Distribution of Globular Clusters After a Merger

Dynamics of Low-Mass Stellar Systems: From Star Clusters to Dwarf Galaxies

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- Globular clusters are born early in the life of a galaxy, in a period when major mergers are still taking place.
- Once the galaxy is fully formed, it is possible for late mergers to disturb the globular cluster distribution.
- Through simulations I show the possible dynamics of globular clusters in a Milky Way type galaxy during and after a late dwarf galaxy merger.

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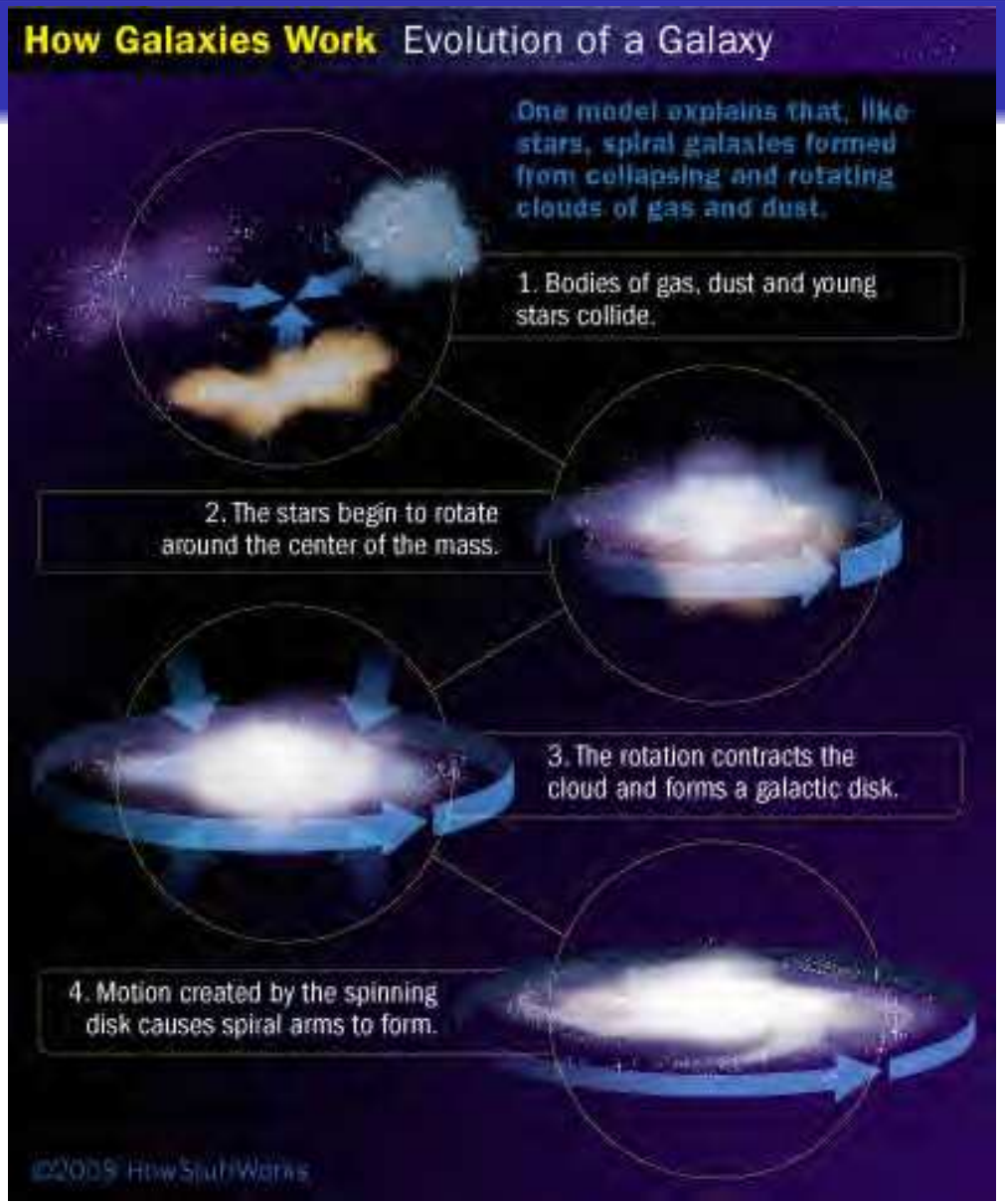
Galaxy Formation

- Galaxies form in dark matter overdensities called halos
- Dark matter interacts only by gravity.
- Ordinary matter particles interact strongly with each other.
- This matter settles into the halos and forms galaxies.

