FARGO3D Workshop (ITA 2021)

1 Default setups

1.1 Standard fargo setup

1. Compile the standard setup with `make SETUP=fargo` and run the fargo3d executable with `./fargo3d setups/fargo/fargo.par`. You may use the utilities provided in `plot_fargo.py` as a starting point. Compilation with `make view` enables live plotting with matplotlib during the simulation run.
   The default configuration simulates planet-disk interaction with a Jupiter-mass planet.

2. Now try to change the planet mass to e.g. $5M_{\mathrm{jup}}$ and $30M_{\mathrm{earth}}$ and see what happens (edit planets/jupiter.cfg). You can also add another planet and activate migration.

3. What happens if you modify the aspect ratio?

4. Is angular momentum conserved in the simulation?

1.2 Multifluid setup

1. Now switch to the `fargo_multifluid` setup. It includes three different dust species with Stokes numbers of 0.1, 1 and 10 (see `fargo_multifluid.par`). How does the dynamics change with the Stokes number?

2. What happens if you switch off dust feedback (in `condinit.c`)?

2 Accretion

With an internal torque G due to viscosity the conservation of angular momentum in the disk leads to:

$$r\frac{\partial}{\partial t}\left(r^2\Omega\Sigma\right) + \frac{\partial}{\partial r}\left(r^2\Omega\cdot r\Sigma v_r\right) = \frac{1}{2\pi}\frac{\partial G}{\partial r} \tag{1}$$

with $G = 2\pi\nu\Sigma r^3\frac{\mathrm{d}\Omega}{\mathrm{d}r}$.
The steady state solution for v_r can be found as follows:

$$r^2\Omega\cdot r\Sigma v_r - \nu\Sigma r^3\frac{\mathrm{d}\Omega}{\mathrm{d}r} = C \tag{2}$$

$$J\cdot r\,v_r + \frac{3}{2}\nu\Sigma r^2\Omega = C \tag{3}$$

$$J\cdot r\,v_r + \frac{3}{2}\nu\cdot J = C \tag{4}$$

$$rJ\left(v_r + \frac{3}{2}\frac{\nu}{r}\right) = C \tag{5}$$

where J is the angular momentum and C an integration constant. Setting C to zero we obtain the equilibrium radial gas velocity in a steady state accretion disk:

$$v_r = -\frac{3}{2}\frac{\nu}{r} \tag{6}$$

Now the tasks are:

- Implement a steady state accretion disk setup in fargo3d. Which geometry should we choose?
- How can we improve the solution? Implement power law extrapolation boundary conditions.
- Try to use damping zones at the boundaries to stabilize the flow

3 β-Cooling and VSI

Now we want to go a step further and add additional physics to the code. In typical disks where we have a short cooling time scale, the Vertical Shear Instability (VSI) can develop. We would like to study this instability in a simple 2D-axisymmetric setup. You'll find the code in the folder `vsi` in `setups`.
What happens when you run the code? You can use the python script `plot_vsi.py` for plotting.
In the following we would like to implement a simple cooling recipe. A straightforward estimation would be to cool all temperatures back to the initial state within a characteristic cooling timescale β:

$$\frac{\mathrm{d}T}{\mathrm{d}t} = \frac{T(t) - T_0}{\beta} \tag{7}$$

The analytic solution is:

$$T(t + \delta t) = T(t) + (T(t) - T_0)\exp\left(\frac{\mathrm{d}t}{\beta}\right) \tag{8}$$

The goal is now to implement this kind of cooling recipe in the `vsi` setup. The location in the code should be in or after `substep_3()`.
You'll need to save the initial state in an extra field. Also note, that the field `Energy` is the internal energy density (erg / cm^3 in cgs units). What happens now, if you enable cooling with $\beta = 10^{-4}$?