Collision detection in astrophysical disks

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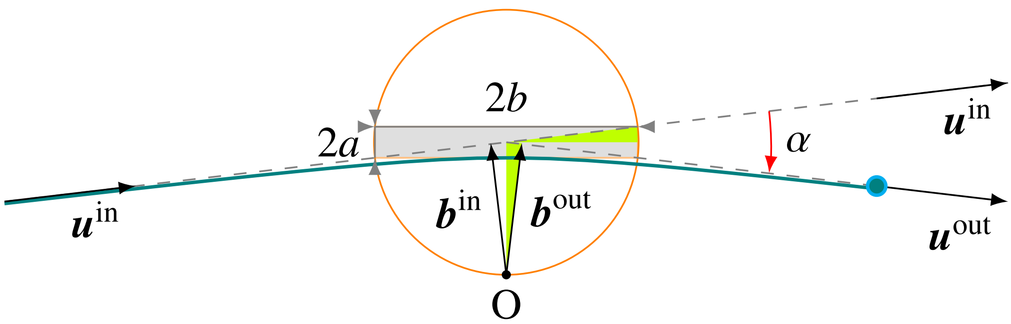
How to simulate planetary dynamics?

Simulations of the dynamical evolution of many bodies are generally computationally expensive. Consider the n-body problem: each particle moves under the influence of the gravitation of all other particles: there are n^2 interactions. There are methods to speed up a numerical simulation. These are Barnes-Hut algorithm[2], where nearby particles are grouped so that interactions can be combined, and the method of Laplace and Lagrange[4], where the particles are in slowly changing Kepler ellipses, so that a time-step covers many orbits. In both methods, however, it is difficult account for collisions, resonances, and very long timescales.

A new method with Collision detection

Collision detection is the problem of finding when planets or asteroids collide. We have found an way to calculate the moment a collision or a close encounter between two planets in Kepler orbits occurs [5, 1, 3], without solving the orbits. We can use this method to create a fast simulation of planetary dynamics: One keeps track of the pairs of particles that are on a collision course, from the soonest to the latest moment of collision. Each step of the simulation involves the implementation of a collision, the calculation of the new collision possibilities, and updating the list[5]. The method can thus account for collisions and the gravitational effect at close encounters.

Until now we have not included the small but cumulative effect of the long-range gravity of distant planets on each other, making our method imprecise. However, there exist yet another method called the Mixed Variable Symplectic (MVS) integrator that accounts for the long-range gravity. It is also based on Kepler orbits and includes corrections at fixed time-instants (of many orbital periods). We therefore want to examine if it is possible to merge the two methods: implement short-range interaction between two planets at an encounter and at these instants also correct for the influence of the distant planets. (i) Can you find out if this method is less accurate or better than the standard MVS? (ii) Can you show that this method can be faster than the Barnes-Hut algorithm? (iii) Can you speed-up or parallelize the code? (iv) Can you run it on the Super Computer Delft Blue? (v) Can your code describe orbital resonances like Jupiter's Trojans?



References

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