CTA200H Project for Karandeep Basi

A frequent way to model gravitational attraction in astrophysics is through N-body techniques, whereby the matter distribution is represented with a system of particles. These particles might represent individual stars (or groups of stars), for example in a globular cluster, or the dark matter distribution in a galaxy halo.

The gravitational acceleration of Newtonian gravity is $\propto 1/r^2$. The acceleration of particle i is given as

$$\ddot{\boldsymbol{x}} = \sum_{j \neq i}^{N} -G \frac{m_j}{|\boldsymbol{x}_{ij}|^2} \hat{\boldsymbol{x}}_{ij} \tag{1}$$

where the summation is over the total number of particles N, $\boldsymbol{x}$ is the position vector, $\hat{\boldsymbol{x}}$ is the unit vector in the direction of $\boldsymbol{x}$, $\ddot{\boldsymbol{x}}$ is the acceleration, G is the gravitational constant and m_j is the mass of particle j.

For this project, write an N-body code to simulate gravitationally attracting astrophysical systems. For a system of N particles, they should store positions, velocities, accelerations and masses. You will find a datafile in the projects directory of the course's github that has initial conditions for two colliding galaxies. The file has positions, velocities and masses for 40,000 particles for the dark matter halo and 20,000 particles representing baryons in the disc of the galaxy. Read the initial conditions into your program and evolve the two galaxies until $t = 10$. Show snapshots of the baryons at various points throughout the collision.

Section III.2 of Ott and Benson's Computational Astrophysics document discusses many related aspects, particularly the integration of the particles forward in time (leapfrog integration, though Euler integration will work just as well), estimating suitable timestep sizes, and softening the gravitational potential to treat close encounters (where $r \to 0$, a problematic case in equation 1).