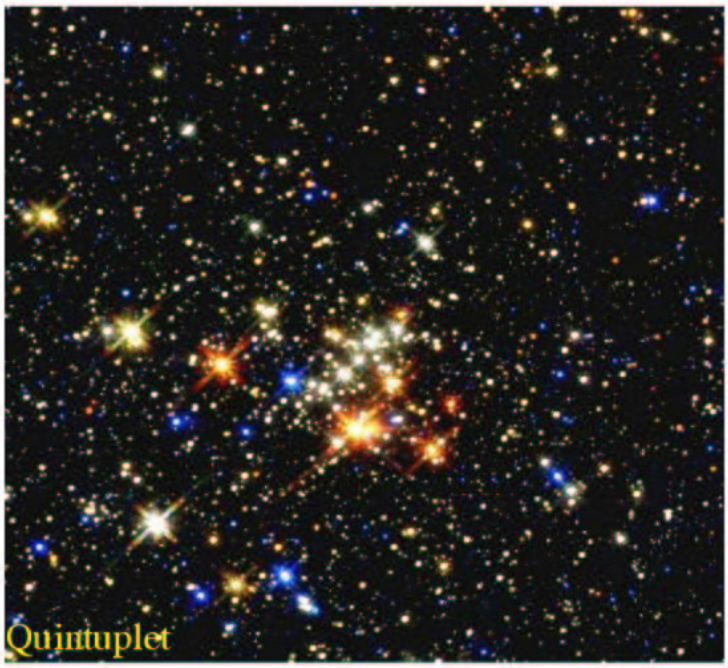
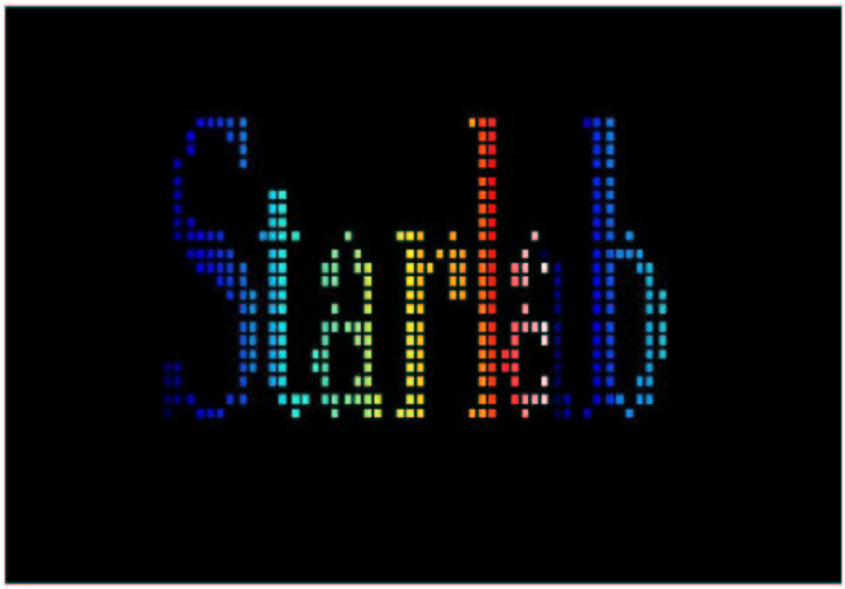
Formation and evolution of intermediate and supermassive black holes

