Ejection of Hyper-velocity stars from Galactic Nuclei by Intermediate-mass Black Holes

Holger Baumgardt

University of Bonn, Germany

in collaboration with

Ulf Löckmann, Simon Portegies Zwart,

Alessia Gualandris

Intermediate-Mass Black Holes (IMBHs):

- IMBHs have masses in the range between a few 10^2 to a few 10^4 Msun, which is intermediate between the solar-mass black holes formed from ordinary stars and the supermassive black holes in galactic nuclei.

Reasons why (IMBHs) could exist:

- The IMF of Pop III stars is believed to have been top-heavy, meaning that a fraction of them could have ended as IMBHs.

- If supermassive black holes formed out of smaller mass ones, some of them might not have been able to make it and still exist as IMBHs.

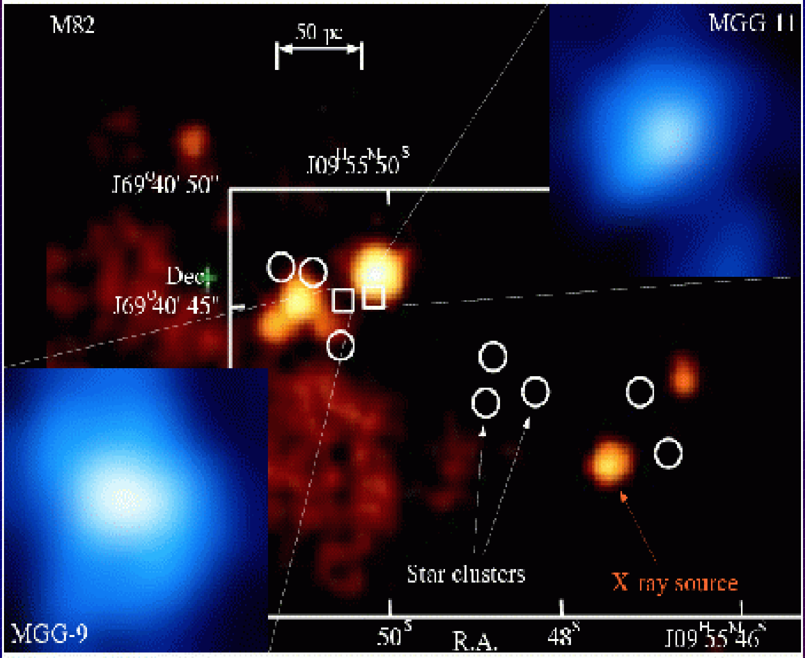
- They might also have been formed in clusters by stellar collisions or black hole mergers.

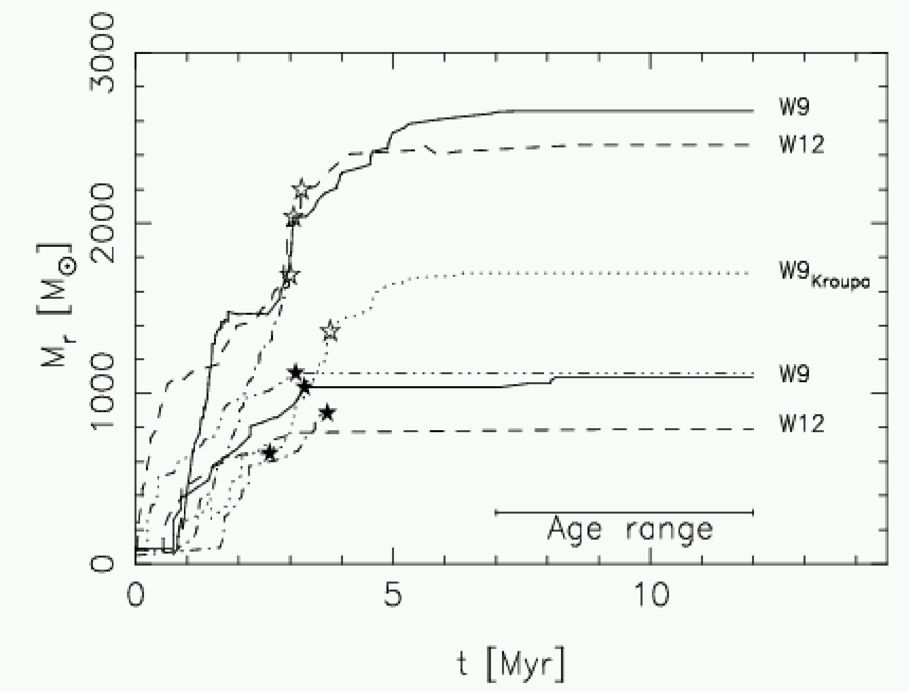
Simulations of IMBH Formation

- Portegies Zwart et al. (2004) followed the evolution of MGG-11 by N-body simulations of star clusters containing N= 130.000 stars, starting from different initial density profiles.

