The Sizes of Globular Clusters as Tracers of Galactic Halo Potentials

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Outline

- The size scale of Galactic globular clusters (GCs)
  - Tow phases of mass-loss
  - Half-mass radius – Galactocentric distance relation

- The effect of different galactic halo potential on the **size distribution** of GCs

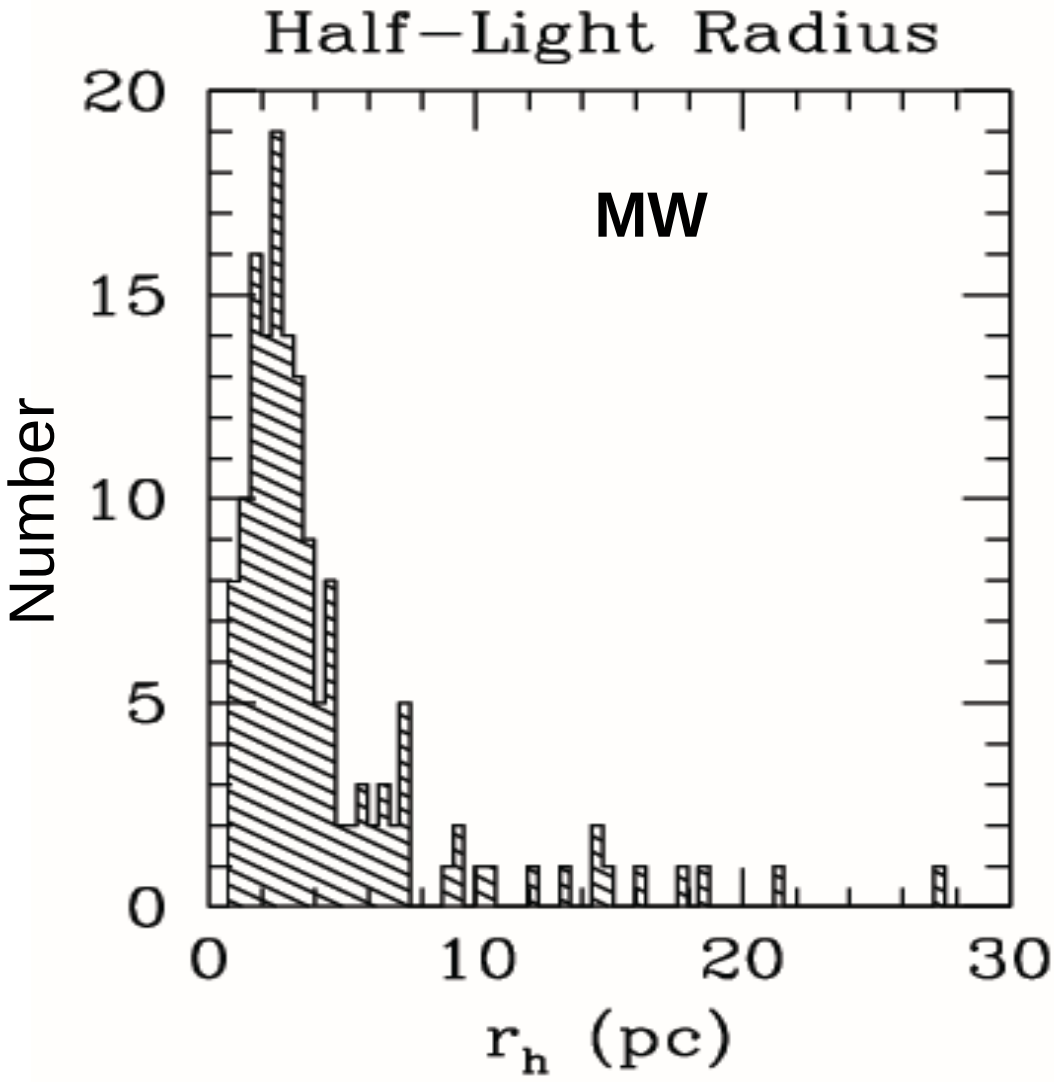
Why study the size scale of GCs

- About 160 GCs are distributed out to more than 100 kpc in our Galaxy.

- The numbers of GCs are roughly scale with their host's mass and density (Mieske, Kupper & Brockamp 2014; Harris, Harris, & Hudson 2015). They are therefore tracers of galaxy potentials.

- The GCs we observe today have survived within the hostile gravitational potentials of their hosts over billions of years (Fall & Zhang 2001; Brockamp et al. 2014).

Most MW Globular Clusters have half-light radius around 3 pc

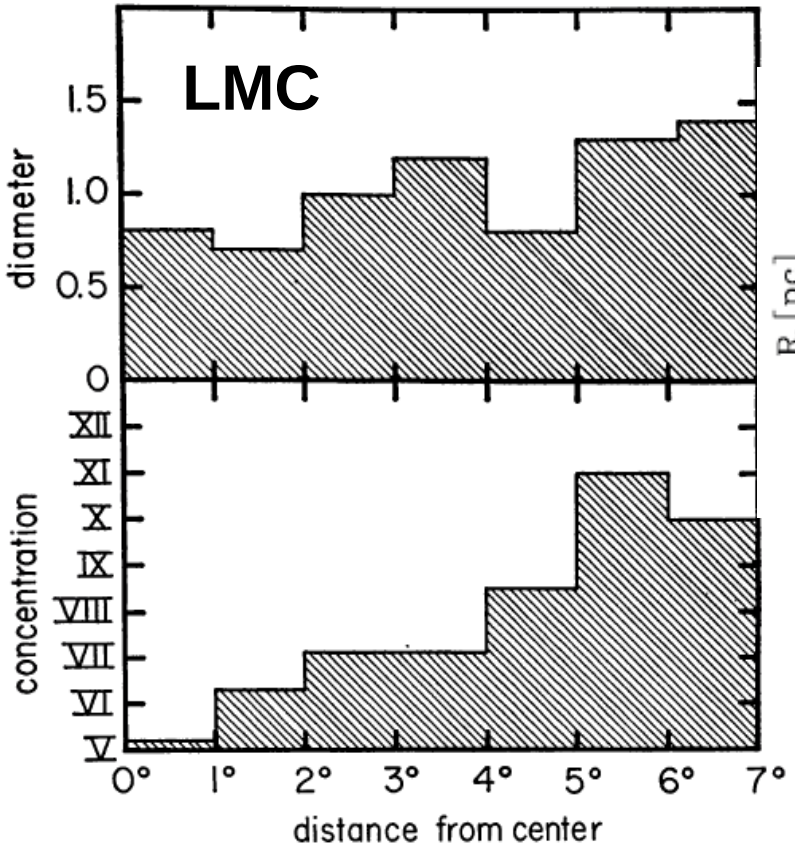


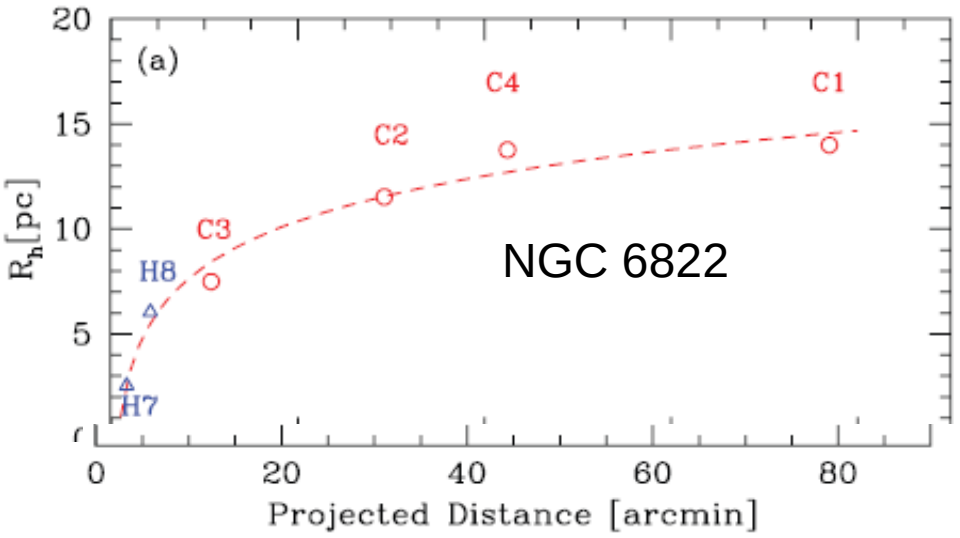
Harris (2010)