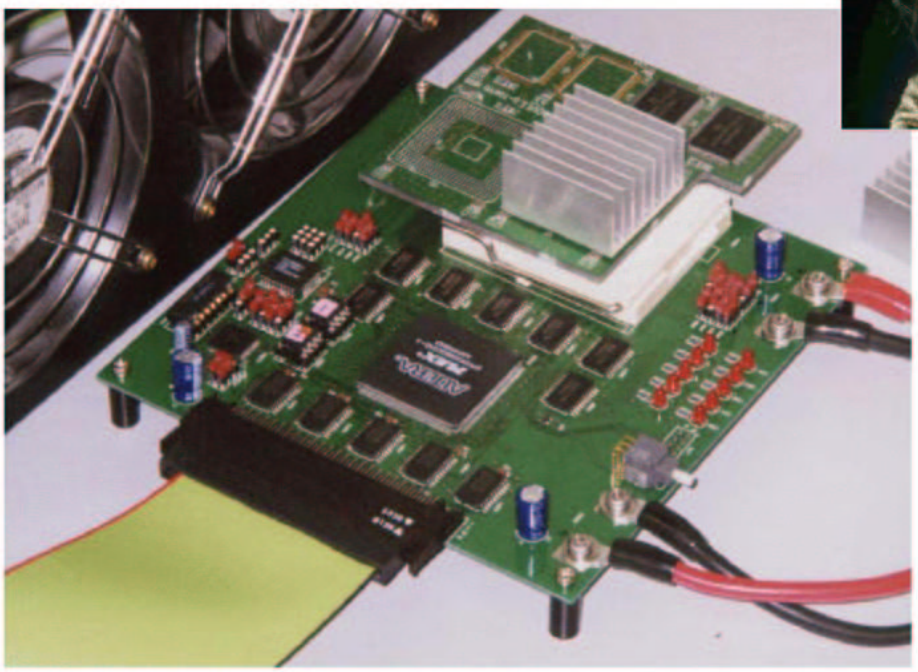


Simon Portegies Zwart
University of Amsterdam

http://manybody.org/starlab.html

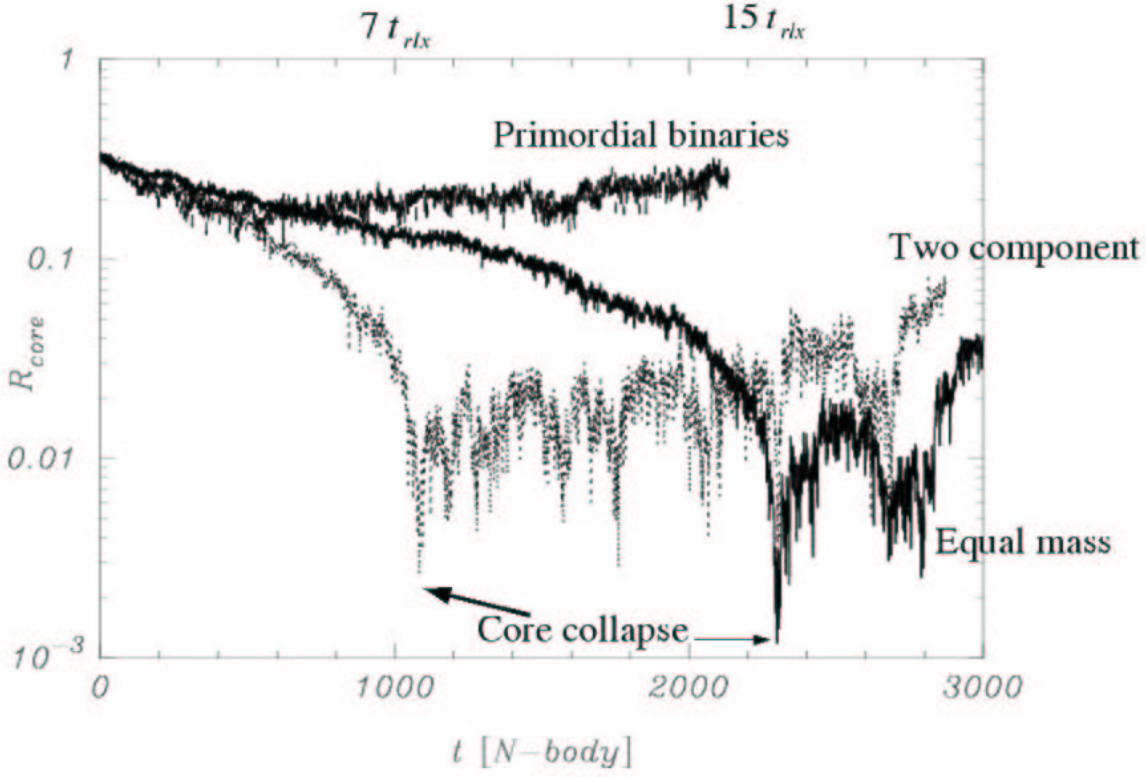


GRAPE-6:
Small, but strong in the force

