The Influence of Eccentric Orbits on Cluster Evolution

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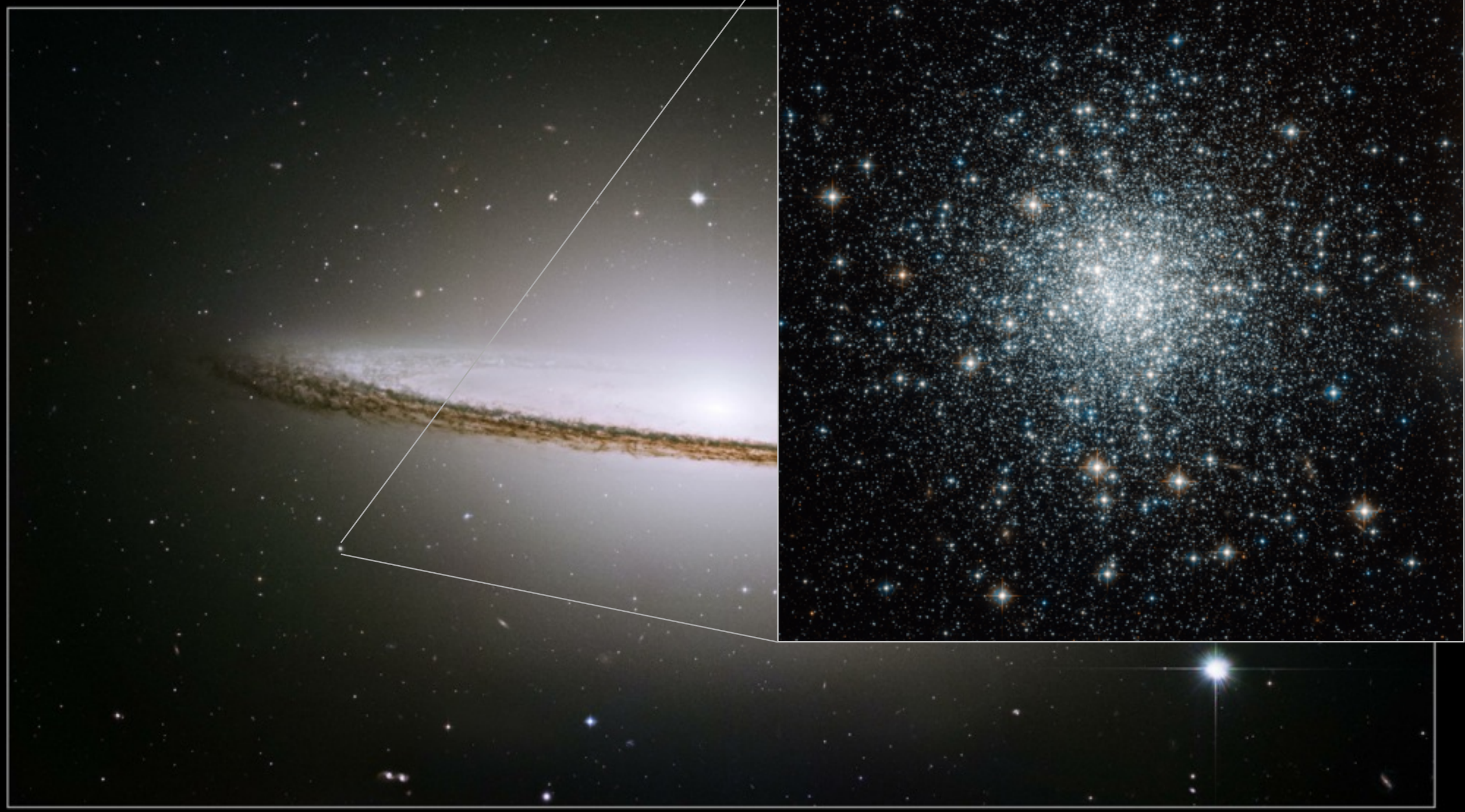
Sombrero Galaxy • M104

Hubble Heritage

Sombrero Galaxy • M104

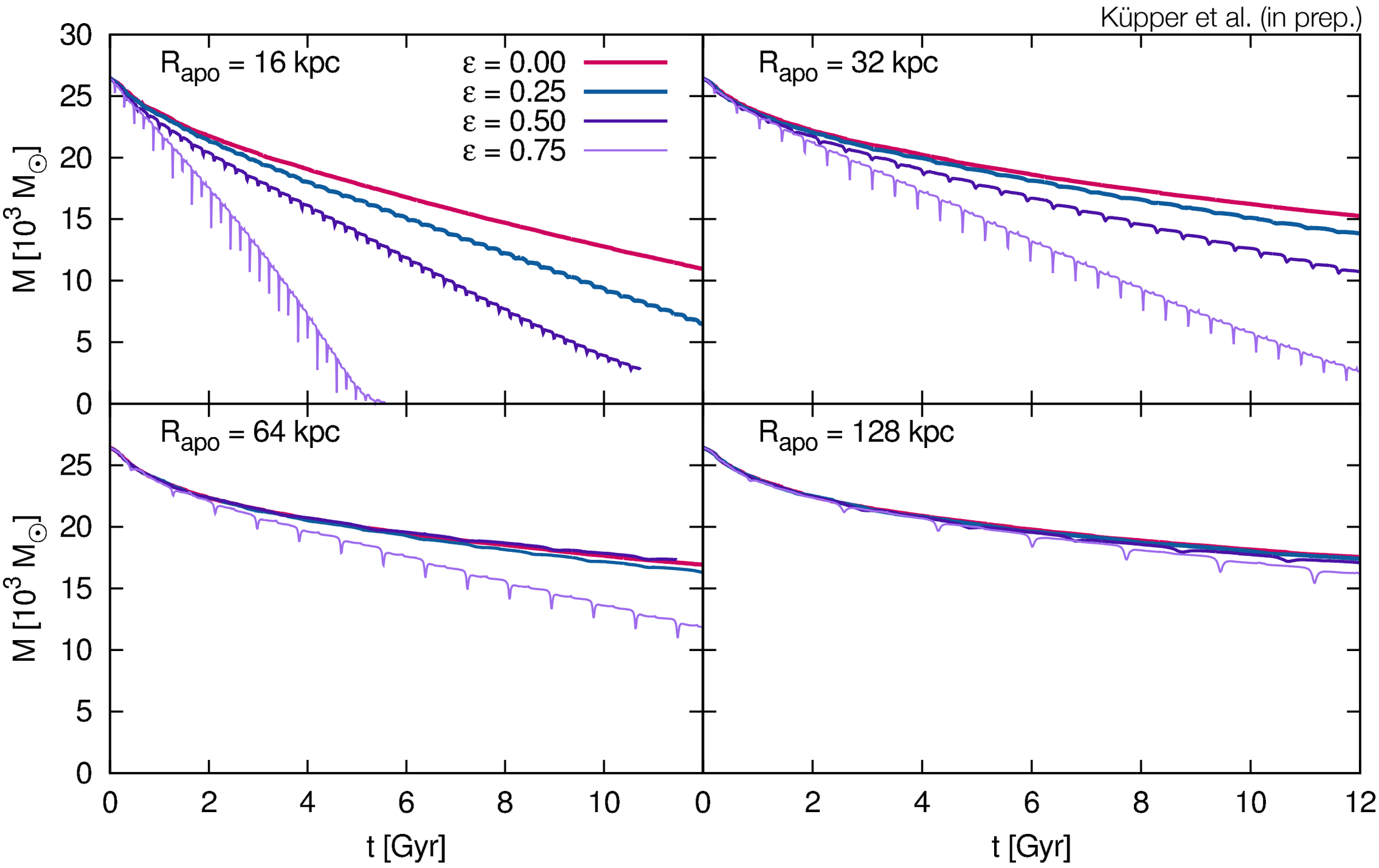


Hubble Heritage

1 Importance for Globular Cluster Systems

2 Importance for Individual Globular Clusters

Orbital eccentricity causes higher mass loss rates



Multi-purpose elliptical-galaxy scf & time-transformed leapfrog integrator

MUlti-purpose **E**lliptical-galaxy **S**cf & time-transformed **L**eapfrog **I**ntegrator - **MUESLI**

Brockamp et al. (2014)

MUlti-purpose **E**lliptical-galaxy **S**cf & time-transformed **L**eapfrog **I**ntegrator - **MUESLI**

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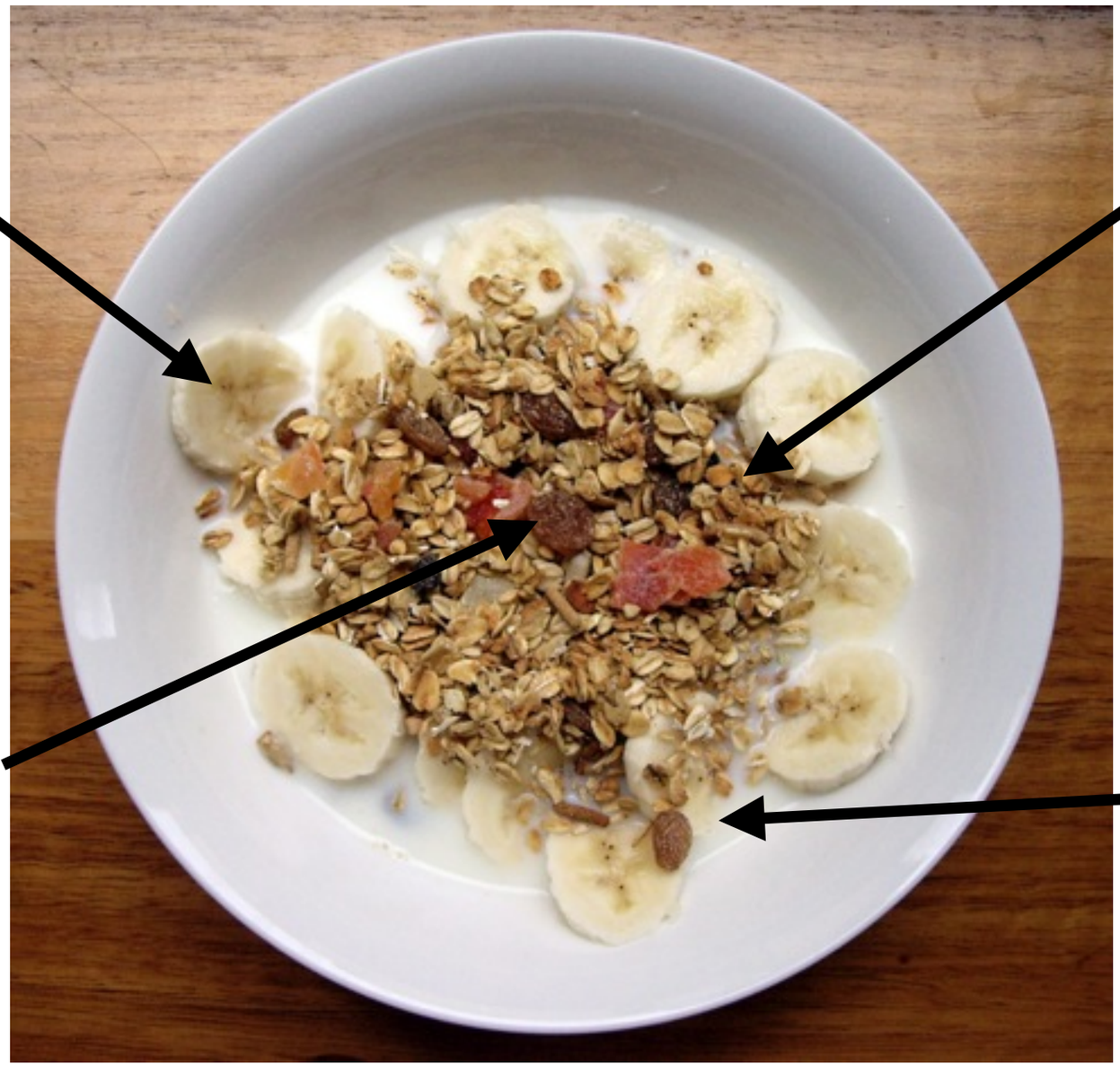
Dynamical Friction

