UNIVERSITÄT GRAZ UNIVERSITY OF GRAZ



SETTLING MOTIONS IN 1-D STRATIFIED MODEL OF SOLAR-CORONA



Presented By: VARTIKA PANDEY M.Sc. PCUM 2021 ABOUT ME :

- Country of origin: India
- Completed my Masters in

August 2020.

• Masters thesis: "Low frequency radio

signatures of deflections on CME's by

Coronal Streamers" completed at Kodaikanal

Solar Observatory ,IIA, India.



- Started PhD at Karl Franzens Universitat Graz in the working group ,MHD simulations for solar corona to study the coronal heating' from December 2020.
- Supervisor: Phillipe Bourdin
- Formal Supervisor: Astrid Veronig

INTRODUCTION:

• Currently we are trying to run a 1-D atmospheric stratification model for the whole solar domain taking the work of Bourdin (2014) as a reference .



Figure 1: Combined average stratification of the temperature (red solid line) and the density (blue dashed) in an analytic hydrostatic equilibrium from the solar interior to the corona from Bourdin(2014).

- The profile should be settled in hydrostatic equilibrium.
- So the model tries to settles by starting relaxation motions which is done by igniting Shock waves.
- The **top boundary** is closed boundary so that the waves reflect back.
- The **bottom boundary** is taken from the photospheric observations i.e. velocity and magnetic field vectors.
- Initial condition: analytic solution of the hydrostatic equilibrium, based on a composite of model solutions for the solar interior and lower atmosphere, extended towards observations of the outer corona.
- **Modules used:** solar_corona.f90, boundcond.f90, hydro.f90



Fig.2. Time evolution of the vertical velocities in a 1D stratified hydrodynamic atmosphere (Bourdin 2014).

EXAMPLE OF SWITCH-ON EFFECT

- •Here we show a 3D MHD setup with a turbulent flow , Bourdin (2014).
- •Left Boundary : Here the mixing is applied through the driving velocities.
- •Right Boundary : It is kept open for outflows.
- •Then we can see the turbulent flow evolving through time in two cases:
 - When switched on smoothy.
 - Instant switching on.

Snapshot #0













Smooth #116



Smooth #117

SWITCH-ON TIME FOR PARAMETERS:

-We are using approach by Bourdin (2014) for switching on different parameters in the simulation domains.

-Strong velocity damping till initial 20 minutes.

-Spitzer-type heat conduction smoothly sets in starting with minute 10 and is fully active at minute 30.

-The radiative losses are smoothly switched on from minute 15 to 35.

-Whole simulation domain cools due to heat conduction.

-Finally, the velocity damping is smoothly switched off over a time interval of 20 minutes, spanning from minute 20 to 40.

-After 40 minutes, all physical terms are fully active and the velocity damping has faded out, see Fig. 3. Now the system evolves self-consistently



Fig. 3 Representation of how the different terms in the model are switched on, Bourdin(2014)

Doing the same method we were still not getting rid of the disturbances and there was a permanent downflow of material due to negative velocities when newton cooling and radiative losses are switched on.

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Fig.4. This is the output of the simulation with newton cooling and radiative losses on and we can see ve clearly the negative velocities suggesting a downflow of material.

Artificial Heating function:

- So now we are trying to introduce a new artificial heating function which we can be switched on from the beginning along with the cooling and the lost energy is provided to the system.
- As this is an artifical function it can be faded out once the system evolves in a stable way.
- There were two possible approaches for this:
 - Heating per volume.
 - Heating per particle.
- We chose the second scheme i.e. heating per particle, as to avoid the runaway effects which can be created when the coronal density is too low i.e. thin corona and it can then get heated up to really high temperatues creating runaway effects.

```
subroutine calc heat cool H part(df,p)
1
  Apply external heating and cooling profile for heating per particle.
1
1
     use Diagnostics,
                           only: max mn name
     use EquationOfState, only: gamma, getmu
     use Mpicomm,
                           only: stop it
1
     real, dimension(mx,my,mz,mvar), intent(inout) :: df
     type (pencil case), intent(in) :: p
I
     real, dimension(nx) :: tmp,n_rho
     real :: mu
     add to energy equation
! Calculate number of particles
        n rho = rho / (pc get parameter ('m proton', label=quantity) * mu)
     1
    call getmu(mu)
    n rho= p%rho/ (1.67d-27/unit mass * mu)
     if (ltemperature .and. ltemperature nolog) then
       tmp = p%rho1 * p%cp1 * gamma * deltaH part_init z(n) * n rho
!write (100+iproc,*) 'delta T :', tmp
! flush (100+iproc)
       df(l1:l2,m,n,ilnTT) = df(l1:l2,m,n,ilnTT) + tmp
       tmp = alog (1 + tmp)
     elseif (ltemperature) then
       tmp = p%TT1 * p%rho1 * p%cp1 * gamma * deltaH part init z(n) * n rho
!write (100+iproc,*) 'delta lnT:', tmp
! flush (100+iproc)
       df(l1:l2,m,n,ilnTT) = df(l1:l2,m,n,ilnTT) + tmp
     else
       if (lentropy) &
            call stop it('solar corona: calc heat cool deltaH part:lentropy=not implemented')
     endif
E
```

 $tmp = p\%Tt1p\%rho * p\%cp1 * gamma * deltaH_part_init(z) * n_rho$

- Here tmp is the function that we have implemented.
- First part of the equation i.e. $\frac{1}{Tt1} * \frac{1}{\rho} * \frac{1}{c_{p1}} * \gamma$ gives $\frac{1}{T*\rho*c_v}$ which is a multiplication factor in the entropy equation in pencil-code.
- We are using logarithmic temperature which can be replaces with entropy.
- deltaH_part_init (z) is the energy differnece profile that is to be provided to compensate for the heat loss.
- At the end n_rho is multiplied to the function because we divided the pervious profile with initial density of the particles (as density evolves in overall simulation, so we take initial density) so as to account for heating per particle.

Future Goals:

- Current goal is to reduce the amplitude of the vertical velocity shock wave disturbance so that our model can be used as a stable initial condition in longer runs.
- Once this is done we can use the same grid, the same diffusion parameters, same boundary conditions and same vertical velocity profile as initial conditions in the production run for reproducing solar coronal structures with different magnetic activity levels.

Thank you?