The mean present-day, half-light radii lie around 3 pc

Rh-Rgc Relation in galaxies

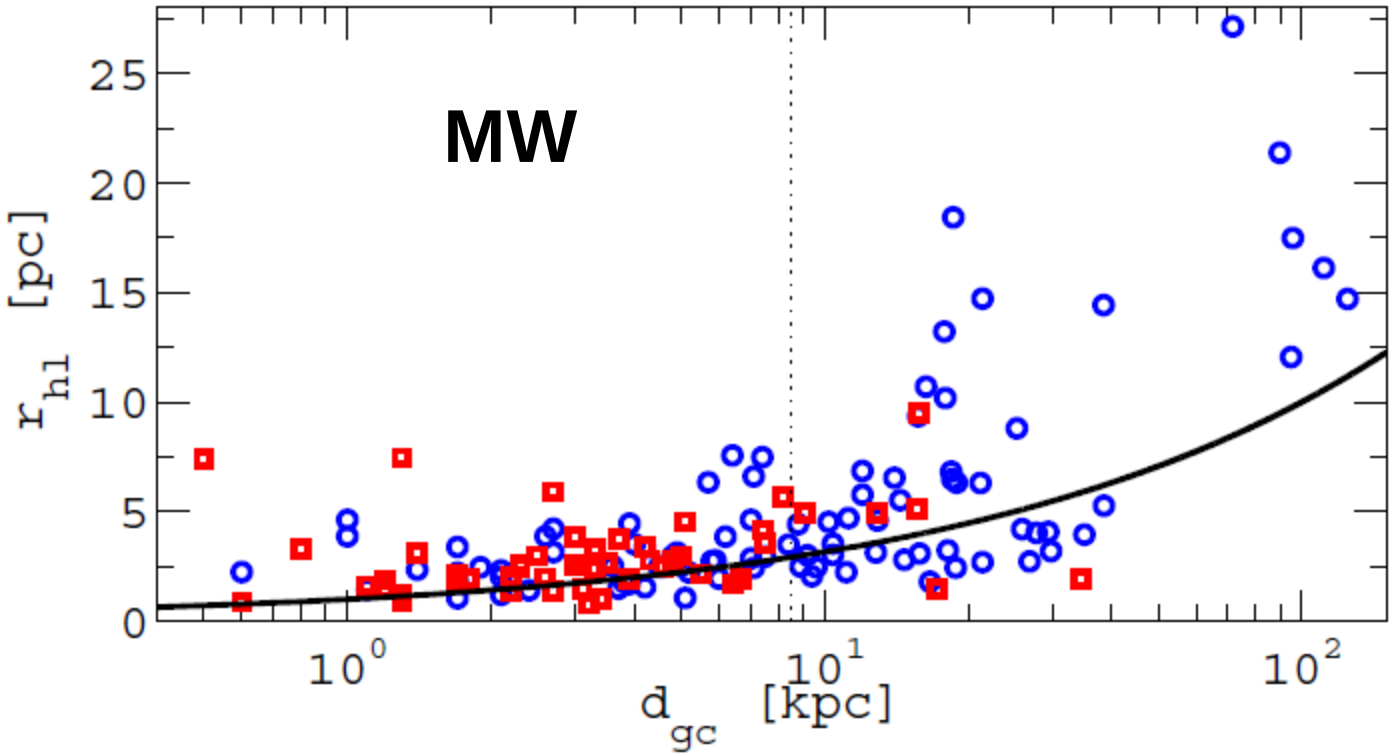
- Historically there are empirical relation between the cluster size and RG (Hodge 1960-62)





Hwang et al. ApJ, 2011

$r_h - R_G$ relation



- Size and galactocentric distance of the MW GC population.

$r_{\rm hl} \approx \sqrt{d_{\rm gc}}$ from van den Bergh et al. (1991).

The origin of $r_h - R_G$ relation

- It could be primordial, i.e., a result of a correlation between cluster size and galactic tidal field strength and/or gas density at formation (e.g, Elmegreen 2008)

- It could be the result of the preferred disruption of extended GCs near the Galactic Center

  (Vesperini & Heggie 1997; Baumgardt & Makino 2003)

- It could be the expansion of initially compact GCs up to the respective Jacobi radius

Phases of mass-loss

- Mass loss from Stellar Evolution
  - Initially increases the cluster size in short time-scale
- Mass lose due to tidal stripping
  - Decreases the size scale and is linked to 2-body relaxation time scale.

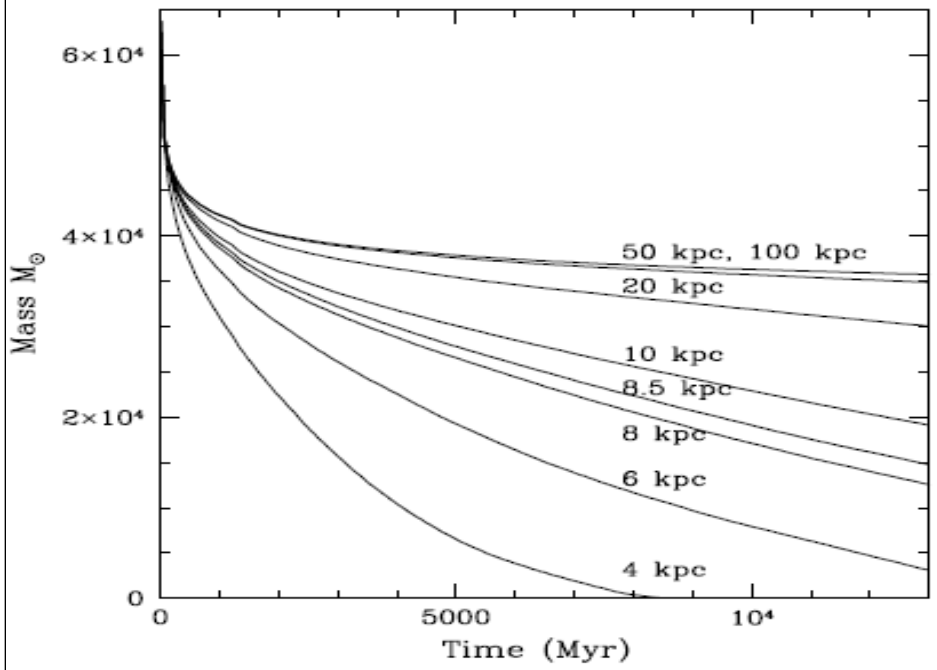
Whether or not either of the two mechanisms dominates will determine the size of the GC

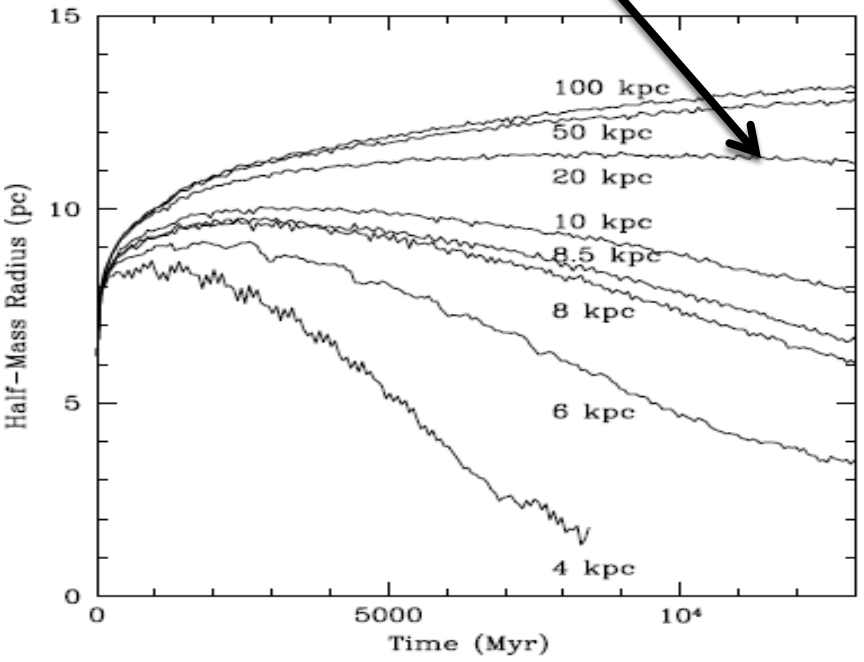
(Gieles et al. 2011, Madrid et al. 2012, Haghi & AHZ, et al. 2014).