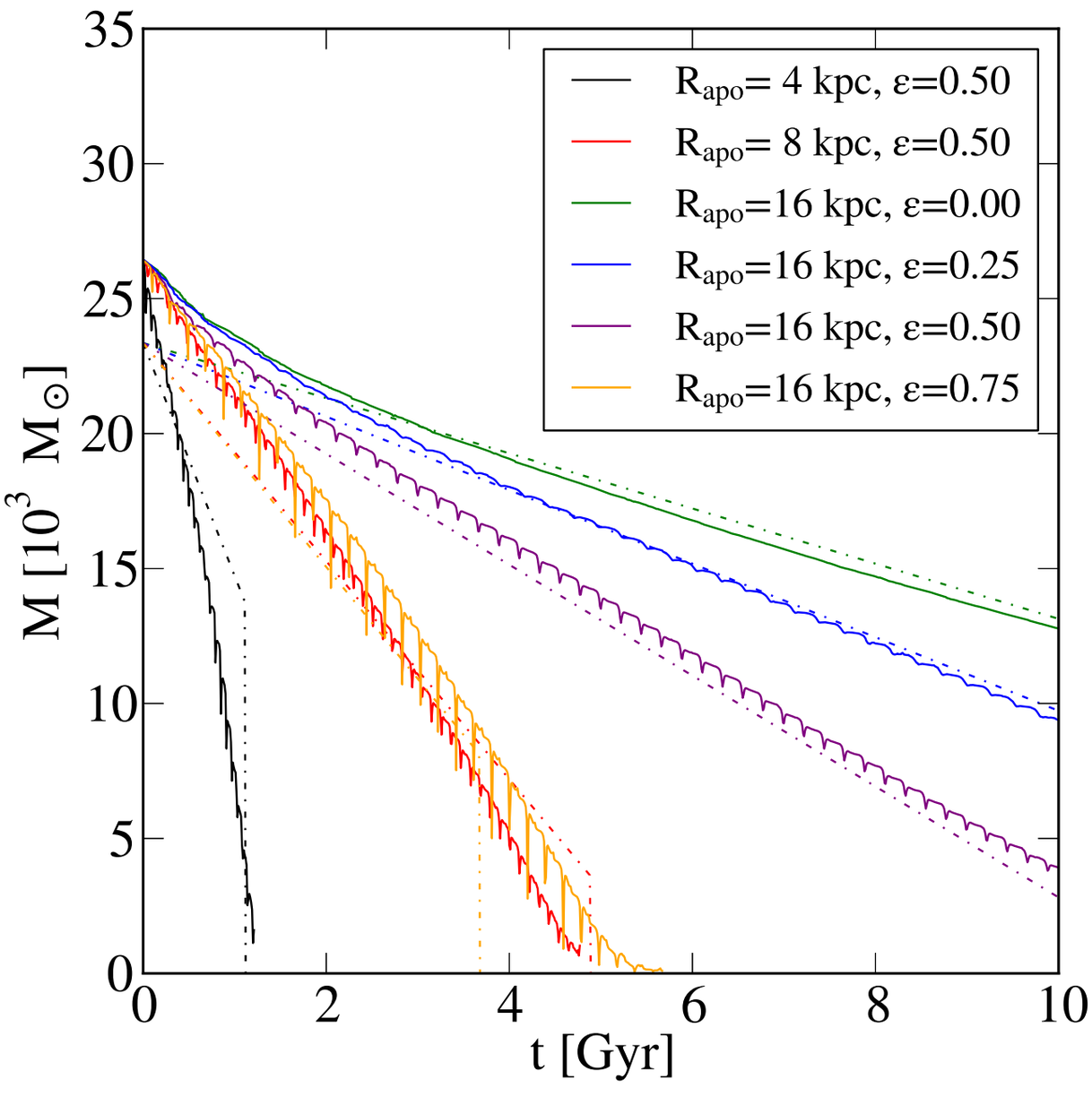
OpenMP

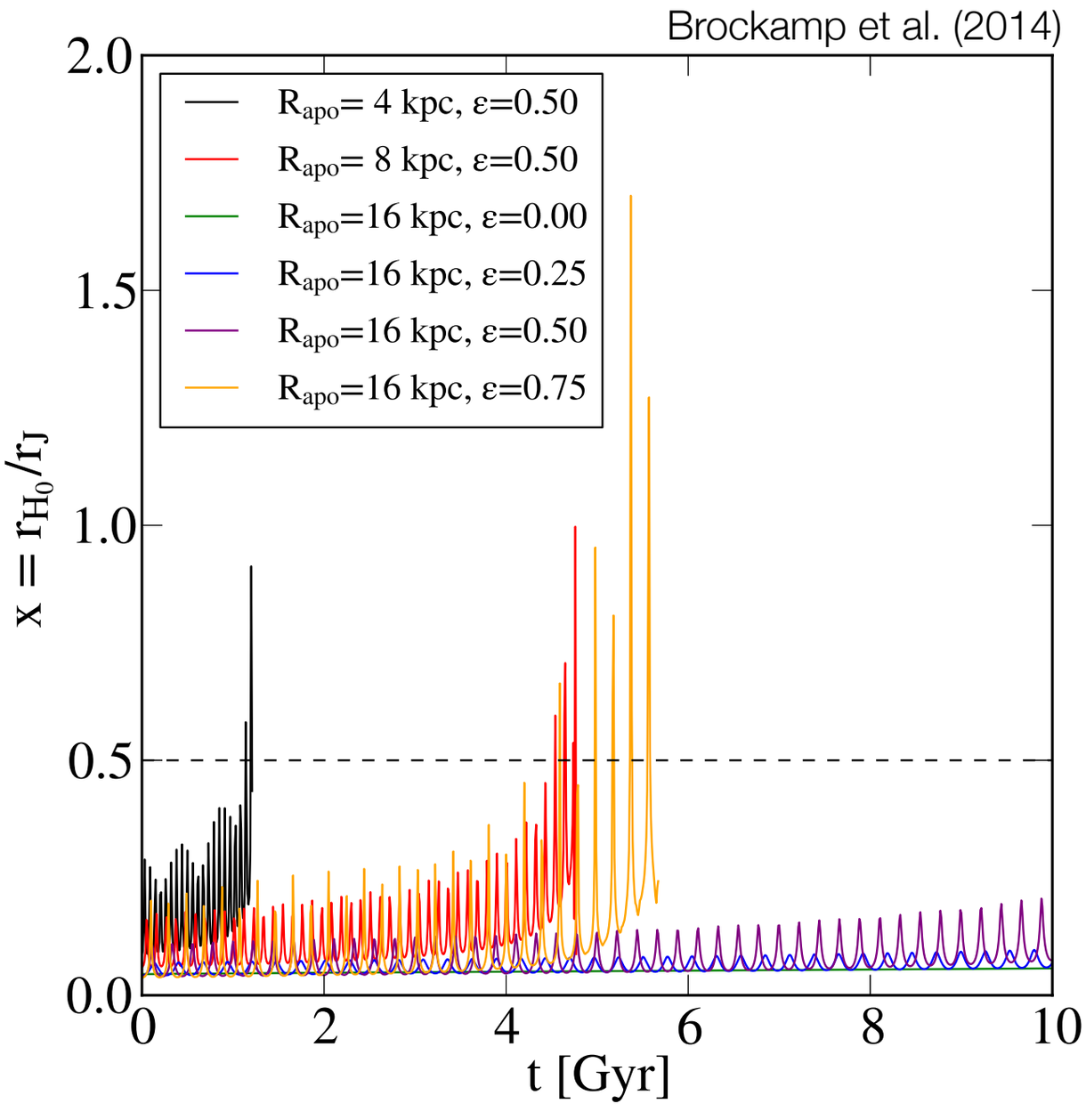


Post-Newtonian Forces

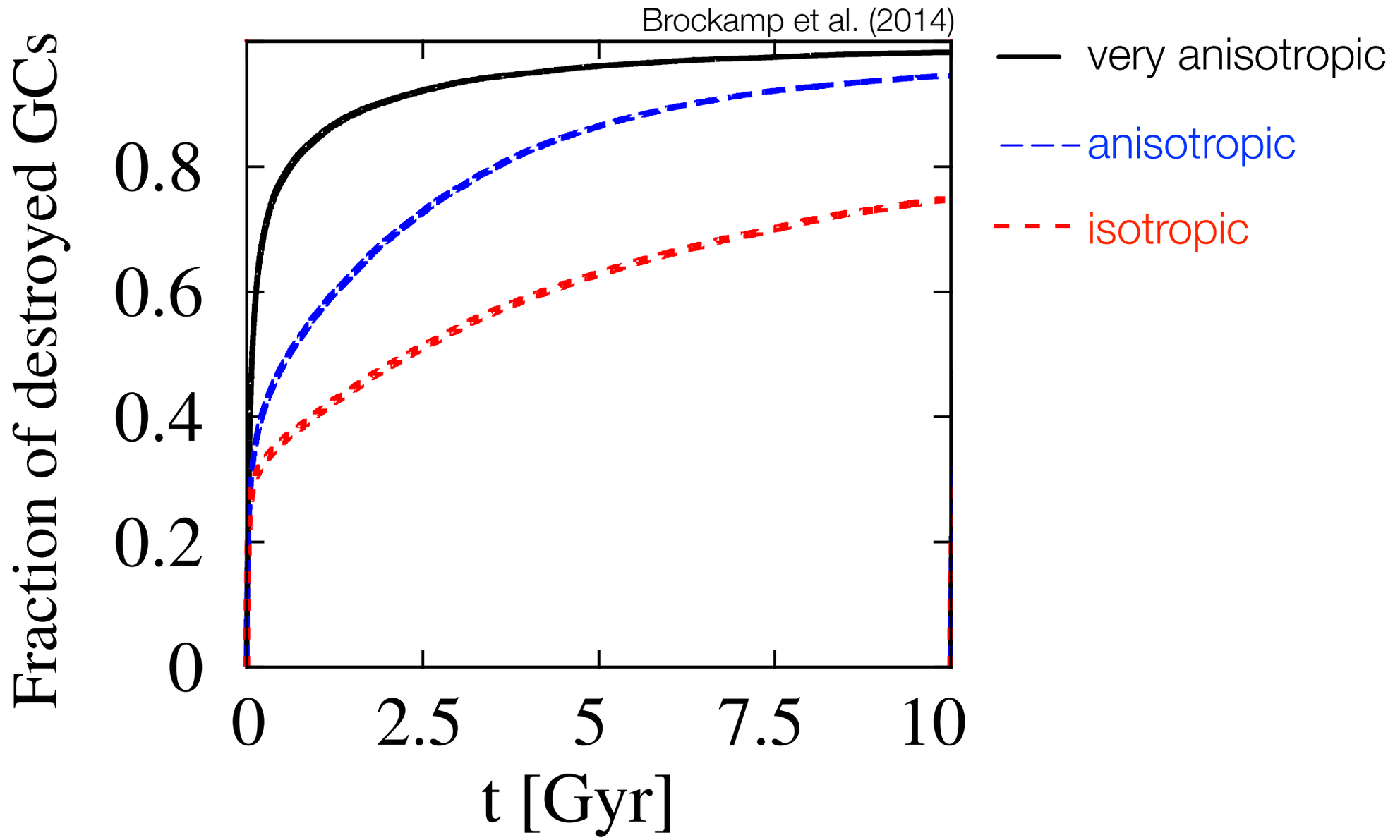
Cluster Mass Loss

Internal cluster evolution (mass loss) is treated analytically





Large fractions of the initial globular cluster population gets destroyed



