Week 5 Report

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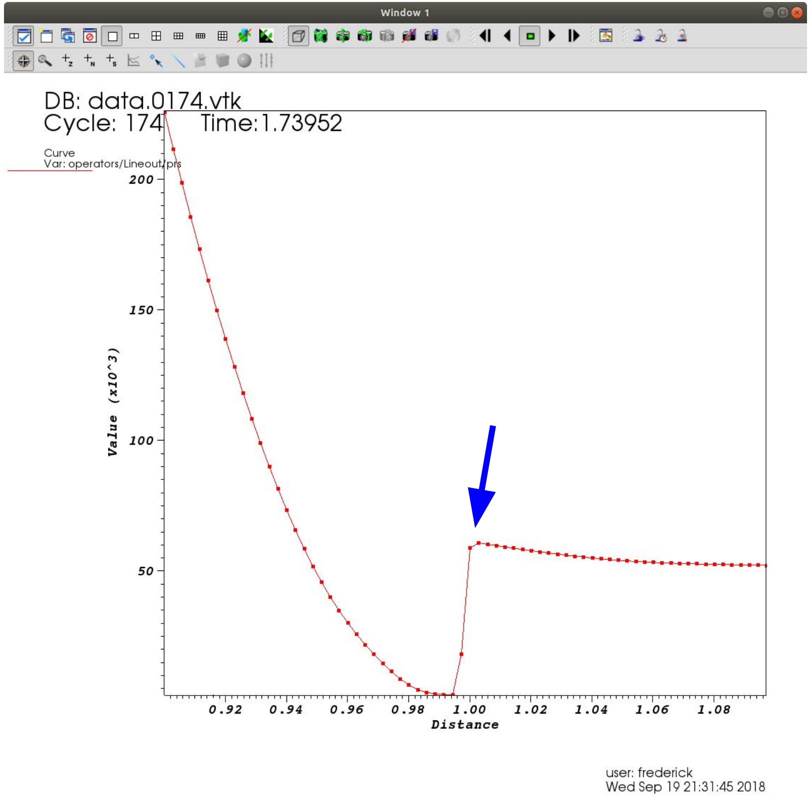
Transitioning to MHD modeling

- Model is stable in HD (hydrodynamic) module, reconfigure setup profile to simulate in MHD module.
    - Equations for poloidal field placed into init.c
        - In running the simulation, negative density errors (high magnitude) result, simulation ultimately stops with NaNs.
    - Showed that model is **generally unstable** in the MHD module
        - Code for magnetic field contribution was commented out. Running the simulation halts after t = 0.08 s with NaNs with highly divergent negative density (1e200).

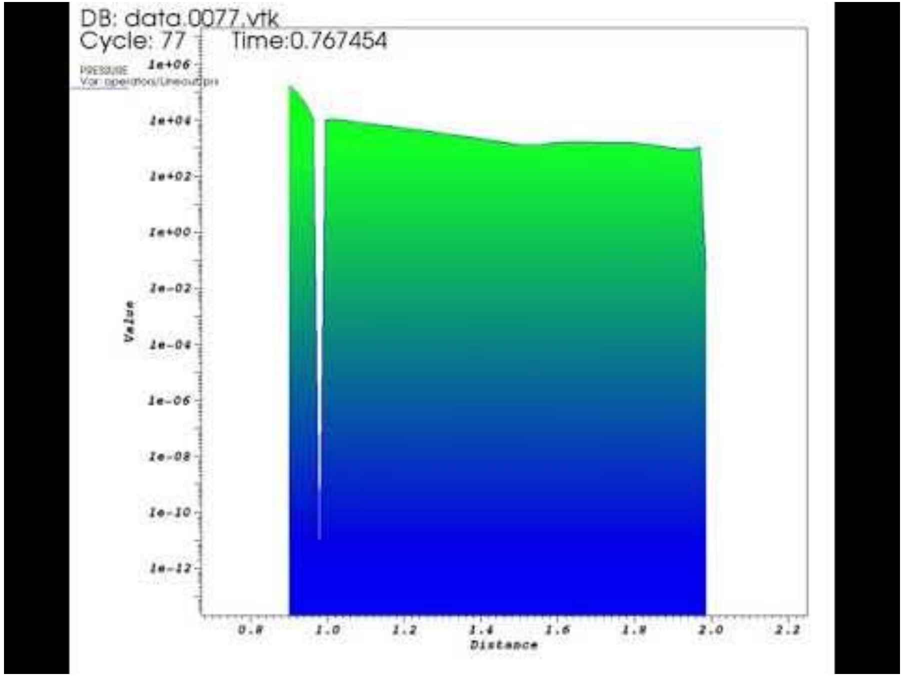
Backing Up Slightly

- Due to large errors in computation for my model in the MHD module, I returned to the HD module to analyze the issue of negative pressure about r = 1.0.
  - Ran high resolution simulation about (0.9 < r < 1.1).
    - Notice unusual disjunction in pressure profile about r = 1.0
      - Such disjunction occurs less severely for density.



