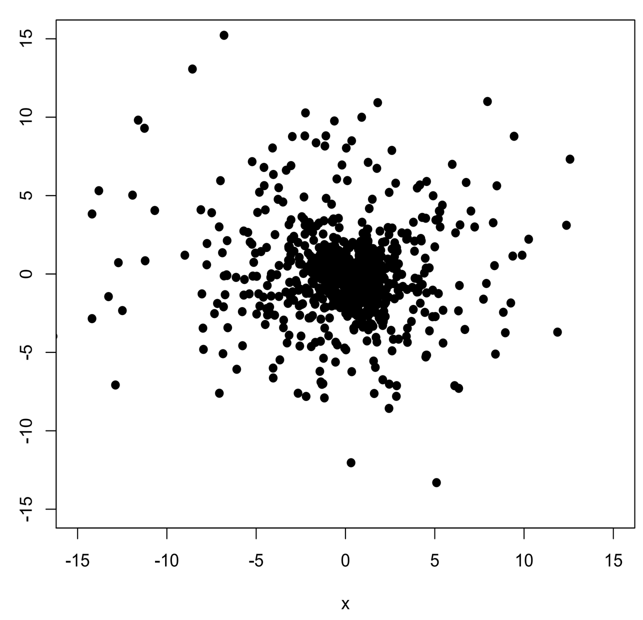
(c) N=5, t=0Myr



(d) N=5, t=10Myr



(e) N=10, t=0Myr



(f) N=10, t=10Myr

Results

We find that the more sub-clusters there are, the more likely it is that a significant cluster survives. In fig. 2 (below) we show the average bound fraction of stars after 10 Myr for each set of simulations from a Q=0.5 (green line at the top), through to Q=4.0 (orange line at the bottom).

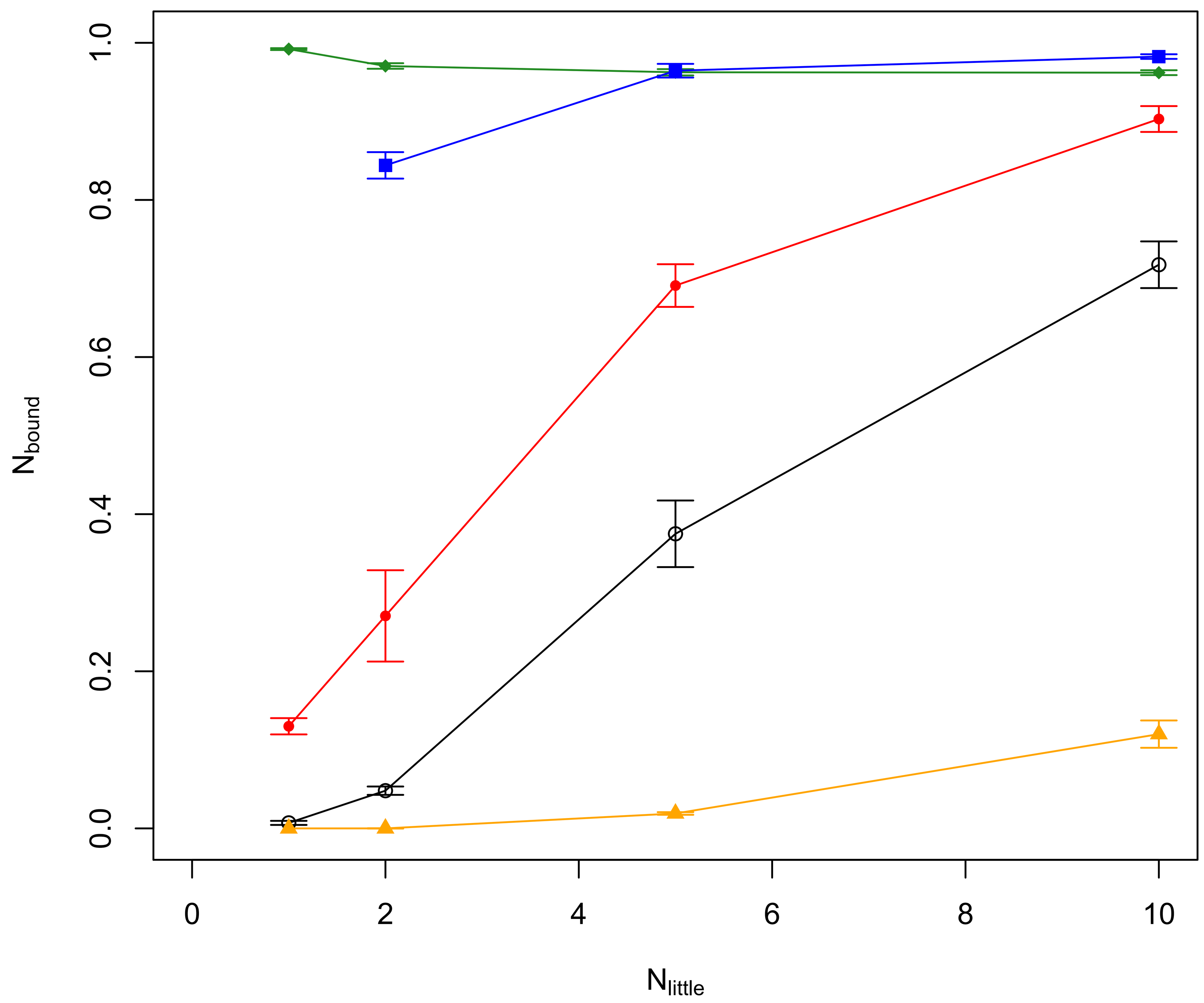


Figure : Fraction of bound stars after 10Myr plotted against the number of sub-clumps for Q=0.5 (green diamonds), Q=1.0 (blue squares), Q=1.5 (red circles), Q=2.0 (black circles), and Q=4.0 (orange triangles).

What can be seen in fig. 2 is that as the number of sub clusters increases, the bound fraction increases. In the critical Q=2.0 (eSFE=25%) case when N=2 (or 1) the cluster is completely destroyed. But, when N=5 or 10, over half of the mass remains in a bound cluster.

Conclusions

We can say that gas expulsion from small sub-clusters in a larger cluster is far less effective at destroying the cluster than might have been expected. This is due to the smaller velocity dispersions in each sub-cluster compared to a single cluster containing the combined mass of all sub-clusters.

Acknowledgements

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