Flattening of velocity dispersion profiles of globular clusters

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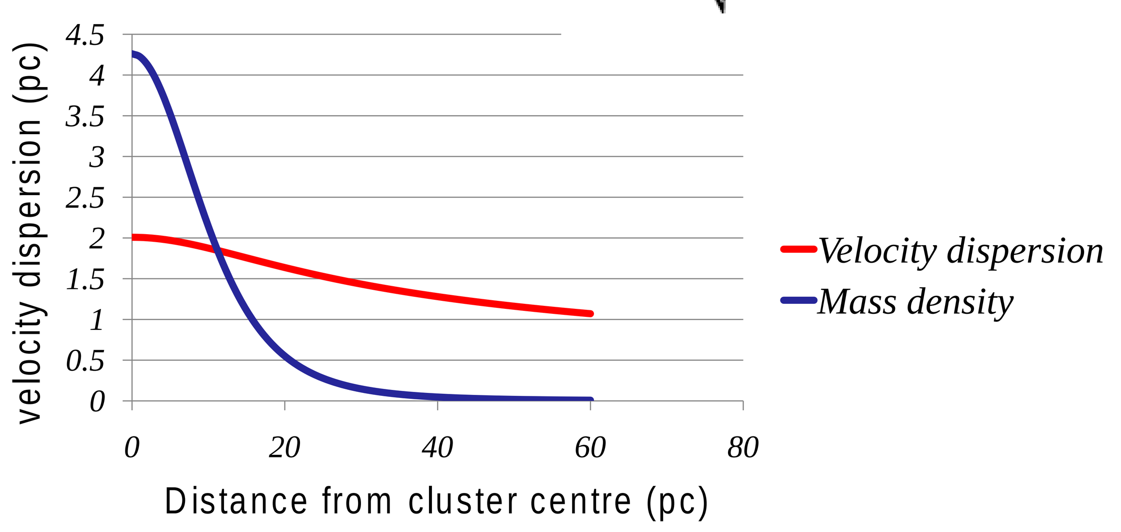
Objectives

- *Study the flattening of velocity despersion profiles of globular clusters by simulation considering psudo forces*
- *Comparing the results of simulation with observational data of Scarpa's papers*

Plummer's Model

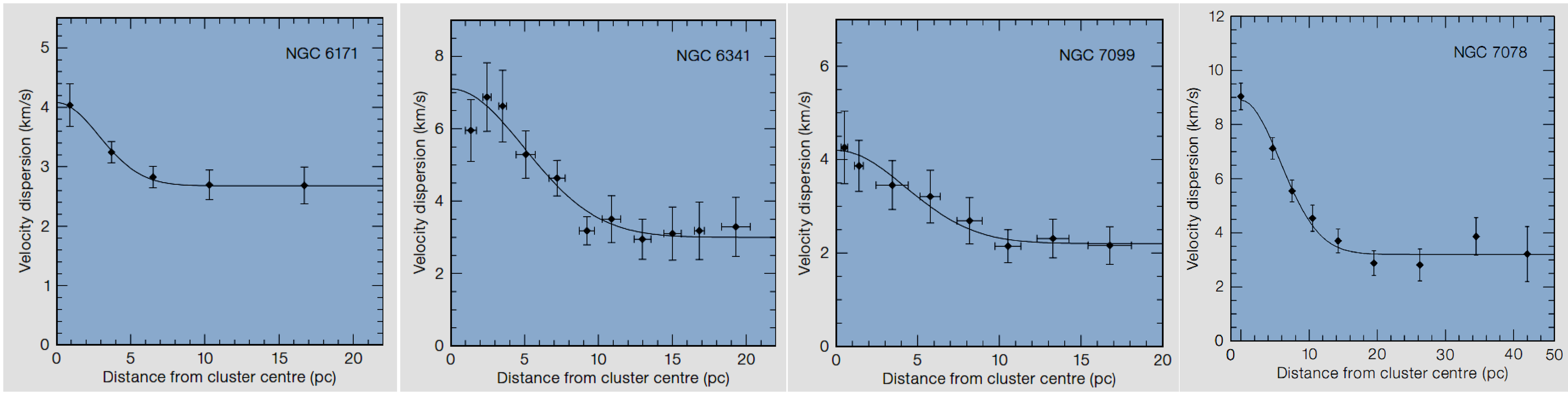
We set Plummer's model as initial condition for our simulation

