Globular Clusters and Nuclear Clusters in the Gravitational Field of Galaxies

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CMOs

Super Massive Black Holes

Nuclear Stellar Clusters

Some times they do coexist

Compact Massive Objects in galactic centers

MBHs and SMBHs - Nuclear Star Clusters (NSCs)

$(10^6 \div 10^{10} M_\odot)$ $(10^5 \div 10^8 M_\odot)$

host galaxies: *decreasing luminosity* ⟶

increasing steepness of the lum. profile ⟶

Brighter galaxies are usually *cored* and host *more* massive and compact objects ⟶

Fainter galaxies have more *peaked* luminosity distribution and host *less* massive and compact objects

GC and NC in the gravitational field…

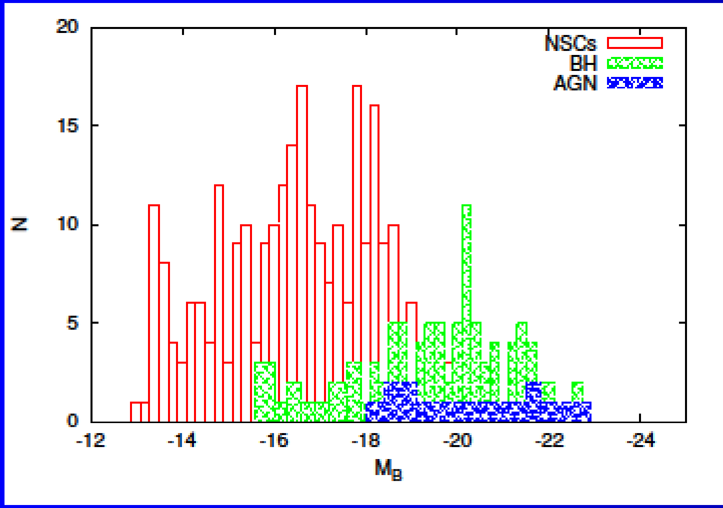
(Capuzzo-Dolcetta & Tosta e Melo 2017)

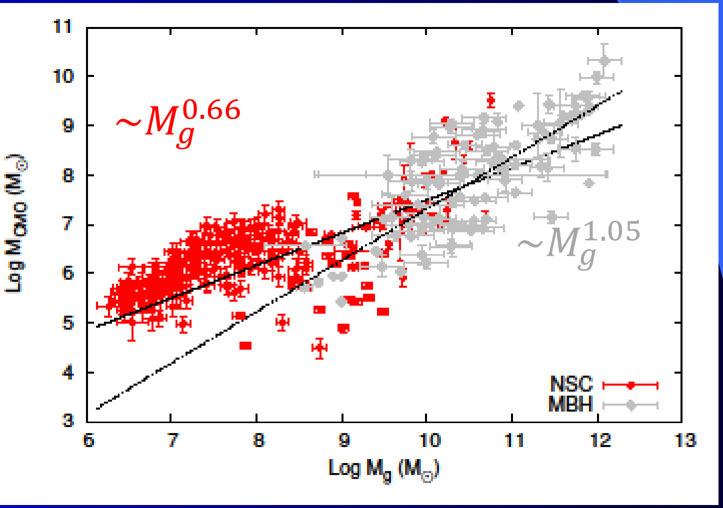
Huge collection of data <u>from</u> HST and else

NSCs: 529, of which

- 220 in nearby galaxies;
- 309 in Virgo, Fornax and Coma clusters.

MBHs: 135





• The MW and other **50** galaxies are known to contain **both** an NSC and an MBH (Seth et al. 2008a, Graham & Driver 2007, Graham & Spitler 2009, Capuzzo-Dolcetta & Tosta e Melo 2017).

The ratio of MBH to NSC mass in these galaxies is of order <u>unity</u>.

Nuclear Star Clusters

- Most massive (up to $10^8\,M_\odot$) and densest (10^6-$10^7\,M_\odot\,pc^{-3}$) star clusters;

- Sited in centers of galaxies of all Hubble types in:
  75% of late-type spirals (Scd-Sm),
  50% of earlier type spirals (Sa-Sc),
  70% of spheroidal (E and S0) galaxies.