- They found that heavy mass stars sink into the cluster center as a result of dynamical friction.

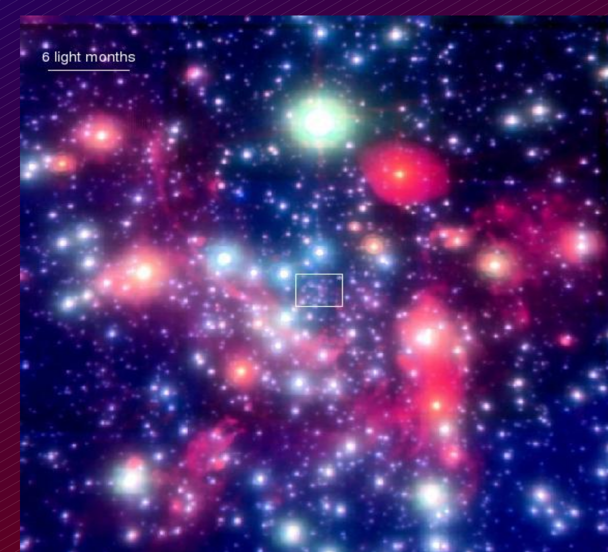
- For high enough central concentrations, this happens fast enough that runaway merging of stars occurs in the center.





……if IMBHs form in star clusters, star clusters in the central few kpc are most likely to harbor them.

In this case the IMBHs would, over time, sink into the galactic center and undergo close interactions with the galactic center stars……



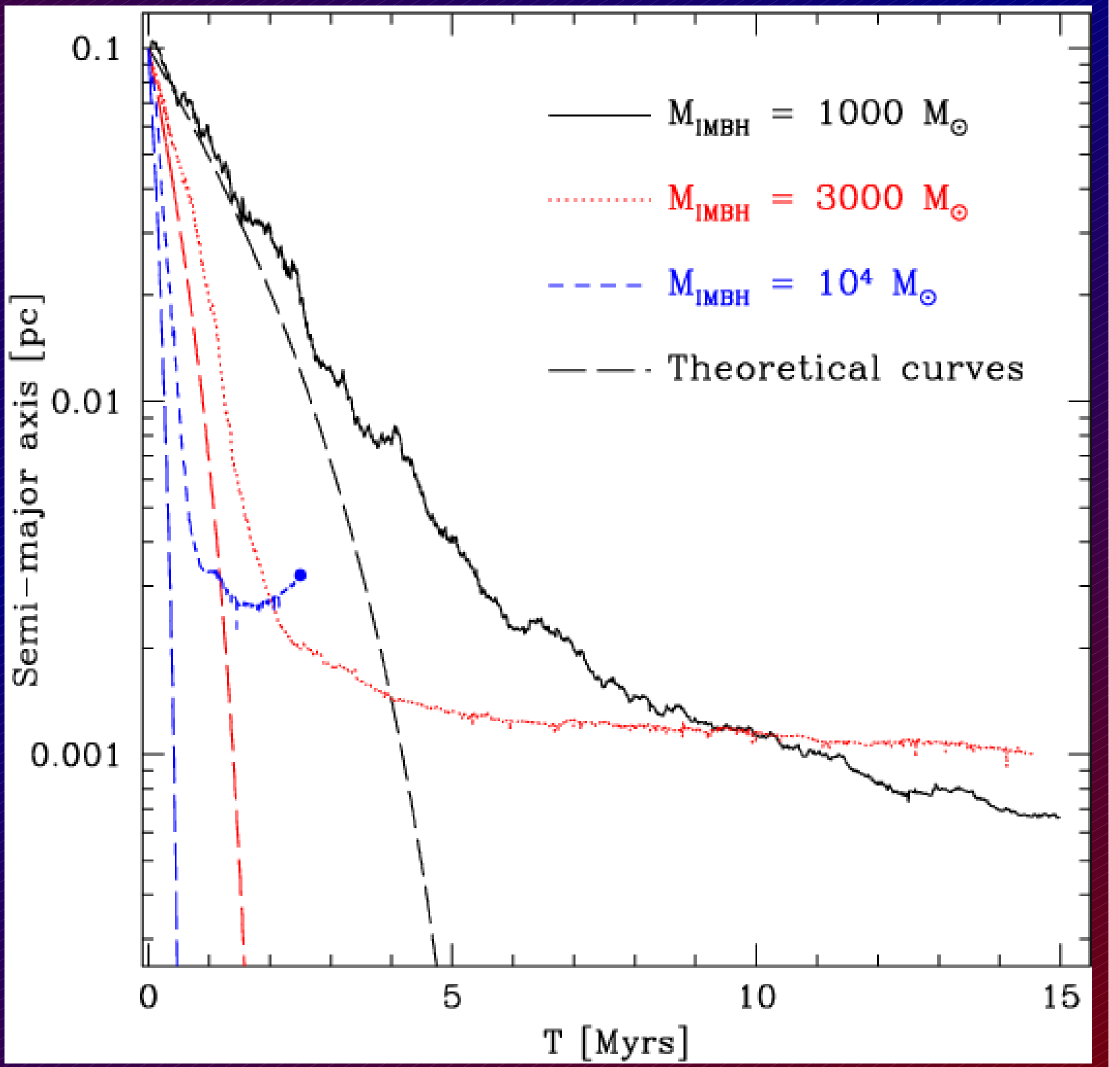
Ejection of hyper-velocity stars by IMBHs

