The Dynamical Evolution of Accreted Star Clusters in the Milky Way

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Two Populations of GCs in MW

Hierarchal structure formation implies both:

1) “In situ” clusters
2) Accreted clusters

- Reflected in properties of MW GCs
- Present day Universe examples (e.g. Sagittarius dwarf)

Forbes & Bridges, 2010
How does the changing tidal field of a galaxy merger affect the dynamical evolution of star clusters?

- Study using N-body simulations
- Specific context of a dwarf-Milky Way merger
Modelling the Tidal Field

Utilize N-body6tt, can specify:

1) Gravitational potential and its time dependence
2) Cluster’s orbit

Two processes to model:

1) MW tidal field strength *increases*
2) Dwarf tidal field strength *decreases*
Dwarf Falls Scenario

**Process #1: MW tidal field increases**

**Separation between static dwarf and MW decreased linearly (after 3 Gyr)**

**Dwarf:**
- Point mass ($M_D = 10^9 M_{\text{SUN}}$)
- Cluster on circular orbit ($R = 4.0 \text{kpc}$)

**Milky Way**
- Bulge + disk + halo

**N-body Cluster Parameters:**
- $N = 50k$, Plummer density profile, $r_{hm} = 3.2\text{pc}$
- Kroupa (2001) IMF, 0.1 – 50 $M_{\text{SUN}}$
• Adjusts to the MW potential on a timescale of 1-2 half mass relaxation times
• **Beginning of size of adjustment ≈ Jacobi radius in MW becomes > Jacobi radius in dwarf**
Dwarf Evaporates Scenario

Process #2: Dwarf tidal field decreases

Mass of dwarf decreased exponentially (after 3 Gyr)

Dwarf:
- Point mass ($M_D = 10^{10} M_{\text{SUN}}$)
- Cluster on circular orbit ($R = 4.0 \text{ kpc}$)

Milky Way
- Bulge + disk + halo
- Dwarf on circular orbit ($R = 20.0 \text{ kpc}$)

N-body Cluster Parameters:
- Same as previous simulation
Half Mass Radius

- Cluster expands immediately in response to changing dwarf mass
- Comparable in size to MW cluster on dwarf dissolution timescale
• Any remaining size differences can be attributed to slight differences in cluster masses
Putting It All Together...

The galaxy with the largest tidal field at the cluster’s position determines the dynamical evolution of the cluster.

True for all simulations in a suite with various:
- Cluster sizes
- Dwarf galaxy masses
- Final dwarf galactocentric radius
Summary

• Galaxy with the strongest tidal field determines the evolution of the star cluster

• Accreted clusters adjust rapidly and should be the same size as in situ clusters on the same orbit after a short time

• Can’t separate the two cluster populations in the Milky Way based on size/filling factor (unless initial conditions are distinct)
Tracing Galaxy Formation and Evolution Using Star Cluster Populations

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Simulations

- Suite of isolated disc galaxies and galaxy mergers (Kruijssen et al. 2011/2012)

- Model for the formation and destruction of star clusters (via tidal shocks & evaporation)

- **AIM:** Characterize the properties of cluster population as a function of local galactic properties

Kruijssen et al. (2012)
First Results

Different symbols correspond to different galaxies

Colours correspond to inner radial bin, middle, outer and total
Summary

• Gas surface density controls the survival and destruction of star clusters due to tidal shocking

• Expected cluster lifetimes much shorter than evaporation only models

• Age distributions reflect the host galaxy gas content