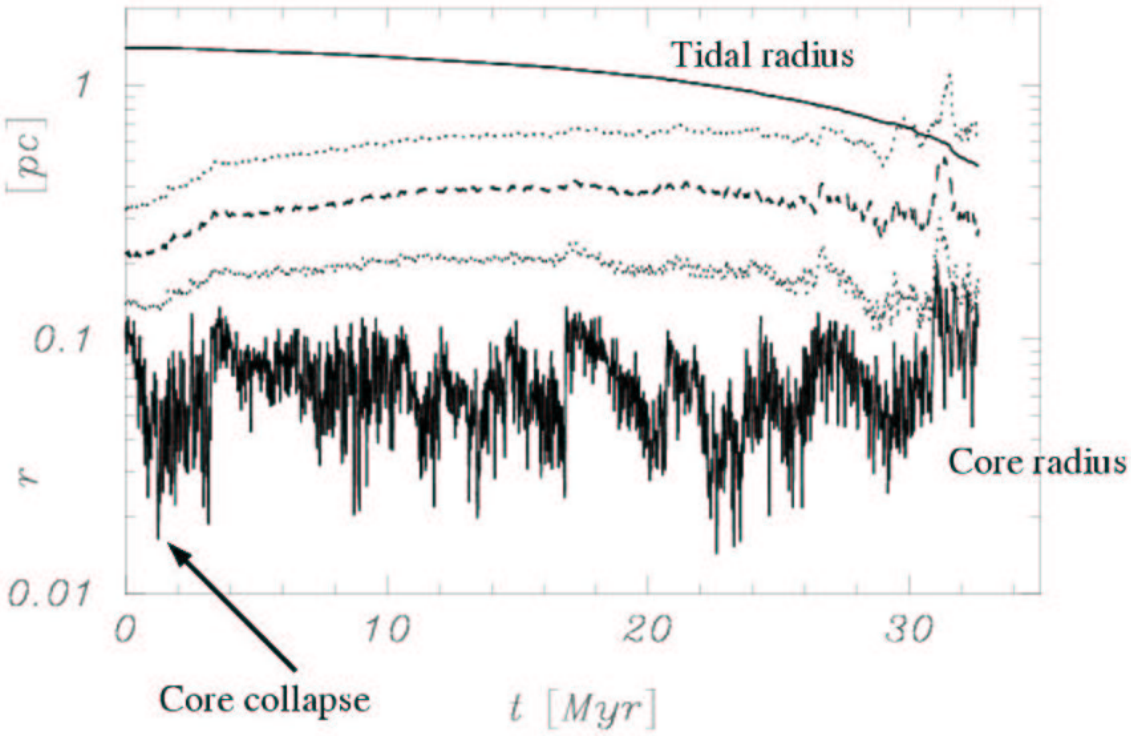


http://www.astrograpе.org

Core collapse in N=10k model



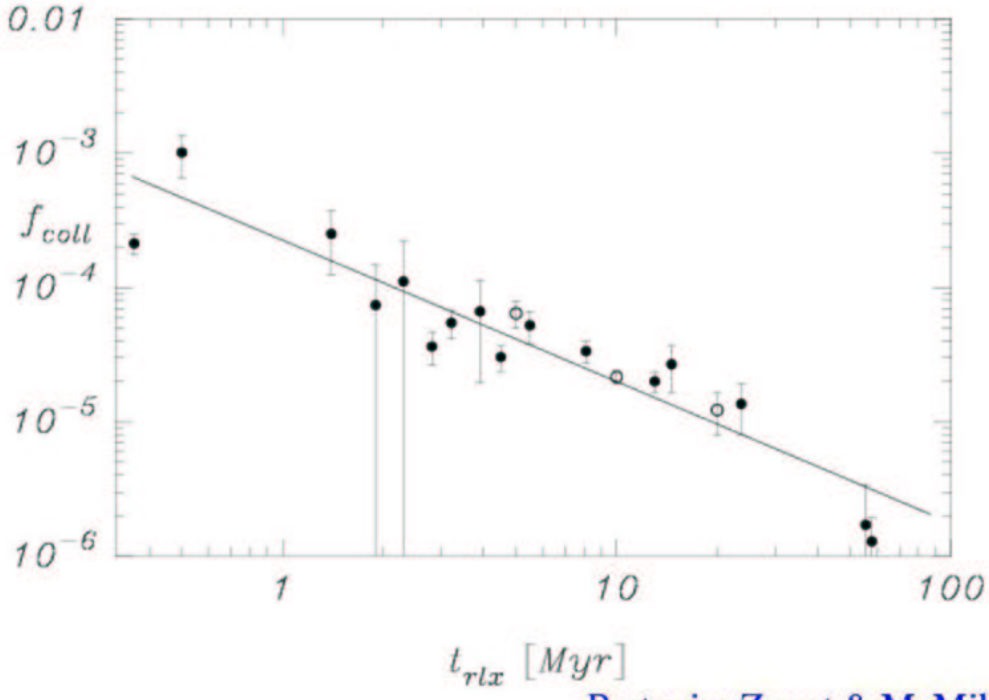
Post collapse in realistic cluster



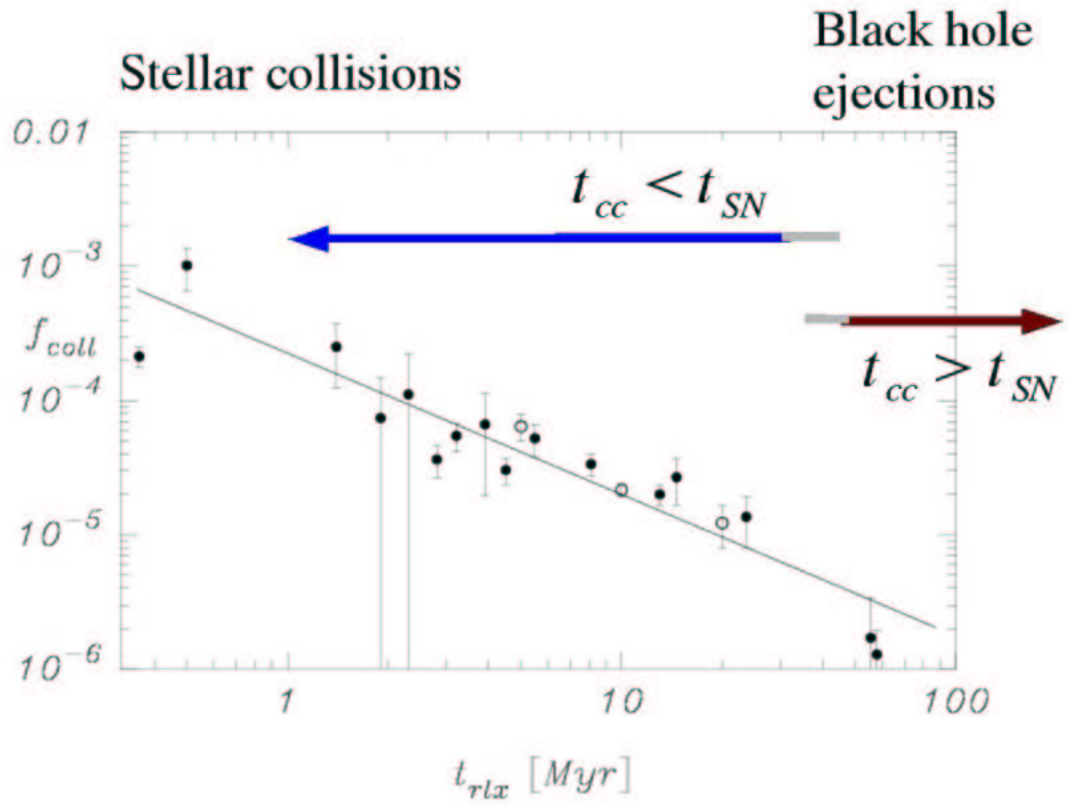
Collision rate:

$$f_{coll} \simeq 10^{-3} \frac{N}{t_{rlx}}$$

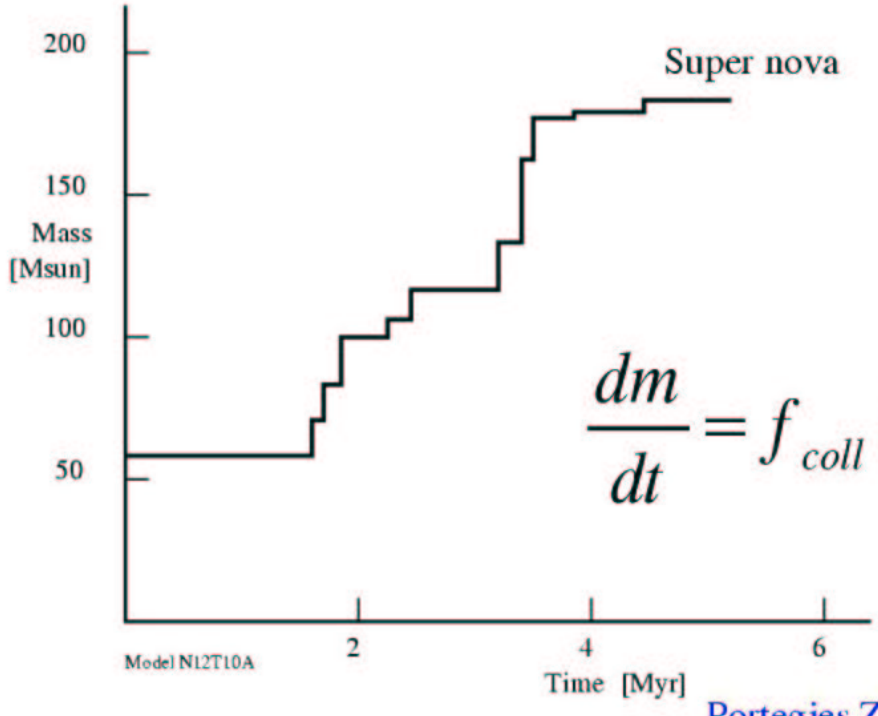
Measured in 42 N-body models



Portegies Zwart & McMillan 2002

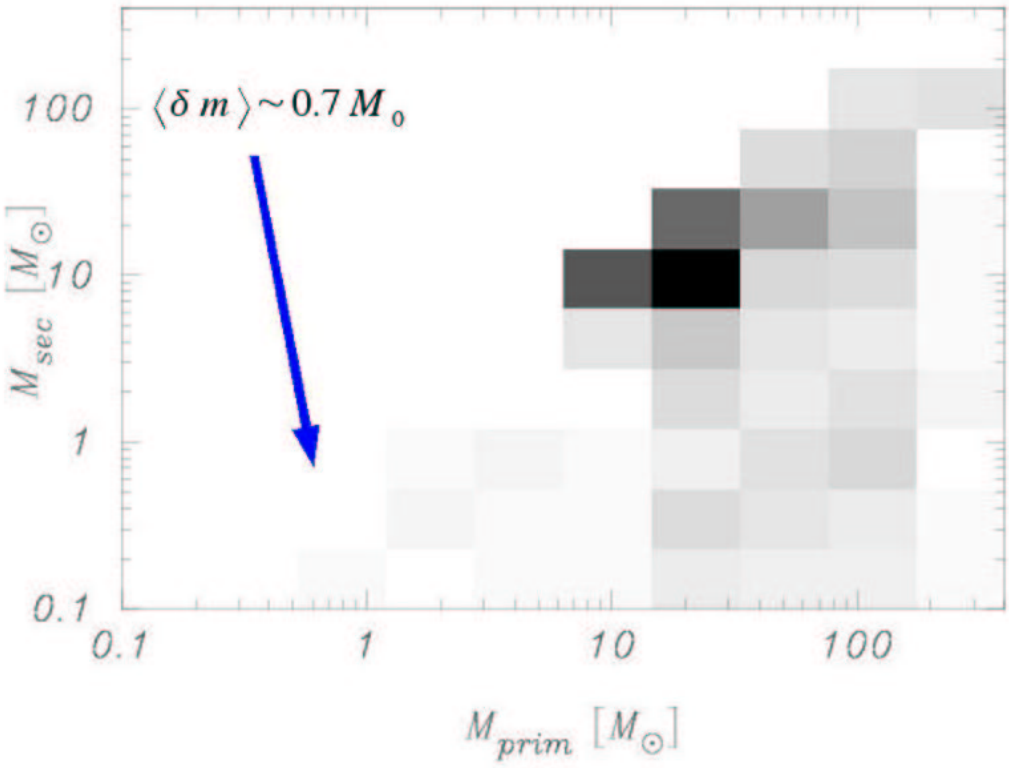


Collision runaway if: $t_{rlx} < 30\ Myr$



Portegies Zwart et al 1999

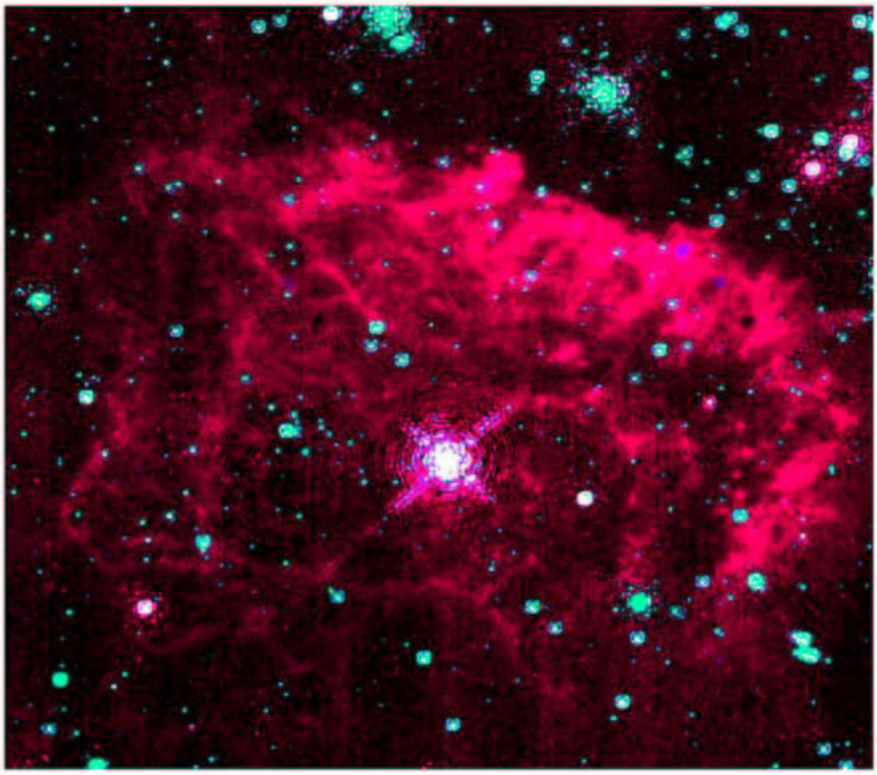
Mass increase per collision $\langle \delta m \rangle \simeq 4 \frac{t_{rlx}}{t} \langle m \rangle$