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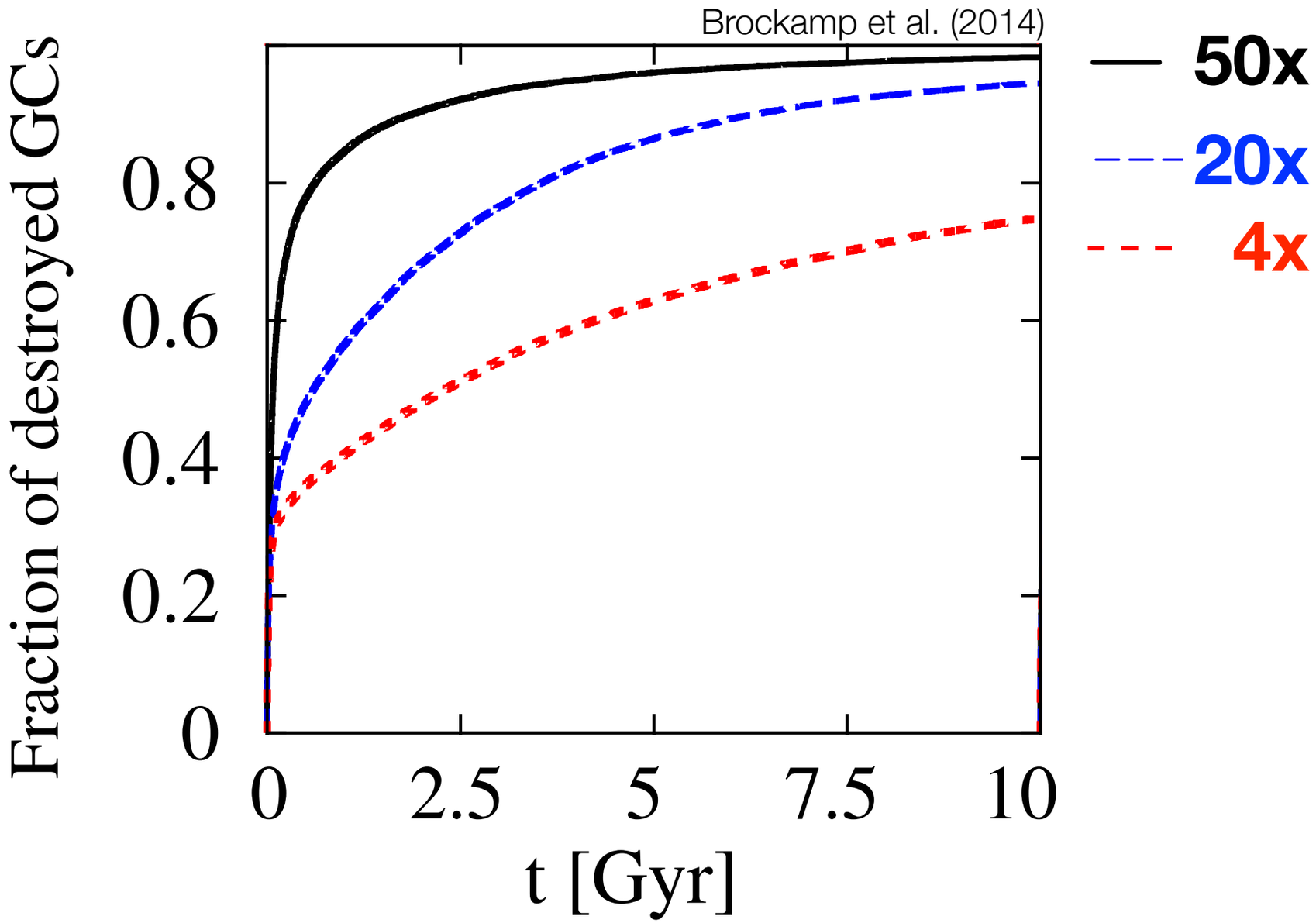
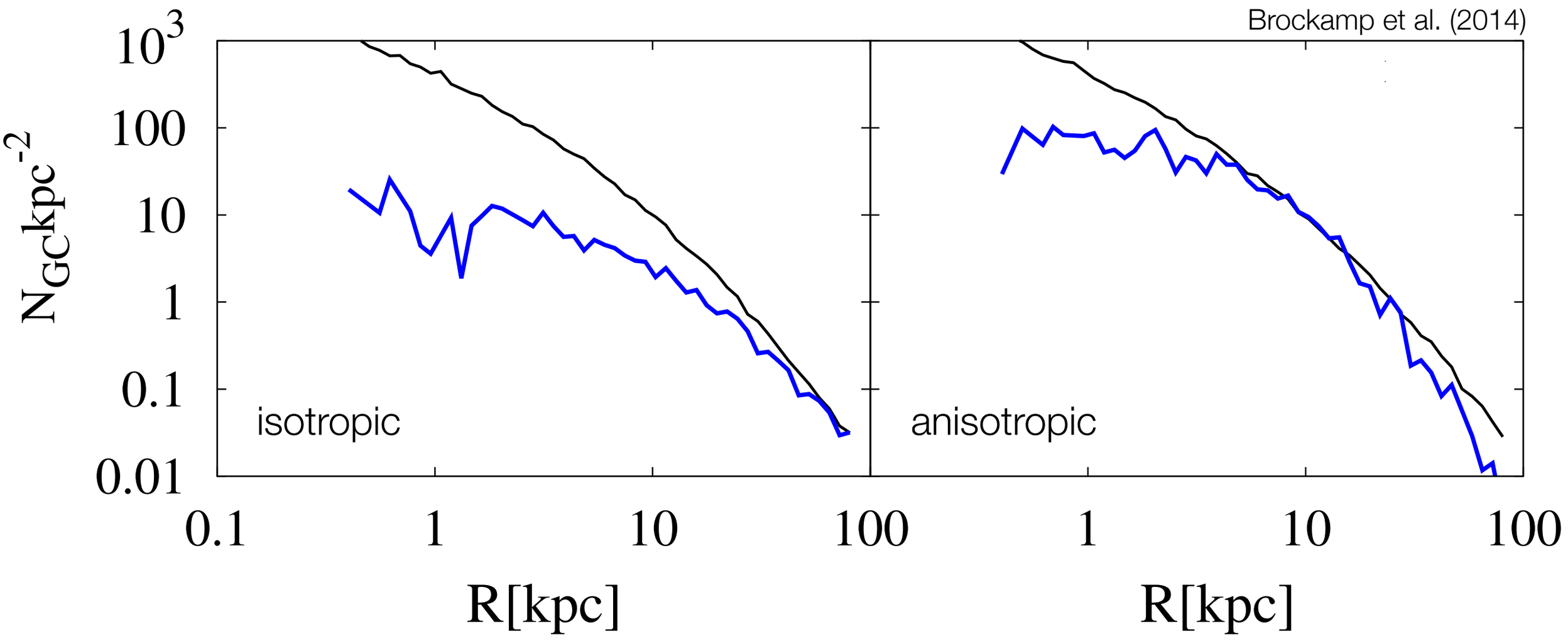
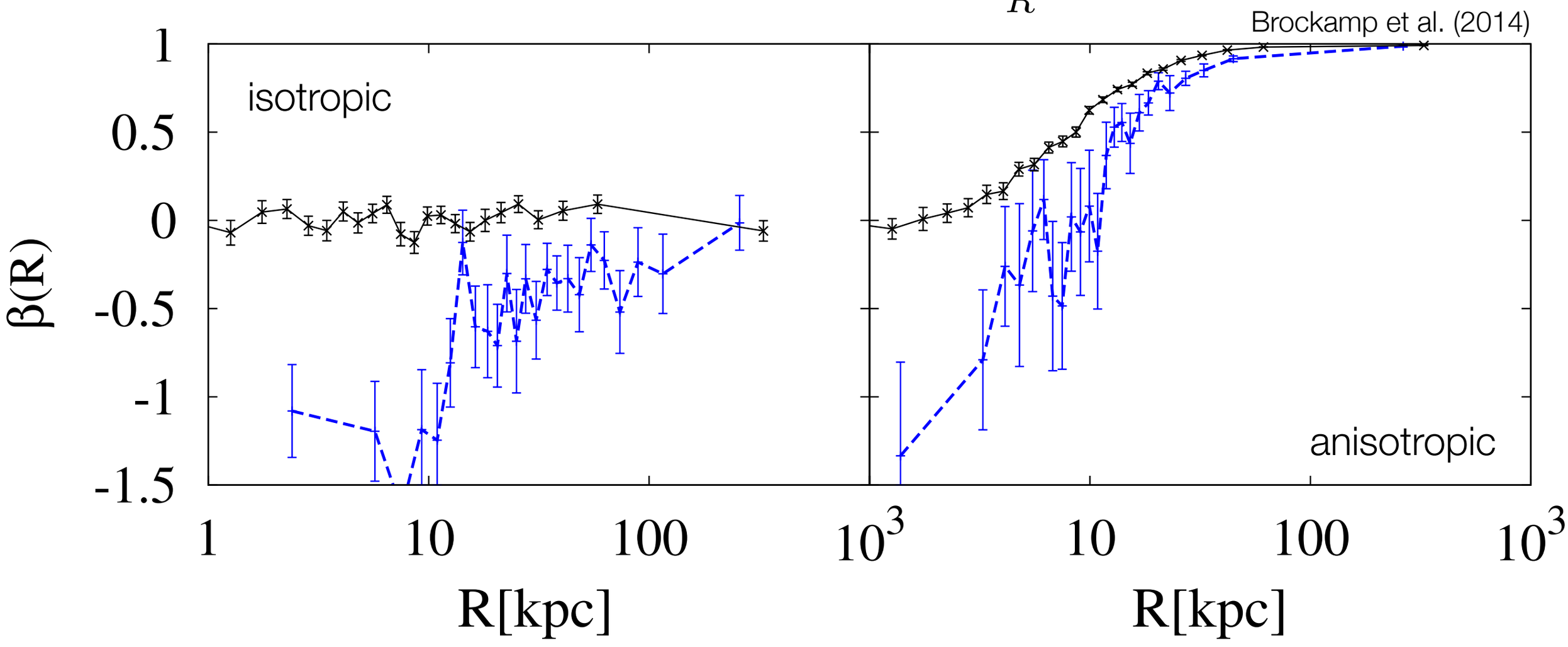


Most clusters are disrupted in the Galactic center



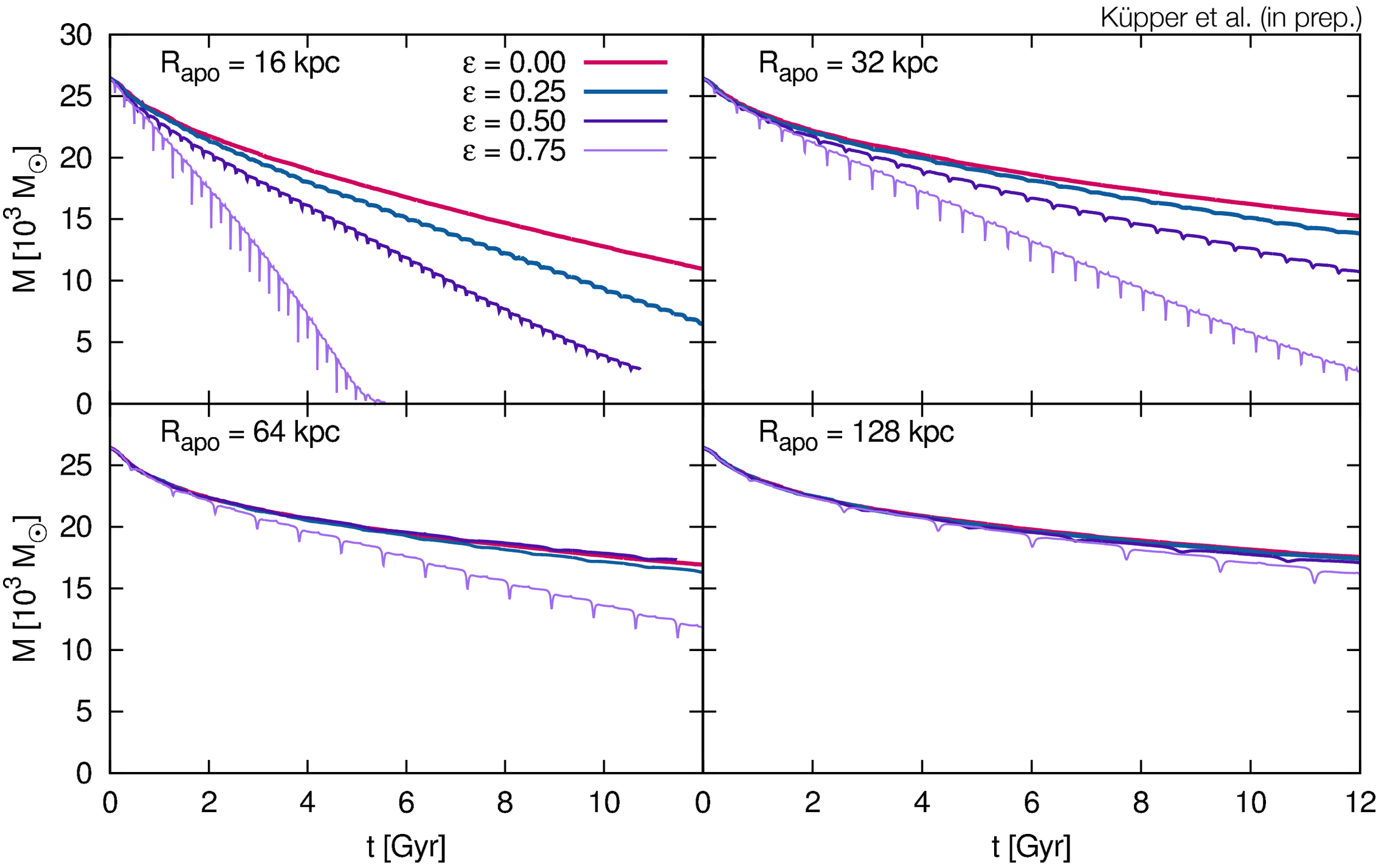
Radial isotropy/anisotropy in the outer halo is conserved, center gets tangentially biased