- In the galactic bulge, star clusters would spiral into the center due to dynamical friction, delivering the IMBHs inside 0.1 – 1 pc of the SMBH.
- Once the clusters are dissolved, the IMBHs spiral in further.
- The IMBHs would undergo close interactions with stars and eject some of them from the vicinity of the SMBH via the slingshot mechanism.
- This might be an explanation for the recently detected hyper-velocity stars (HVS) in the galactic halo (Brown et al. 2005, 2006, 2007, Edelmann et al. 2005, Hirsch et al. 2005).

Results: IMBH Inspiral

- Depending on their mass, IMBHs spiral into the center within a few Myrs.

- The inspiral stalls once the IMBHs have reached a radius of about 0.001 pc.

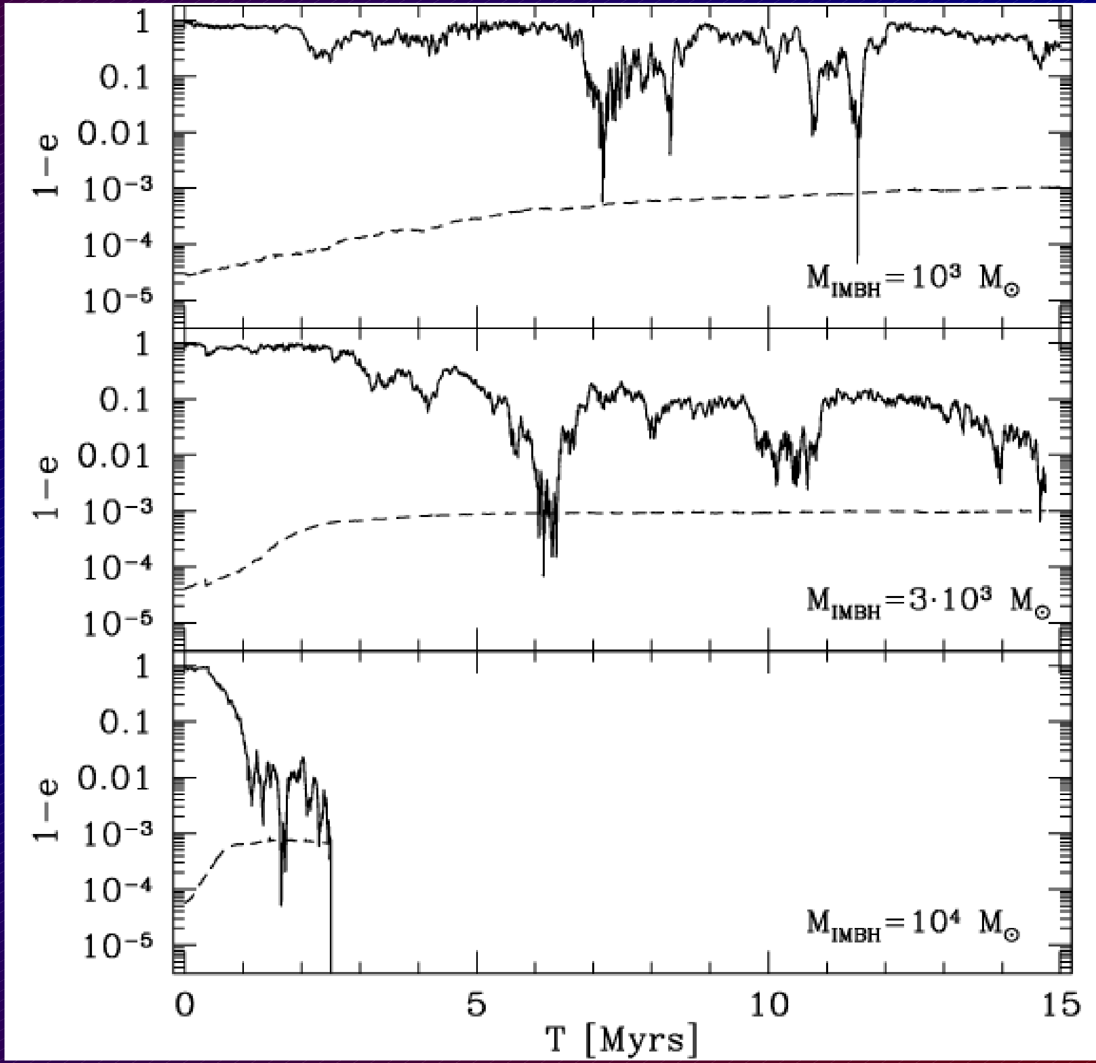


(from Baumgardt et al. 2006)

Results: Eccentricity evolution

- Orbits become highly eccentric once the IMBHs have reached the center.

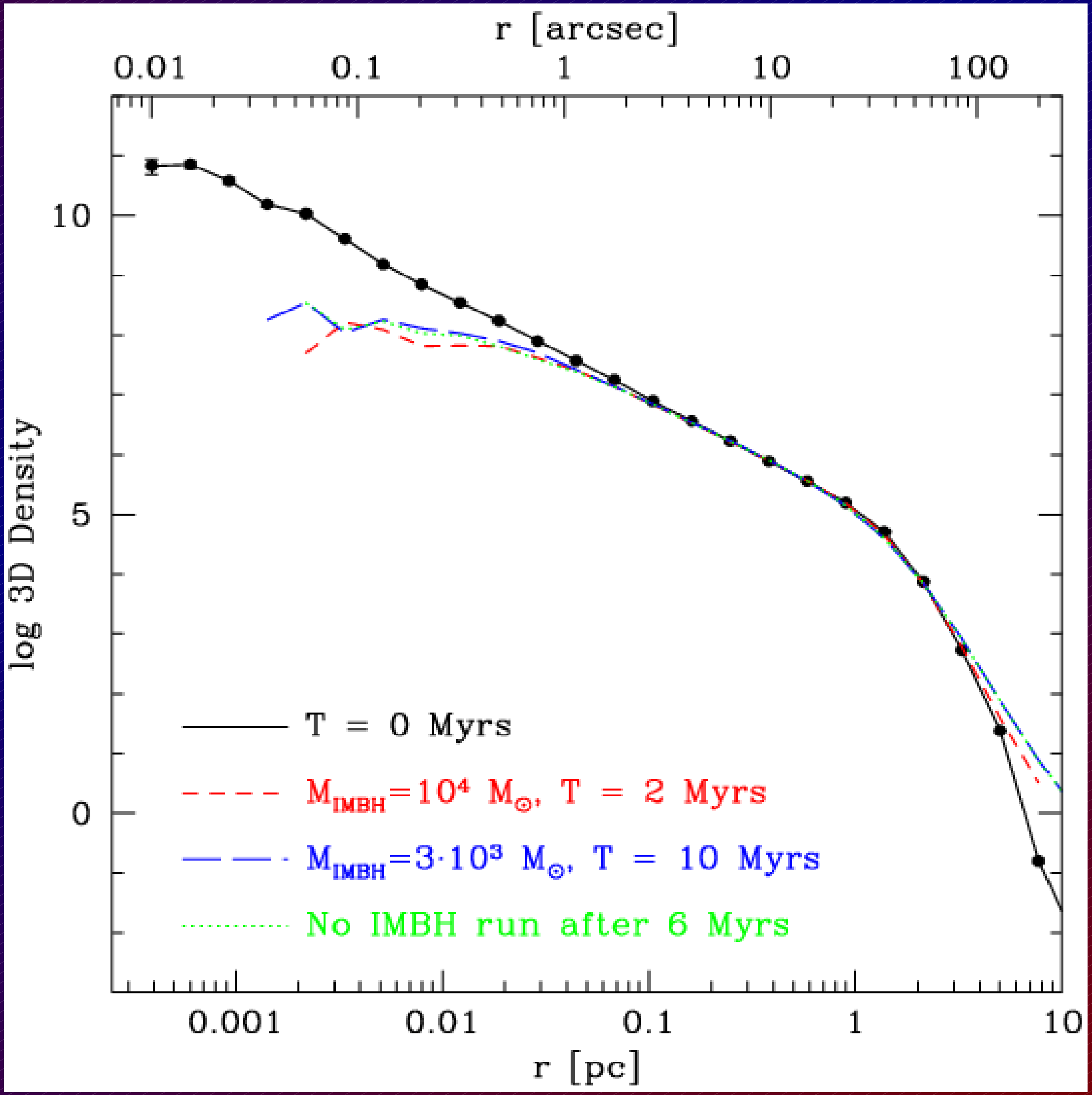
- As a consequence, they would merge with the central SMBH within a few Myrs due to emission of gravitational waves.