Runaway collision model

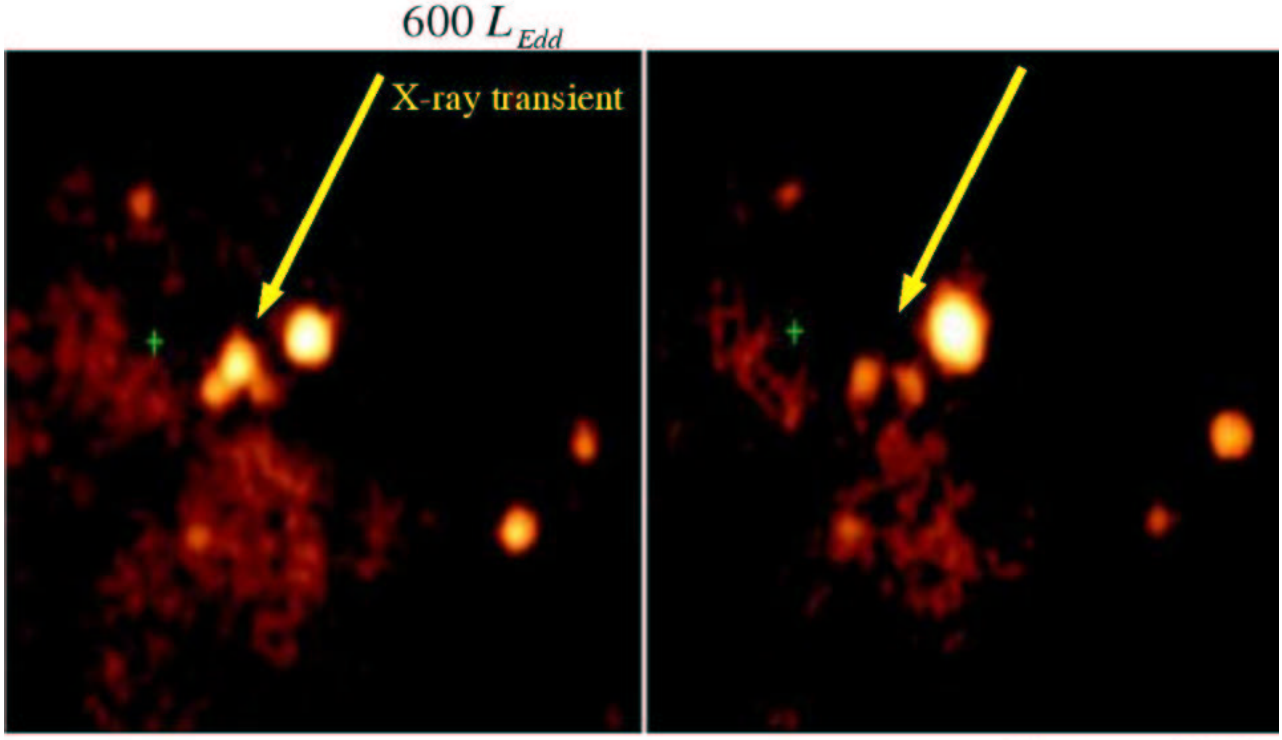
- Star cluster is born with relaxation time < 30Myr
- Massive stars sink to cluster center..... $t_{df} \sim t_{rlx} \frac{\langle m \rangle}{m}$
- Before the first supernova (~5 Myr)
- Core collapse sets in at..... $t_{cc} \sim 0.2\, t_{rlx}$
- Binaries are formed
- Collisions occur..... $f_{coll} \simeq 10^{-3} \frac{N}{t_{rlx}}$
- Same star keeps colliding
- Mass increase per collison..... $\langle \delta m \rangle_{coll} \simeq 4 \frac{t_{rlx}}{t} \langle m \rangle$
- Final product collapses to black hole