- **All** NSCs have an underlying **old** ($\geq$ 1 Gyr) population and most also have a **young** component ($\leq$ 100 Myr)

Nuclear Star Clusters and Globular Clusters

NSC

The MW NSC: $10^7 M_\odot$ in about 4 pc radius around Sgr A*

A dense GC →

M 80

Nuclear Star Clusters and Globular Clusters

Van der Marel (2007): NSCs have similar structural properties as globular clusters.

SMBH

Mass: $10^6 \div 10^{10} M_\odot$
Length: $10^{-7} \div 10^{-2}$ pc
Density: $\sim c^6/(2G)^3 M^{-2}{}_{BH}$
Location: galactic centre

NSC

Mass: $10^6 \div 10^8 M_\odot$
Length ~ 4 pc
Density: $>10^6\ M_\odot\ pc^{-3}$
Location: inner pcs

GC

Mass: $10^4 \div 10^6 M_\odot$
Length: $2 \div 5$ pc
Density: $10^3 \div 10^6\ M_\odot\ pc^{-3}$
Location: kpcs

GC migration to the center?

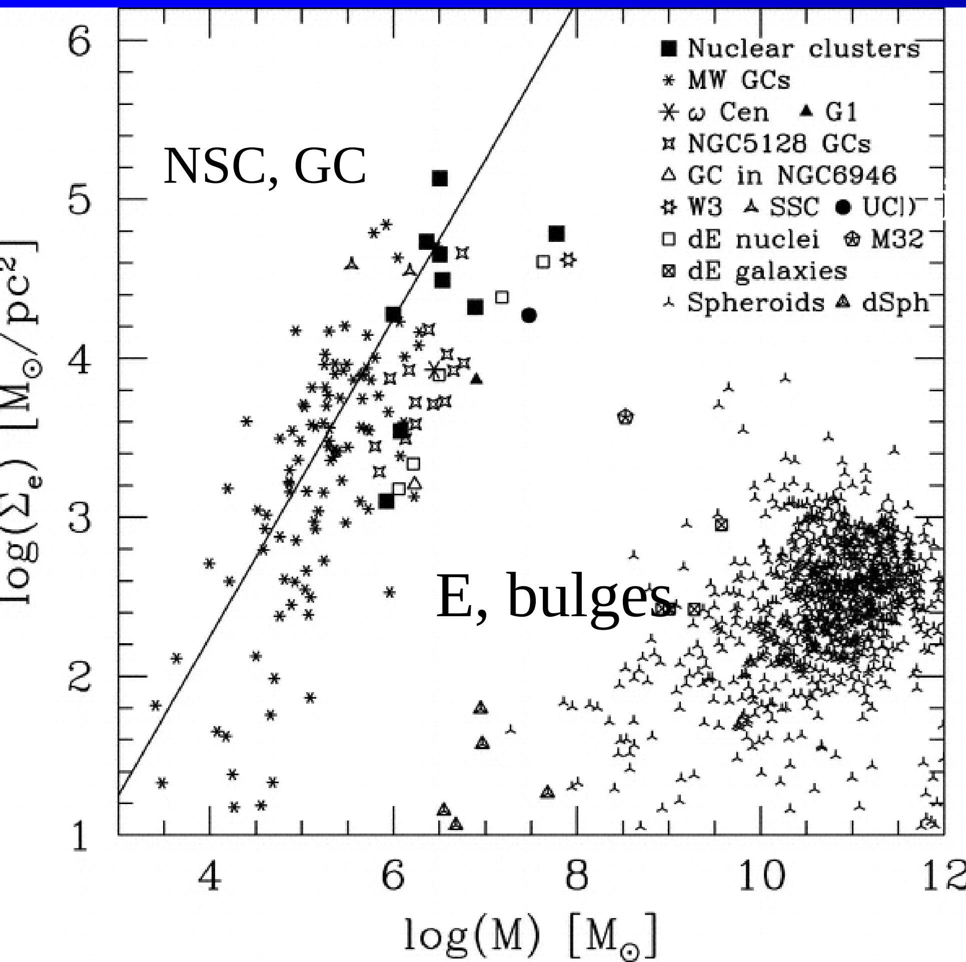
An almost *dissipationless* merger of ~ 10 – 100 GCs could give origin to an NSC **if** the kpc width scale is **shrunk** to pc: a 1000 contraction

