N-Body Problem: Motion in a Field of Point Charges

Objectives

In this activity you will model the motion of an electron moving through a cluster of 50 charges. Before doing this activity you should have completed VP02 and/or have read Section 13.9 of the *Matter & Interactions 4e* textbook, which discusses the structure of a computational model that includes the Coulomb force and electric field.

After completing this activity you should be able to:

- Write a program to model an electron interacting with N-objects through the Coulomb (or any) force
- Learn how to read in a set of data
- By varying initial speed, generate several very different electron trajectories, including escape trajectories
- Discuss the issue of sensitivity to initial conditions
- Discuss ways to add more physics to the simulation

1 Reading in Data from a File

In VP02 you studied the motion of the electron around two protons and all data was typed directly into your vpython script. If you have a large set of data, this is very impractical. Instead one stores the data in a file (text file or other format) and uses various functions to read in the data during the running of your script. In this exercise, we will use the python command *loadtxt* which reads the data file ef1.txt. It is a math function contained in numpy. Google *numpy loadtxt* for the various options. The command is already in the shell script.

The data file contains the positions and charges (in units of e) for 50 point charges given in four columns, x, y, z, q. You may view ef1.txt with some editor like vi, emacs, etc. The loadtxt command reads the file and dumps the data into appropriate arrays. This is just one possible solution for data input.

2 Electron motion near point charges

Following a similar approach as you did for VP02, add code to follow trajectories of the electron. Appropriate places in the code are marked with ##
⇒ Add code to compute the net Coulomb force on the electron due to all of the charges
⇒ Add code to update the electron's momentum and position
⇒ Give the electron an initial velocity of $\vec{v}_e =< v_x, v_y, v_z >$ and run the code
⇒ Vary the initial velocity and position of the electron to get different trajectories

Check your work before continuing.

3 Add Vector Arrows

Now add vector arrows for the net force and momentum of the electron
⇒ Use Farr in the code to show the force vector
⇒ Experiment with Fscale to give a reasonable looking vector arrow
⇒ Repeat for the electron momentum vector

Check your work before continuing.

4 Improving the Physics

This exercise is an example of an N-body simulation. However, some physics is missing. For example, the figure shows the time series for a simulation of a large number of galactic-size dark matter objects which interact via the universal gravitational force. Over time, the galaxies begin to clump since the gravitational force is attractive. For

our simulation of N charges, answer the following questions, but do not implement in the code (unless you really want to), to improve the physics that is being simulated:

⇒ What changes would you have to make to the while loop that calculates net force?
⇒ What changes would be needed for the position and momentum update equation section?
⇒ What other properties of the charges are needed?
⇒ What would you expect to happen to the charges?

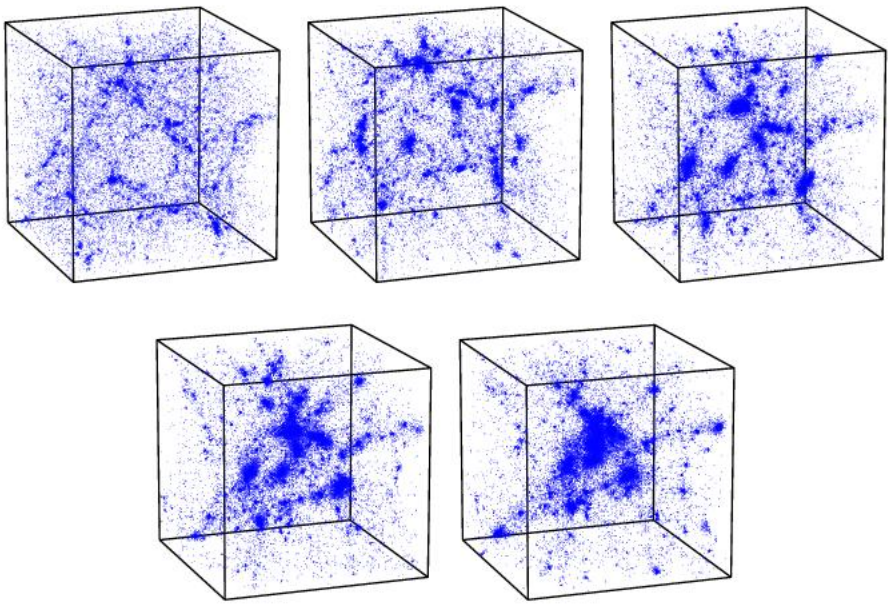

Figure 1: N-body simulation of dark matter clumps over time

5 Turn in Your Program

⇒ Unless your instructor specifies otherwise, restore your program to use the initial velocity and position given in the shell code.
⇒ Embed answers to all questions as comments in the code
⇒ List group member names
⇒ Email your final program to me at pstancil@uga.edu. Send me the code by Monday Dec. 5, 2022, 11:59pm. One copy per group.