LittleUniverse Examples

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This guide presents a brief walk through of some of the interesting situations that can be investigated in LittleUniverse and the correlation functions they generate. For a beginner, it is best read ater the document nbody_physics.pdf. It is recommended that you download a version of the code to run along with this guide.

1 Guide

Let's start with a pretty basic setup; a section of universe containing 20 particles at random initial positions and velocities. We will set the mass of all the particles to be the same, such that we can assume they all represent the same object. In this case, it will allow us to make the claim that we are generating a simulation of the behaviour of dark matter particles, which we assume to be made up of identical elementary particles (more info about this dark matter approximation is included in nbody_physics. pdf. This generates the initial plot and correlation function shown in figure 1 (exact position will differ to your own given the randomness).

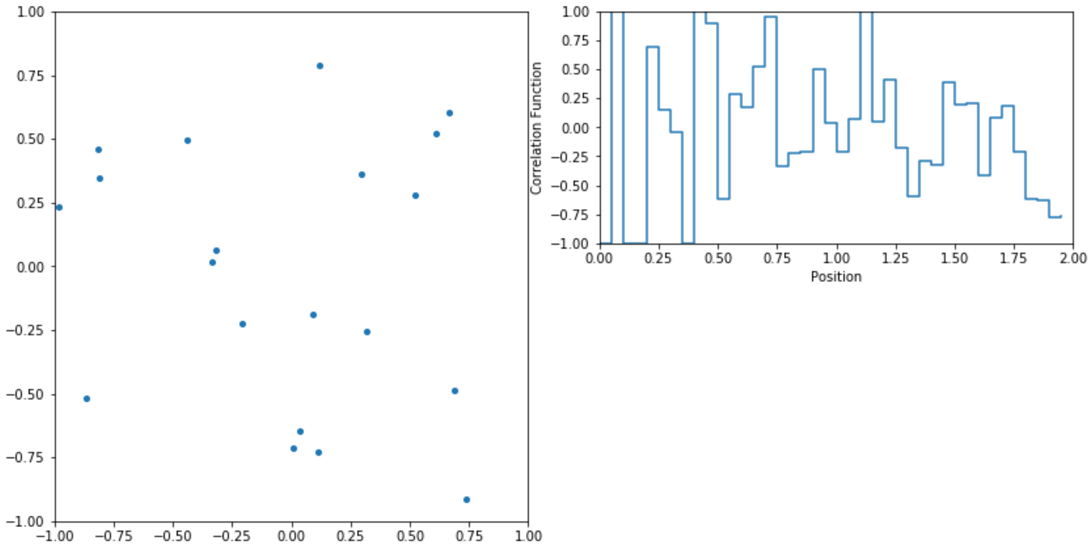

Figure 1

As I said, this is a very basic picture of our universe. But what we should observe is that the dark matter particles interact as we would expect them to under gravity. That is if you slow down the simulation, particles nearby will attract and revolve around each other before possibly moving off. It is unlikely that any particle will travel along a straight trajectory given the gravitational forces acting on it. This may be more noticeable with a larger particle count as it will become more difficult for individual bodies to escape any gravitational influence. The correlation function appears to be dropping off over time, as would be expecting given the attraction of gravity (particles will want to move closer together). Unfortunately, the correlation function is quite noisy, and it is difficult to see the pattern. However, let's examine how this looks at an evolved timestep (figure 2). As you can see, the pattern (disregarding noise) remains pretty much

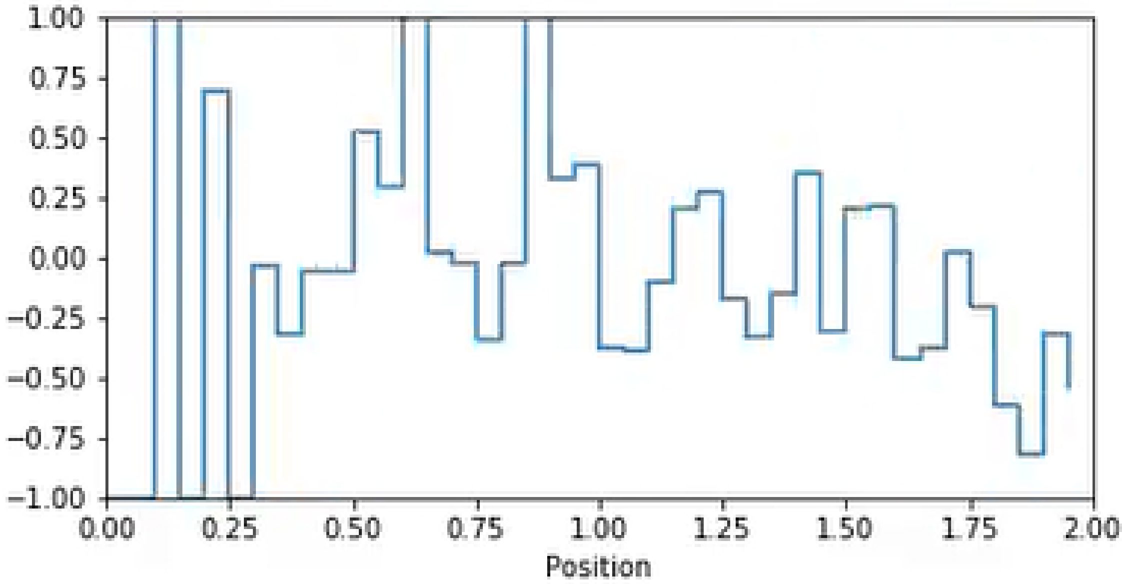

Figure 2

the same. There is a higher probability of finding particles at lower separations, and this drops off as the separation increases.