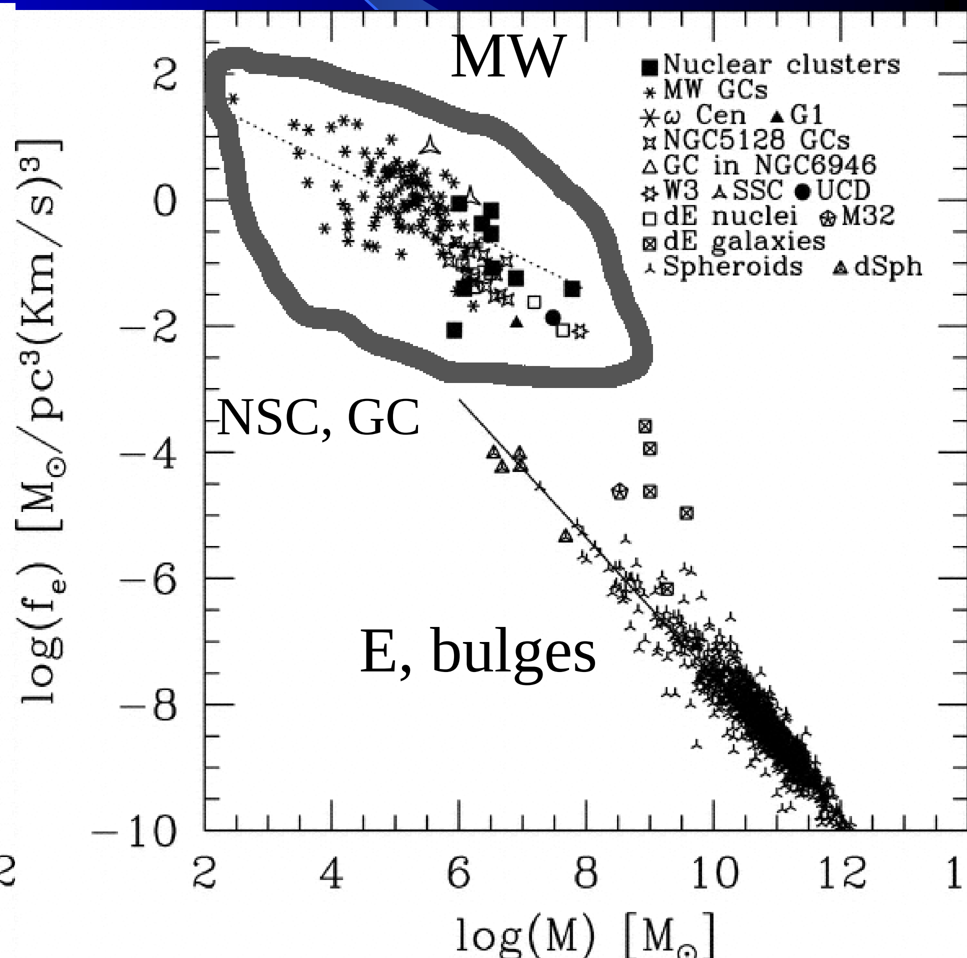
HYPOTHESIS: Merger works

Nuclear Star Clusters and Globular Clusters

Respect Vlasov equation $\frac{df}{dt} = 0$

MW little peculiar, $f = \rho/\sigma^3 \sim 200$

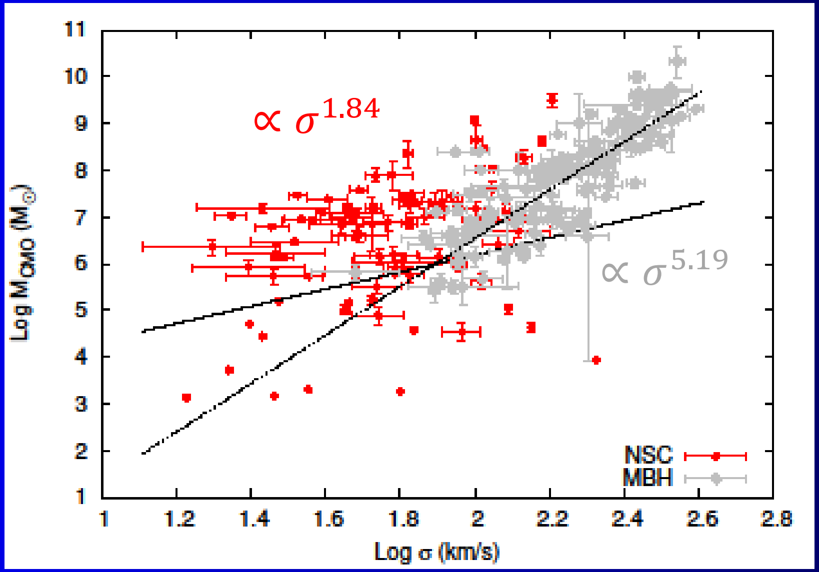




Nuclear Star Clusters and Globular Clusters

mass vs σ relation: a debated thing

$M_{BH} \propto \sigma^{5.2}$, $M_{NSC} \propto \sigma^{1.8}$



(*Capuzzo-Dolcetta & Tosta e Melo, 2017*)

A simple interpretation of the NSC M vs σ scaling law

Hypothesis: singular isothermal sphere

