1. **Abstract**

The project is an investigation into the underlying effect of artificial viscosity in a smoothed hydrodynamics code. The purpose is to find the most effective and accurate way of applying artificial viscosity.

2. **Smoothed Particle Hydrodynamics**

Smoothed Particle Hydrodynamics is a method of modeling fluid flow. It was first developed more than three decades ago by Lucy (1977) and Gingold & Monaghan (1977). Since then it has become one of the standard and widely used computational techniques for modeling astronomical fluids.

It is a particle based model, where each particle has its own mass $m_i$ and specific energy $\epsilon_i$. All other properties are inferred from neighbouring particles through a weighted average.

For a continuous distribution, the average value of some quantity $A$ at the location $i$ would be

$$A_i = \int W(r - r_i) A(r) \, dV$$

where $W$ is the smoothing kernel, in SPH the integral is replaced by a sum,

$$A_i = \sum_j \frac{m_j}{\rho_j} A_j W_{ij}$$

which extends over all particles $j$, within the smoothing sphere. Where $\rho_j$ is the density of particle $j$.

The smoothing kernel is monotonically decreasing with distance, this infers the property of weight, the closer the neighbouring particle the more influence it has over the particles properties.

The SPH code which I use is that developed by Thomas & Couchman (1992), which is called Hydra, named after the mythical beast of the same name.

One of the largest problems associated with SPH when in the presence of shocks, is stopping gases from passing through each other and intermingling. In SPH the standard way of preventing this from happening is by introducing an artificial viscosity term.

3. **Artificial Viscosity**

The artificial viscosity works by introducing an additional pressure to prevent flows from interpenetrating. This pressure is applied when calculating the properties of the particles, it takes convergent flows slows them down and dissipates the energy into heat, to equate for conservation of energy.

In Hydra, the artificial viscosity is added by replacing the pressure force $f_i$ with a pressure force $g$, where

$$g = \frac{2\pi}{3} \left( \alpha M_y + \beta M_y^2 \right)$$

and $\alpha, \beta$ is the particle’s specific energy, $\epsilon_i$ is the neighbouring particles’ properties, $M_y$ is the Mach number given by

$$M_y = \begin{cases} 0, & r_y \cdot \nabla_r > 0, \\ h_y \left( \frac{r_y \cdot \nabla_r}{c_y} \right), & r_y \cdot \nabla_r < 0, \\ \frac{c_y + c_y}{2}, & \text{particle separation}, \end{cases}$$

where $h_y = 0.1 c_y$, $r_y = \sqrt{r_y^2 - r_i^2}$

We test different values of $g$, to find the most appropriate value for the artificial viscosity, for several different shock tests.

4. **Testing**

We set up 4 different shocks ranging from no shock to a shock jump of 4 in density. Testing with different values of $\alpha$ and $\beta$. The diagram on the right shows a typical density jump of 3.

Running these on for a standard period of 2 time units, andInvesting the accuracy of the shock produced. The below diagrams show the change after a time 2 with different values for the artificial viscosity constants $\alpha$ and $\beta$.

A graph showing the density for a jump of factor 3 at time zero, before Hydra has been run

5. **Conclusions and Future Work**

From the results, it shows that there is a middle ground in which to place the artificial viscosity. Too much artificial viscosity and the shock dampens out too little and the shock is not accurately modelled, and oscillations occur. For many different shocks a standard form of $\alpha=1$ and $\beta=2$ give a good model of the shock.

Future tests and experiments, include changing the force $g$, to find a more appropriate way of equating the artificial viscosity for a range of shocks.

We will also look at an experiment, whereby two different gases pass by each other without any kind of shock occurring. Since particles in this situation would be converging at times, there would be as it stands an artificial viscosity applied, However this is not what is required as it will push the two gases apart and create a gap.

6. **References**