$$\beta(R) = 1 - \frac{\sigma_\theta^2 + \sigma_\phi^2}{2\sigma_R^2}$$

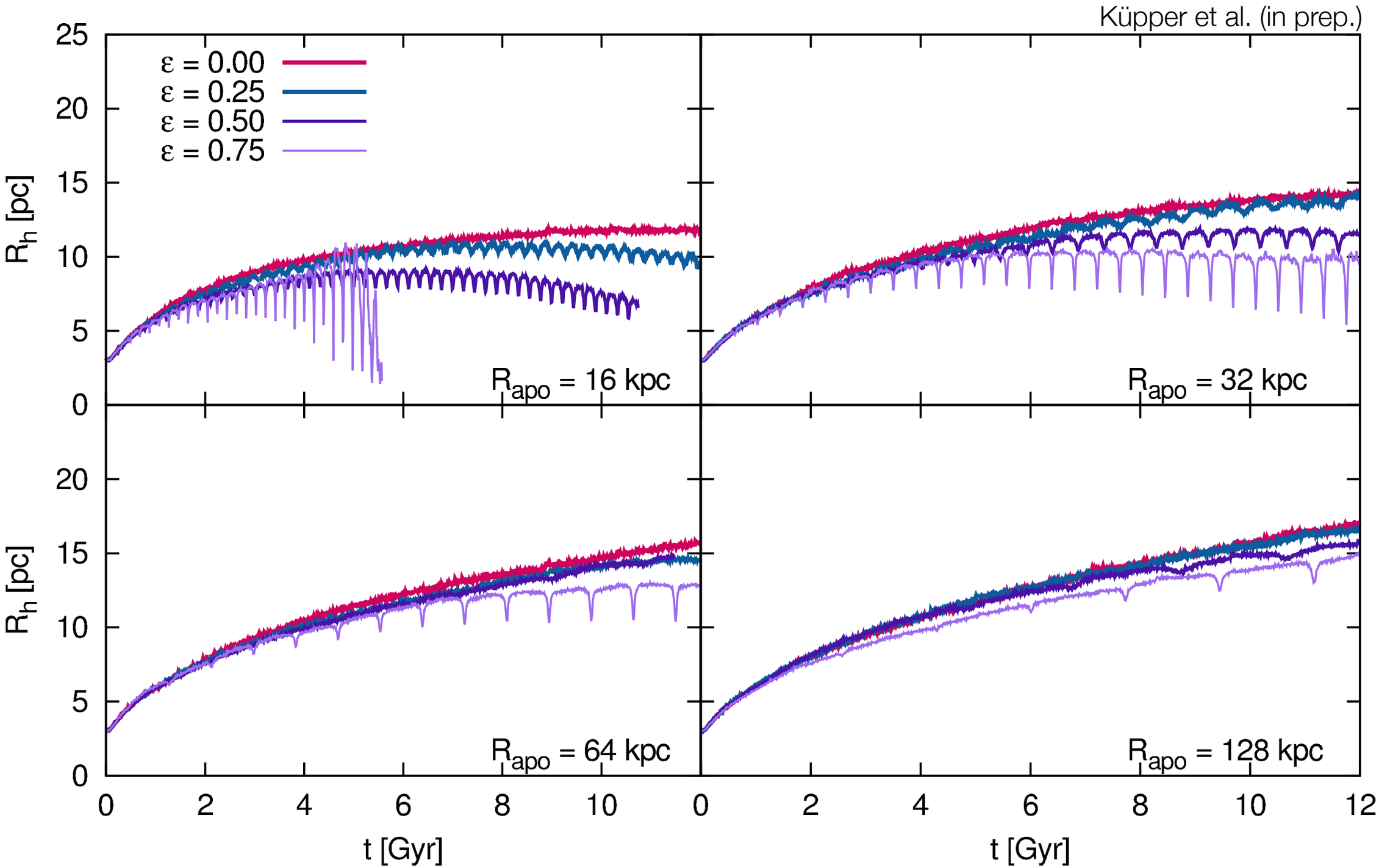


2 Importance for Individual Globular Clusters

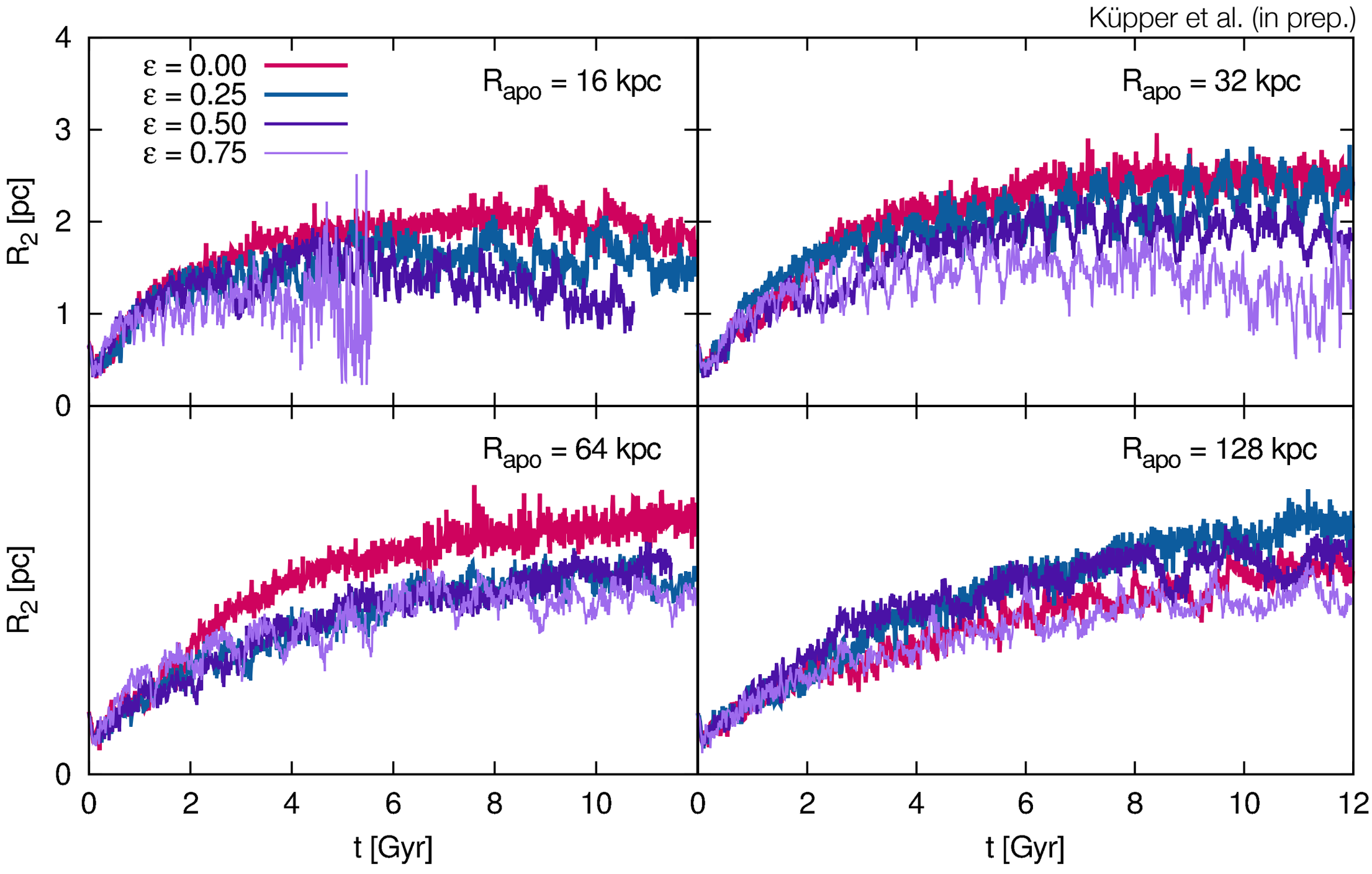
Orbital eccentricity causes higher mass loss rates



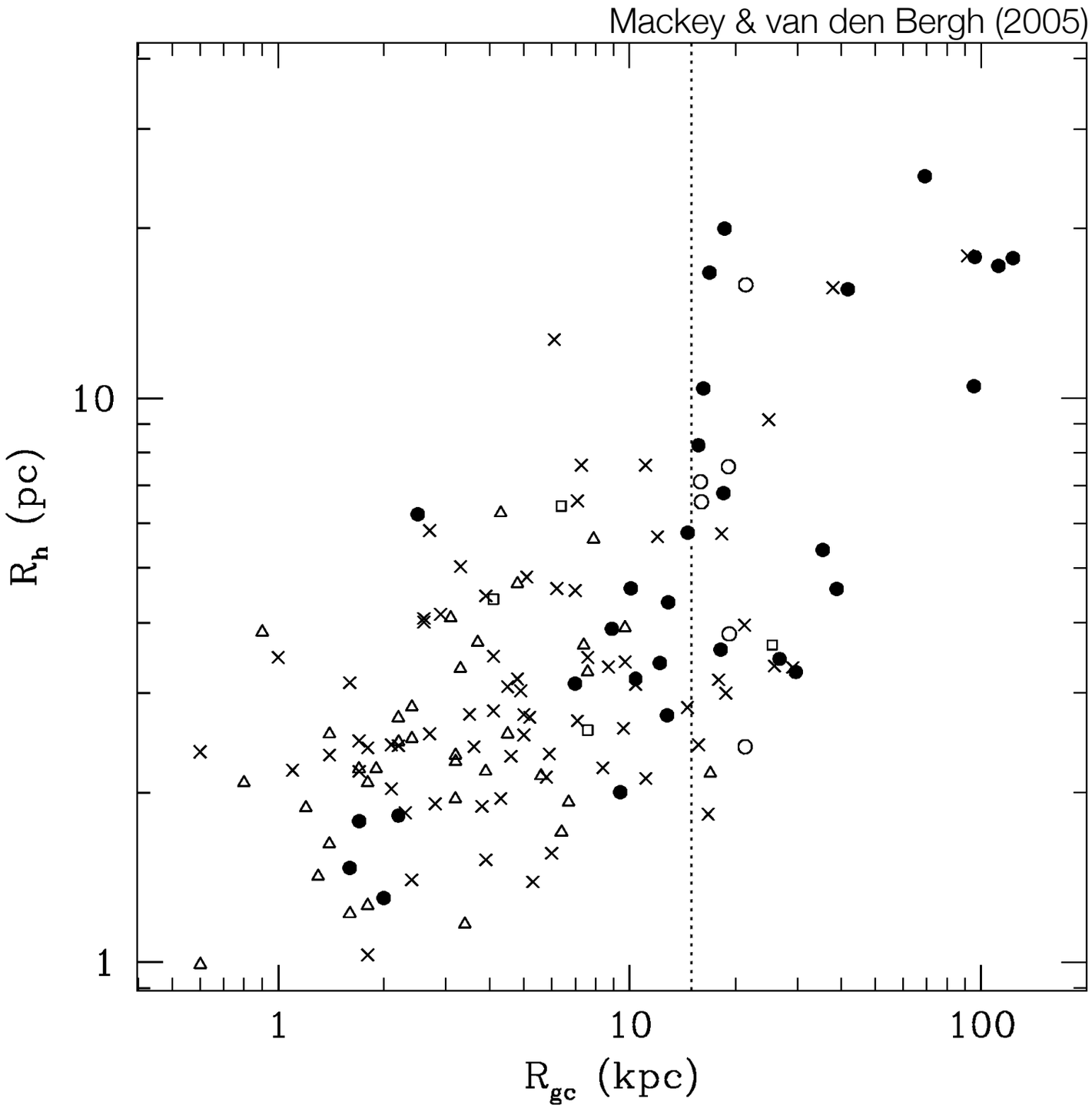
All clusters expand rapidly into their Roche lobe



