Hello everyone, my name is Gerwyn Jones, and today I will be talking about my project, which is also called N-body simulation of young protostellar systems. To start off this presentation I will make a quick overview of how these systems are formed, the purpose of my project, the methods and the results of the project and also the future endeavours of my project.

Protostars are formed through the collapsing of molecular clouds.

It was thought in the 1960 that molecular clouds fragment or split up as they collapse. And the fragmentation of these clouds were thought to be through hierarchical fragmentation. Hierarchical fragmentation is simply where, as the cloud starts to collapse, the jeans mass which you can see on the screen is inversely proportional to the density, and therefore jeans mass decreases and there comes a time when the mass of the cloud is greater than the jeans mass and therefore fragments a bit like what’s on the screen.

These fragmentations and the collapse itself was thought to be spherical in nature, but it was recently found by Philippe Andre in 2010 with the Herschel Gould Belt Survey that molecular clouds actually form filamentary structures during these collapses which were due to turbulences and magnetic disturbances, these filamentary structures are like long spaghetti and are roughly cylindrical in nature.

The objective of the project is to revisit and change the geometry of the protostar forming region from a spherical region to a cylindrical region, and to observe the interactions of the protostars over a long period of time around 1 megayear and hopefully get chaotic motion as seen on the screen, I will observe how they interact within these filamentary structures and determining various parameters such as semi-major axes and eccentricities of binary systems, and probability of ejectas.

To replicate these regions I decided to create a code which places groups of protostars randomly in a circular region inside the cylinder and have each group separated by a distance of around 0.1pc, this is done because when they fragment, the two fragmented clouds contract leaving regions of space between them. There are 10 groups in total in the cylindrical region and each group is virialised and have a drift velocity of around 0.2km/s. due to many stellar multiplicity reports, groups ten to form multiple stars within them, and therefore it was decided that each group has between 3 to 6 stars within them placed at random in a spherical region.

To show that the code and the setup was working correctly I decided to look at an extreme case where there were roughly 10000 groups and 200 stars in each group.

Setting up the masses of each star required the initial mass function or the imf to be used, this is simply the probability density function of having a certain mass star formed, and is generally represented as a power law which can be seen on the screen, the mass of each star is dependent on the number of stars in each group, i.e if you have 1000 stars in the group you have more probability to get a 100 solar mass star inside the group than if you had 3 stars in the group.

To find the position at each point in time, I evolved a verlet method of integration and using the newtons laws of gravitation, many methods of integration could’ve been used which vary from Euler, verlet and Runge kutta and I’m sure there are more ways as well. As you can see on the screen this is the verlet method used to find the positions of the stars.

The time steps are very important in n-body simulations, having them too big can create massive errors in the positions of the protostars, having them too small can cost massive amounts of time.

Using adaptive timesteps ensures that we have accurate positions when the acceleration of the protostars are high, i.e close encounters where accuracy matters. And making sure that its time effective when accuracy isn’t all that important when the acceleration is low, i.e weak to no interactions.

To make sure that my integrator worked I decided to make a model of the sun earth moon system, which can be easily checked to see if the integrator is indeed correct.

From first glances it appears that the model is indeed correct and if I zoom in we can see that the moon orbits the earth.

Knowing that the integrator works I decided to run the code with 10 groups over a period of 1 megayears and a side not this code took around 18 hours to run compared to the sun earth moon model which only took 10 minutes. As you can see from the graph it looks rather puxxling and unexpected, this is because these straight lines are all the ejectas or the protostars that have left their groups. If we zoom in, we can see something a little more reasonable and also that the first two groups have collided with each other which is something that we can expect from these chaotic motions. I decided to make a little clip of the interations between these two groups to show what happens.

From these runs I will try and find various parameters such as how many binary systems form within these runs, what kind of eccentricities do they have and also what is the length of their semi major axes, to make things more interesting I also plan to vary the initial conditions of the groups by making the groups hotter and colder i.e varying the kinetic and potential energies so that they aren’t initially virialised and observe wether there is any differences in the parameters and wether there are more or less ejectas observed.