The evolution of star clusters at different galactocentric distances

Expansion driven by the internal dynamics is balanced by the presence of the tidal field

Madrid, Hurley, Sippel, ApJ, 2012

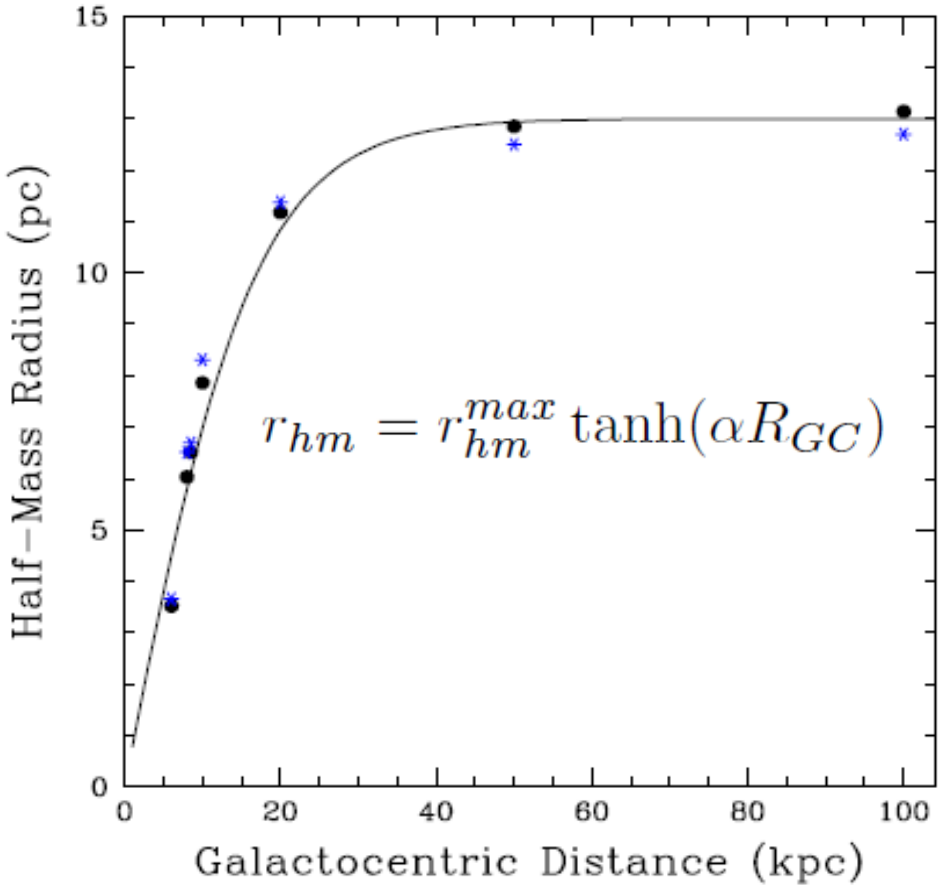




N=100,000 r=6.2 pc

$r_h - R_G$ relation

What we can learn from the properties of a galaxy's present-day GC population about the galaxy itself ?



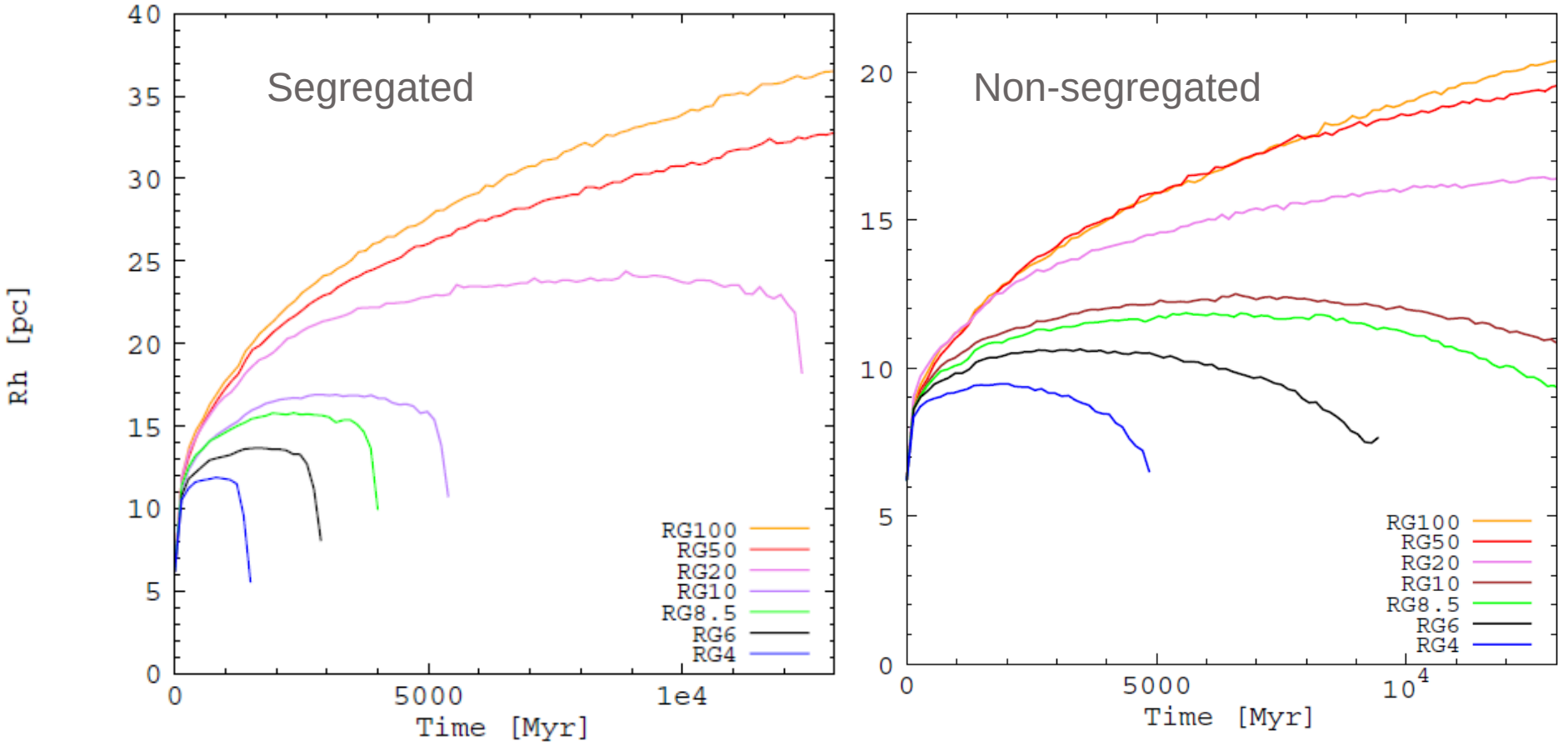
Madrid, Hurley, Sippel, 2012

Dependence on the birth conditions

Degeneracy between the sizes GCs can reach in a given host gravitational potential and their birth conditions.

