Evolution of the Vertical Distribution of Open Clusters in the Milky Way

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ICCUB-IEEC September 2023

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- Thickness of the Galactic disk traced by old stellar clusters is larger than that defined by young clusters.
- Mechanisms have been proposed, such as dynamical heating and the disk being thicker in the past.
- OCs are not point sources and have internal structure.
- OCs can be disrupted by internal and external mechanisms.

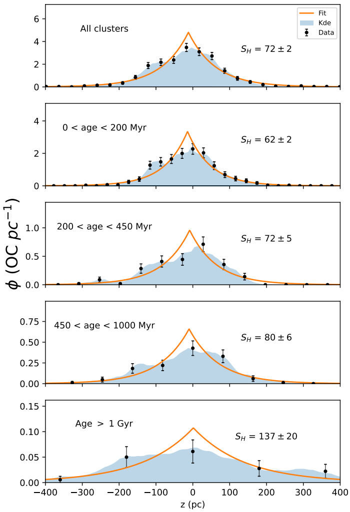
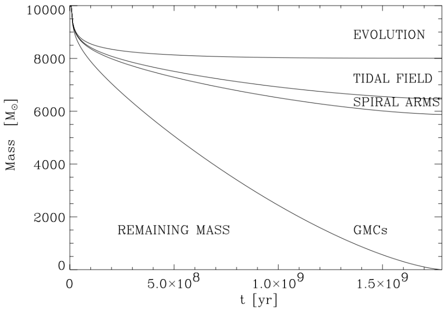
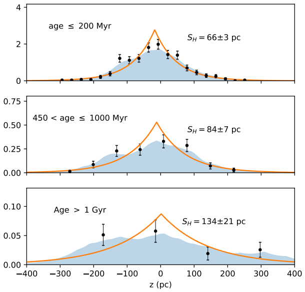


Figure: Vertical distribution of OCs (Dias et al. 2021 catalogue).

Our approach





$10^4\ M_\odot$ cluster (Lamers & Gieles (2006)).

- GMCs encounters are the main cause of disruption of OCs.
- GMCs are mainly located near the Galactic plane.
- Can the observed increase of scale height be a consequence of disc phenomena such as encounters with GMCs ?

The Model

We built a model with the following ingredients:

- Generates OCs with:
  - a specified formation rate.
  - heights following a Laplace (double exponential) distribution:

$$f(z; \mu, B_{SH}) = \frac{1}{2B_{SH}} \exp\left(-\frac{|z-\mu|}{B_{SH}}\right)$$

  - a mass distribution following an initial cluster mass function: $dN/dM \propto M^{-\alpha}$ with $\alpha \approx 2$ (Lada & Lada 2003).
- Integrates the orbits of the OCs using Galpy (in a 3D Milky Way potential).
- The OCs can be disrupted by:
  - Encounters with GMCs.
  - Mass loss from stellar and dynamical evolution.

Model - disruption

The encounters with GMCs are implemented with the following considerations/assumptions:

1. The vertical distribution of GMCs ($\mathrm{D_{SH}}$) is approximated by a Laplace distribution.
2. The probability of an encounter is given by the GMC distribution:

$$p(\mathrm{z}; \mathrm{D_{SH}}) = p_0 \exp\left(-\frac{|z|}{\mathrm{D_{SH}}}\right) \Delta t$$

3. The OCs are completely disrupted in a single encounter.

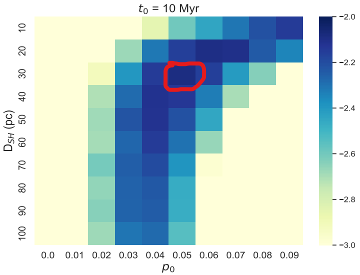
The disruption time of clusters in a tidal field of a galaxy, is taken to depend on the initial mass as: $t_{dis} = t_0 (M_i/M_\odot)^\gamma$, with $\gamma = 0.62$ (Lamers et al. 2005).

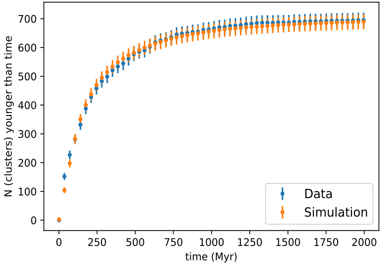
Parameter Inference

The model has 4 free parameters: B_{SH}, D_{SH}, p_0 and t_0.

Through manual tuning, we inferred: $B_{SH} = 94$ pc.

There is degeneracy in the parameters space: different combinations of D_{SH} and p_0 lead to the same SH evolution.

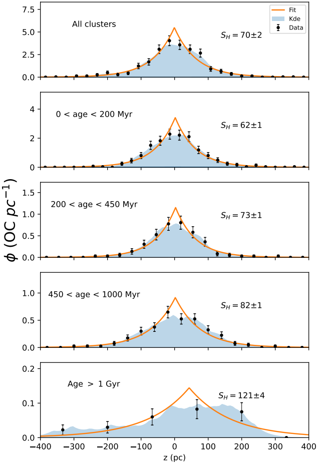




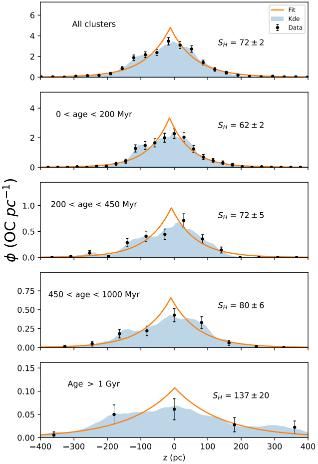
Likelihood from SH and number of OCs comparison between simulations and observations.

Results - Scale Height Evolution

$B_{SH} = 92$ pc, $D_{SH} = 30$ pc, $p_0 = 0.05$ and $t_0 = 10$ Myr



Observations



Observations from Dias et al. 2021 OC catalogue, for distance < 1.75 kpc.

Follow up work

In the future, we hope to improve the model:

- Full kinematic comparison with the observations (using Gaia proper motions and RVs). Consider initial velocities in the model.
- Allow the OCs to not be completely disrupted in a single encounter.
- A more sophisticated inference of the model parameters.

Acknowledgements

Fundação
para a Ciência
e a Tecnologia

This work was supported by the Portuguese Fundação para a Ciência e a Tecnologia (FCT) through the Strategic Programme UIDB/FIS/00099/2020 and UIDP/FIS/00099/2020 for CENTRA.

The mass evolution of the OCs that are loosing mass by both effects can be described as:

$$\mu(t; M_i) \equiv \frac{M(t)}{M_i} \approx \left[(\mu_{ev}(t))^{\gamma} - \frac{\gamma t}{t_0} \left(\frac{M_{\odot}}{M_i} \right)^{\gamma} \right]^{1/\gamma} \quad (1)$$

The left term describes stellar evolution, the right term describes the mass loss due to tidal effects and t_0 is a normalization factor.