Results: The stellar cusp after IMBH Inspiral

- The central cusp inside 0.03 pc becomes depleted in stars and takes at least 100 Myrs to rebuild it.

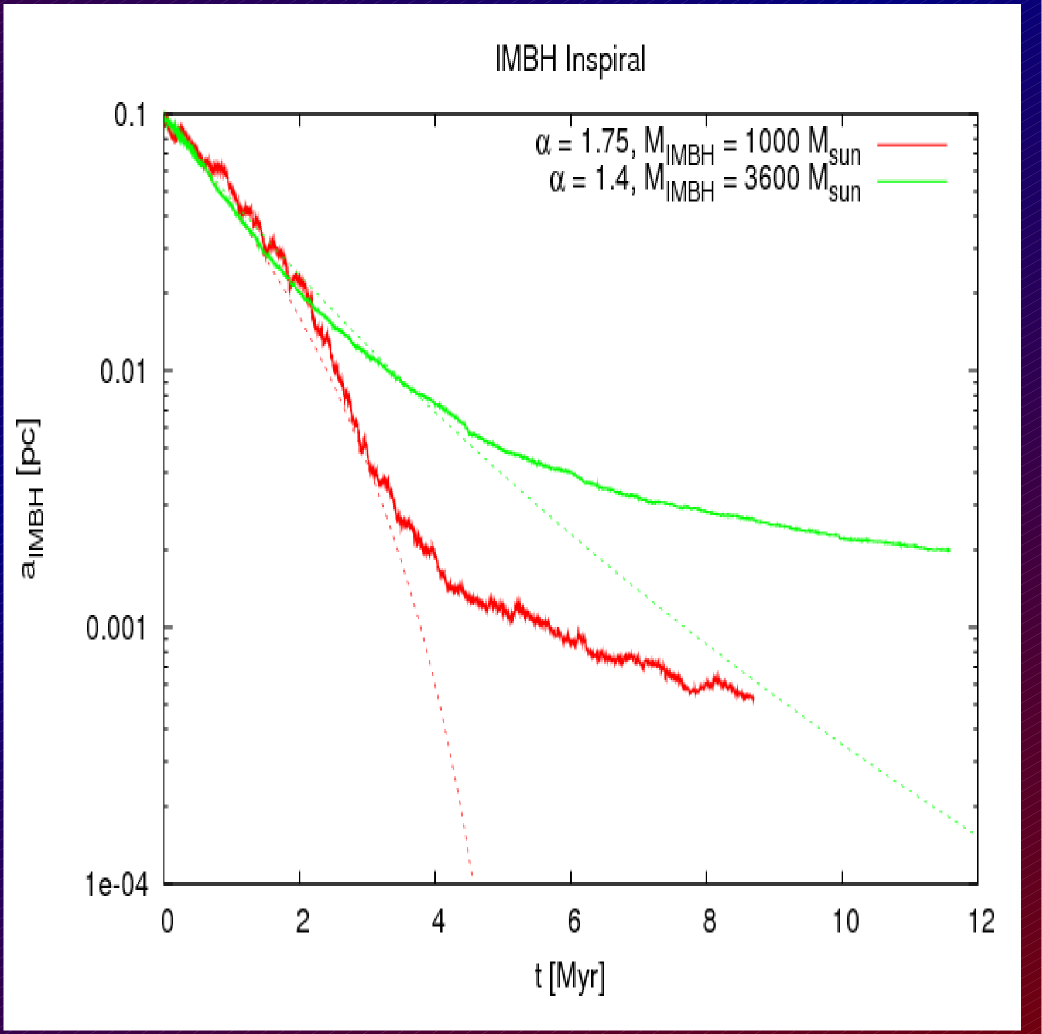
- The remaining cusp has a much flatter density profile. This break in slope could become observable in the future.



Results: IMBH inspiral in flat cusps:

- In flatter cusps the inspiral stalls at much larger radii, meaning that the IMBH gets stuck before GW emission can take over.