Impact of Primordial Mass Segregation

Haghi , AHZ et al , MNRAS, 2014



Birth masses of GCs can be constrained by present-day MF-slope (Webb & Liegh 2015, Zonoozi et al. 2011, 2014)

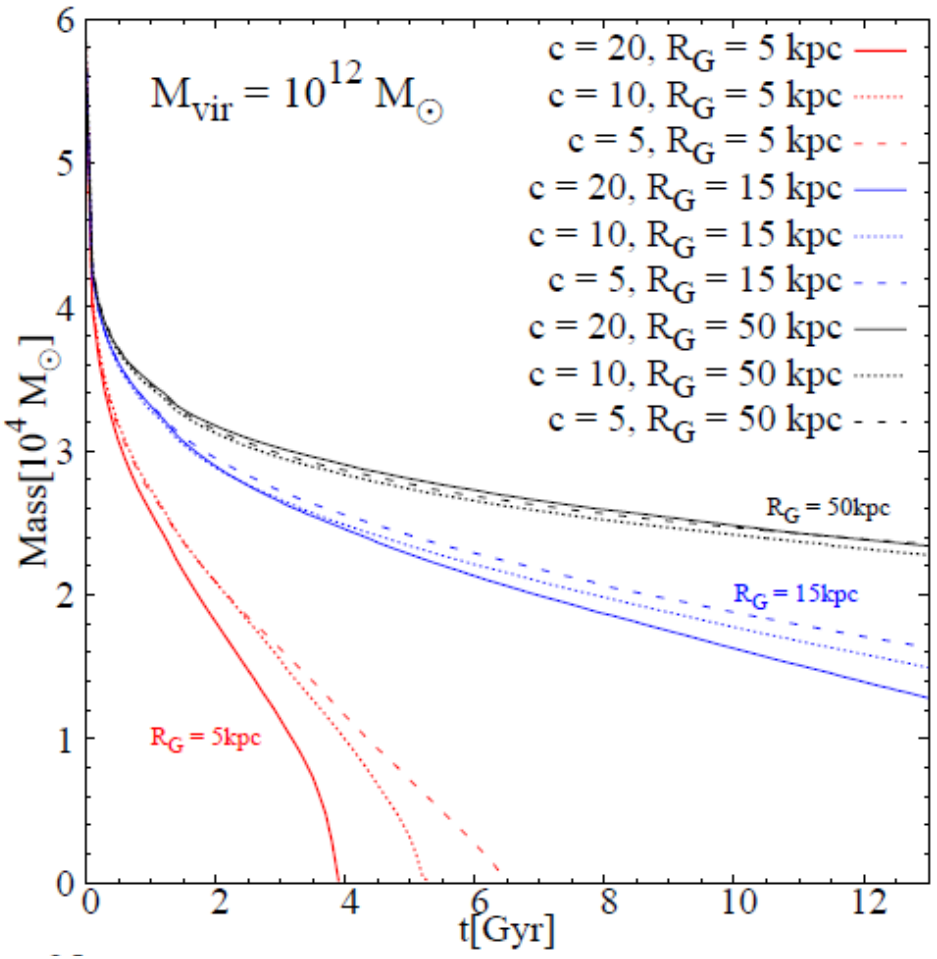
What we can learn from the properties of a galaxy's present-day GC population about the galaxy itself?

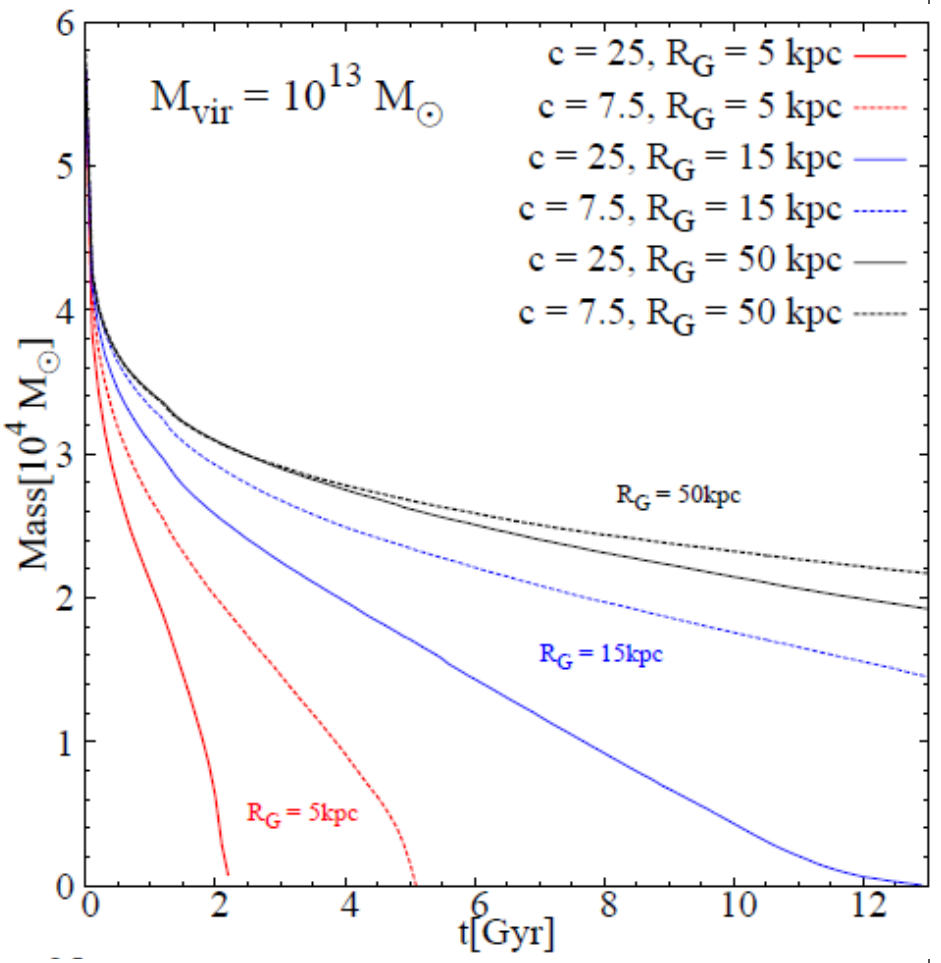
DESCRIPTION OF THE DIRECT N-BODY MODELS

- *N*-body6 code
- Number of stars N ~ 100,000, half-mass radius=6 pc
- Evolution time: 13 Gyr
- Tidal effect: galactic potential (3-component)

NFW halo $$\Phi(r) = -\frac{GM_{vir}}{r}\frac{\ln(1+r/r_s)}{\ln(1+c)-c/(1+c)}$$

Two-parameter NFW halo: (c, Mvir)