$$\rho(r) = \frac{1}{2\pi G}\frac{\sigma^2}{r^2},$$
$$v_c^2 = 2\sigma^2.$$

The GC orbital evolution due to dynamical friction is governed by

$$\frac{dL}{dt} = \sqrt{2}\sigma\dot{r} = r\ddot{r}_{df} = -0.4276\frac{GM\ln\Lambda}{r}$$
$$r^2(t) = r^2(0) - 0.6GM\ln\Lambda\frac{t}{\sigma}$$
$$r(0) \le \sqrt{0.6GM\ln\Lambda\frac{t}{\sigma}}$$

If GCs had an initial galactic distribution $\rho \sim r^{-\alpha}$, $0 \le \alpha \le 3$

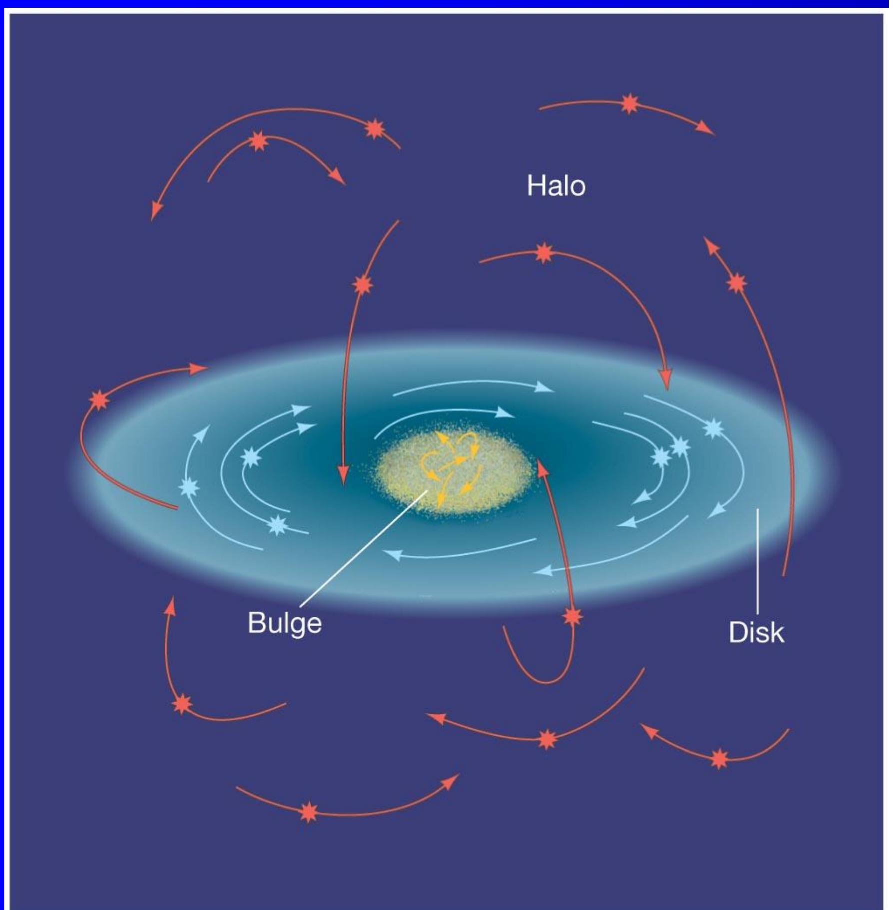
$$M_n(t) = At^{\frac{3-\alpha}{2}}\sigma^{\frac{1+\alpha}{2}}$$

