A: Retake Exam Computational Astrophysics 2019

July 19, 2019

Friday 19 July from 12:00 to Monday 22 July at 9:00.
Total credits: **None**
Verdict: **pass** or **fail**
Hand in: sent a tarred directory email to: **sanderschouws@gmail.com**
Criteria: handing is the assignment after the deadline results in: **Fail**.

Warning: This is an exam. You can discuss with your fellow students, but do not copy each other's code. Copying code will be treated as plagiarism. The punishment for this will be severe.

The debris disk around the moon Titan

We are going to simulate the evolution of a debris disk in orbit around a moon which orbits a planet that orbits a star. Circum-lunar disks have not yet been observed, but there is no particular reason why they should not exist. One good candidate would be Saturn's largest moon Titan. This moon does not have moonlets and there is no disk around the moon. But can we understand why such a moon has no moons of itself?

Initial conditions and run-script

Write an *AMUSE* script to simulate the evolution of the circum-lunar disk of Titan in orbit around Saturn which orbits the Sun.

0.0.1 Generate the initial conditions

First generate a separate script called: `make_initial_conditions.py`. This script should take the current known orbit of Titan and Saturn around the Sun and places a disk around the moon. The orbital elements will have to be converted to Cartesian coordinates in order to be able to integrate the equations of motion.

The script should write two files with the initial conditions. They should be called `SunSaturnTitan_i0000.amuse` for the sun, planet and moon. The file for the debris disk should be called `disk_i0000.amuse`.

The planet and moon should have current orbital parameters.

The disk should have an inner radius of 0.03 of the Hill radius of the moon in orbit around the planet and an outer radius of 0.5 Hill radii. The total mass of the disk should be 10% of the Moon's mass. Use a power-law projected density profile $\Sigma(r) \propto r^{-1.5}$ and a disk-thickness parameters $Q = 10$. The disk should be stable and composed of 10^3 particles with a mean density of 3g/cc. Disk particles should have a mass function, taken from a power-law with a -2 slope and ranging over over 2 order of magnitude between the lowest and highest mass object. The radii of the disk particles should be set accordingly.

0.0.2 Generate the run script

Write the integrator script, and call it `run_debris_disk_around_Titan.py`.

This script should either read in the two generated files or call the script for generating initial conditions. It should dump data to stdout, and write snapshots to files in temporal order called `SunSaturnTitan_iXXXX.amuse` for the sun, planet and moon, and `disk_iXXXX.amuse` for the debris. Here `XXXX` range from 0001 to 250 for the 250 snapshots you are going to produce.

The script should be composed of two integrators

> One for performing the orbital integration of the moon around the planet around the star. We call this the first integrator.
>
> One integrator with a shared time step and collision handling enabled. We call this the second integrator.

You are going to use `Huayno` for both integrators.

You will use the 2nd order Huayno integrator for the Sun-Saturn-Titan system, and the 4th order integrator for the debris disk. Both codes should be coupled via the 4th order Bridge.

0.0.3 Generate the data reduction script

Write the data reduction script, and call it `reduce_and_plot_data.py`.

Questions

Run the code for one Saturn orbit around the Sun. Produce 250 diagnostics outputs at equal distance in time.

> make a figure of the positions of the planet (blue), moon (red) and debris (green) at zero age, at the end of the simulation and two figures at equal time distance. All four panels should be on a single page.
>
> Make a plot of the energy in the various integrators (first, second and the bridge) as a function of time.
>
> Make a cumulative distribution of the density of disk particles as a function of the distance to the moon. Make one curve for the initial, final and the two snapshots in the middle.
>
> Make two scatter plots for the orbital parameters (semi-major axis and eccentricity) of the particles that originally ware member of the disk: One plot for the initial conditions and one for the final conditions (after one Saturn orbit around the Sun). Use the following color coding: red for the particles bound to the Sun, blue for the particles bound to Saturn and black for the particles bound to titan.
>
> Make two scatter plots (at the start and at the end of the simulation) in Cartesian coordinates of the Saturn-Titan system. Use the same color coding as in the orbital-parameter plot.

Describe globally what happens to the debris disk around Titan?

What influence does the debris disk has on the moon's orbit?

What mass of a moon can be produced at most in the circum-lunar disk?

What happens to the debris when they escape the disk?

What fraction of the debris will end-up in orbit around the Sun, rather than around Saturn or titan?

Finally, make an animation from the 250 snapshots in Cartesian coordinates and centered around the Sun.

Submitting your work

Submit your work by email. This email should include

- The three AMUSE scripts.
- The figures in one pdf.
- The animation.
- An ASCII file in which the questions are addressed.