Zonoozi et al. 2015, ApJ, submitted

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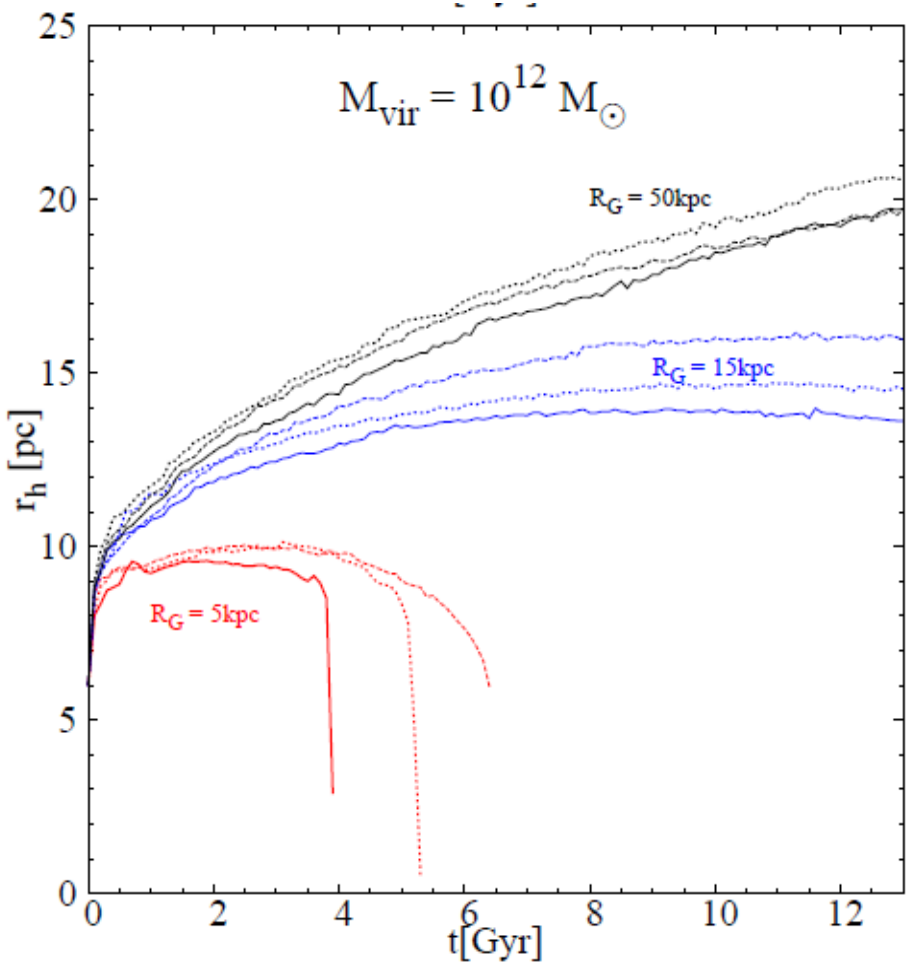