Boundary Conditions

- In order to constrain the pressure exterior to the star, a boundary condition is set at the outermost edge of the computational domain.
    - This boundary is time independent, and takes values for vacuum pressure and density.



Log(pressure) vs. Radius for (0.9 < r < 1.1)
Notice the sharp disjunction that develops at r = 1.

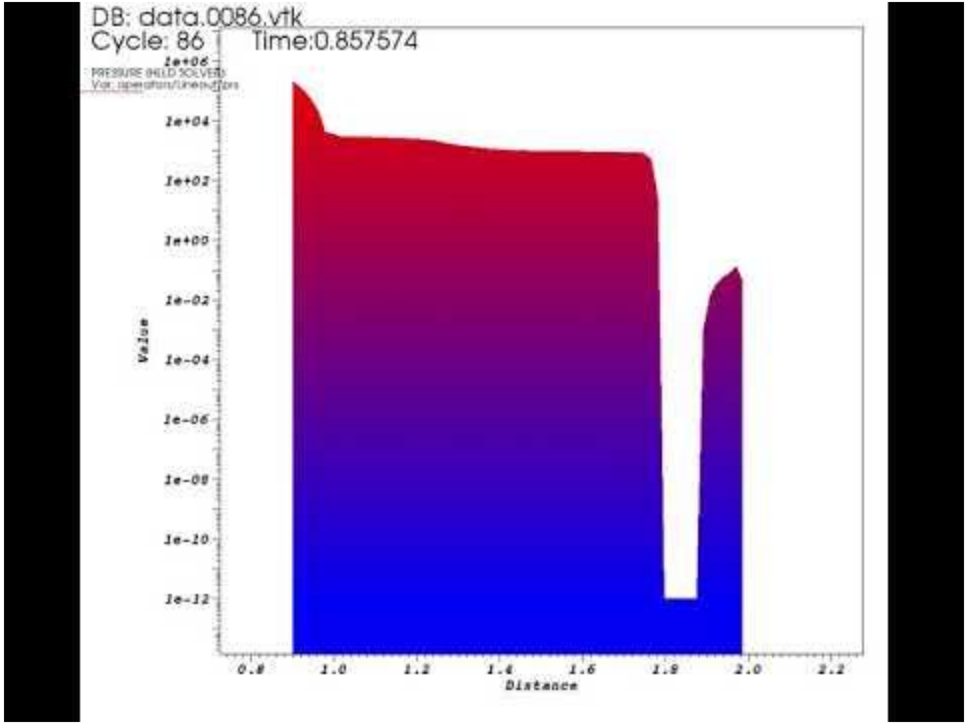
Changing Numerical Solver Method*

- For the prior simulation (and all prior analysis), the ‘tvdlf’ solver was implemented, which uses a Lax Friedrichs scheme for iterating computation results.
    - Such a computational method is the *least* accurate (however efficient) method of numerical iteration.
        - Categorized with “greatest diffusion” (a negative attribute) among PLUTO’s various solver schemes.
- In the interest of investigating how changing our solver method alters the simulation, we choose the ‘hllc’ solver, which is a Harlen, Lax, Van Leer approximate Riemann Solving scheme that “restores middle contact discontinuity”.