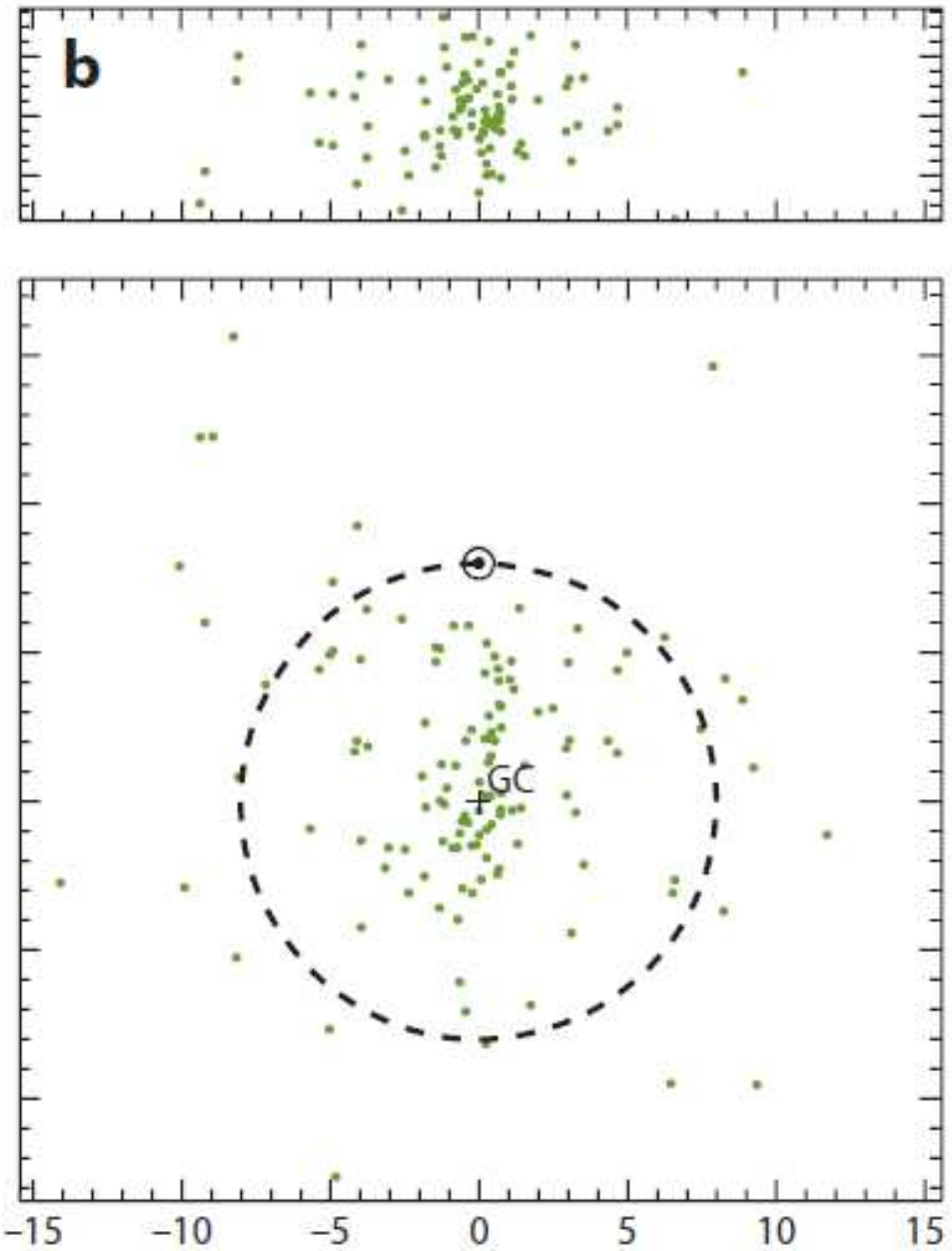


Globular Clusters

- Globular clusters are collections of a few$\times 10^5$ stars
- 160 are known in the Milky Way
- Very old, form early in the history of galaxies

Figure: Globular cluster 47 Tucanae in the southern constellation Tucana is the second brightest from Earth's perspective. Figure credit: Dieter Willasch

Globular clusters



Axes are in kiloparsecs from the Milky Way galactic center (GC). Data from the Harris (1996) catalog.

Globular Clusters

As satellites fall to the center of dark matter overdensities, the initial distribution of globular clusters most likely is disturbed.

I aim to study how an initial distribution of globular clusters is disturbed by a satellite merger.

