*The Interplay among Black Holes, Stars and ISM*
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# Run-away IMBH formation in dense star clusters

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**Abstract.** We have established under which conditions core collapse of a spherical cluster occurs before massive stars have time to evolve off the main sequence (MS). We consider cluster central velocity dispersions of $100\,\mathrm{km\,s^{-1}}$ and higher, appropriate for galactic nuclei. At such high velocities, binary stars play little dynamical role and are therefore neglected. On the other hand whether collisions allow the growth of very massive stars (VMS, with $M_* \gg 100\,M_\odot$) or, on the contrary, grind them down is a central unknown addressed in this work. We find that, in spite of the high relative velocities, run-away growth of a VMS, a likely progenitor for an intermediate-mass BH (IMBH), occurs in all clusters with short enough a core collapse time.

## 1. Fast core collapse of a stellar cluster

We are exploring pathways through which dynamical evolution of a stellar cluster may lead to the formation of an intermediate-mass black hole (IMBH).

We consider the evolution of spherical clusters with a broad mass function ($M_* = 0.2 - 120\,M_\odot$, typically). Using so-called "Monte Carlo" (MC) and "gaseous" simulation techniques, we have shown that core collapse, driven by mass-segregation, occurs very quickly, i.e. within of order 15 % of the central relaxation time (Gürkan, Freitag & Rasio 2004). During core collapse, the central regions of the cluster become completely dominated by the most massive stars. The central density steadily increases until the first stellar collisions occur. However, the central velocity dispersion *decreases* during most of the evolution, as a result of a tendency toward kinetic energy equipartition between massive stars and lighter ones, see Fig. 1. Hence relative velocities of a few $1000\,\mathrm{km\,s^{-1}}$ are never reached and one may expect disruptive collisions to be rare.

## 2. Collisional run-away

In recent MC simulations, we have introduced collisions between single MS stars (Rasio, Freitag, & Gürkan 2004; Freitag, Gürkan & Rasio, in preparation). Our prescription for the outcome of collisions is based on ~ 15 000 SPH simulations (Freitag & Benz 2004). Hence, we do not assume that collisions are perfect mergers but allow for collisional mass loss and fly-bys, a likely outcome for encounters with relative velocities of a few $100\,\mathrm{km\,s^{-1}}$. However, we observe that, provided core collapse occurs within less than ~ 3 Myrs (the time needed for massive stars to evolve off the MS), the cluster always enters a run-away phase in which a star more massive than $1000\,M_\odot$ grows through repeated mergers (mostly with $\sim 100\,M_\odot$ stars). This is shown, for one simulation, in Fig. 2. Such a very massive star (VMS) is a likely progenitor for an IMBH.

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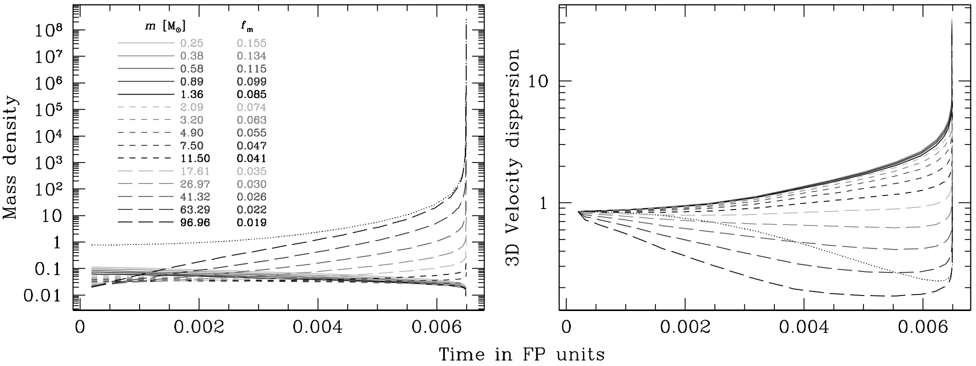

**Figure 1.** Core-collapse evolution of a multi-mass stellar cluster simulated with the gaseous model (Spurzem & Takahashi 1995). Left: Evolution of the central density for the 15 individual mass components ($m$ is the mass of the stars in the component, $f_m$ the fraction of the total mass). The dotted line shows the total density. Right: Evolution of the central velocity dispersions. The dotted black line shows the mass-averaged value. $N$-body units are used for the $y$-axes.

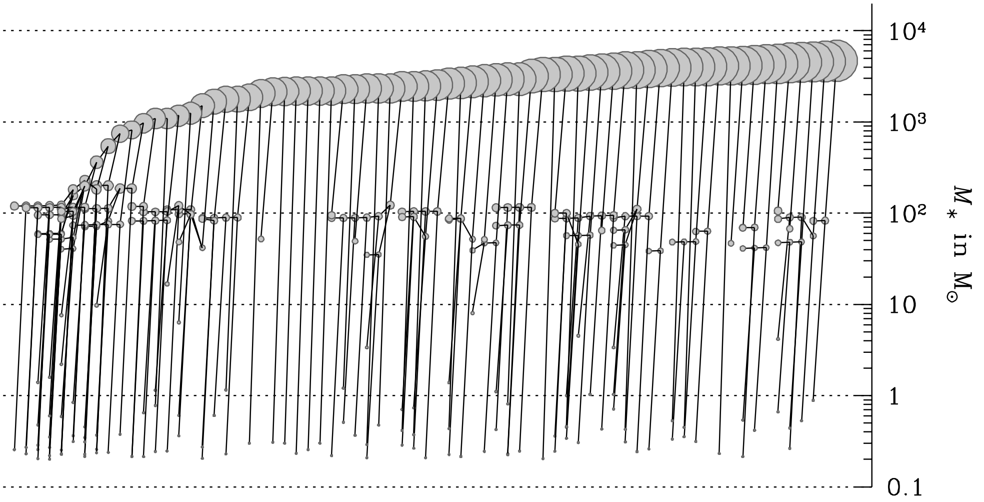

**Figure 2.** Collisional run-away in a typical MC simulation with $10^6$ particles. The initial 1D velocity dispersion is $130\,\mathrm{km\,s^{-1}}$. Shown is the merger tree for the run-away VMS. Evolution is from left to right. The vertical axis indicates the stellar mass. Note that the largest fraction of the final mass of the VMS comes from stars near the top end of the IMF, around $100\,M_{\odot}$.

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## References

Freitag, M., & Benz, W. 2004, MNRAS, submitted (astro-ph/0403621)

Gürkan, M. A., Freitag, M., & Rasio, F. A. 2004, ApJ, 604, 632

Rasio, F. A., Freitag, M., & Gürkan, M. A. 2004, in *Coevolution of Black Holes and Galaxies*, (ed. L. C. Ho), Cambridge: Cambridge Univ. Press, p. 138

Spurzem, R., & Takahashi, K. 1995, MNRAS, 272, 772