To get a better feel for the correlation function, let's scale this simulation back significantly for a moment. Keeping all other input values the same, we will simply generate a simulation of two particles. At random positions, the output should show a correlation function with a spike at the particle separation. This is what we observe.

Now that the concept of the correlation function is clear, and we are comfortable running the code. It's time to make the simulation more accurately approximate our universe. For example, we could investigate a system of galaxies by assigning a random mass on the scale of 1 to 100 to each particle. What you will notice, is that the heavier particles will move very slowly while lighter

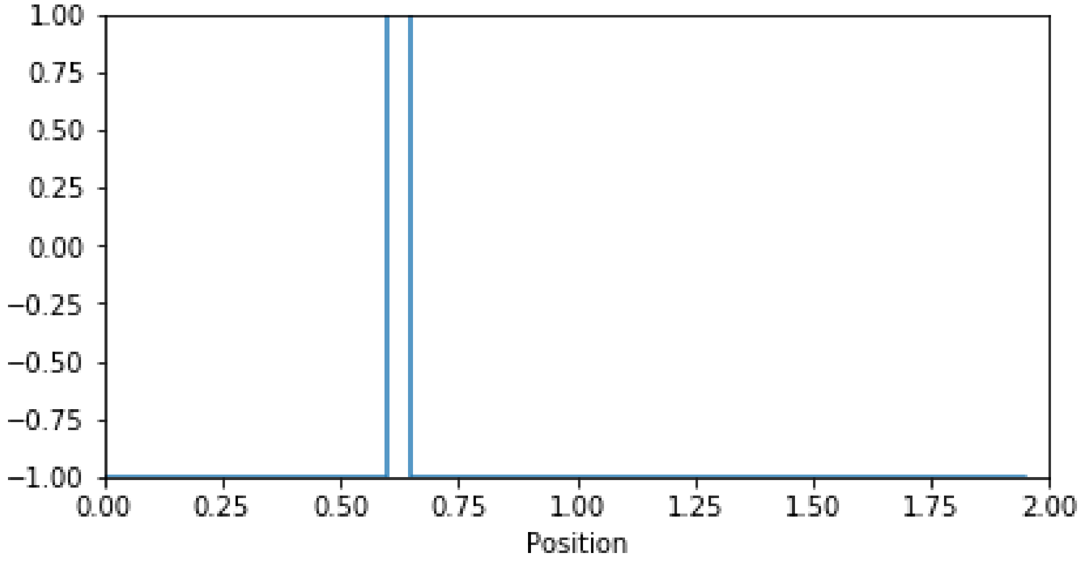

Figure 3

particles will be attracted to them gravitationally. This has the effect that the correlation function drops off much faster (again, the noise makes this difficult to see) compared to the random, even mass distributions. This makes sense, as with a few larger masses will dominate the gravitational forces and cause the majority of lighter particles to clump around them. This means that we are much more likely to find particles that are closer together. It is recommended that you turn the number of timesteps up for this run as the particle movement can become quite fast.

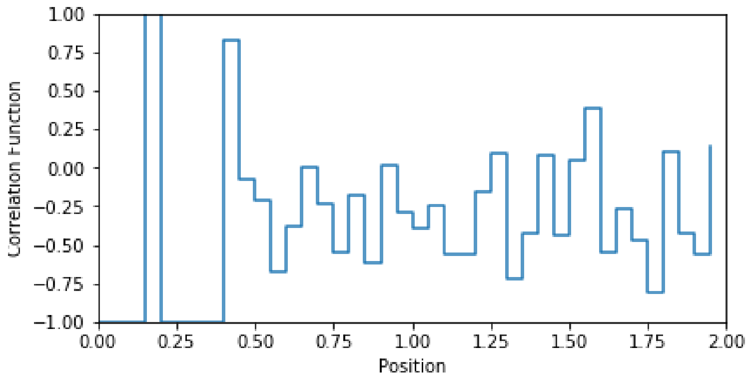

Figure 4

A further interesting situation we could now investigate is, the situation of an expanding universe. Again, making our simulation more representative of the real world. This is easily done in the code, as all it requires is selecting the option '4' when asked to choose initial velocities. This option sets all velocities to be a random fraction of the maximum, but adds an extra constant velocity to all particles to account for expansion (for the purposes of this simulation we ignore the accelerating expansion of the universe due to dark energy, and assume expansion occurs at a constant rate).