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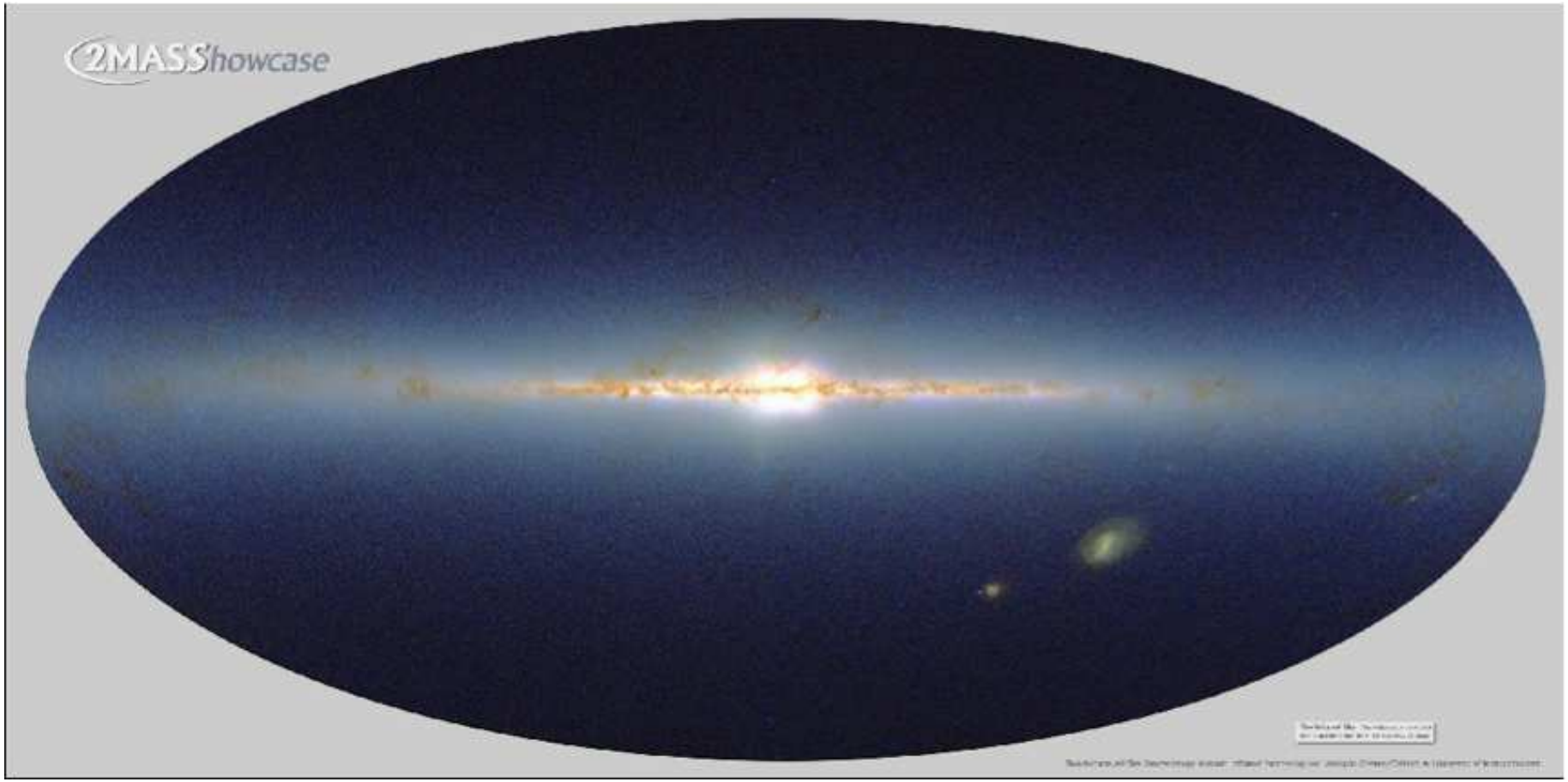
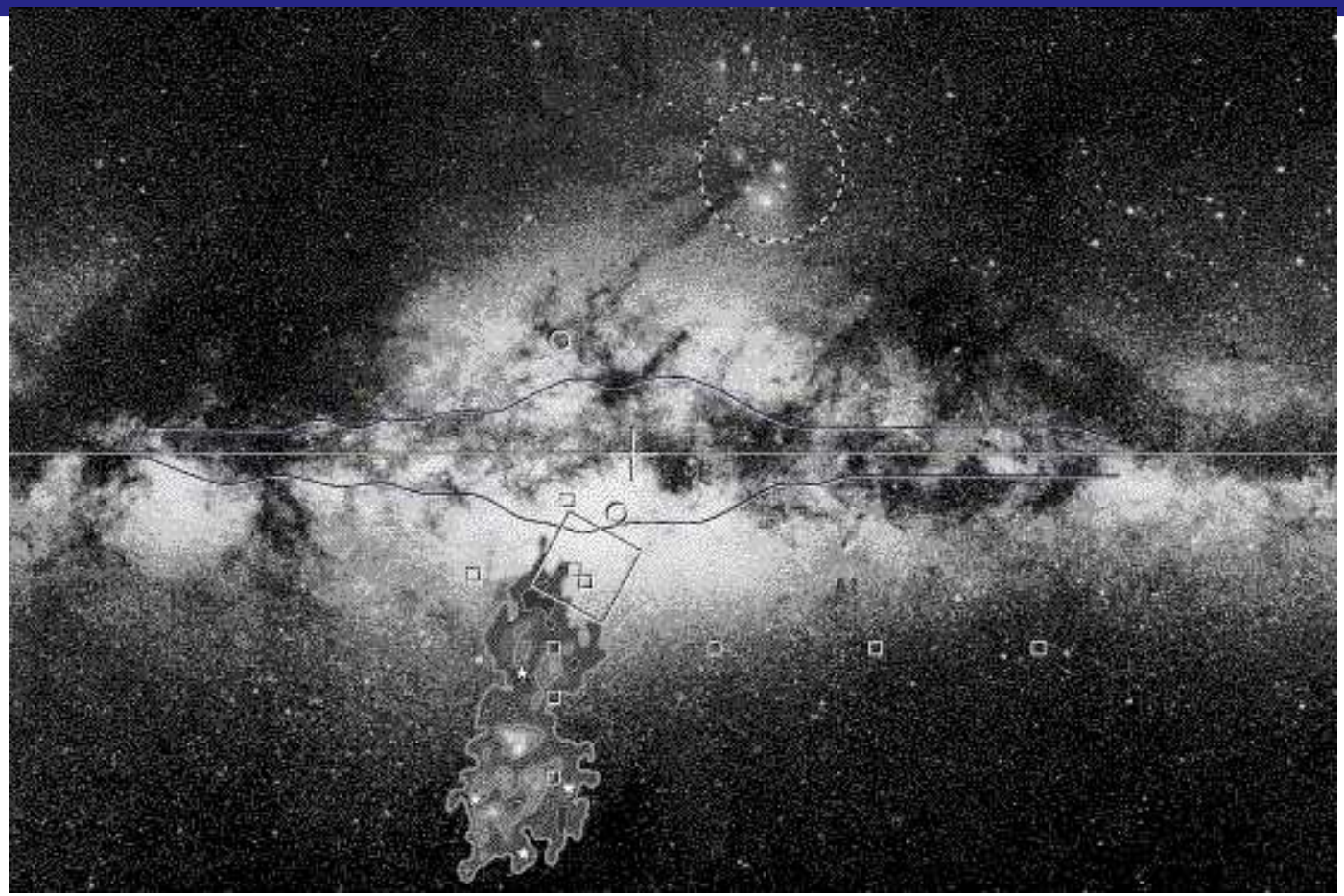
Satellite

What type of satellites fall into our Milky Way?



The mass of the Milky Way is $10^{12} M_{\odot}$ and the mass of the Large Magellanic Cloud is $5 \times 10^{9} M_{\odot}$ (Alves and Nelson 2000).
The Large Magellanic Cloud will merge with the Milky Way after a few gigayears.



The Milky Way's Sagittarius Dwarf Elliptical Galaxy is shown as the extended irregular shape below the Galactic Center. Figure credit: R. Ibata (UBC), R. Wyse (JHU), R. Sword (IoA).
The mass of the dwarf is $3 \times 10^8 M_\odot$ (Law and Majewski 2010)