Clusters have a tiny core collapse in the beginning



In the Milky Way halo outer-halo clusters have all large half-light radii



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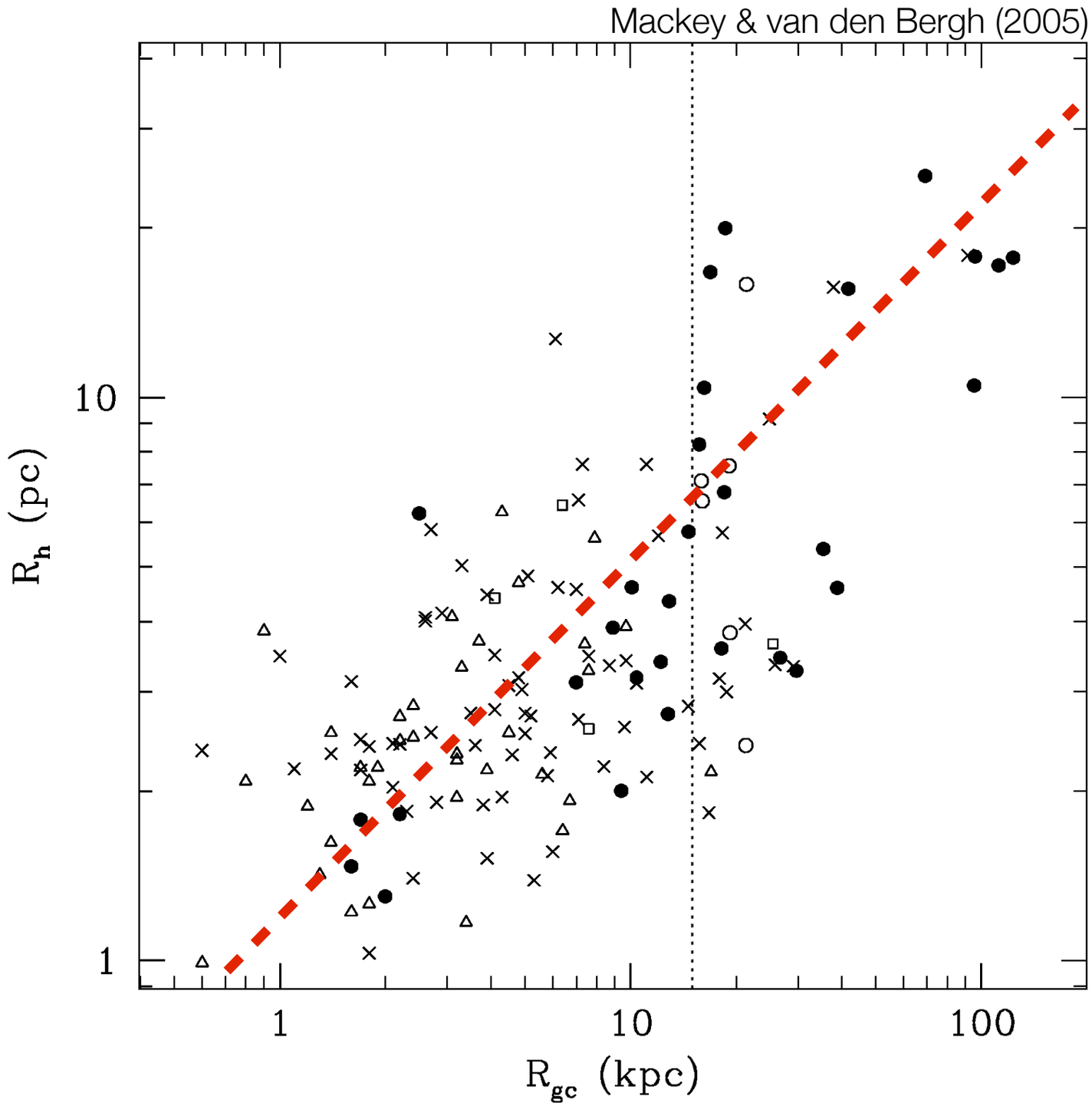
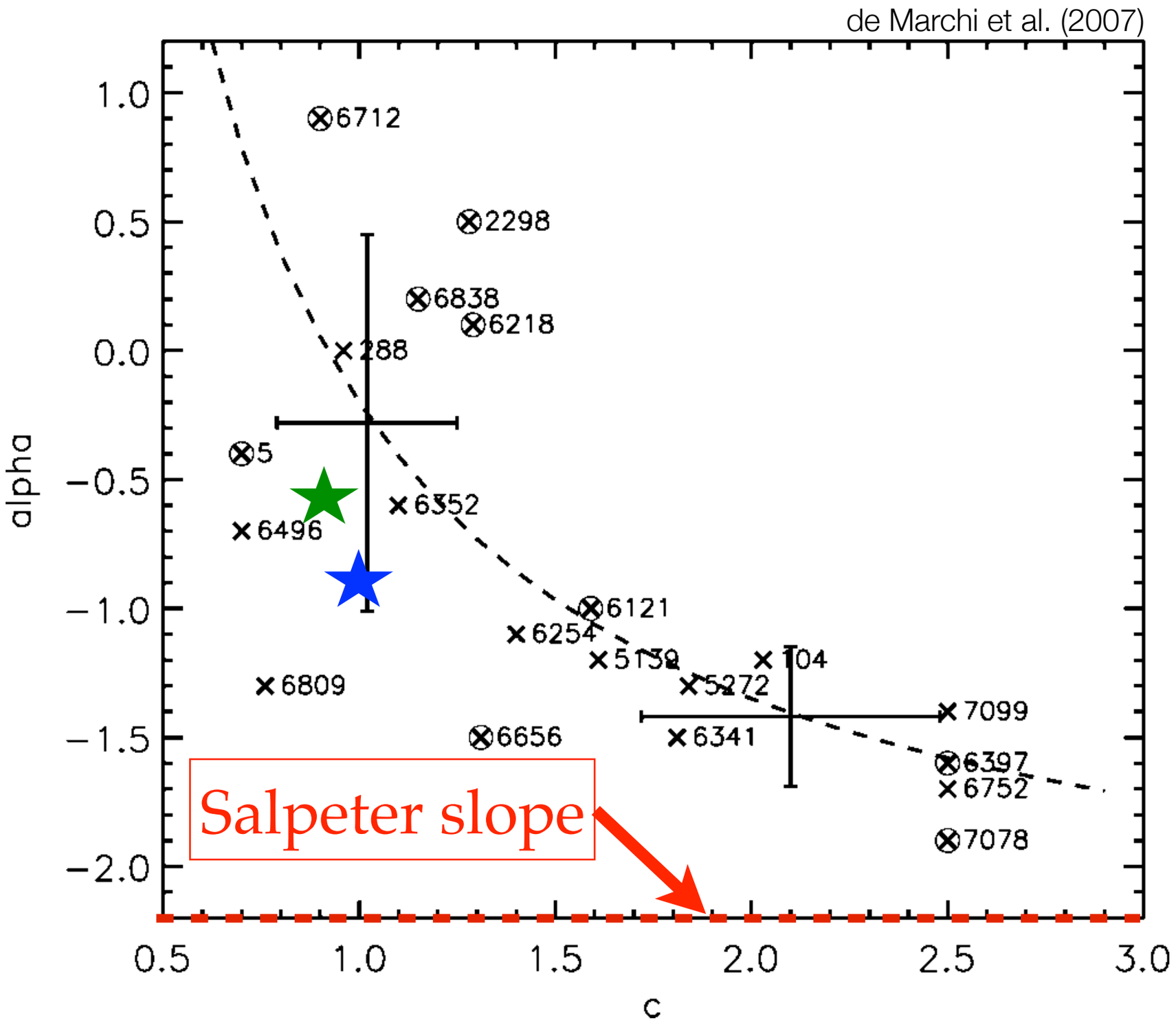
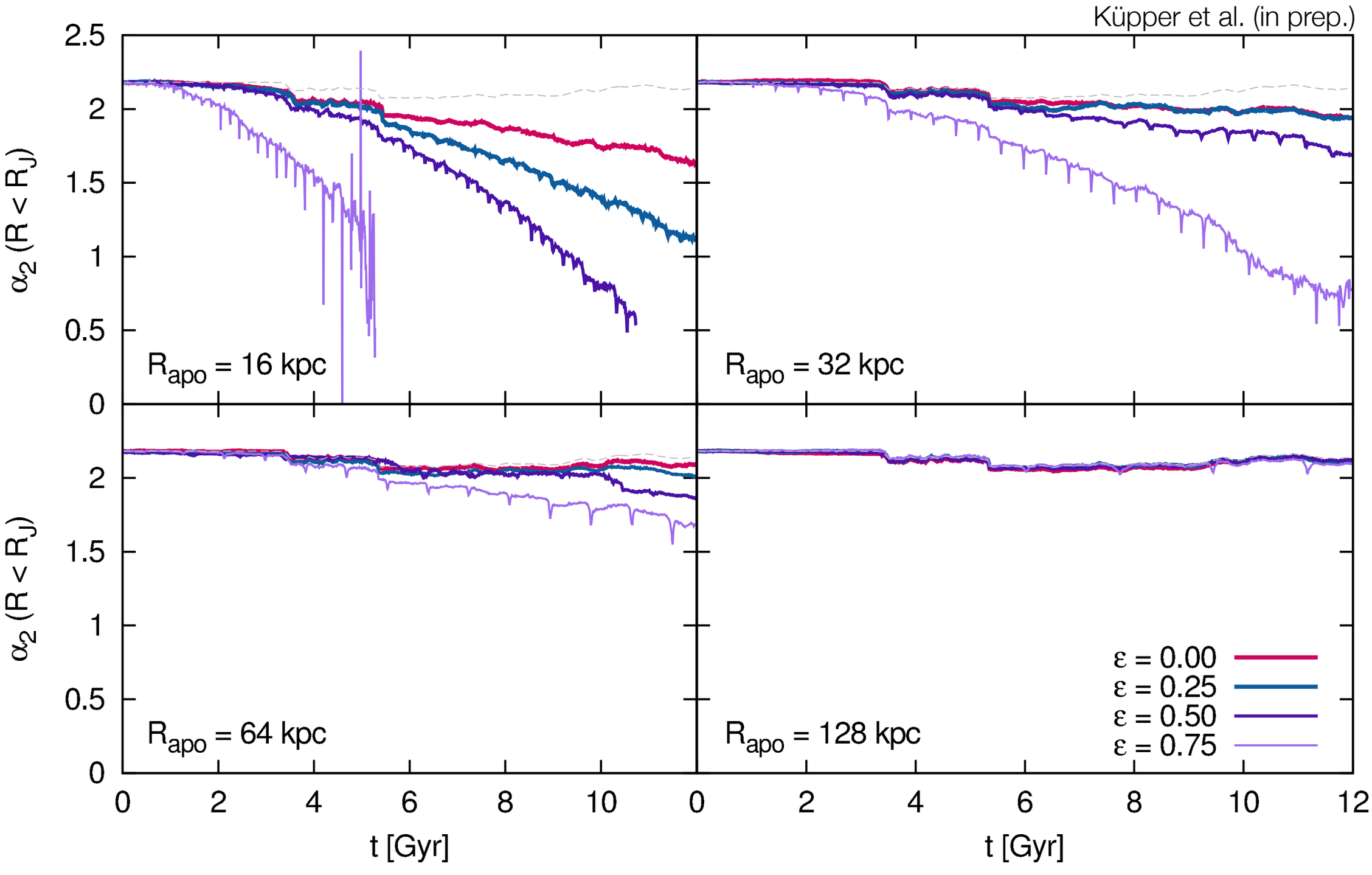


Orbital eccentricity causes higher mass loss rates

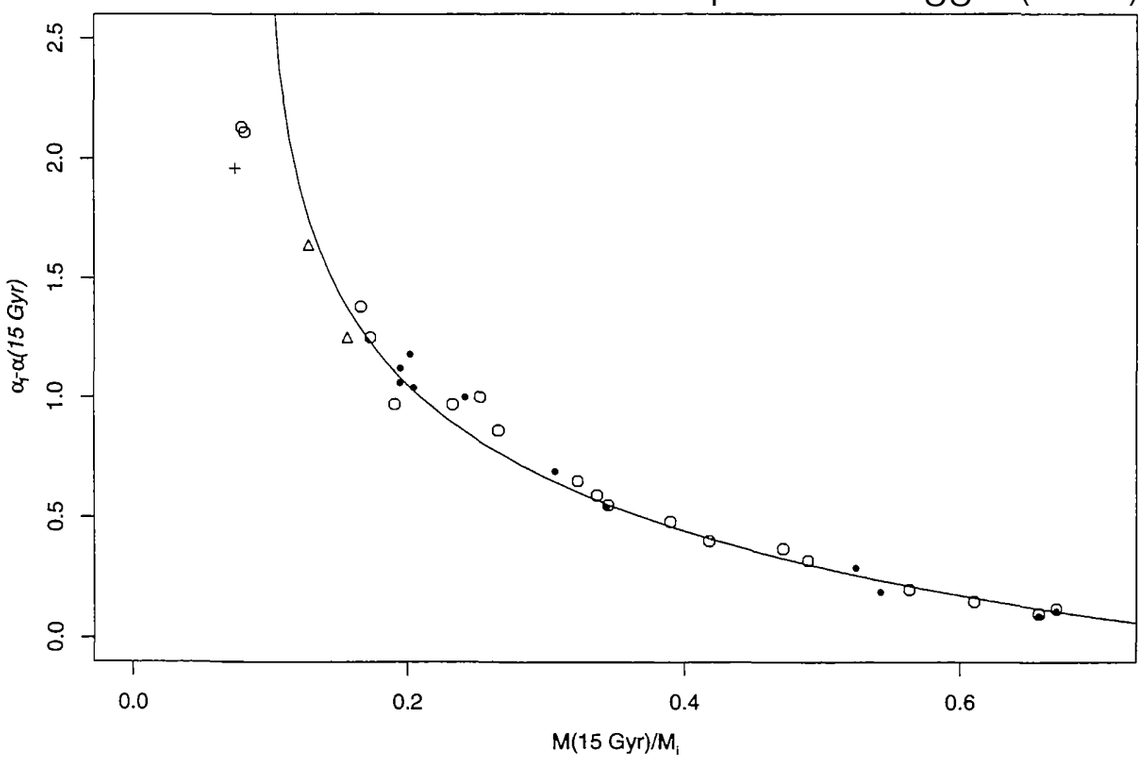
de Marchi et al. (2007)



