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 1: Colliding protoplanetary disks

Introduction

Stars are not formed in isolation but in clustered environments, up to thousands at a time [Lada and Lada, 2003]. Protoplanetary disks are a natural outcome of the star formation process. During their first stages of evolution they are immersed in an environment that is dense in gas and nearby stars. This ambient can be hostile for disk survival for many different reasons, such as the disks being exposed to photevaporation, supernovae explosions, ram pressure stripping, and close-by encounters with other stars [Portegies Zwart, 2016, Concha-Ramírez et al., 2019]. In this project the students will use an SPH code to study the interactions between two encountering protoplanetary disks.

1 Initial conditions

- Create two stars like the sun.
- Locate the stars at 300 au from each other, both at $y = 0$.
- Using the `protodisk` class from AMUSE create a protoplanetary disks of radius $R = 100$ au around each of the stars.
- Give the stars and disk particle opposite velocities so that they collide head-on.

- The `ProtoPlanetaryDisk` function returns a set of particles. Start an instance of the SPH codes `Fi` or `Gadget2` and add the protoplanetary disk particles as gas particles. Add the stars as dark matter particles ($\mathtt{dm}_particle, inthecontextoftheseSPHcodesitreferstoaparticlethataccretesgas$).

2 Disk collision

Evolve the model for 5 Myr or until the collision phase ends. How much mass is lost from each disk in the collision? Do any of the disks survive, or are they completely dispersed? If they survive, what are their radii after the collision? Make a movie of the simulation.

3 Different configurations

Repeat the same experiment but with combinations of different initial configurations, such as:

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

- Vary the mass of one of the stars between $0.5M_\odot$ and $3M_\odot$. Scale the radius of the initial disk using the following formula:

$$R = R' \left(\frac{M_*}{M_\odot}\right)^{0.5}$$

where M_* is the mass of the star and $R' = 100$ au is a constant.

- Give one of the disks different inclinations $(15°, 45°, 90°)$ with respect to the collision direction.

- Change the impact parameter of the collision: instead of having both disks at $y = 0$, move one of them along the y axis. Try configurations such as $y = R_1/2$, $y = R_1$ and $y = R_1 + R_2$, where R_1 and R_2 are the radii of the disks.

How do the different initial configurations change the amount of mass lost and the survival of the disks? Choose a few of your favorite cases and make movies of the simulations.

Imagine that a planetary system like our own was already forming within 40 au of the disk of the solar mass star. Would it have any chance to survive in any of these collisions?

References

[Concha-Ramírez et al., 2019] Concha-Ramírez, F., Vaher, E., and Portegies Zwart, S. (2019). The viscous evolution of circumstellar discs in young star clusters. , 482(1):732–742.

[Lada and Lada, 2003] Lada, C. J. and Lada, E. A. (2003). Embedded Clusters in Molecular Clouds. *Annual Review of Astronomy & Astrophysics*, 41:57–115.

[Portegies Zwart, 2016] Portegies Zwart, S. F. (2016). Stellar disc destruction by dynamical interactions in the Orion Trapezium star cluster. , 457(1):313–319.