Contents

Simplifications

- One host galaxy
- One satellite
- Both spherically symmetric

Dynamical Friction

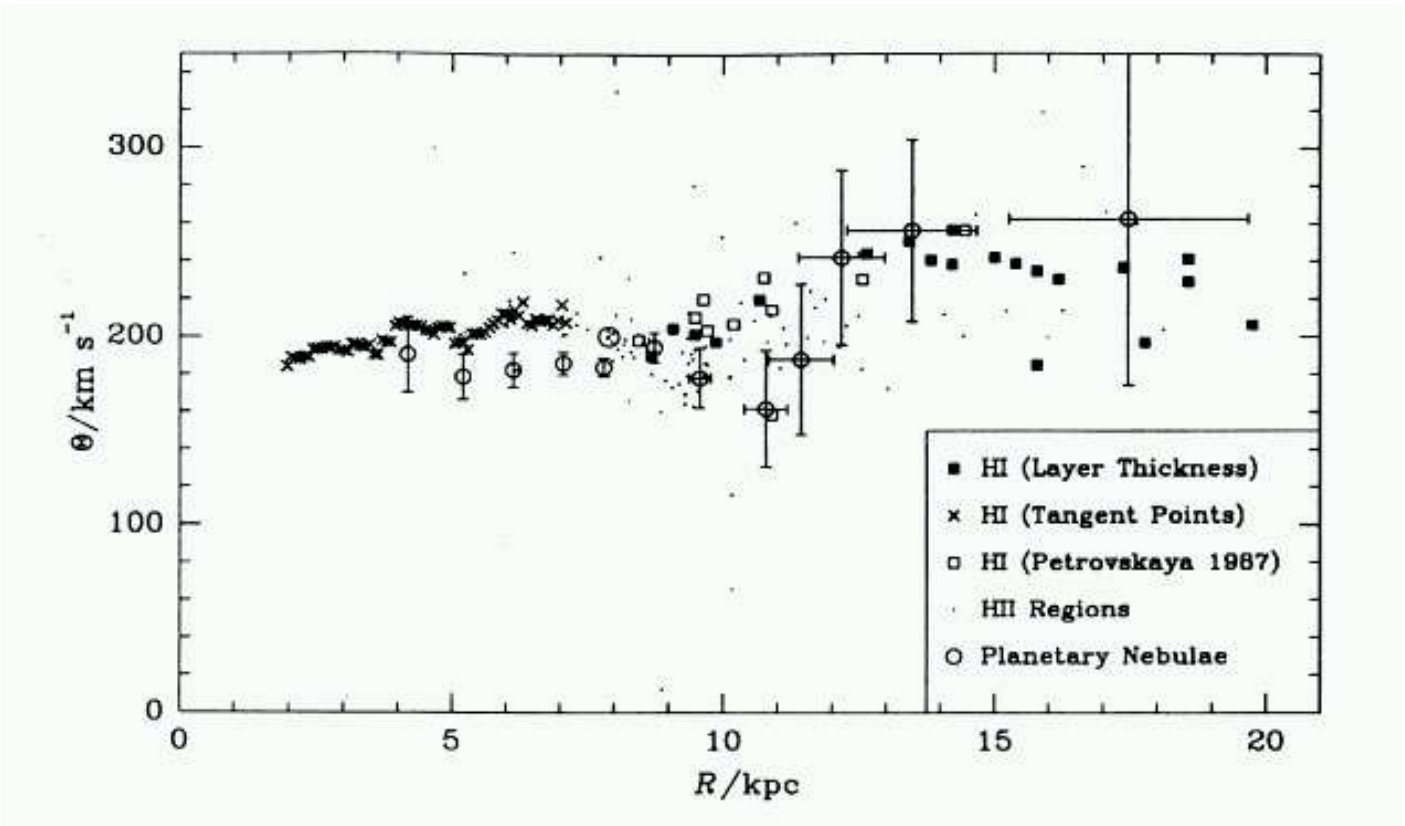
Dynamical friction is an important key to these simulations, as it causes the satellite and some of the globular clusters to slow down in their orbits and merge with the host galaxy. We've used the standard dynamical friction from Binney and Tremaine's "Galactic Dynamics."

Another Simplification

- Satellites leave a small amount of gas and stars behind as they merge, but we just assume all mass goes to the middle of the host galaxy.
- Host galaxy NGC 5907 has wrapped around it the remains of a merger satellite. Figure credit: IAC press release, 2008.

The Milky Way

Rotation curve (radius vs circular velocity) plot of the Milky Way: flat out to at least 20 kpc and circular velocity of 200 km/s.
Figure credit: Merrifield 1992, AJ, 103, 1552.