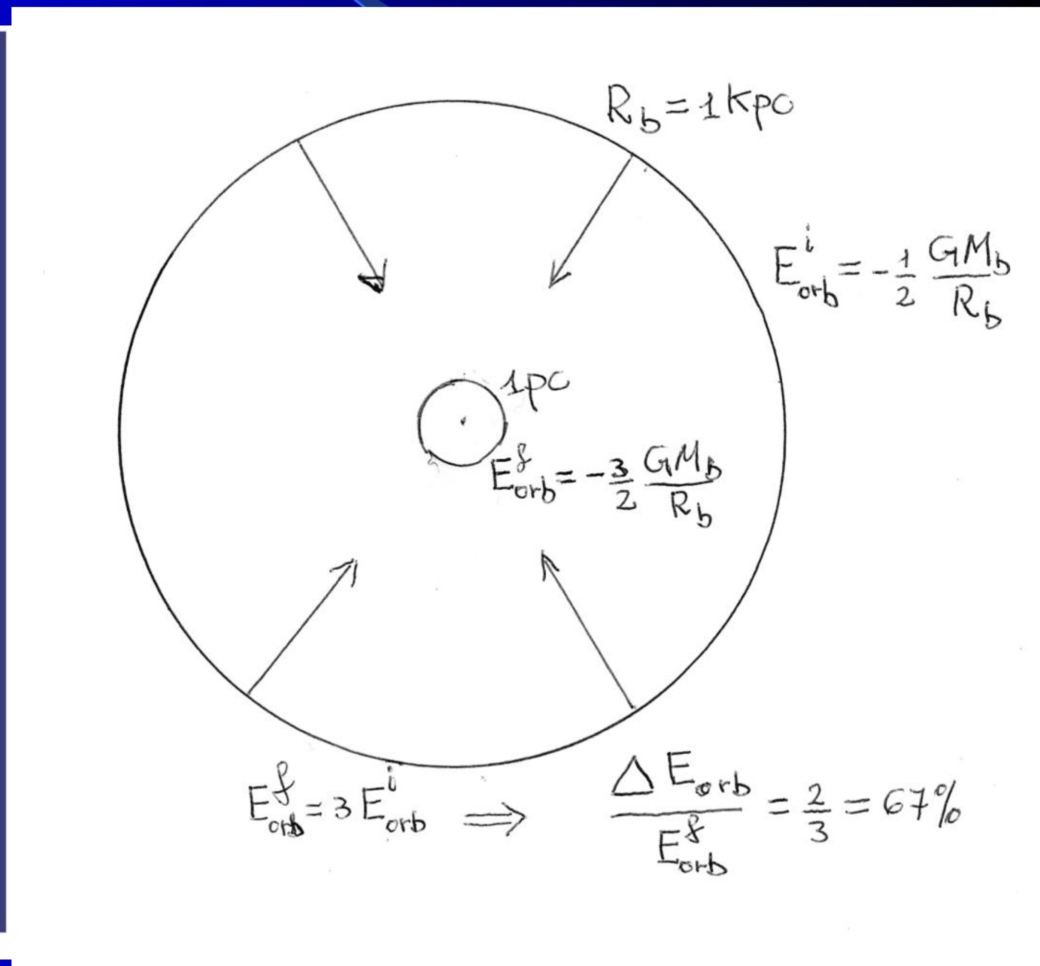
that means for σ an exponent

$$\frac{1}{2} < \frac{1+\alpha}{2} < 2,$$ 3/2 for $\alpha=2$

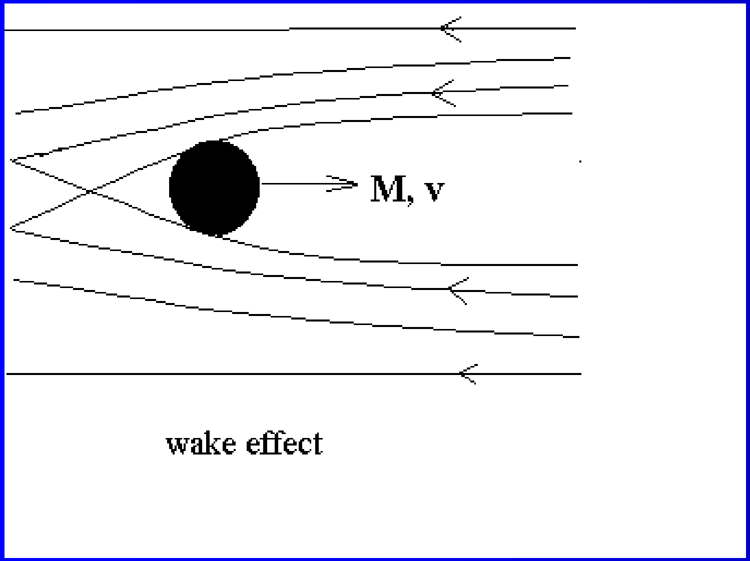
GC migration to the center?

Factor 1000 in radius factor → 3 in energy





GCs in the external field



a) Dyn. Friction + b) tidal galatic filed

