Practical exam Computational Astrophysics

Spring 2015

Time: 3 hours (10.00 13.00)
Expected: one ASCII file with source code (and comments) and pdf or eps figuers separately
Clearly state your name and student number

Exam A

We want to study a large system of self-gravitating particles distributed in a virialized Plummer sphere and with a mass function from $0.1\,\mathrm{M}_{\odot}$ to $100\,\mathrm{M}_{\odot}$. However, we have insufficient computer resources to perform the entire calculation using a direct N^2 method. At the same time we require a precision that exceeds standard tree-code precision. We therefore decide to opt for a hybrid method in which we combine tree-code with direct N-body by interfacing the two codes using `Bridge` within the AMUSE framework.

We divide the stars over the two codes, where the tree-code handles the low-mass stars (those with $m < m_{\rm cut}$) and the direct N-body code will take care of the high-mass stars (those with $m \geq m_{\rm cut}$).

In order to study how to make a cut in the particle distribution, we intend to study the behavior of the hybrid code as a function of the mass cut which decides which particles are treated by the tree-code and which by the direct N-body code.

Although, we will perform the numerical experiments with units, we will not take stellar evolution into account, because we are currently only interested in validating the here proposed *split-method*.

Questions 1

Why do we split the particle set in mass rather than, for example, in distance from the center-of-mass or as a function of local density?

Questions 2

Give an estimate of the bridge time step relative to the typical orbital timescale you will use for your calculation.

Questions 3

Write the hybrid code and give it an interface such that you can run it from the command line.

Run the code for $N = 1000$ stars with a virial radius of $r = 3\,\mathrm{pc}$ for $10\,\mathrm{Myr}$.

Perform three runs with the following conditions and store the data with a time resolution of $0.1\,\mathrm{Myr}$:

- all stars in the tree-code (solid curve in the plot),
- all stars in the direct code (dotted curve),
- $m_{\mathrm{cut}} = 0.3\,\mathrm{M}_\odot$(dashed curve).

Make two plots (each run will result in one curve in each of the two plots).

- One plot of the relative energy error compared to the initial conditions as a function of time.
- One plot of the half-mass and core-radii as a function of time.

Make a table with the wall-clock times of these three runs.

Good luck!
Simon & Edwin

Theoretical exam Computational Astrophysics

Spring 2015

Time: 3 hours (10.00 13.00)
Expected: one ASCII file (or by hand) with the answers to the questions.
Clearly state your name and student number

Exam B

Questions 1: general AMUSE questions

1. The Astrophysical Multipurpose Software environment allows researchers to couple numerical codes as modules into new heterogeneous multi-scale and multi physics solver.
   (a) What is the philosophy behind AMUSE?
   (b) What different type of physical domains are being addressed in the AMUSE framework?
   (c) What are the ingredients of the AMUSE data model?
   (d) Why does the AMUSE framework not form a computational bottleneck, even though it is written in a very slow and descriptive language?
2. Bridge enables a coupling between two or more different codes.
   (a) What is required of the underlying physics to be able to allow Bridge?
   (b) To what order is `Bridge`, and what does this mean?
   (c) What is required of the code in order to make a higher order bridge.
   (d) Is the time-step of the `bridge` the same as of the bridged codes, and explain how this works.
   (e) What physics do you neglect if you bridge hydrodynamics with gravitational dynamics.
3. AMUSE is built around various communication libraries.
   (a) What are the differences between `MPI`, `sockets` and `Ibis`?
   (b) Name at least one advantage of each of these communication libraries?

Questions 2: circum binary disks

In [Pelupessy & Portegies Zwart2013] AMUSE is used to study planet formation in a circum-binary disk to explain the systems Kepler 16, 34 and 35.

1. What make Kepler 16, 34 and 35 so special?
2. Why do they use an SPH code to simulate the circum-binary disk?
3. What would be an alternative code to use?
4. the authors write that:
   BRIDGE provides a symplectic mapping for gravitational evolution in cases where the dynamics of a system can be split into two (or more) distinct regimes.
   What is a *symplectic mapping* in this context. Why use `bridge` for the code coupling, what codes are actually coupled, and what do the authors mean with *distinct regimes*?
5. The authors use a Kepler solver in universal variables to simulate the dynamical evolution of the binary star. Why do they not use a direct N-body code? Wouldn t a direct N-body code be much more accurate?
6. Why do the authors perform separate calculations for 3-body dynamics?

Questions 3: embedded star clusters

In [Pelupessy & Portegies Zwart2012] the authors study the evolution of embedded star clusters.

1. What codes do the authors use to simulate each of the physical processes?
2. How many codes are running at the same time?
3. Describe the run time cycle used in their AMUSE script.

Good luck!
Simon & Edwin

References

[Pelupessy & Portegies Zwart2012] Pelupessy, F. I., Portegies Zwart, S. 2012, MNRAS , 420, 1503

[Pelupessy & Portegies Zwart2013] Pelupessy, F. I., Portegies Zwart, S. 2013, MNRAS , 429, 895