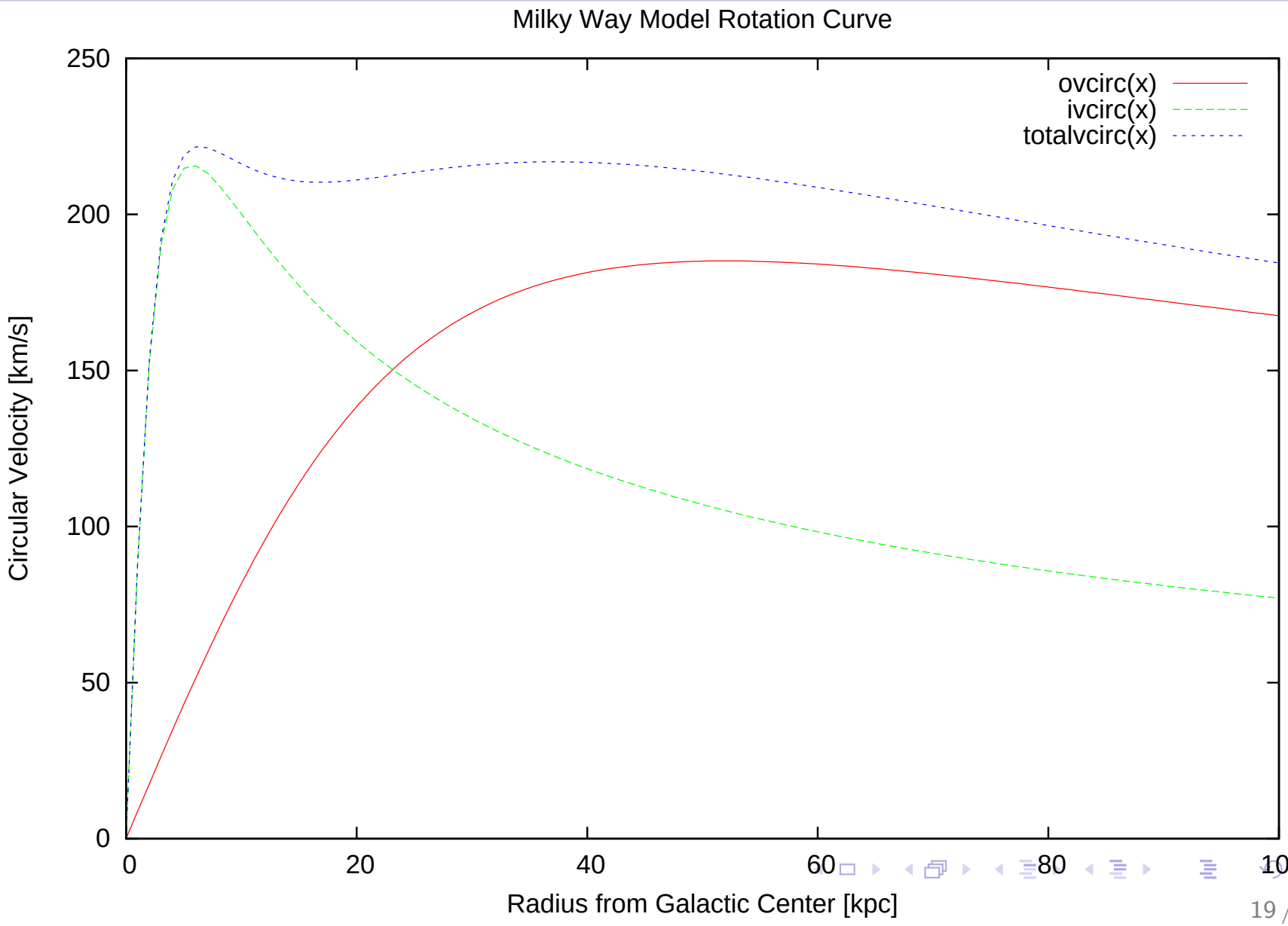


The Milky Way Model

Parameters chosen to make the best fit rotation curve to the Milky Way:

- Total galactic mass is $1.1 \times 10^{12} M_{\odot}$
- Inner galaxy is 13 percent of the total galactic mass
- Outer galaxy includes the rest of the galactic mass
- Half mass radius of the outer galaxy is 30 kpc
- Half mass radius of the inner galaxy is 3.3 kpc

Milky Way Model



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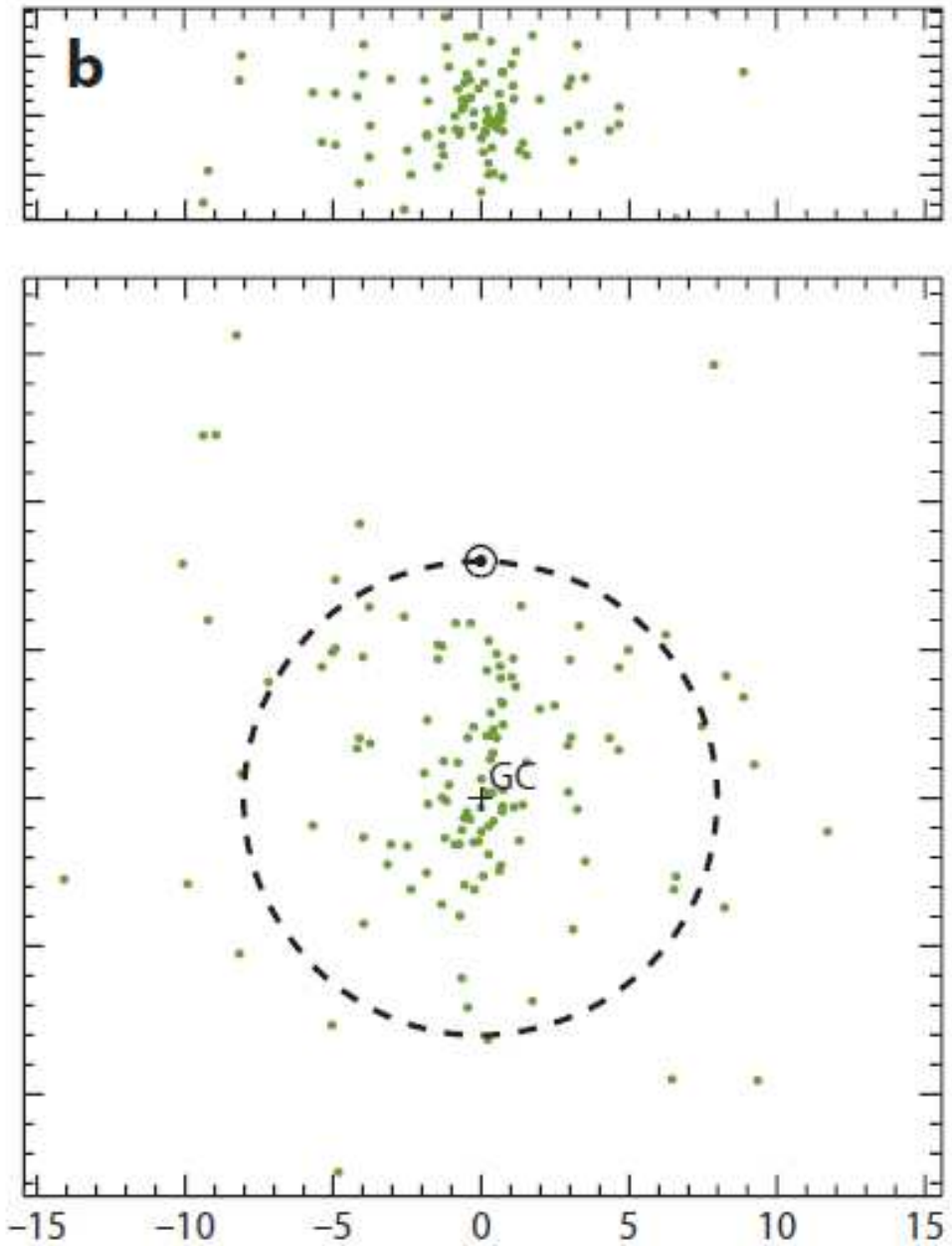
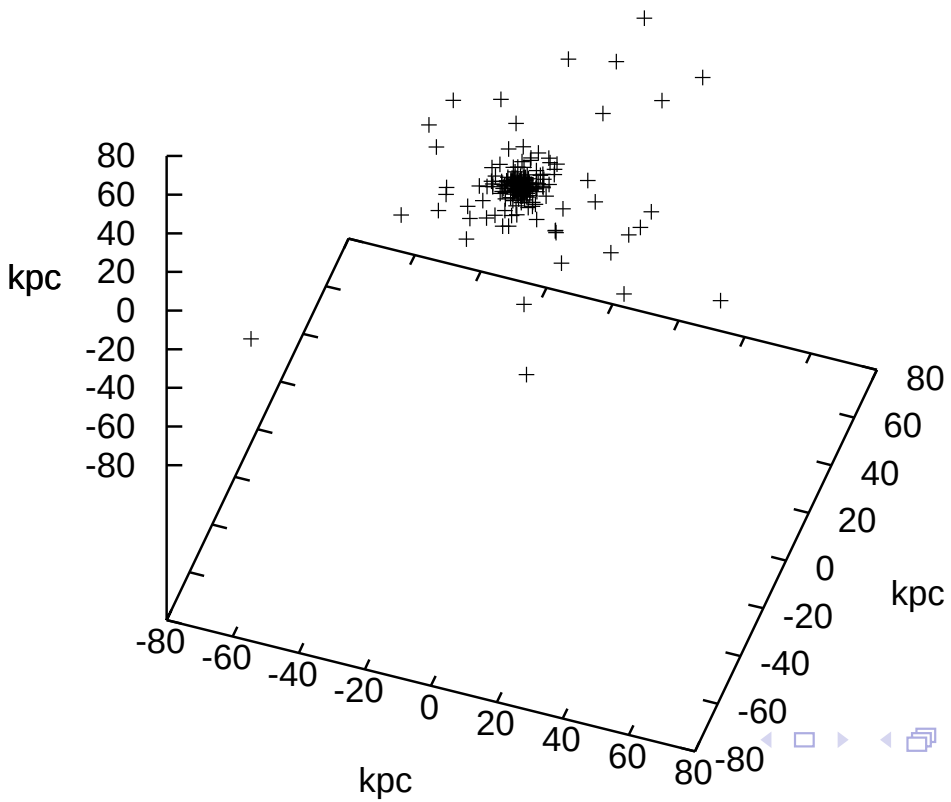
Globular clusters