*See page 36 of PLUTO User Manual for more information

Changes in Simulation from Switching Solver

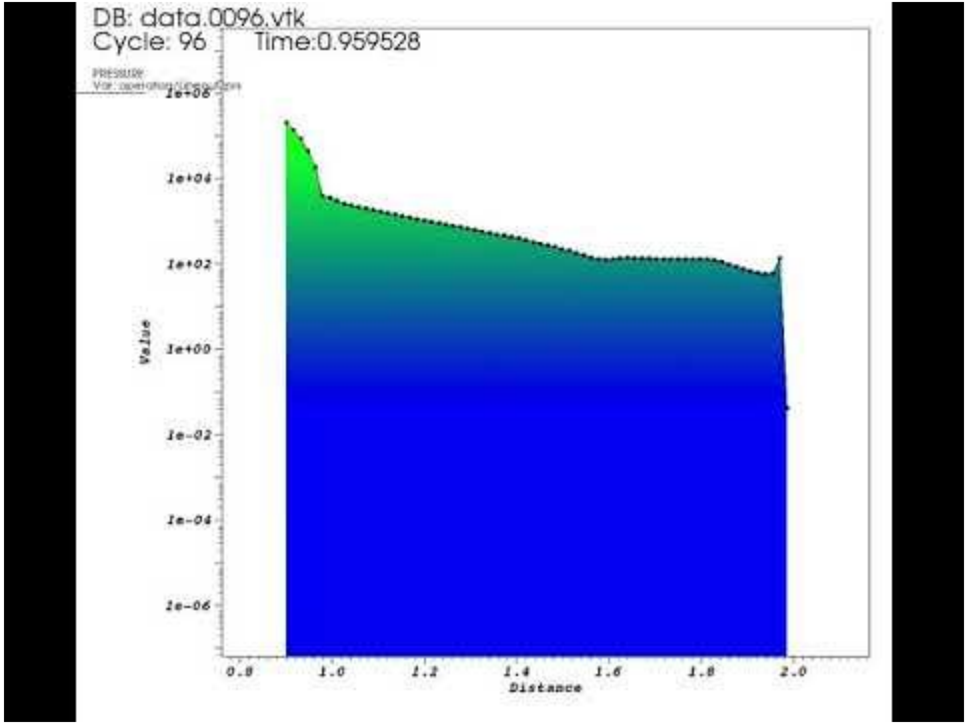
- With all other parameters kept the same, we change from the ‘tvdlf’ to ‘hllc’ solver and simulate our results. We see that by changing our solver, we eliminate the persistent discontinuity at r = 1 in the former simulation using the ‘tvdlf’ solver. Despite these gains, we also notice that discontinuities external to the star persist with time.



Log(pressure) vs. Radius for (0.9 < r < 1.1)

Pressure Floor

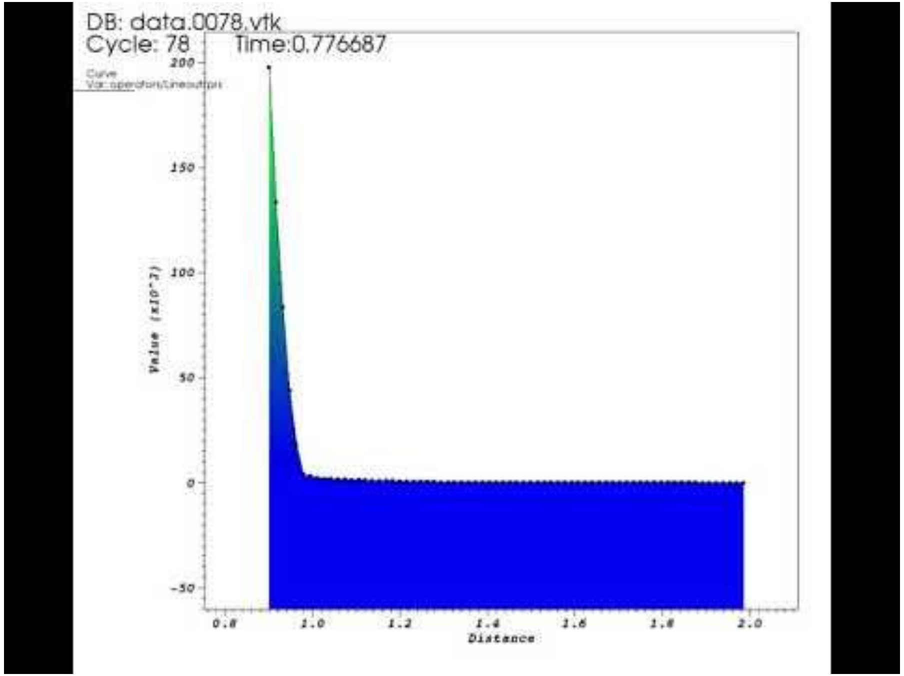
- In line with former conditions imposed for density and pressure at r_0, I create a User-Defined Boundary Condition for pressure, specifying that pressure must not go below vacuum pressure (a value specified based on vacuum density).
- Simulations with the imposed pressure floor show the well-behaved nature of the pressure profile



Log(pressure) vs. Radius for (0.9 < r < 1.1)

Achieved Stability in MHD

- Taking our updated HD model (no magnetic component) and re-running the code with the MHD module, we see that the model **is stable** over the computational time domain {t = 0, t = 2}.



Pressure vs. Radius for (0.9 < r < 1.1)
Notice not log[pressure]!

Goals for Next Week

- With the precondition of stability in the MHD model being satisfied, we can now work to implement the magnetic field components:
    - Pure Poloidal Field
    - Pure Toroidal Field
- This will require computing boundary conditions for the magnetic field. Such boundary conditions will be motivated by Kuhn’s former analysis of such regions.