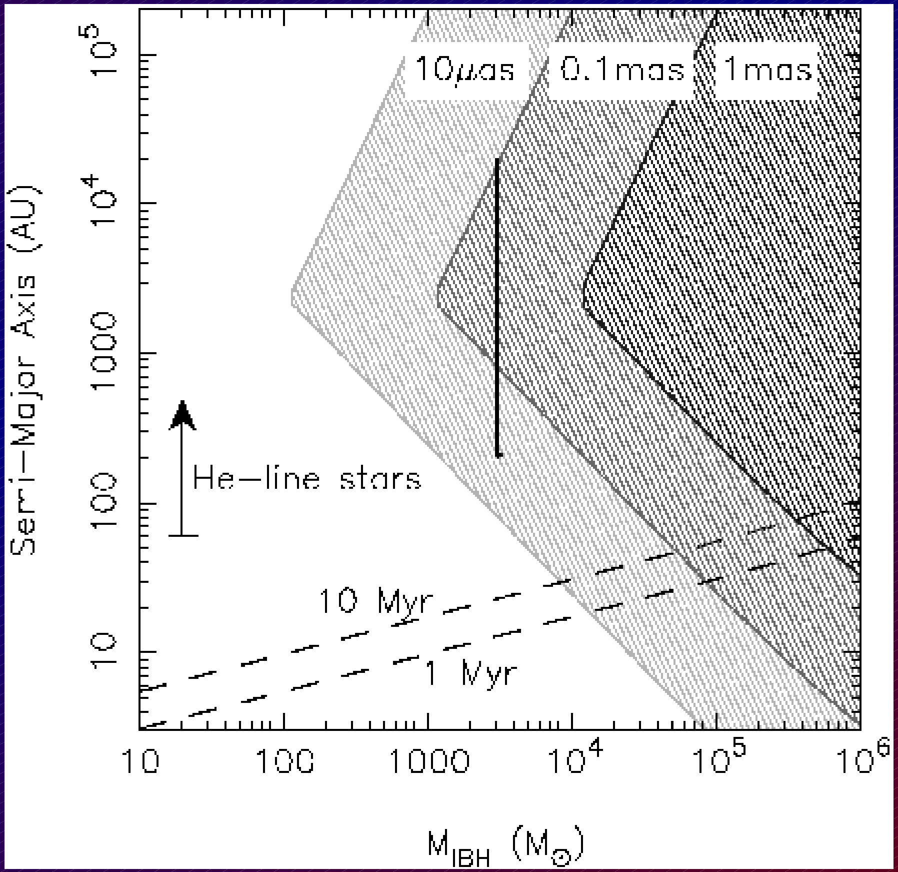
- In this case a single IMBH could eject stars over a much longer timescale (possibly up to 100 Myrs).



(from Löckmann & Baumgardt 2007)

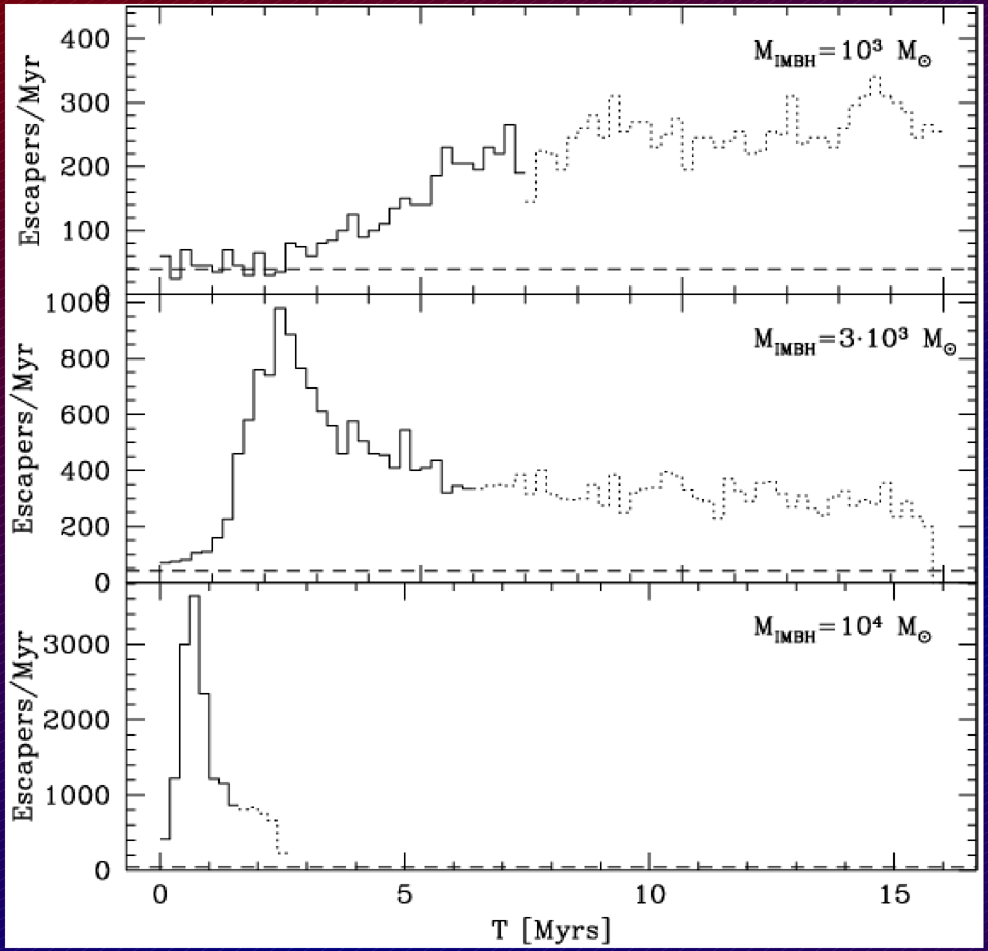
Results: IMBH inspiral in flat cusps (II):