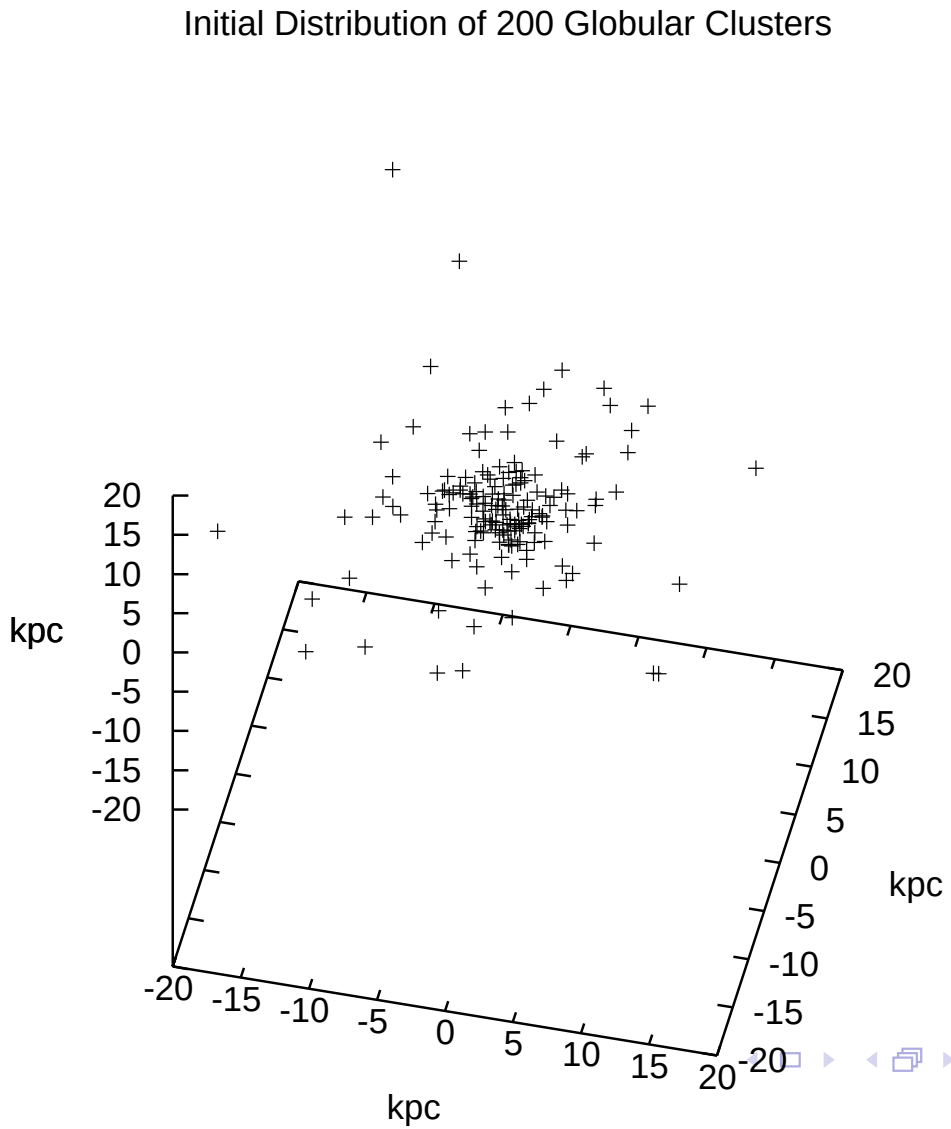
Axes are in kiloparsecs from the Milky Way Galactic Center (GC). Figure credit: Zwart, Simon F., et al. 2010.