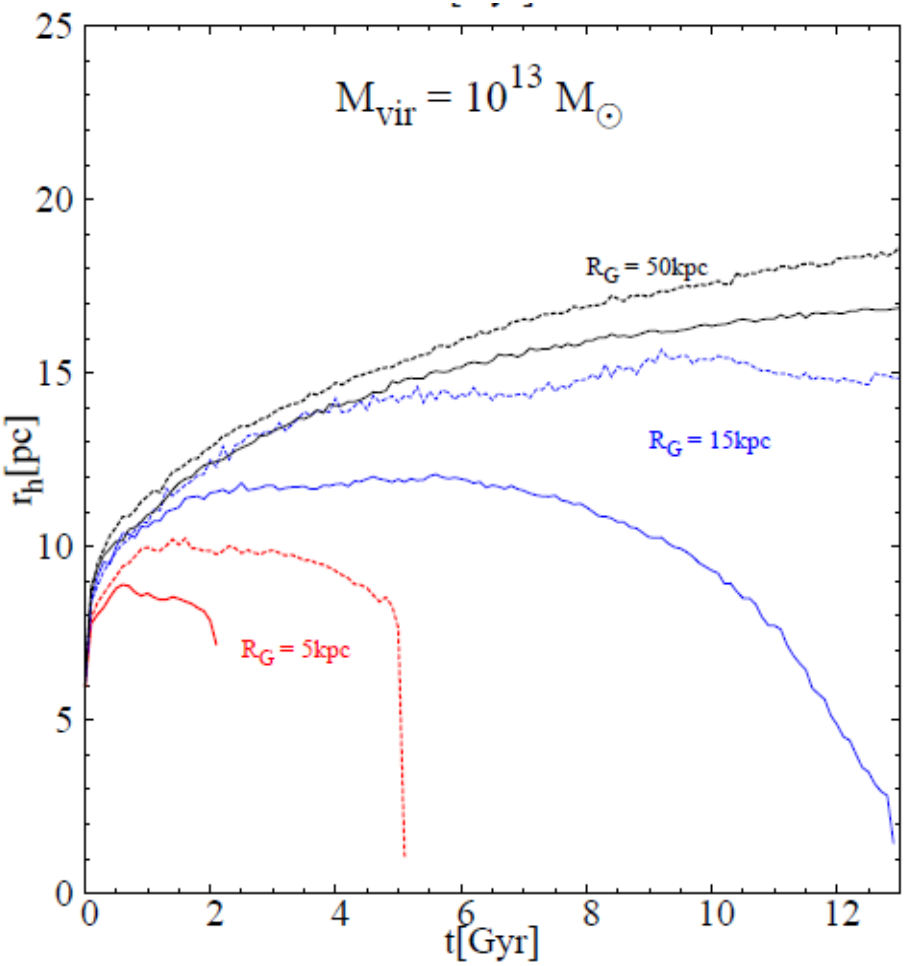

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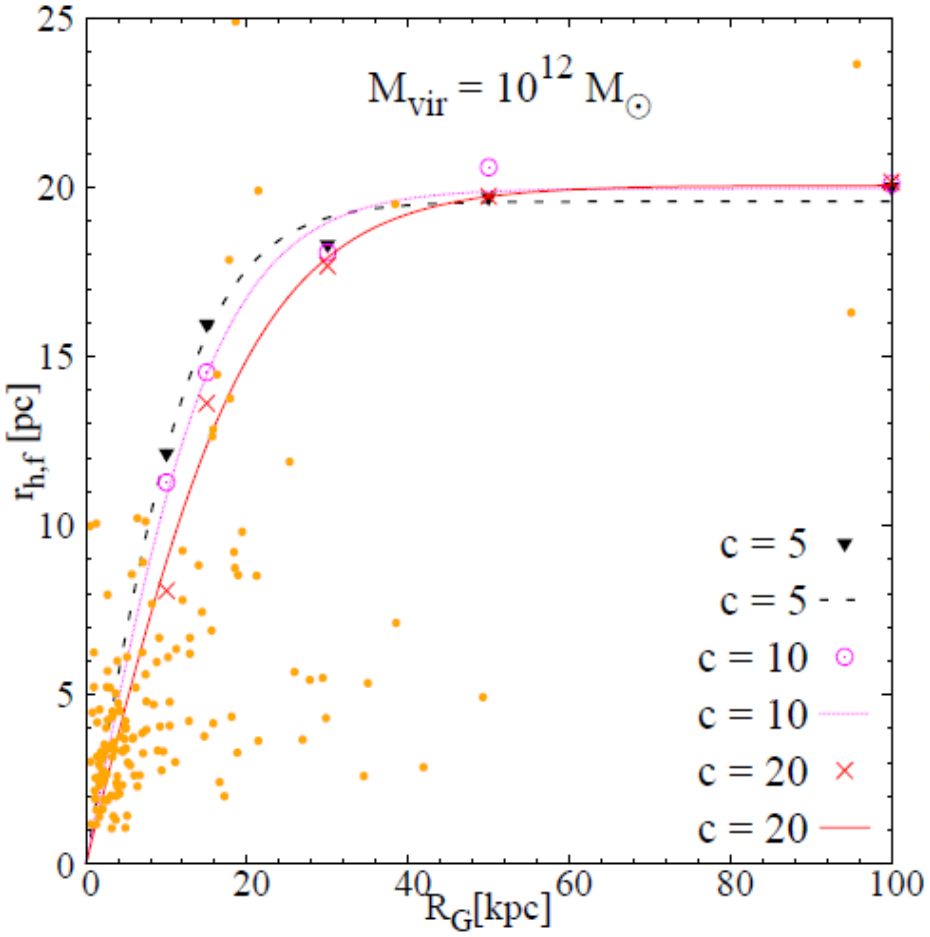
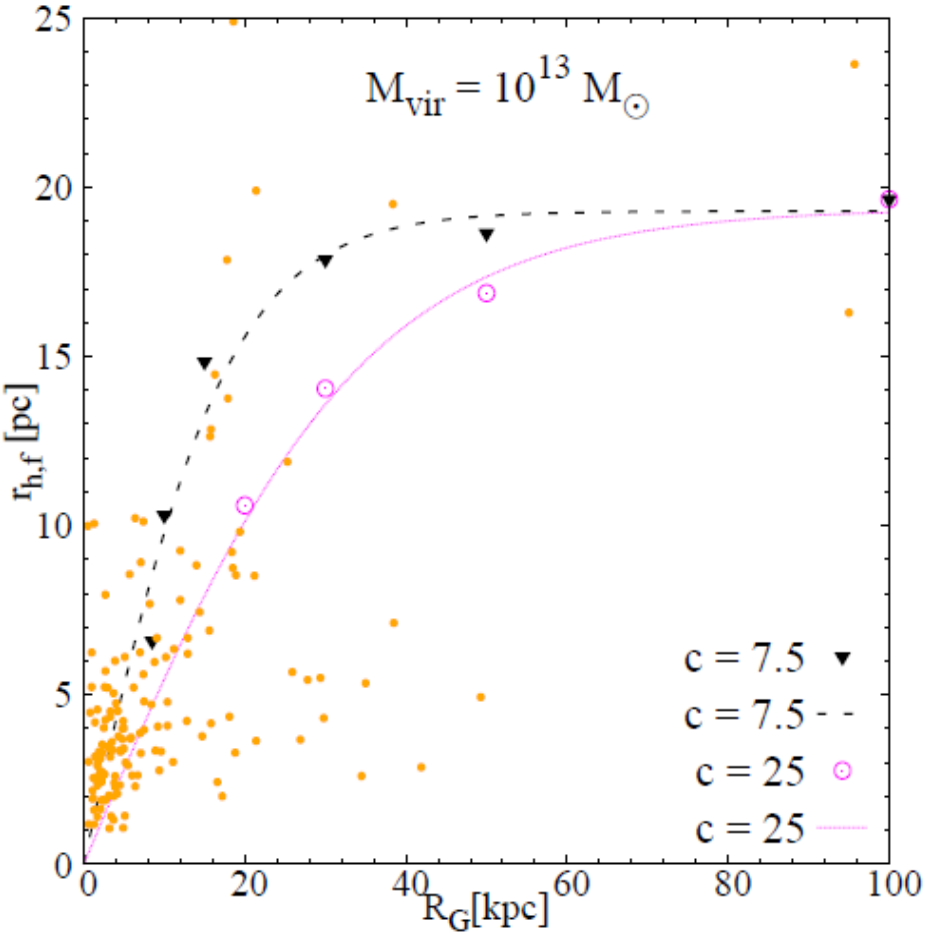
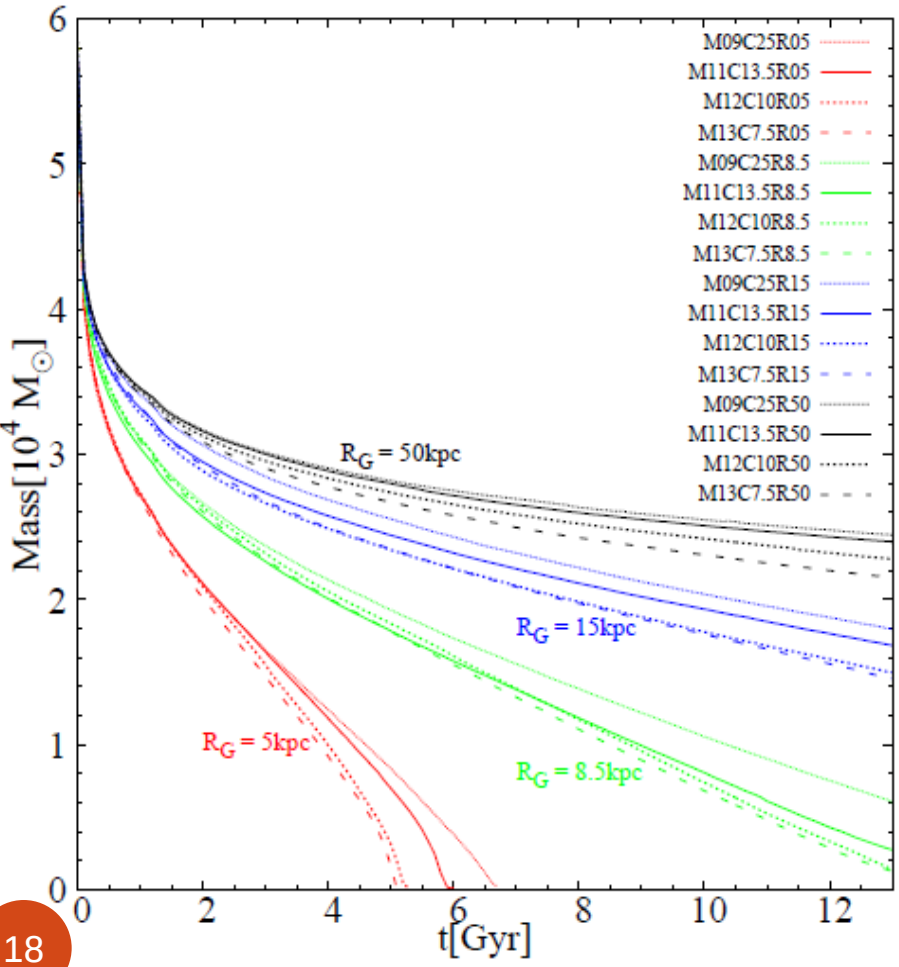


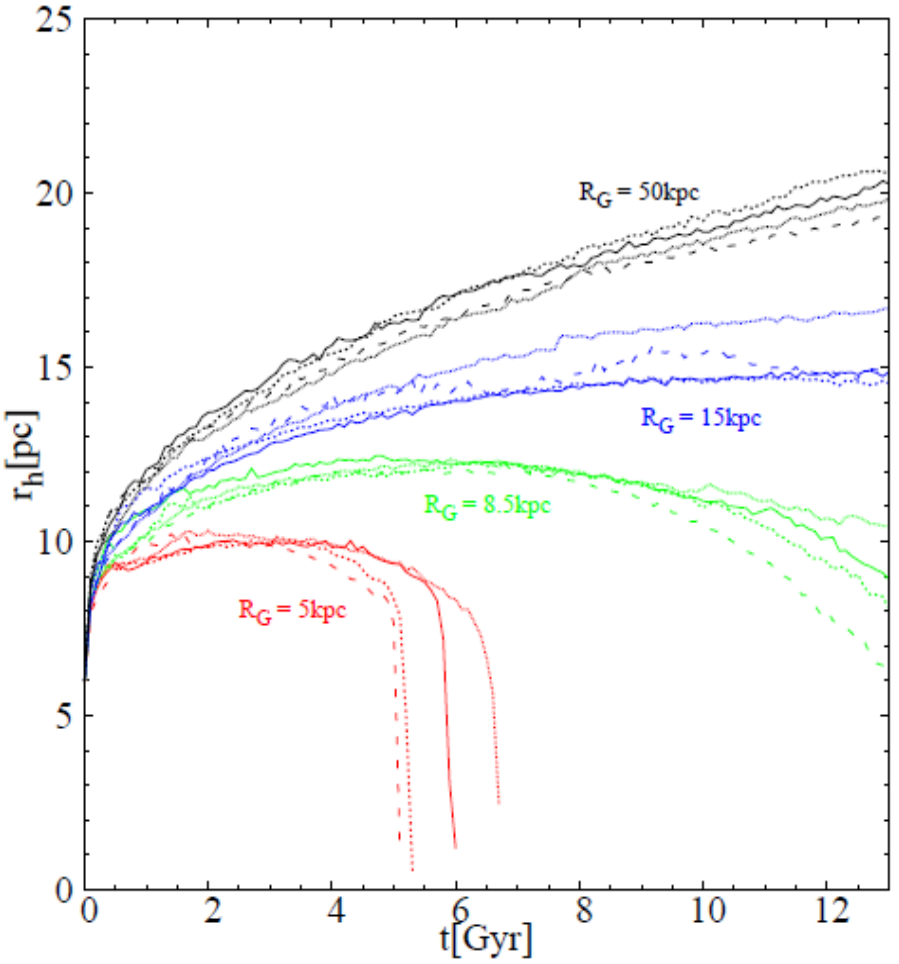


Zonoozi et al. 2015, ApJ, submitted

One-parameter NFW halo: (c, Mvir)