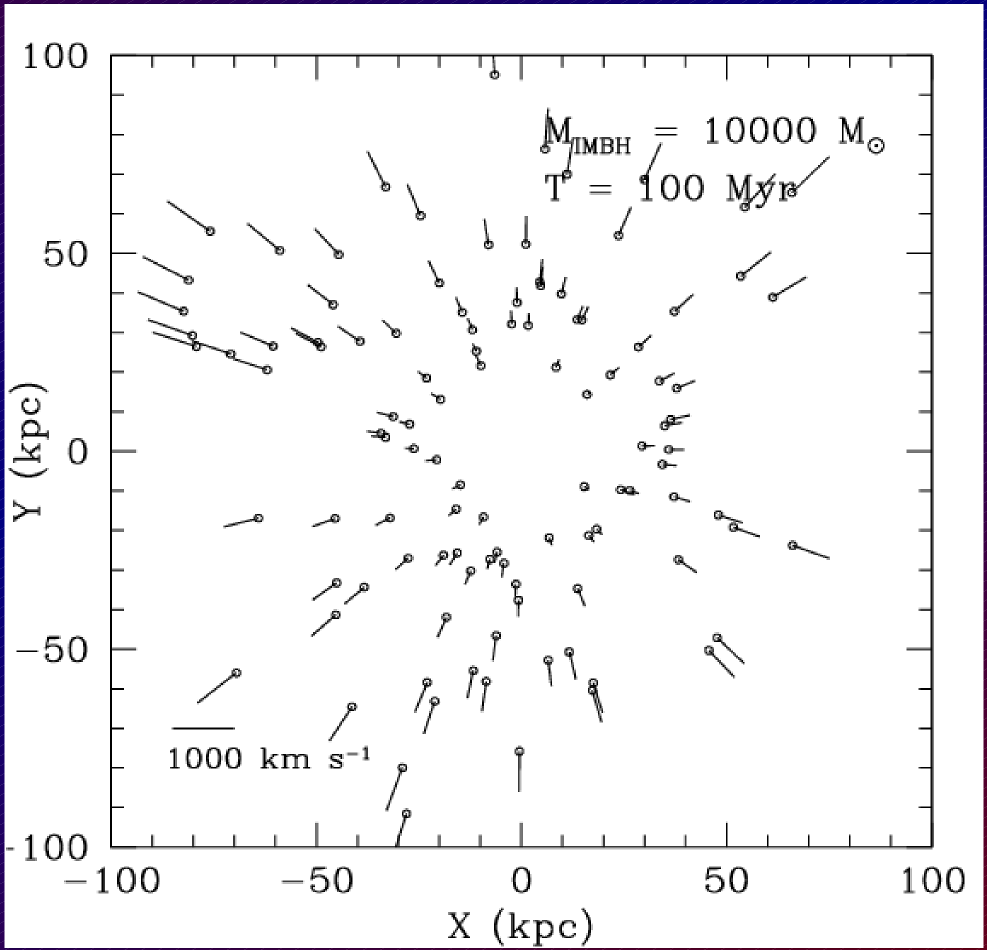
- The stalling radius would be such that the IMBH should be visible with current or future astrometric radio observations of SGR A*.