GC mechanical energy dissipation going into

a) External degrees of freedom
dynamical friction
→ galaxy *heating*

b) Internal degrees of freedom
tidal effect
→ GC *heating*

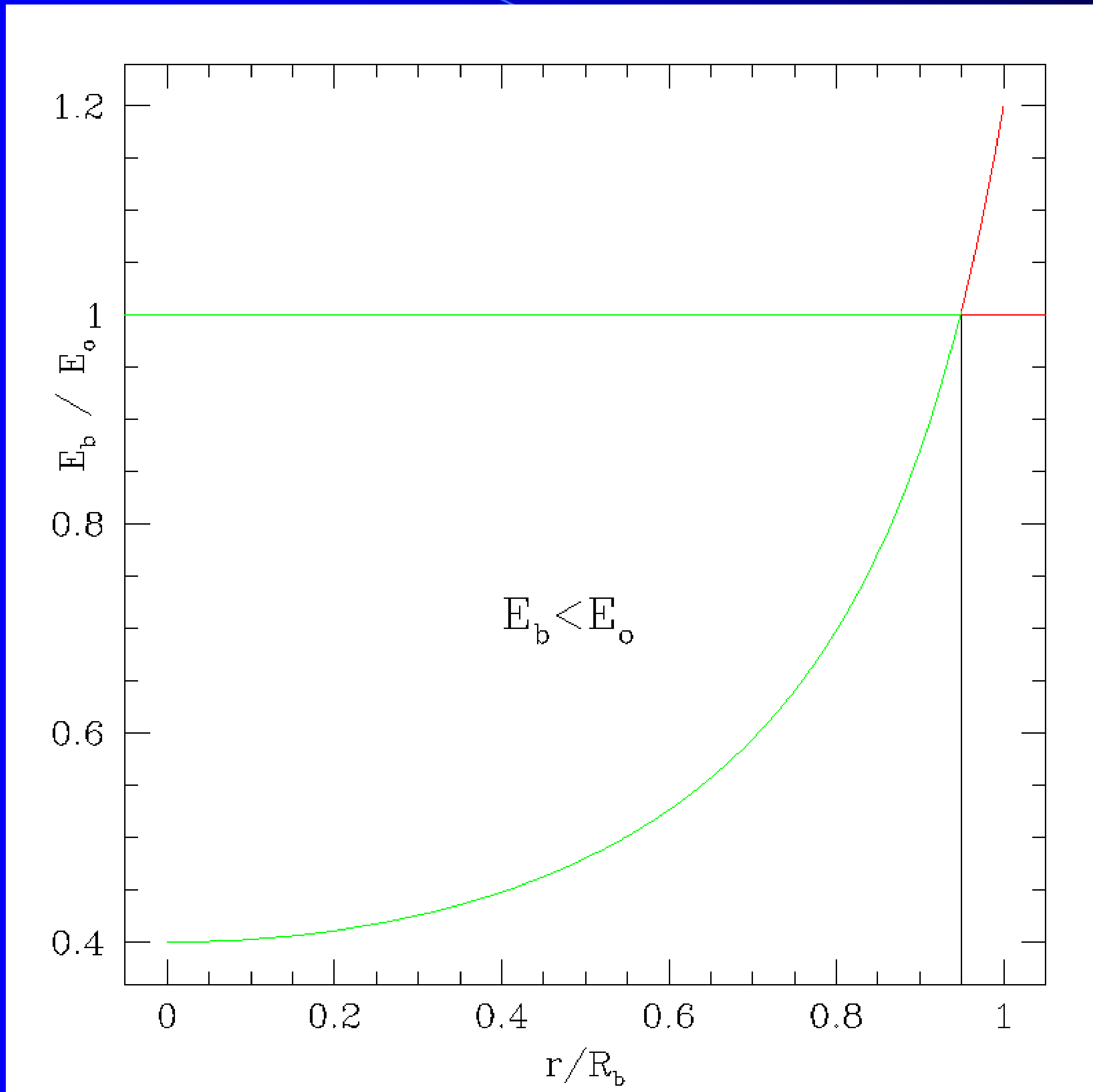
Actually a) and b) are non linearly interconnected, just full *N* body simulations provide accurate answers.