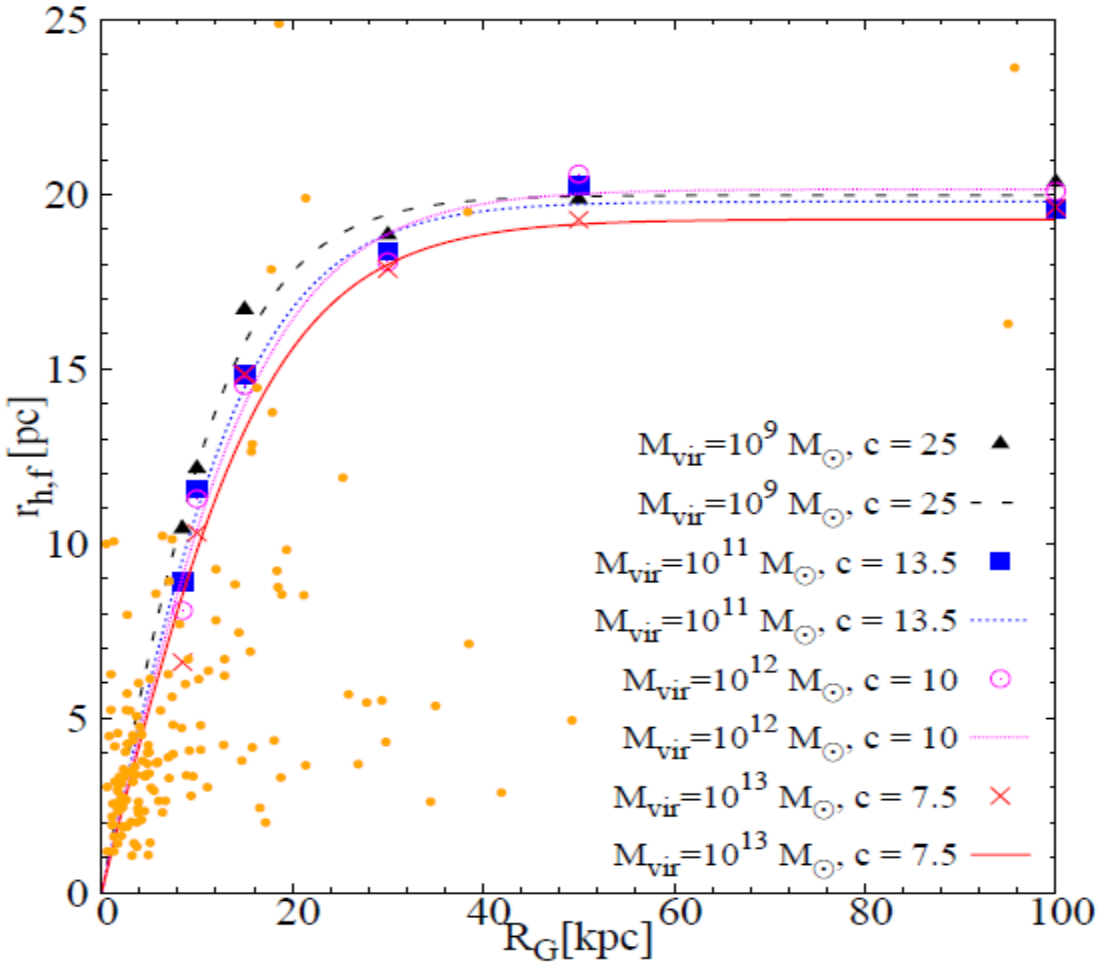
$$\log_{10}(c) = 1.025 - 0.097 \log_{10}\left(\frac{M_{vir}}{10^{12} h^{-1}\,\mathrm{M}_\odot}\right)$$



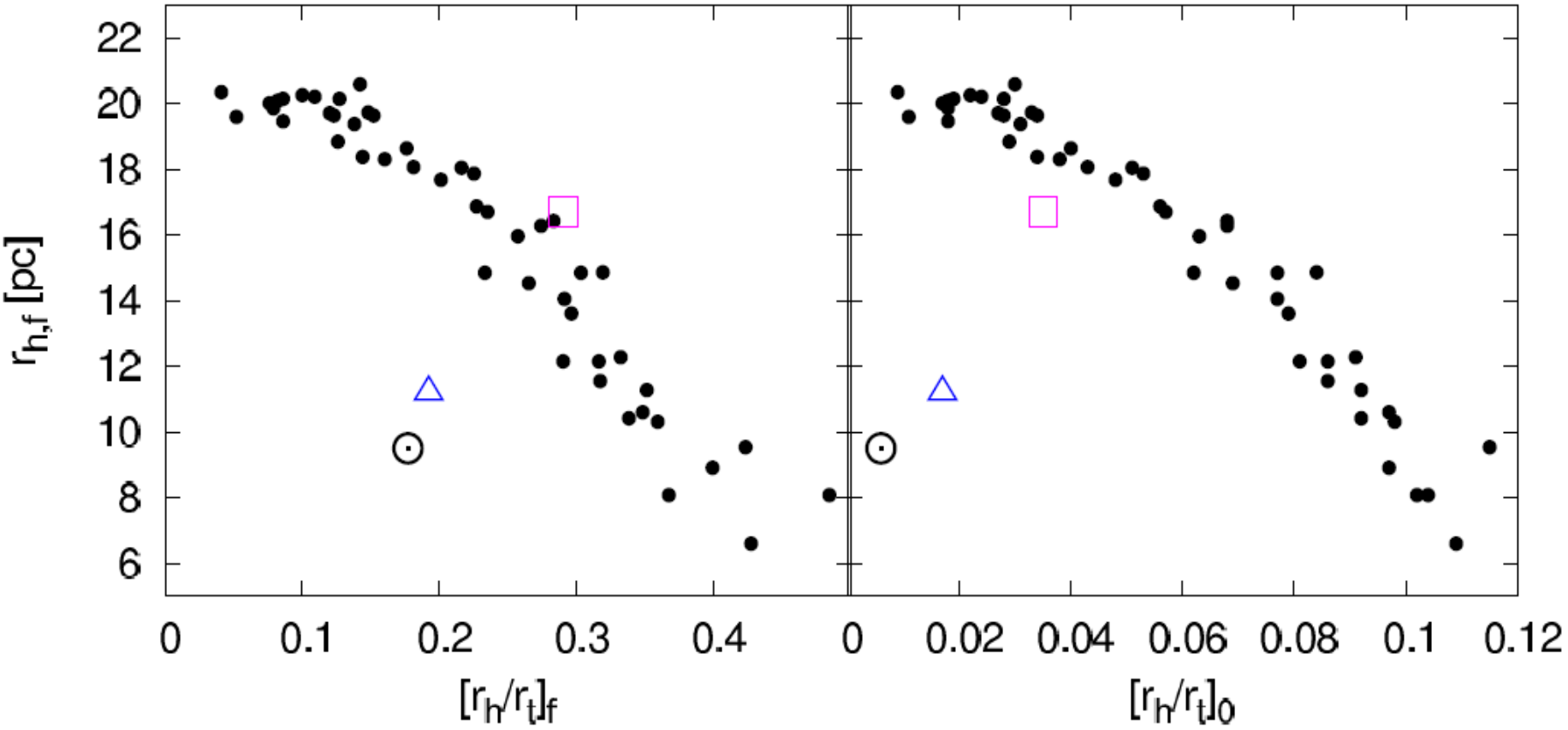


One-parameter NFW halo: (c, Mvir)

