Leiden-BNU Astronomy Summer School
Computational Astrophysics projects

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Please refer to the Github repository[1] for template scripts for the projects. You can also find additional examples in the AMUSE repository[2].

Project 2: Finding the solar siblings

Introduction

Most stars are not born in isolation. They are formed in clustered environments, gravitationally tied to other stars [Lada and Lada, 2003]. In time, clusters evolve and eventually dissolve, populating the field stars. There is observational evidence that our Sun was born in such environment [Portegies Zwart, 2009]. However, where the siblings of the Sun ended up after the cluster dissolved is not easy to determine. The dynamical evolution of star clusters depends on both internal and external factors. Internal factors are, for example, two body relaxation and stellar evolution. External factors can be the interaction with the tidal field of the galaxy or with giant molecular clouds. In this project we will study how clusters are affected by these different processes, and we will try to find the distribution of the solar siblings. We will begin by integrating the orbit of the Sun back in time, and then starting a cluster in that position to analyze where in the galaxy the rest of the stars could be located.

1 Initial conditions

1. Create a semi-analytic galactic potential for the Milky Way.
2. Start an N-body code with only one particle. This will be the current Sun. Use the following initial conditions for the particle (the Sun's current location):

$$\boldsymbol{x} = (-8400, 0.0, 17.0) \text{ pc}$$

$$\boldsymbol{v} = (-11.35, -232.1, -7.41) \text{ km/s}$$

2 Finding the past location of the Sun

Integrate the N-body code backwards, until 4.56 Gyr ago (the estimated age of the Sun). Where was the Sun located then?

3 The birth cluster of the Sun

Initialize a star cluster on the location where the Sun was born using the following parameters:

1. Number of stars $N = 1000$.
2. Plummer sphere spatial distribution, radius $R = 1$ pc.

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[1] https://github.com/franciscaconcha/LeidenBNU2019
[2] https://github.com/amusecode/amuse/tree/master/examples

3. Virial ratio $Q = 0.5$ (meaning the cluster is in virial equilibrium)

4. Kroupa initial stellar mass distribution [Kroupa, 2001] with upper limit 100 $M_\odot$.

Integrate the cluster using `BHTree`, and use `Bridge` to couple it with the Galactic background potential. Evolve the system for 4.65 Gyr. Adopt a softening length of 1 pc.

4 Probablity of finding a solar sibling

Plot the cumulative distribution of the distance between the Sun and any of the stars in the cluster. What is the probability of finding a Solar Sibling within 100 pc from the current location of the Sun? What velocity would this star have with respect to the Sun?

Perform the same calculation with 50, 100, 200, ..., 2000 stars in the cluster. Make a plot of the number of stars you expect to find within 100 pc from the Sun as a function of the number of stars in the parental cluster. Is it obvious that with a richer cluster you expect a higher probability of a nearby Solar Sibling?

5 Useful scripts

The following scripts from the AMUSE examples will be useful for this project:

- `/examples/textbook/gravity_minimal.py`
- `/examples/textbook/gravity_potential.py`
- `/examples/textbook/solar_cluster_in_galaxy_potential.py`

References

[Kroupa, 2001] Kroupa, P. (2001). On the variation of the initial mass function. *Monthly Notices of the Royal Astronomical Society*, 322(2):231–246.

[Lada and Lada, 2003] Lada, C. J. and Lada, E. A. (2003). Embedded clusters in molecular clouds. *Annual Review of Astronomy and Astrophysics*, 41(1):57–115.

[Portegies Zwart, 2009] Portegies Zwart, S. F. (2009). The Lost Siblings of the Sun. , 696(1):L13–L16.