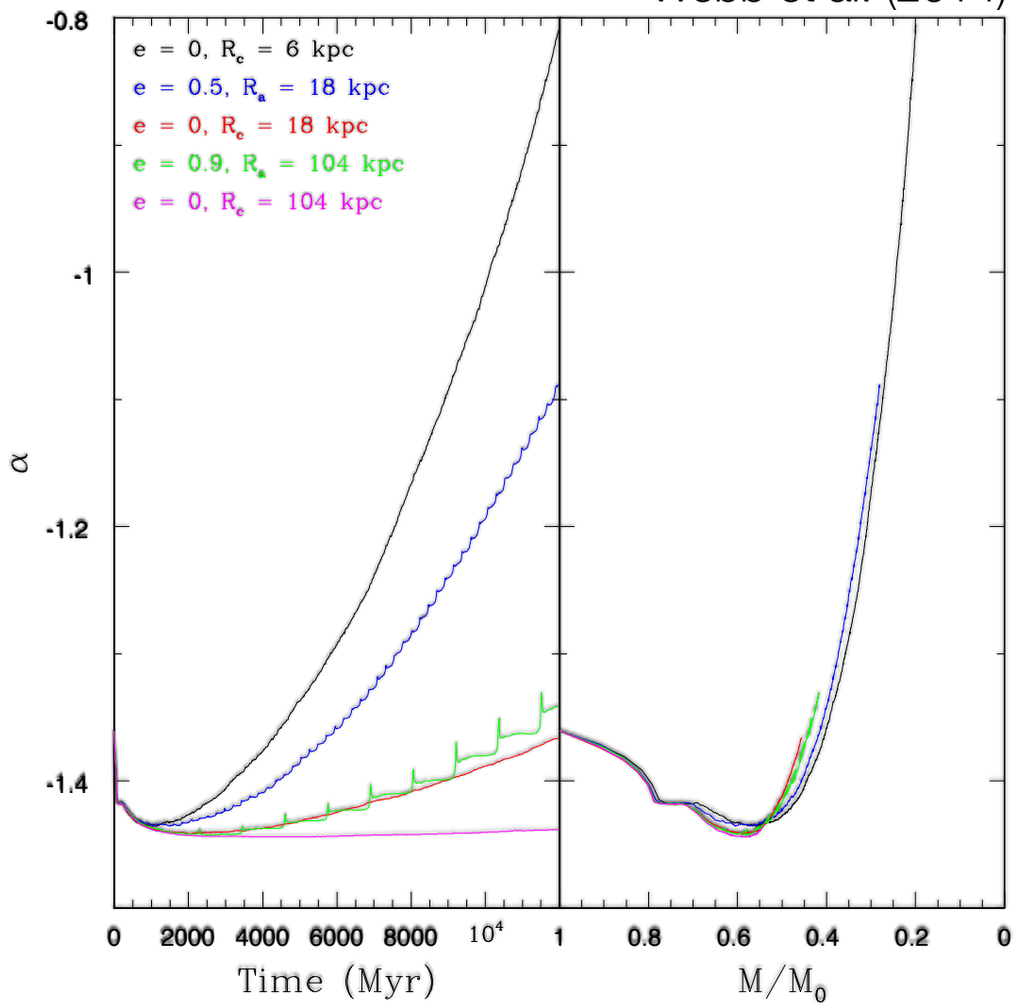
Global mass function gets depleted as cluster loses mass



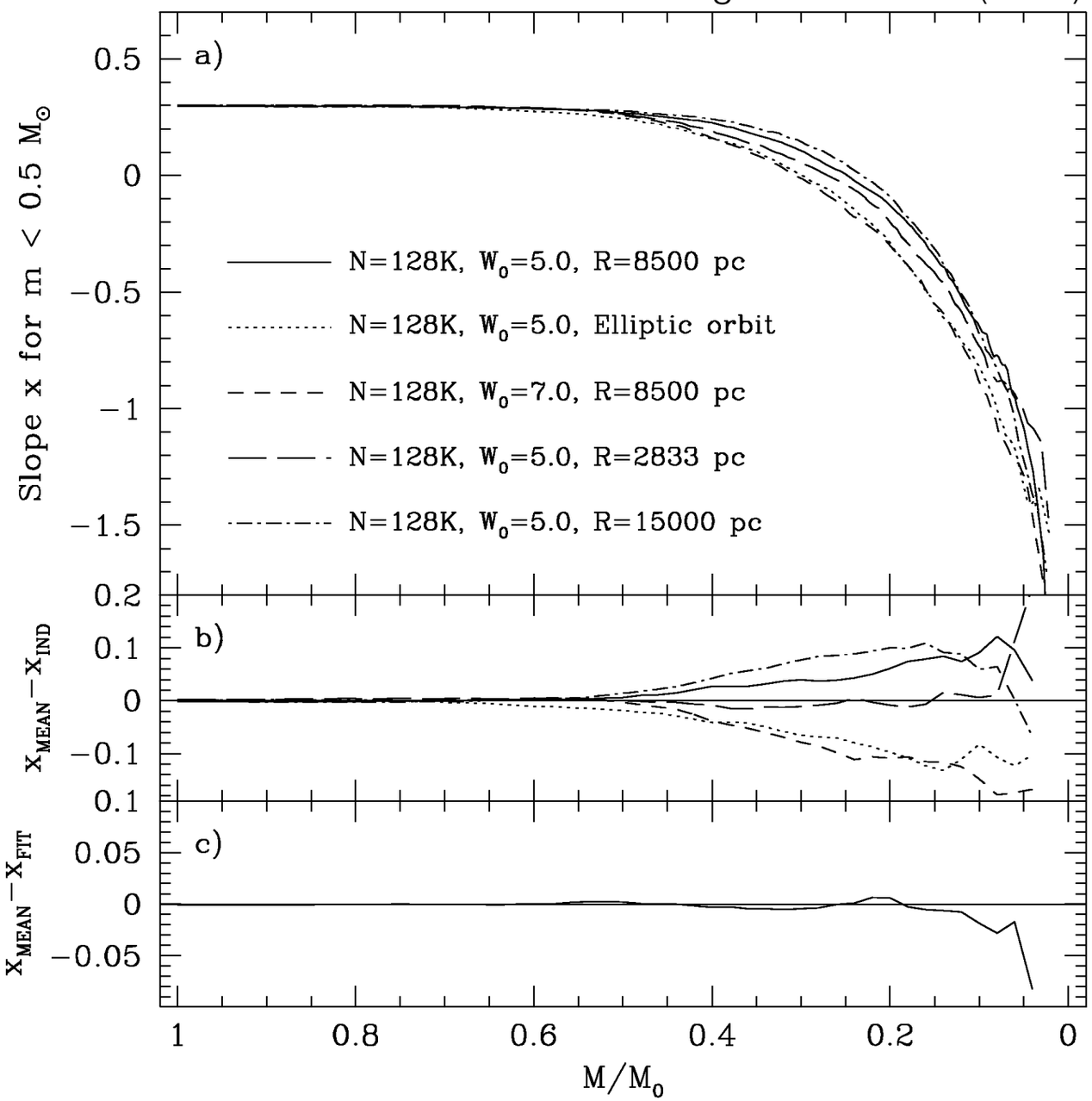
Vesperini & Heggie (1997)



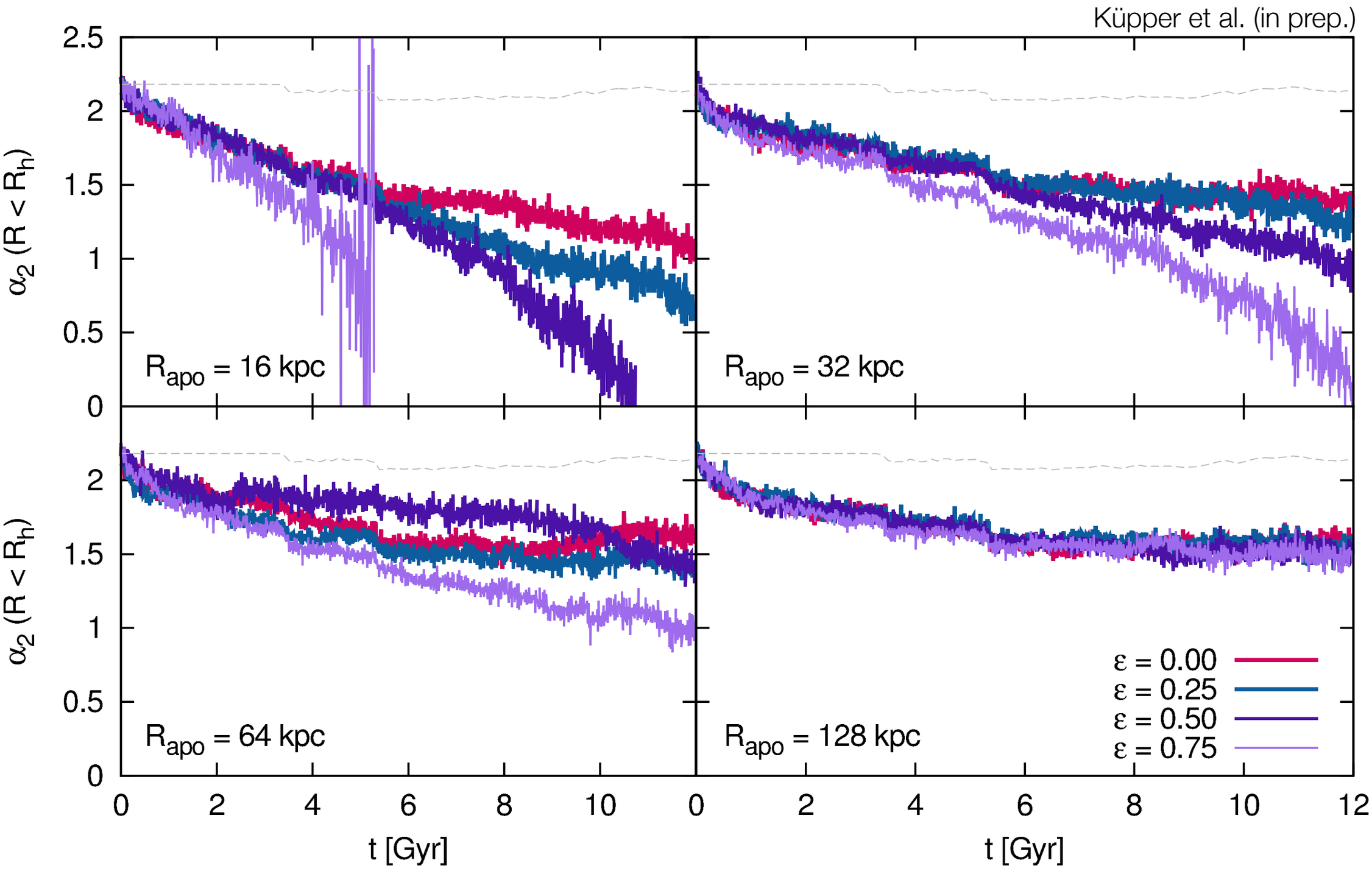
Webb et al. (2014)