The same $r_h - R_G$ relation for all galaxies



Final size vs. Filling-factor



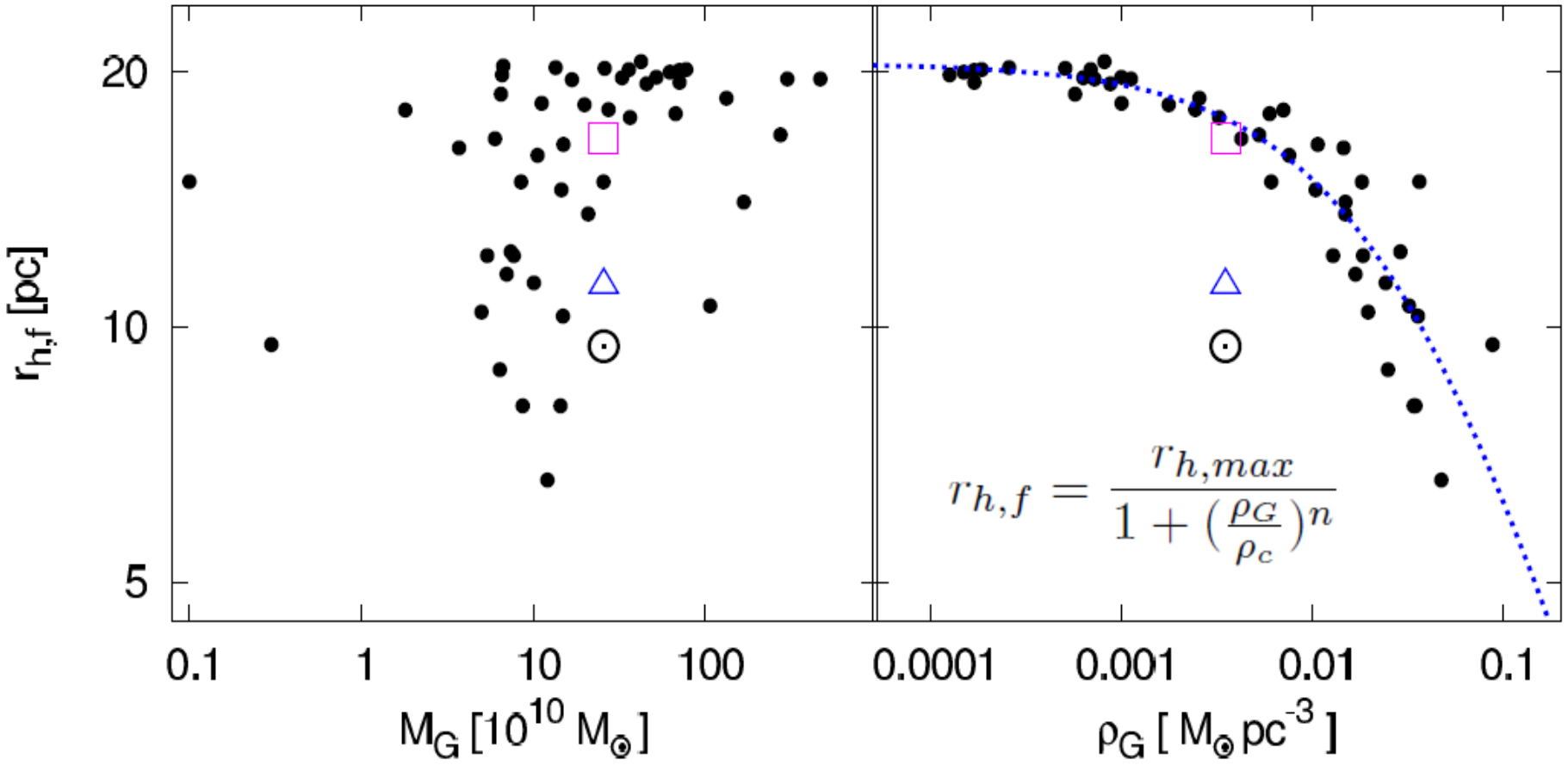
Are the sizes of star clusters uniquely determined by their filling factors?

Additional models with initial size of

0.5, 1.5, and 3 pc

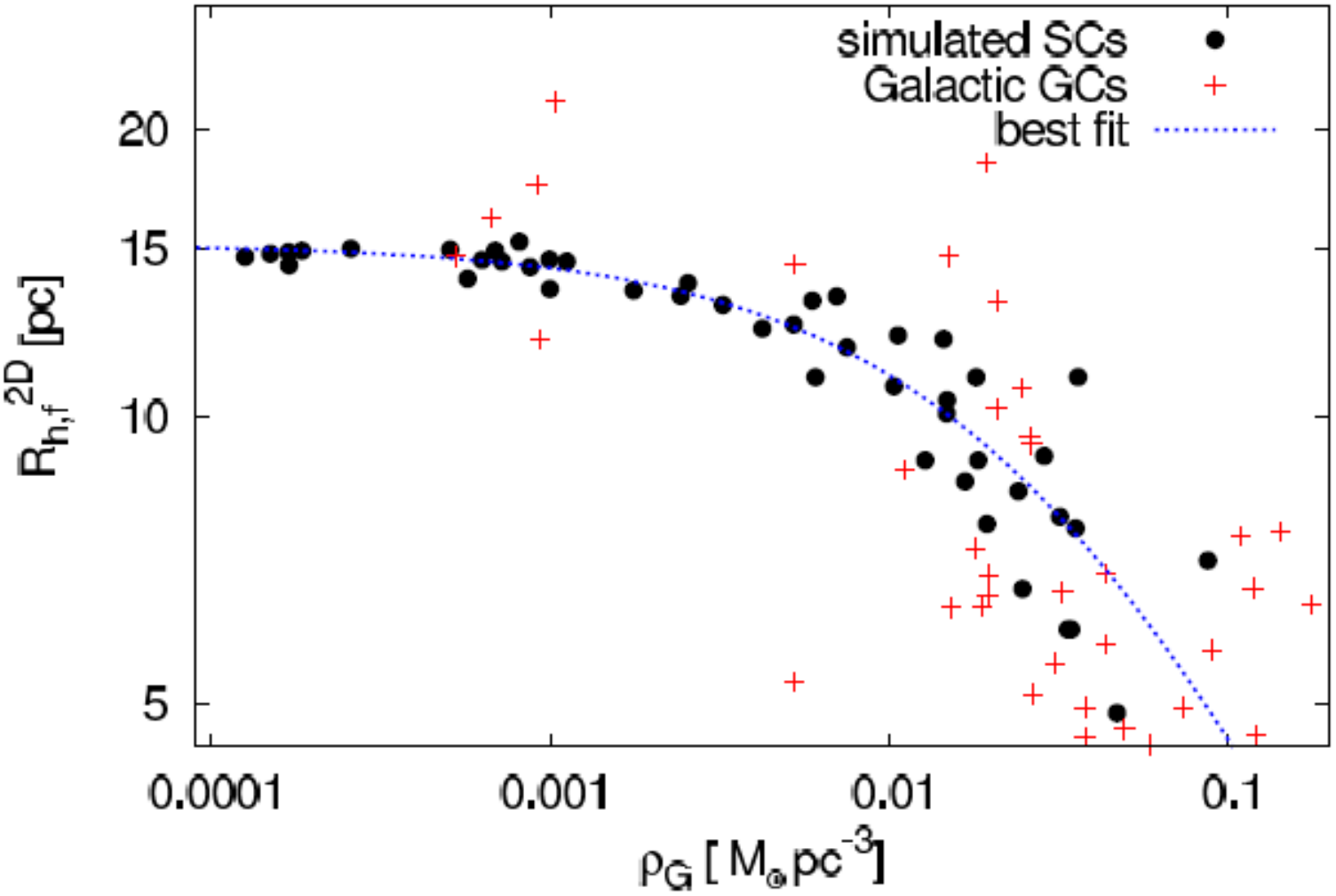
$N = 41000$

Final size vs. Enclosed Mass and Density



- Final seizes are correlated to the enclosed mass density rather than the total enclosed mass.

Comparison with Galactic GCs



Zonoozi et al. 2015, ApJ, submitted

Conclusion

- Sizes of globular clusters are determined by the galactic mean-mass density rather than the enclosed mass of the host galaxy.

- Size-distance relationship will be nearly independent of total halo mass, if one assumes Mvir and c as two correlated parameters, as is suggested by cosmological simulations.

- Possible solution for the lack of GCs in some dwarf galaxies and a rich GC population in some giant galaxies