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 4: Evolution of a triple stellar system

Introduction

The triple system Muscae comprises the WC5/6 Wolf-Rayet star WR48 on an inner orbit with period $P_{in} \approx 19$ days around an O6/7V star, with an O9.5/B0Iab companion on a much wider outer orbit [Sugawara et al., 2008]. The other orbital parameters are not known, but each of the three stars has a strong stellar wind. We can easily integrate the equations of motion of such a triple system within AMUSE, taking the mass loss of each star into account, by coupling a stellar evolution code with an N-body integrator.

1 Initial conditions

- Create the three stars with masses $60M_\odot$ (for WR48) and $30M_\odot$ for the inner two binary stars, and $20M_\odot$ for the outer companion.
- The nature of the Wolf-Rayet star suggests that the system is at least a few megayears old. Evolve the three stars to an age of 4.5 Myr using `SeBa`. What is the stellar mass now?
- Initialize the N-body code `Huayno` in a configuration consistent with the observed orbit. Assume that the outer orbit has an inclination of 30° relative to the inner one, with an inner eccentricity of 0.2, and an outer eccentricity of 0.6. Use an initial mean anomaly and argument of periastron of 180° , and an outer orbital separation of 100 AU.
- During the integration continue evolving the stars using `SeBa`.

2 Dynamical evolution

- Evolve the model for 10^3 yr. Create a plot of semi-major axis in time for the inner binary and the companion, and see how the orbits evolve.
- Re-run the simulation without stellar evolution during the integration. How do the orbits differ from the previous case?
- How do the initial orbital parameters affect the results? Re-run the simulation (for a shorter amount of time, if necessary) for different combinations of orbital parameters. How does this change the final orbits?

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

3 Stellar evolution

How does the mass lost from each star affect their orbits? How does the orbital evolution change when the stellar masses are more similar?

4 Useful scripts

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

- `/examples/textbook/evolve_triple_with_wind.py`

References

[Sugawara et al., 2008] Sugawara, Y., Tsuboi, Y., and Maeda, Y. (2008). Redshifted emission lines and radiative recombination continuum from the Wolf-Rayet binary Muscae: evidence for a triplet system? , 490:259–264.