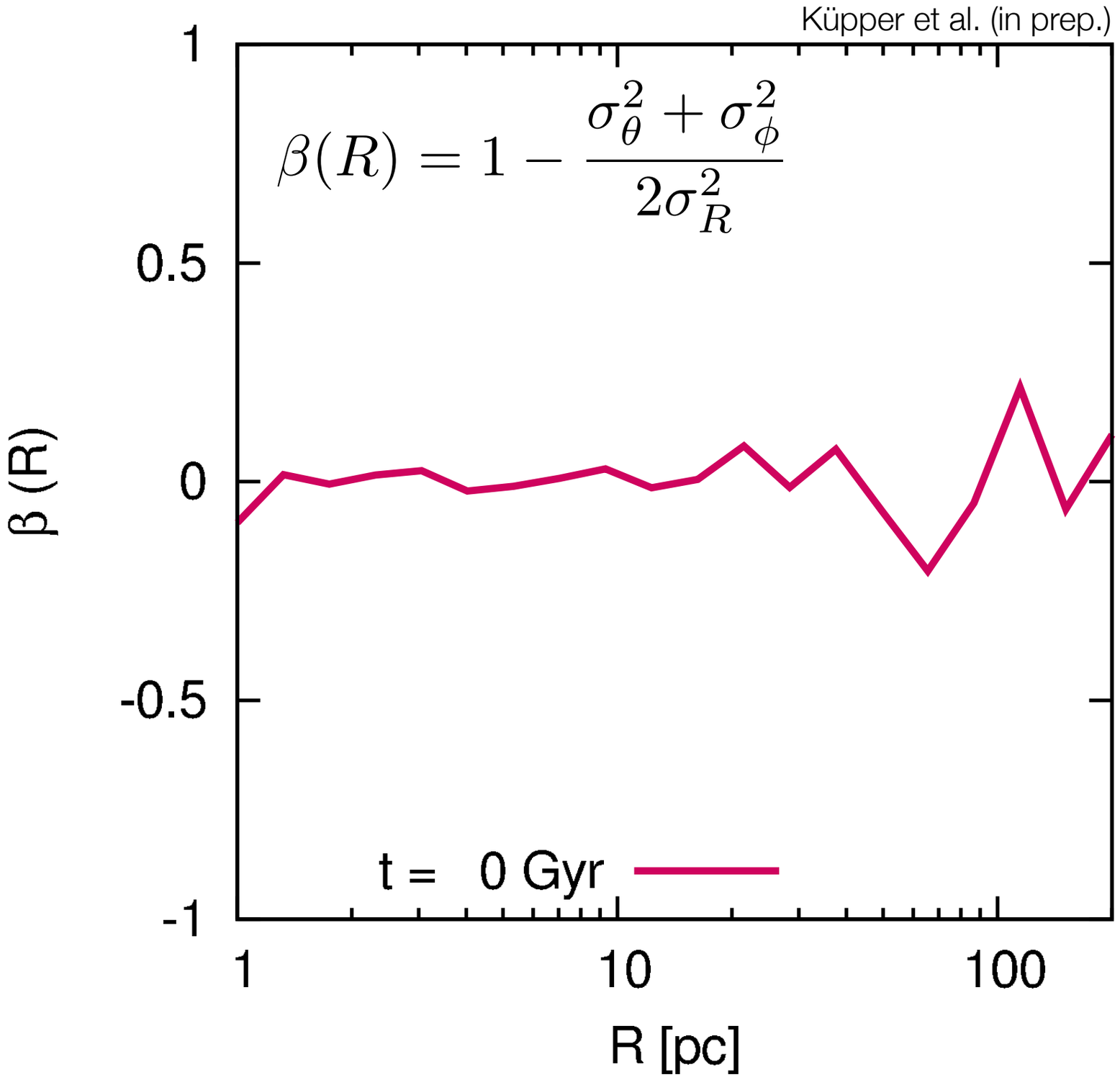
Baumgardt & Makino (2003)



Mass function inside half-mass radius gets flattened even without significant mass loss



Low-mass stars are being kicked on long radial orbits into the halo of the cluster



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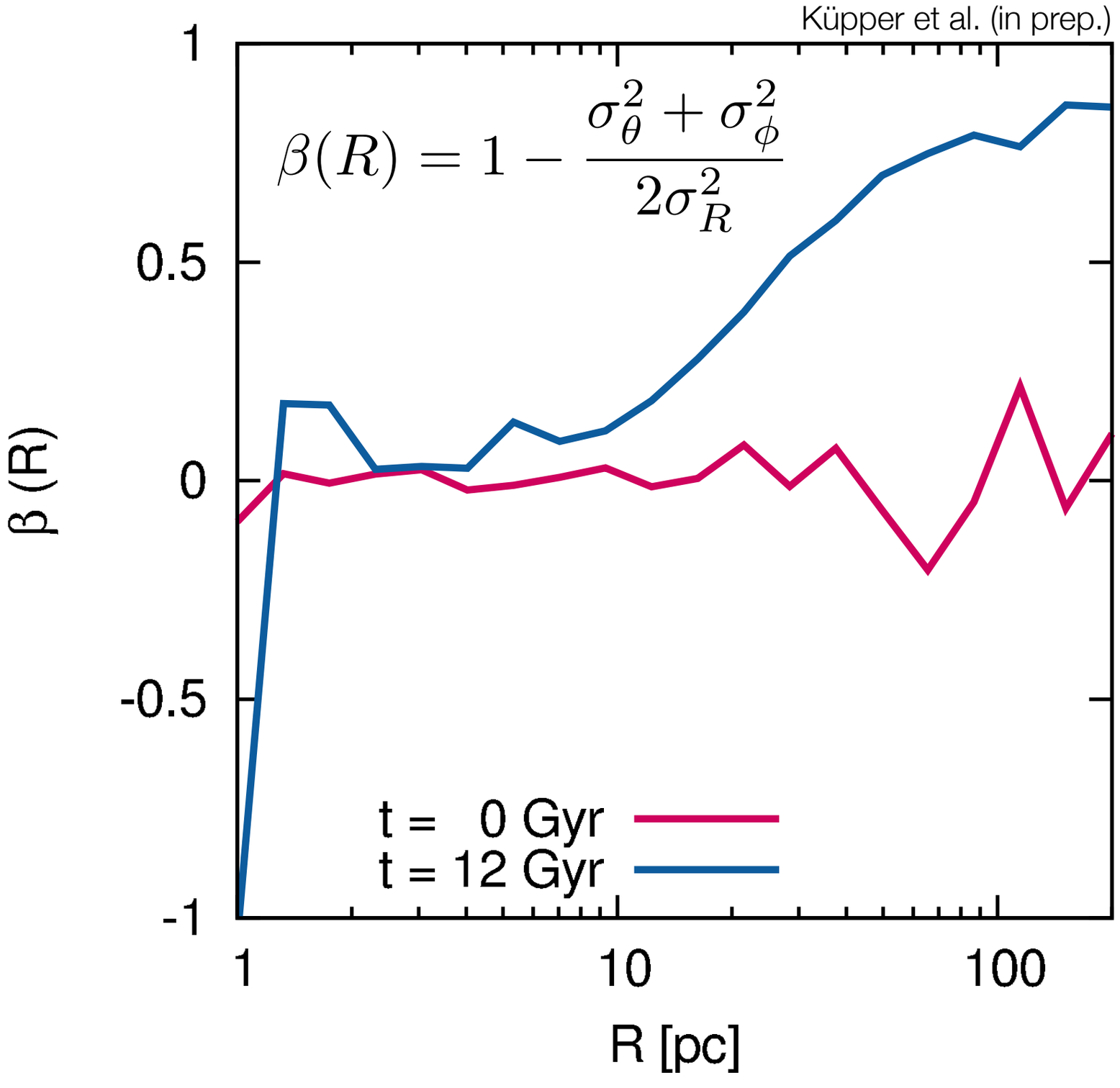
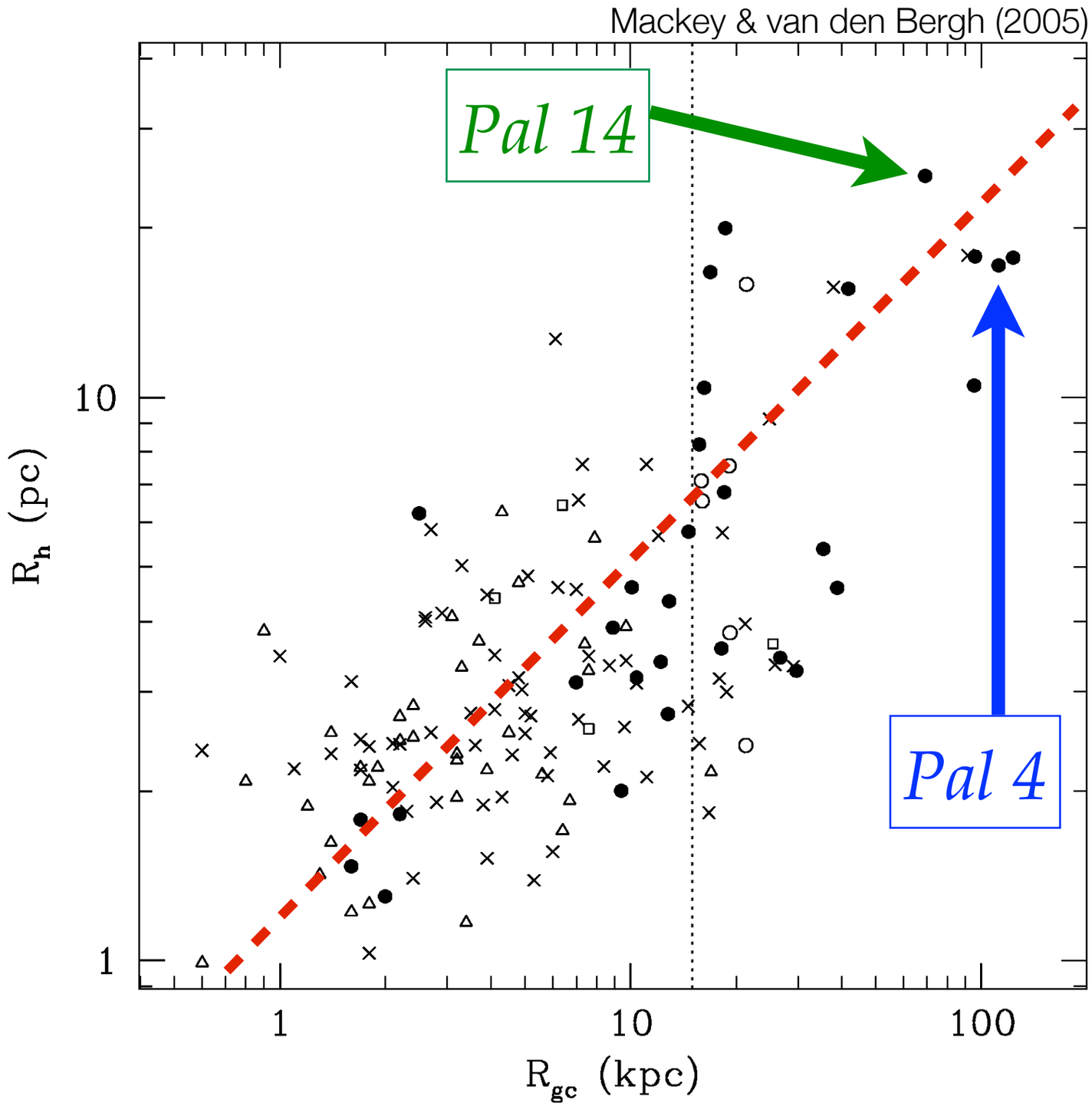


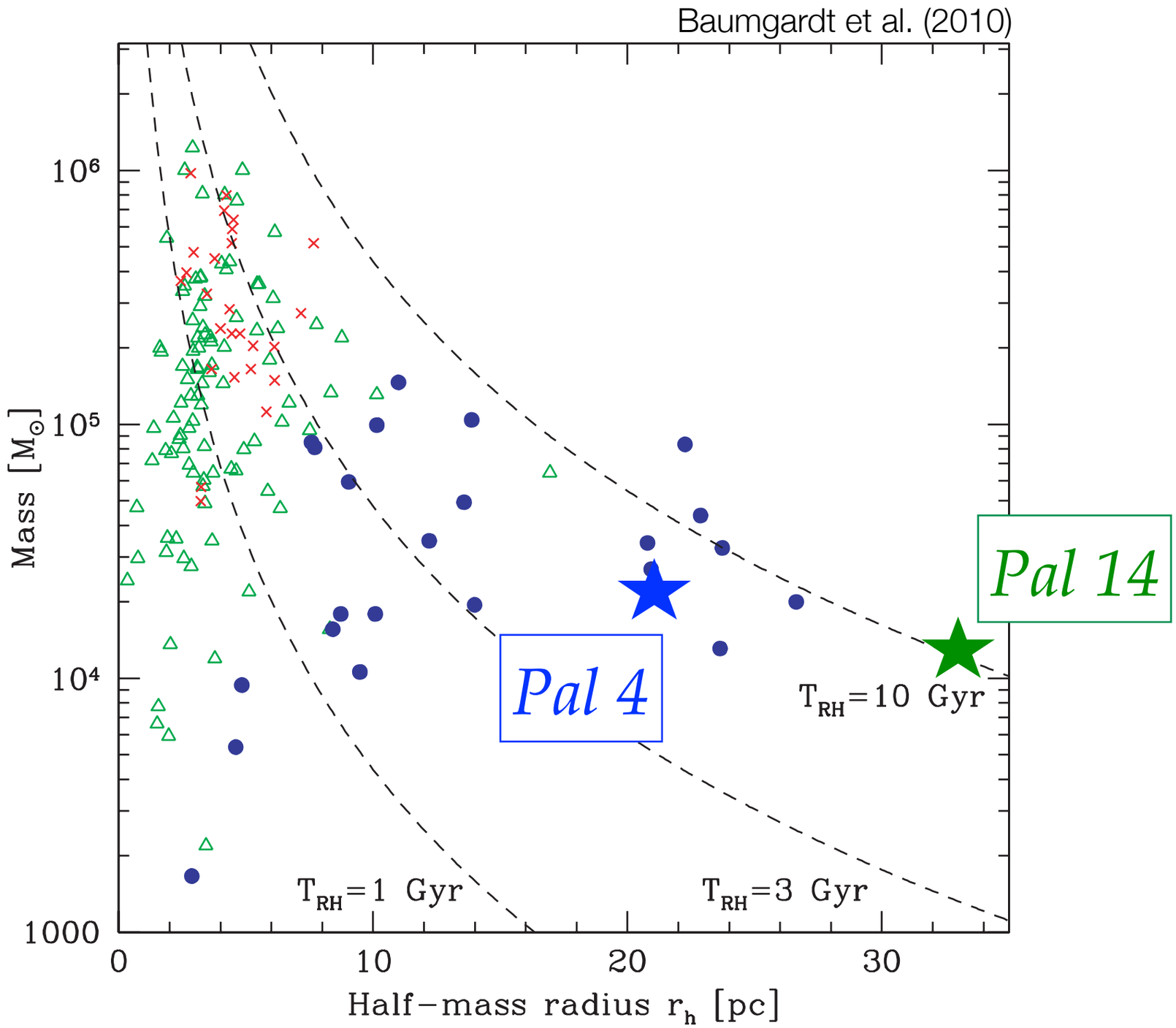
+ Most GCs got disrupted by the Galactic tidal field
+ Today rather tangential orbits in the Galactic center
+ Anisotropy in the outer halo is conserved