$$\rho = \frac{3M}{4\pi a^3}\left(1+\frac{r^2}{a^2}\right)^{-\frac{5}{2}} \qquad \sigma = \sqrt{\frac{GM}{6a}\left(1+\frac{r^2}{a^2}\right)^{-\frac{1}{2}}}$$



Observational profiles given by Scarpa

(The globular Clusters in MilkyWay that we want to study)



Current proposals to explain the flattening

- *Dark Matter*

  Observable matter in galaxies and clusters of them cannot produce sufficient gravity to explain their dynamics. Then we have to consider extra matter so-called Dark Matter. But there is a theory that says there is no dark matter in globular clusters.

- *Modified gravity*

  MOND by Milgrom (1983 ApJ)
  MOG by Moffat (2005, 2009 ApJ)

Because we want to work with near to centre globular clusters that the acceleration exerted on them is higher than the MONDian aceleration, this method for studying the flattening is useless as well.

Third proposal : Tidal interaction (our work)

Each globular cluster goes around the center of Milky-Way and around itself. Then we can consider pseudo-forces such as Coriolis and Centrifugal forces on stars of globular clusters and tidal forces as well.

THEORY

As in standard theory (Chandrasekhar 1942) we describe the position of a star in a rotating, accelerated coordinate system with origin at the centre of the cluster, and axes aligned towards the galactic anticentre, in the direction of galactic motion of the cluster, and orthogonal to the plane of motion of the cluster, respectively. Then the equations of motion are