Pistol star



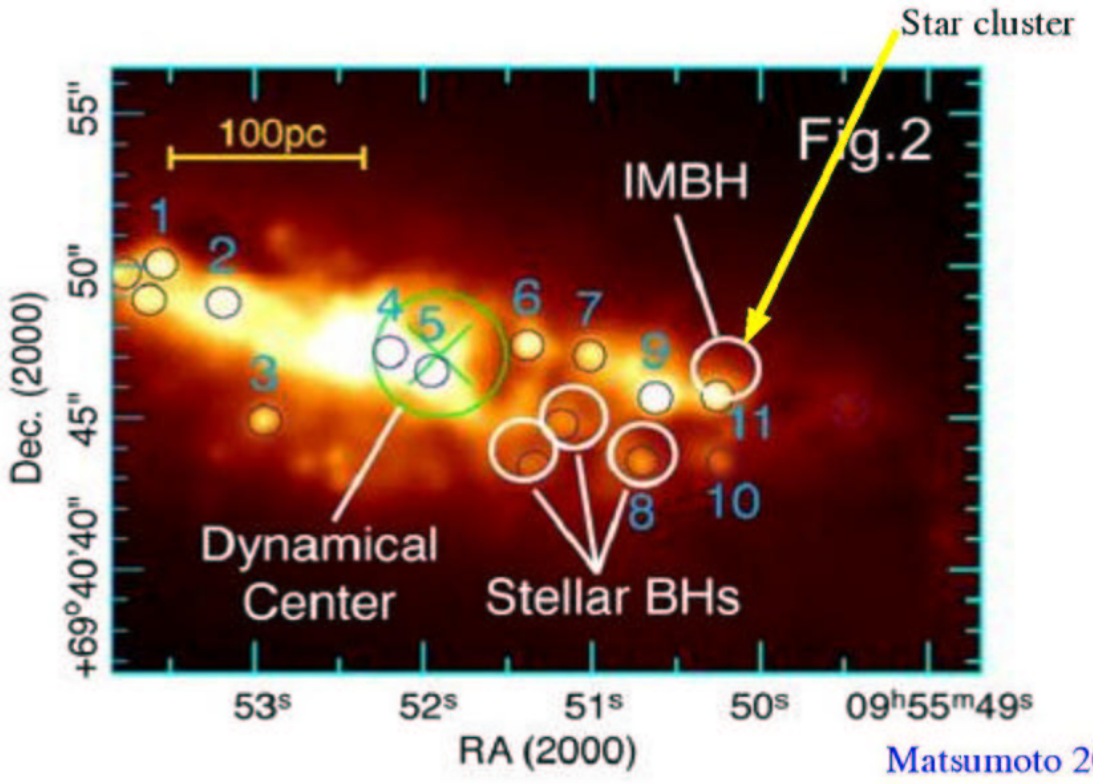
Figer 1999

Chandra observation of M82

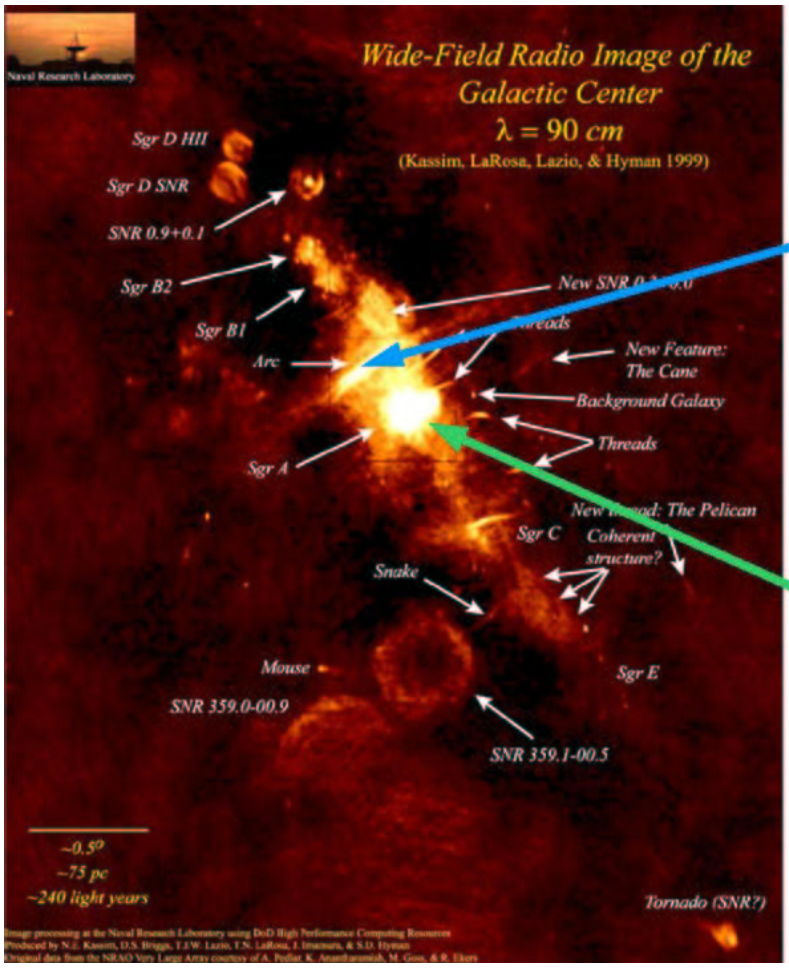


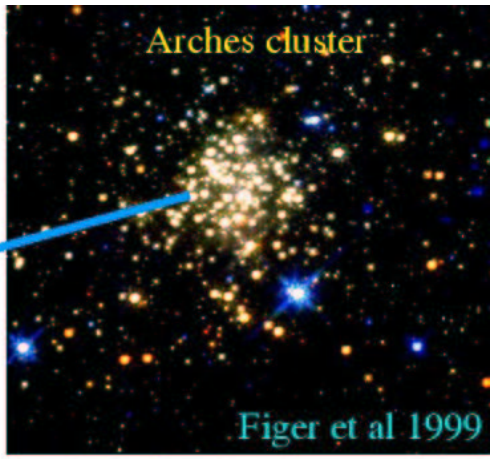
Kaaret et al 2001

Subaru Observations of M82

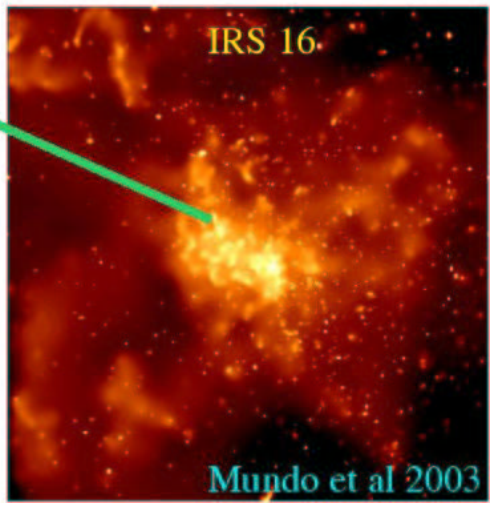


Matsumoto 2002



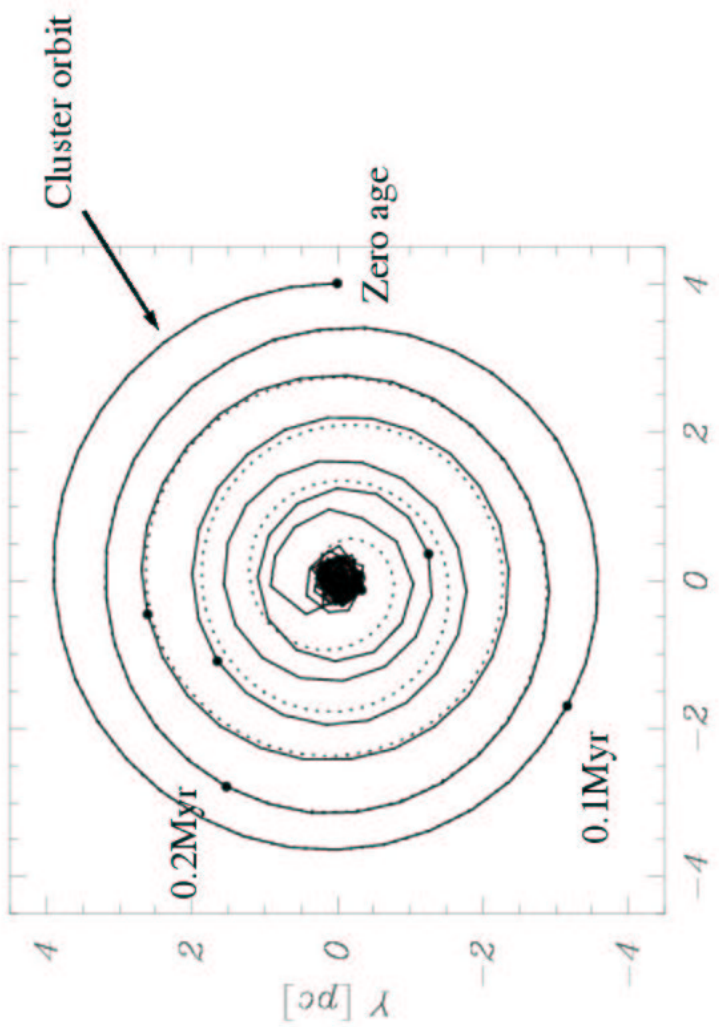


Figer et al 1999



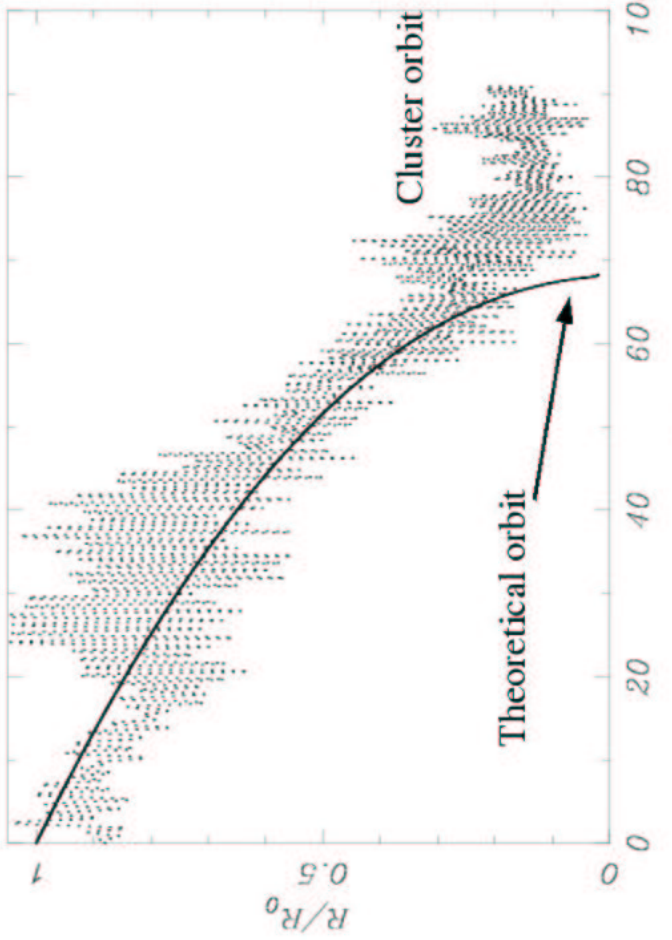
Mundo et al 2003

Star cluster sinks to Galactic center