+ Eccentricity causes higher mass loss for inner halo
+ Evolution similar for deeply embedded clusters
+ Low mass stars are efficiently removed from center

Palomar clusters are very extended and in the very outer halo

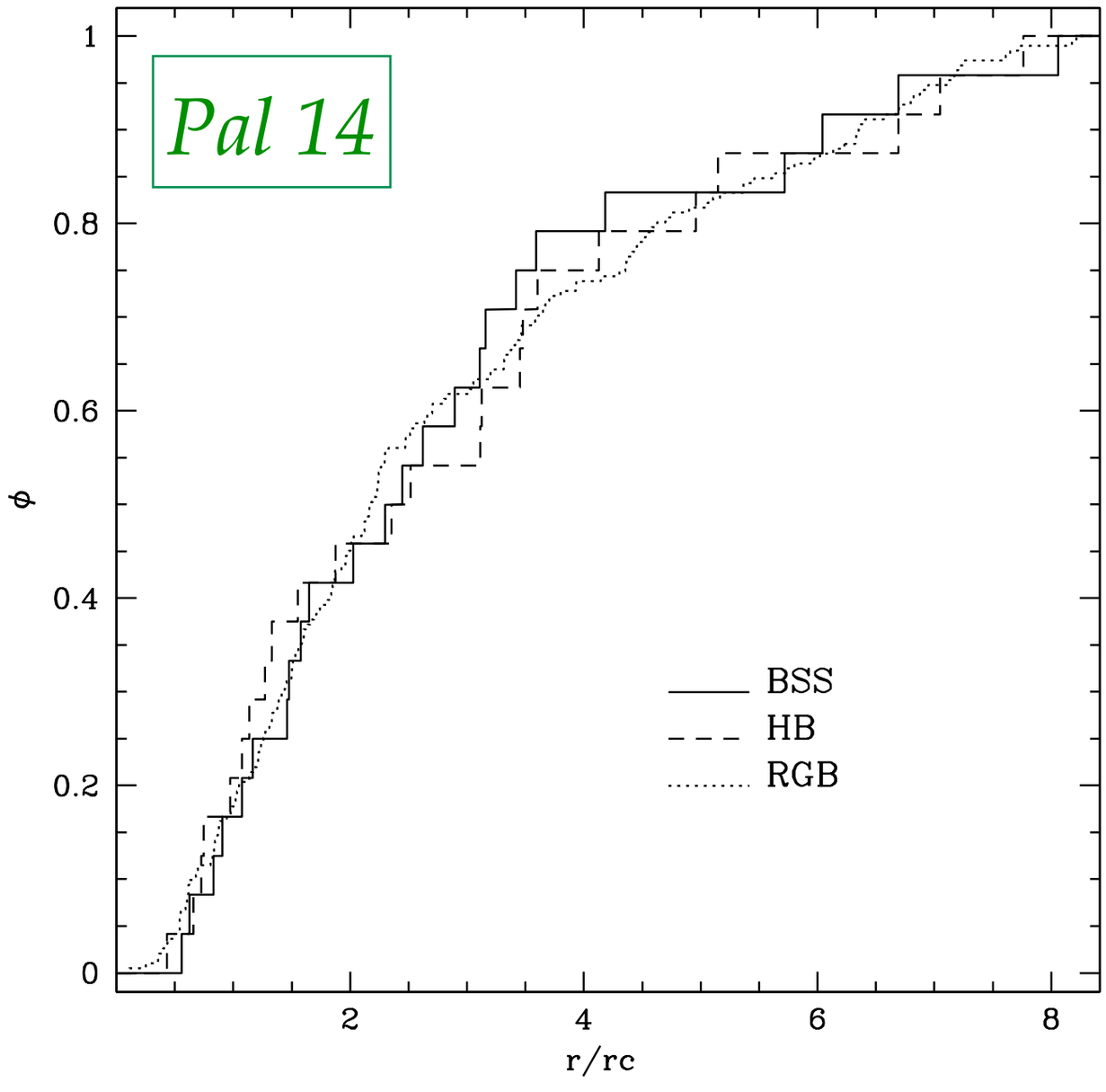


Extended clusters have present-day two-body relaxation times of many Gyr



High-mass stars at present day don't seem/don't need to be segregated

Beccari et al. (2011)



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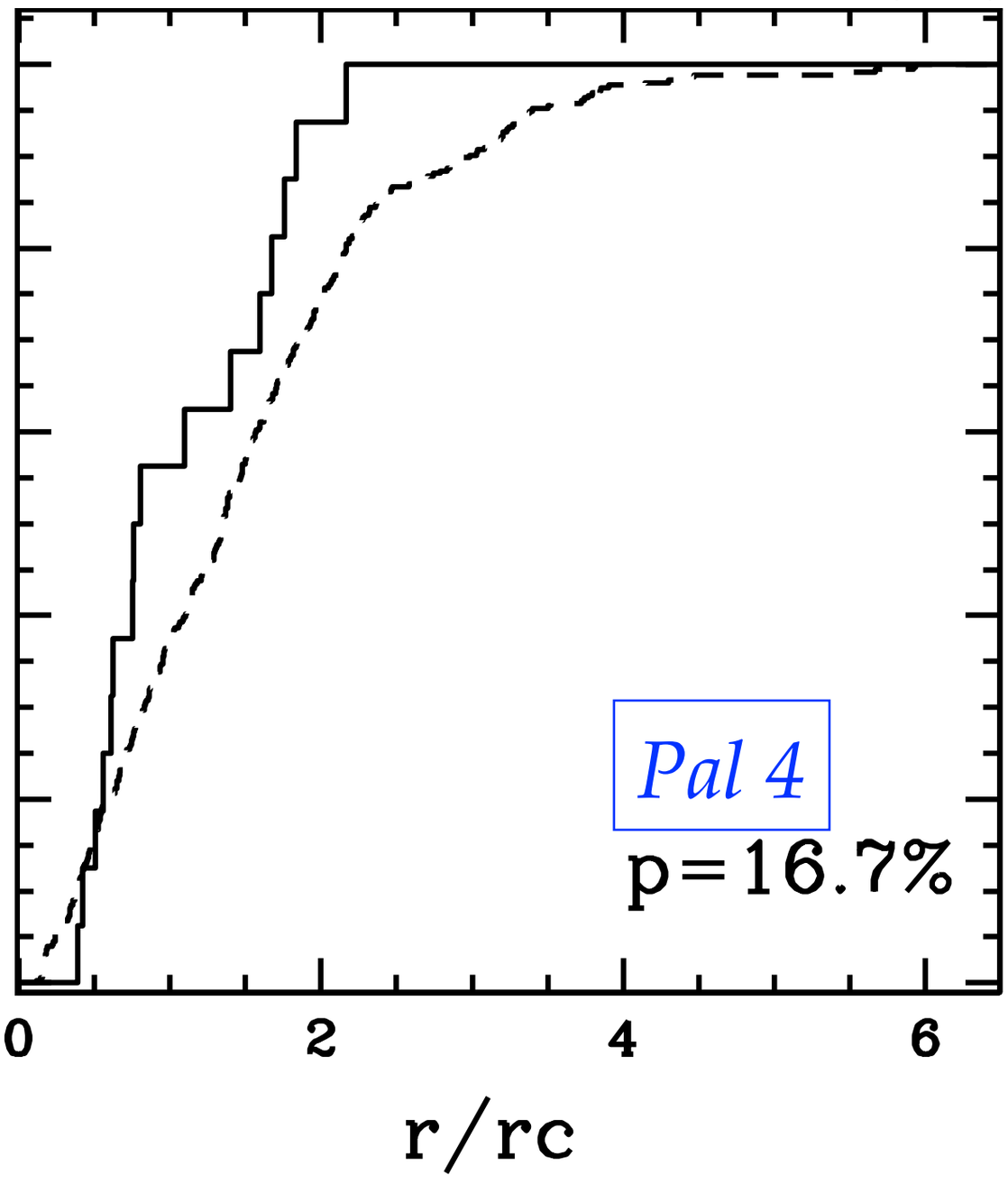
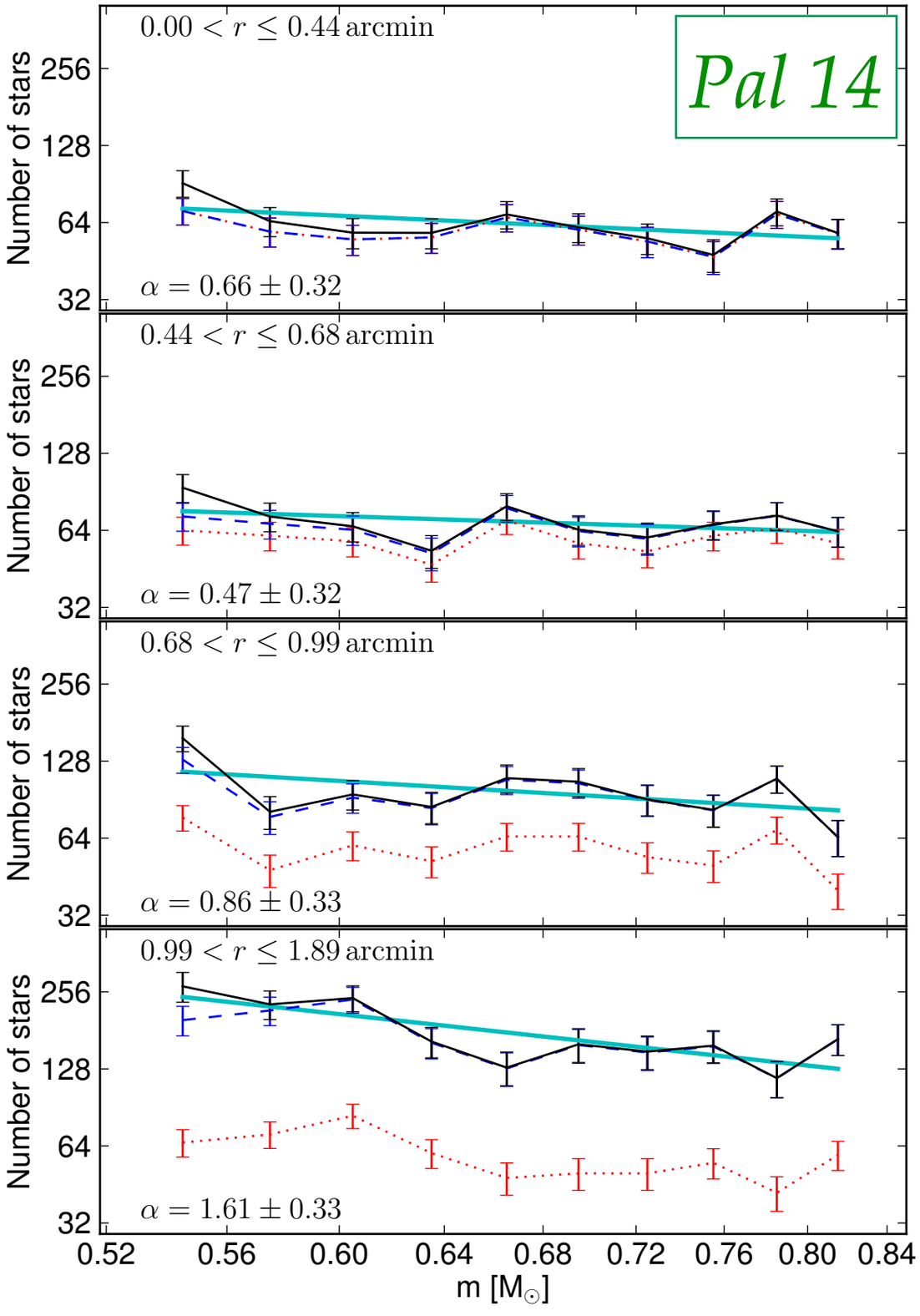


Frank et al. (submitted)



Frank et al. (2012)