Initial Distribution

Initial Distribution of 200 Globular Clusters



Initial Distribution

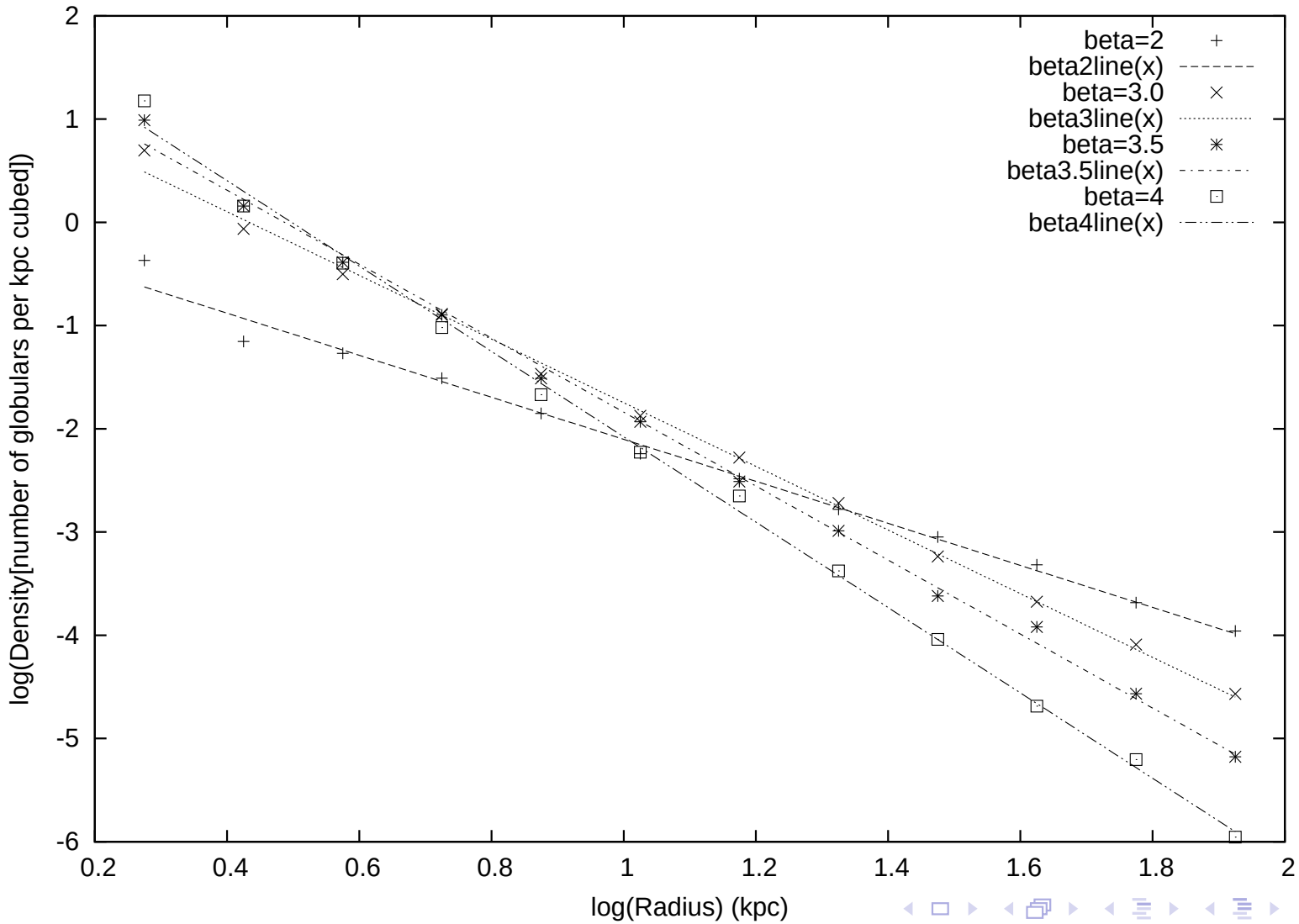


Initial Distribution

The initial distribution is set up to resemble today's Milky Way globular clusters:

- 200 globular clusters
- power law distribution of density $\rho \propto r^{-3.5}$

