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 3: Dynamical modeling of the Milky Way-Andromeda merger

Introduction

Galaxy mergers are one of the most important dynamical processes in the dynamical history of galaxies. Depending on the speeds, impact angles, and mass ratio, galaxy mergers may produce irregular galaxies, lenticular galaxies, elliptical galaxies, or spiral galaxies. In the Local Group, the Andromeda galaxy (M31) is approaching the Milky Way galaxy at a speed of roughly 110 km/s [Sohn et al., 2012]. It is predicted that the two galaxies will eventually collide in about 4.5 Gyr from now, merging into an elliptical galaxy, nicknamed Milkomeda or Milkdromeda [Cox and Loeb, 2008]. To study the merging process, the student is expected to model the velocity and impact angle of the two galaxies according to observational data, and then carry out the simulation using a GPU-accelerated tree-code (e.g., Bonsai, Bédorf et al. [2012]).

1 Initial conditions

Find the mass and radius of the Milky Way and Andromeda galaxies. Create a model of them in AMUSE. Begin with 20.000 particles for the halo, 10.000 for the bulge, and 10.000 for the disk. Play around with the number of particles to get a good trade off for running time. Investigate the estimated velocities and impact angle of the encounter and give your galaxies the proper initial parameters.

2 Collision

Evolve the model for at least 200 Myr. Create a plotting script to keep track of the collision at different snapshots. Only include the bulge and disk particles in your plots.

3 Understanding merger evolution

1. How do the galaxies interact? What type of merger product do you think the collision will result in?
2. How much mass is lost from each of the galaxies after the collision?
3. What is the final mass of the merger product?

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

4 Different configurations

Explore merger results for different galaxy configurations. Create one galaxy with the same initial conditions as before, but change the initial shape of the second galaxy: create an spherical galaxy using only a bulge and no disk, for example, or create a larger disk and smaller bulge. How do the merger results change?

5 Useful scripts

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

- `/examples/textbook/merge_two_galaxies.py`

References

[Cox and Loeb, 2008] Cox, T. J. and Loeb, A. (2008). The collision between the Milky Way and Andromeda. *Monthly Notices of the Royal Astronomical Society*, 386(1):461–474.

[Sohn et al., 2012] Sohn, S. T., Anderson, J., and van der Marel, R. P. (2012). The M31 Velocity Vector. I. Hubble Space Telescope Proper-motion Measurements. , 753(1):7.