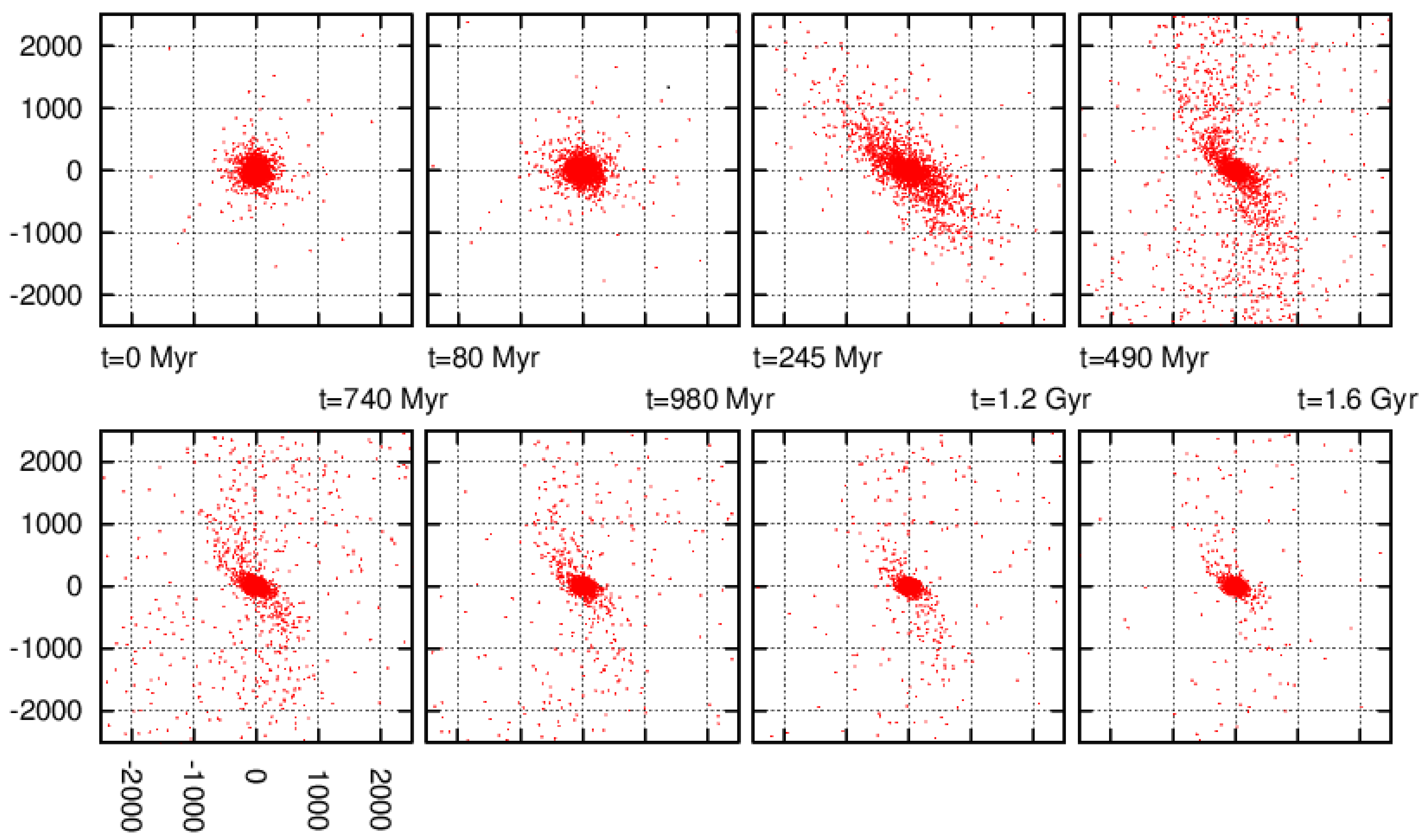
$$\ddot{x} - 2\Omega\dot{y} + (\kappa^2 - 4\Omega^2)x = -U_x \quad (1)$$

$$\ddot{y} + 2\Omega\dot{x} = -U_y \quad (2)$$

$$\ddot{z} + \omega_z^2 z = -U_z, \quad (3)$$

where Ω is the angular velocity of the cluster around the galaxy, κ is the epicyclic frequency, ω_z is the frequency of motions orthogonal to the plane of motion of the cluster, and U is the gravitational potential of the cluster stars.

Our simulation



Heating

When you heat something that the outer parts become warm sooner than inner parts. Because the inner parts of GCs are much more gravitationaly bound than outer parts, only the energy of stars at the outer parts is increased remarkably due to effects of considering pseudo-forces and tidal forces.

It causes that the velocity dispersion at the outer parts of GCs is increased.

Our results up to now

As it is obvious in the above figure, the tidal tails are formed as we expected.
But our velocity dispersion results haven't fitted the Scarpa's data. Therefore we are trying all the time running the NMODY code to find the problem because we know it should work.

Using an n-body code named NMODY we have some snapshouts of steps of the evolution of a star cluster. we analyse the results using some codes that I have written to calculate the velocity dispersion and actually the line of sight VD to produce the profiles we need to compare with scarpa's data. NMODY is a particle mesh based code which solves the poisson equation and is developed by Ciotti, Londrillo and Nipoti (2006).

This method is applied to an artificial GC by Kupper and he saw that it works.

we want to do that for 4 realistic globular clusters.

References :
1) *Book: The gravitational million body problem, Douglas Heggie and Piet Hut, Cambridge.*
2) *Scarpa R. et al.,'Using GCs to test gravity in the weak acceleration regime', Astronomical Science, June 2007.*
3) *Kupper A. et al., 'Tidal tails of star clusters', Astronomical Society, October 2009*
4) *Kupper A. et al., 'The velocity dispersion globular cluster Palomar 4', MNRAS , 2011.*