b) Internal degrees of freedom: *tidal heating effect*

Assume a homogeneous GC of mass M_{GC} and typical radius R_{GC} moving on a circular orbit of radius r in a homogeneous bulge of mass M_b and radius R_b

$$\frac{E_{bind}}{E_{orb}} = \frac{2}{5}\frac{M_{GC}}{M_b}\frac{R_b}{R_{GC}}\frac{1}{1-\frac{2}{3}\left(\frac{r}{R_b}\right)^2} \longrightarrow \quad 2/5 \le \frac{E_{bind}}{E_{orb}} \le 6/5$$

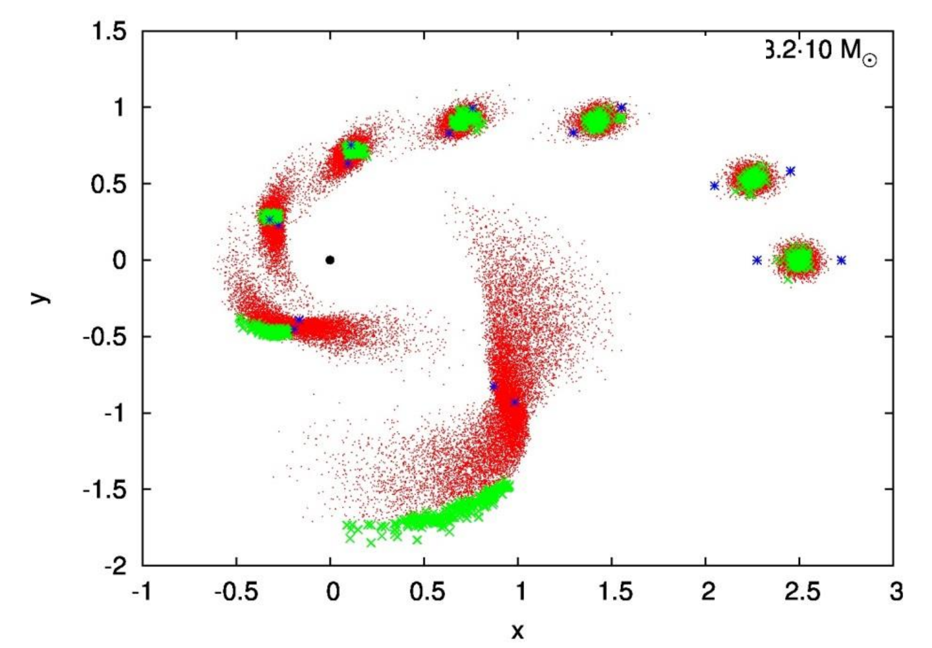
GCs and NCs in the gravitational field…



Consequences of the GC infall

- NSC formation;
- Mutual feedback with a local MBH;
- High velocity star generation;
- Possible growth of a pre-existent local BH.

High velocity star generation



A «3-body» effect

(*Capuzzo-Dolcetta & Fragione 2015, etc*.)