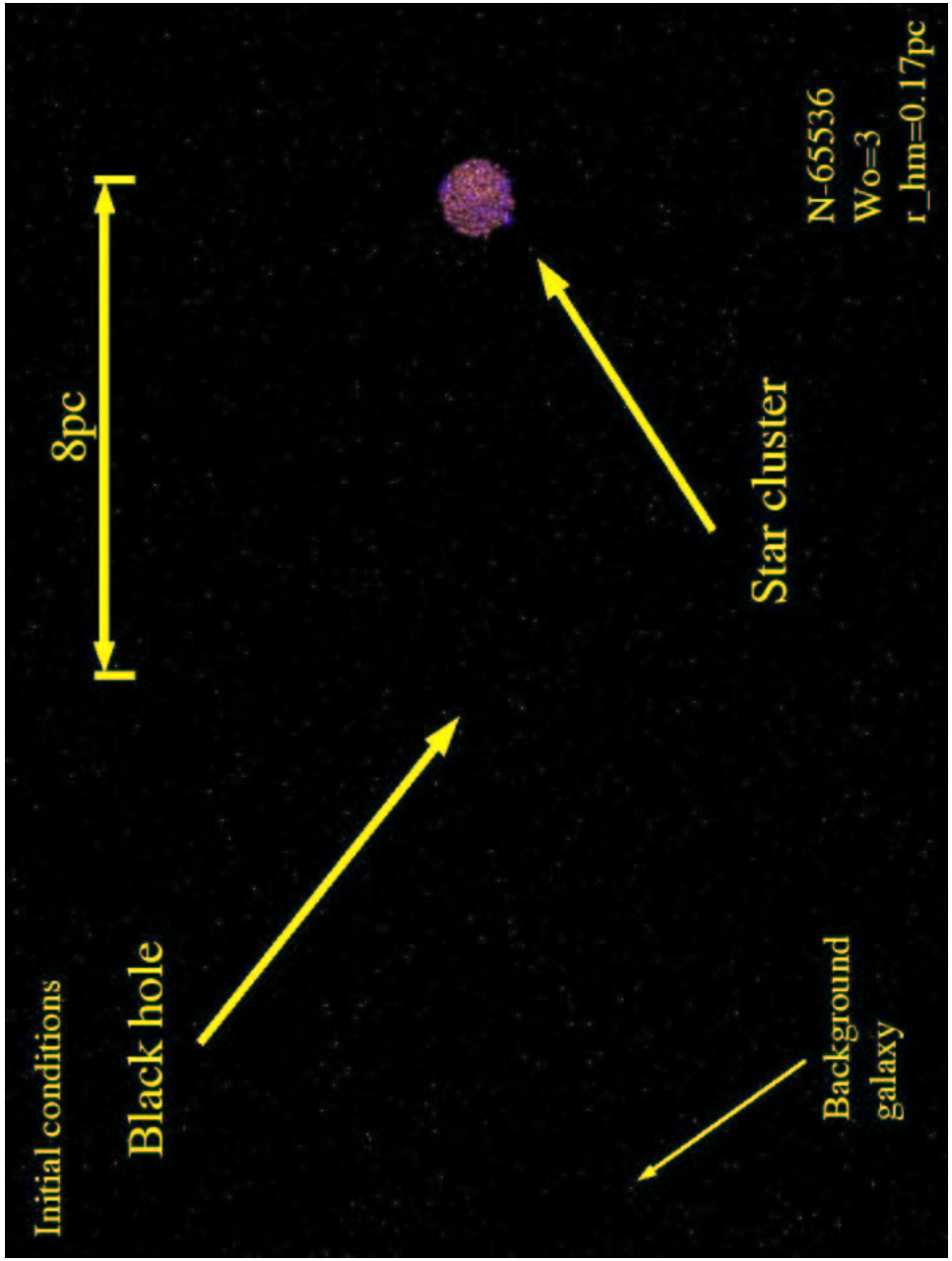


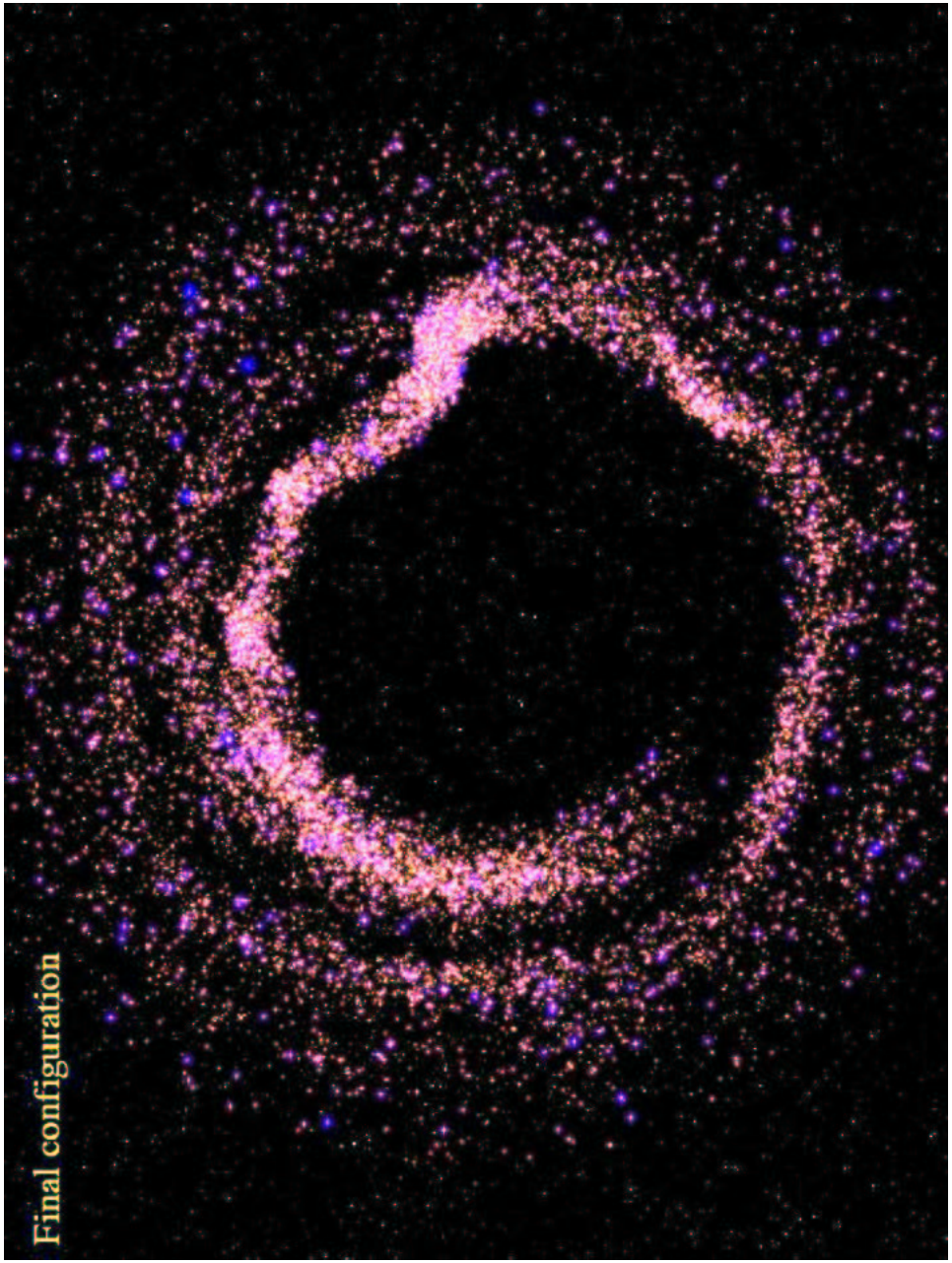
Portegies Zwart, McMillan & Gerhard 2003

Sinking to the Galactic center

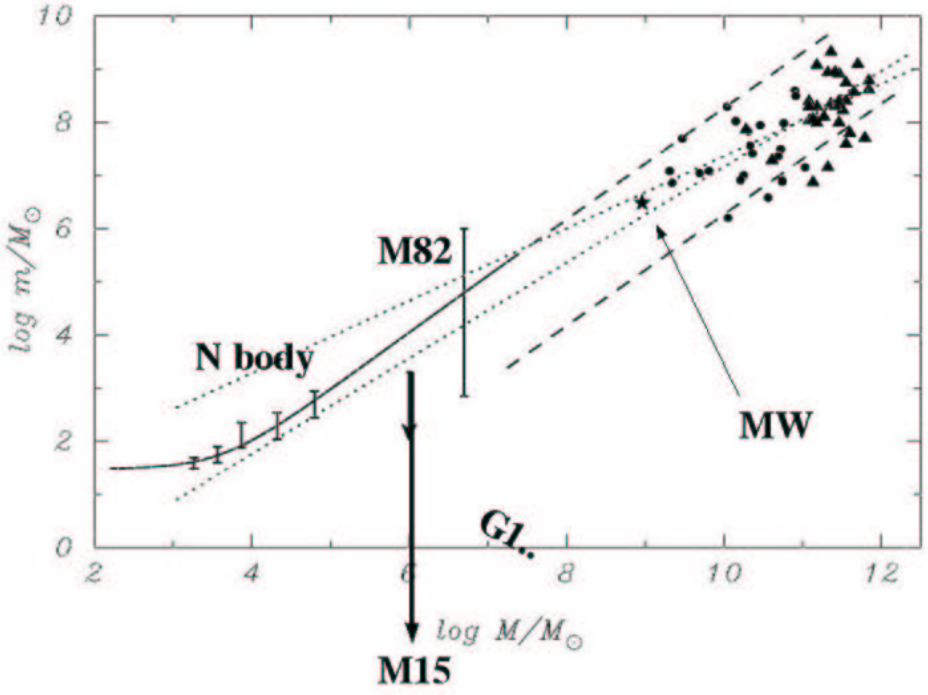


Spinnato et al 2003


Initial conditions
Black hole
8pc
Star cluster
N-65536
Wo=3
r_hm=0.17pc
Background
galaxy


Final configuration

$$m_r = m_{seed} + 4 \times 10^{-3} M_{cluster}$$



Forming supermassive black holes

The star in the cluster

- Stars are born in cluster
- Cluster in core collapse
- Massive stars collide in collision runaway
- Blue-blue straggler collapses in supernova
- IMBH forms
- Cluster dissolves

Portegies Zwart & McMillan 2002

The cluster in the Galaxy

- Cluster is born near the GC
- Dynamical friction drives cluster closer to GC
- Cluster dissolves and deposits IMBH
- Each Myr a fresh IMBH is deposited
- IMBHs merge to SMBH

See Ebisuzaki et al 2001