(from Hansen & Milosavljevic 2003)

Results: HVS escape rate and spatial distribution

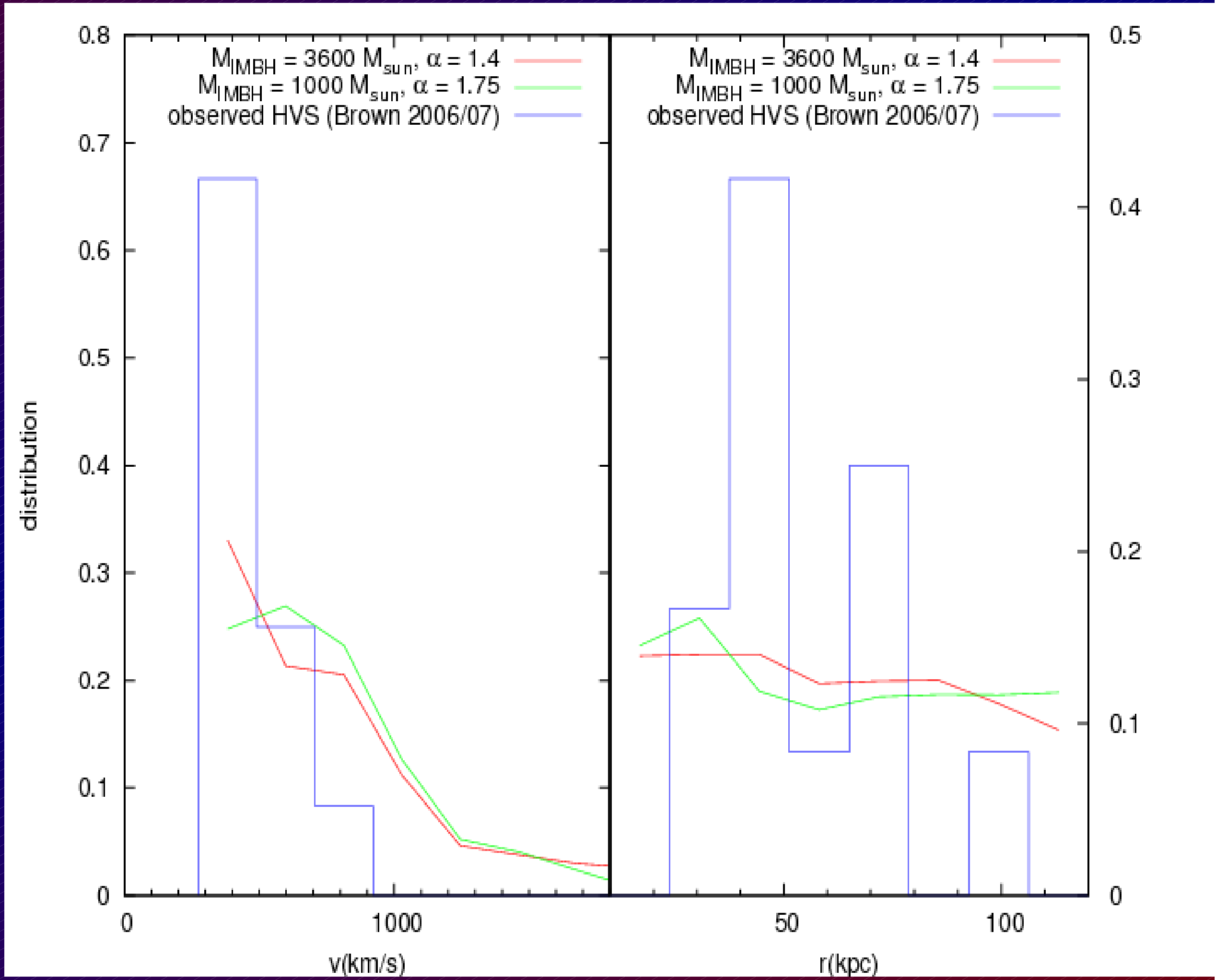




Ejection of HVS by a single IMBH is strongly peaked in time. Hence, by the time they reach the halo, fastest HVS have traveled furthest.

Results: Velocity distribution of HVS

- Velocity distribution of HVS seems to extend to higher velocities than what is observed.
- However, low-velocity HVS may not all come from the galactic centre.
- Also, low-number statistics might be a problem.



(from Löckmann & Baumgardt 2007)

Summary and Conclusions

- The inspiral of IMBHs into the galactic centre was followed by means of N-body simulations.

- We found that inspiral in steep density cusps happens very fast and the IMBH is swallowed by the super-massive black hole within a few Myrs. In this case several IMBHs would be necessary to explain the observed HVS.

- In flatter density cusps, swallowing takes much longer and the IMBH which created the HVS might still orbit around SGR A*.

- HVS ejected by IMBHs should have a flat velocity profile. The observed profile of HVS seems to drop of steeper, however low-number statistics does not (yet) allow firm conclusions.