Initial Power Law Distribution



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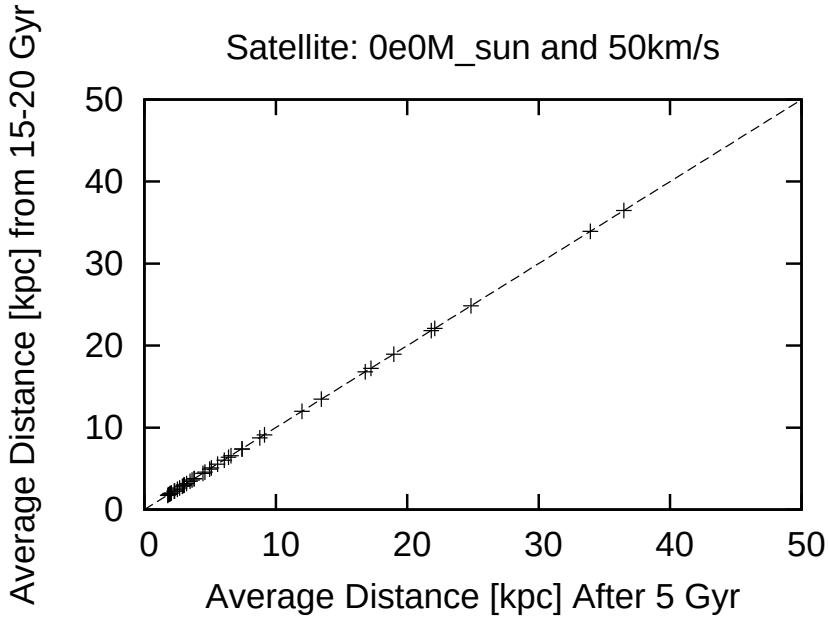
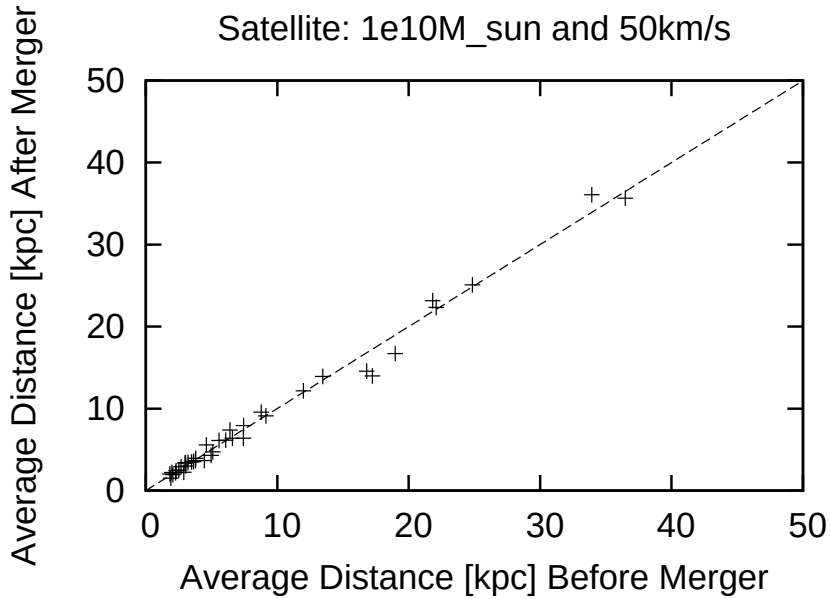
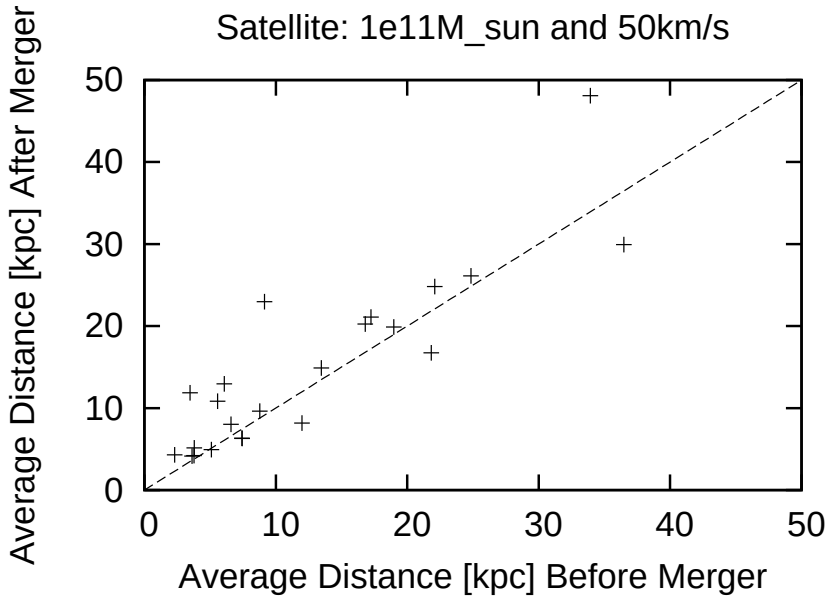
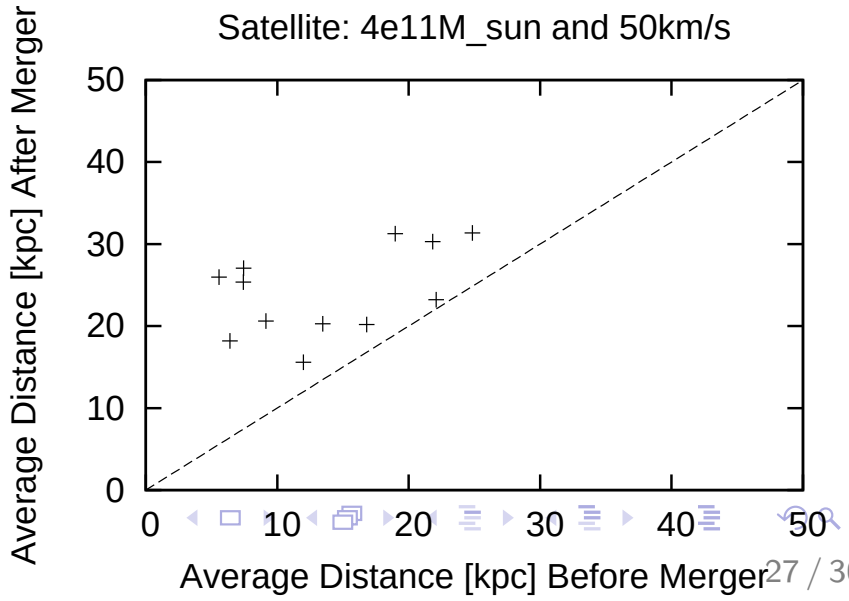

Satellite: 0e0M_sun and 50km/s
Average Distance [kpc] from 15-20 Gyr
Average Distance [kpc] After 5 Gyr
0
10
20
30
40
50


Satellite: 1e10M_sun and 50km/s
Average Distance [kpc] After Merger
Average Distance [kpc] Before Merger
0
10
20
30
40
50


Satellite: 1e11M_sun and 50km/s
Average Distance [kpc] After Merger
Average Distance [kpc] Before Merger
0
10
20
30
40
50


Satellite: 4e11M_sun and 50km/s
Average Distance [kpc] After Merger
Average Distance [kpc] Before Merger
0
10
20
30
40
50

End

Summary and Future Work:

- Stable globular cluster system around the Milky Way.
- The satellite 1/3 the mass of the Milky Way greatly disturbs the average globular cluster distance from the galactic center.
- Run many simulations and vary the satellite mass, velocity, and angle of approach.
- Determine if the dynamical friction really makes sense.

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Dedication

This presentation has been dedicated to my loving Mom and Dad.
Thanks!
Email me: sarah.bird at utu.fi