Settling motions in 1D stratified models of solar corona.

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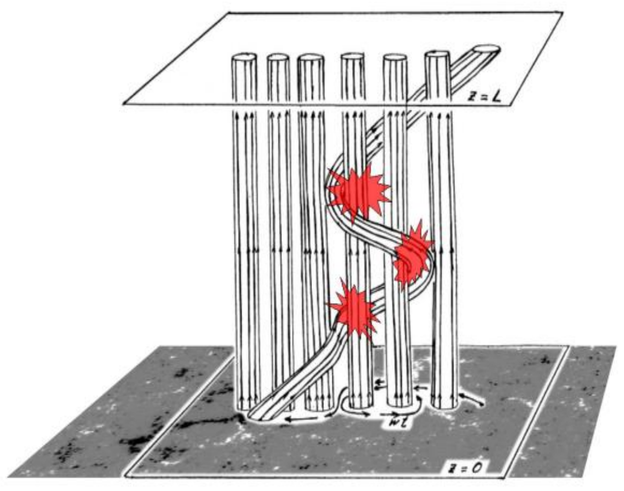
Abstract

We aim at setting and driving 3D magneto-hydrodynamic simulations of the Sun with photospheric magnetogram observations to get a better understanding of the heating mechanism and energy dissipation in the solar corona and thus aiming to move a step closer towards the long-standing solar coronal heating problem.There are already some models that study coronal heating using different heating mechanisms. The working mechanism for our model is the field-line braiding mechanism generating an upward Poynting flux, where plasma motions advect the field. This flux travels as magnetic perturbations into the corona indicating actual magnetic-energy transport. These perturbations can then induce electric currents in the solar corona which are then dissipated due to DC heating.We start the computation with an initial atmospheric stratification that is usually not in hydrodynamic equilibrium. Because settling the initial inequilibrium is costly in large-scale 3D models, instead, we use a 1D model that spans from the solar interior to the corona for finding the numerical equilibrium that exactly fits to the simulation parameters. This new atmospheric stratification we can now use as the initial condition for large simulation runs. Also, we implement and employ an artificial heating function that compensates for a lack of heating in the early phase of the model, where perturbations have not yet reached the corona. We like to start the 3D model with the most realistic physics and less vertical settling motions. This procedure finally allows us to compare our model output with actually observed Doppler shifts in the corona.

Overview

- In our study we tackle the long standing coronal heating problem.
- We run observationally driven 3D MHD model to verify the field line braiding mechanism proposed by Parker (1972); FIG. to the right.
- Initial profiles used, spans from solar interior to corona.
- Numerical equilibrium ≠ Analytical equilibrium.
- Deviation causes the profiles to settle by igniting shock waves that deteriorate the final result.
- Thus, these profiles are settled in hydrodynamic equilibrium that fits exactly to simulation parameters .
- The output equilibrated profiles then can be used as initial condition for larger runs.



Working Mechanism

Initialise 1D model with temperature and density stratification. → **Smoothly switch-on simulation parameters** → **Let the simulation settle into hydrodynamic equilibrium.** → **Use 1D settled atmosphere as initial condition for 3D model.**

Methods

- In our 1D stratification model the physical box size is 163.8 Mm.
- The number of grid points in z-direction are 4096.
- The vertical resolution is 40 km.
- We use the pencil-code together with six order spatial derivatives.
- BOUNDARY CONDITION: The box is closed for heat flux as well as mass transport at top and bottom boundaries.
- Different parameters are switched on smoothly in simulation domain:
  - Strong velocity damping in beginning for 5 hours and than fades out smoothly .
  - Viscosity(nu) and heat conduction(chi) are of order 10^8 m^2/sec.
  - We include radiative losses (Cook et.al. 1989).
  - Newton cooling stabilises the chromosphere and lower transition region.
- We implement an artificial heating function with two schemes to compensate for the lost energy.
  1. Heating per volume : sometime leads to runaway effect.
  2. Heating per particle : give better results.
- The main equation used for heating per particle is:

$$\frac{d(lnT)}{dt} = \frac{1}{T} \cdot \frac{1}{\rho} \cdot \frac{1}{c_p} \cdot \gamma . (heat\_profile) . n$$

Initial atmospheric stratification

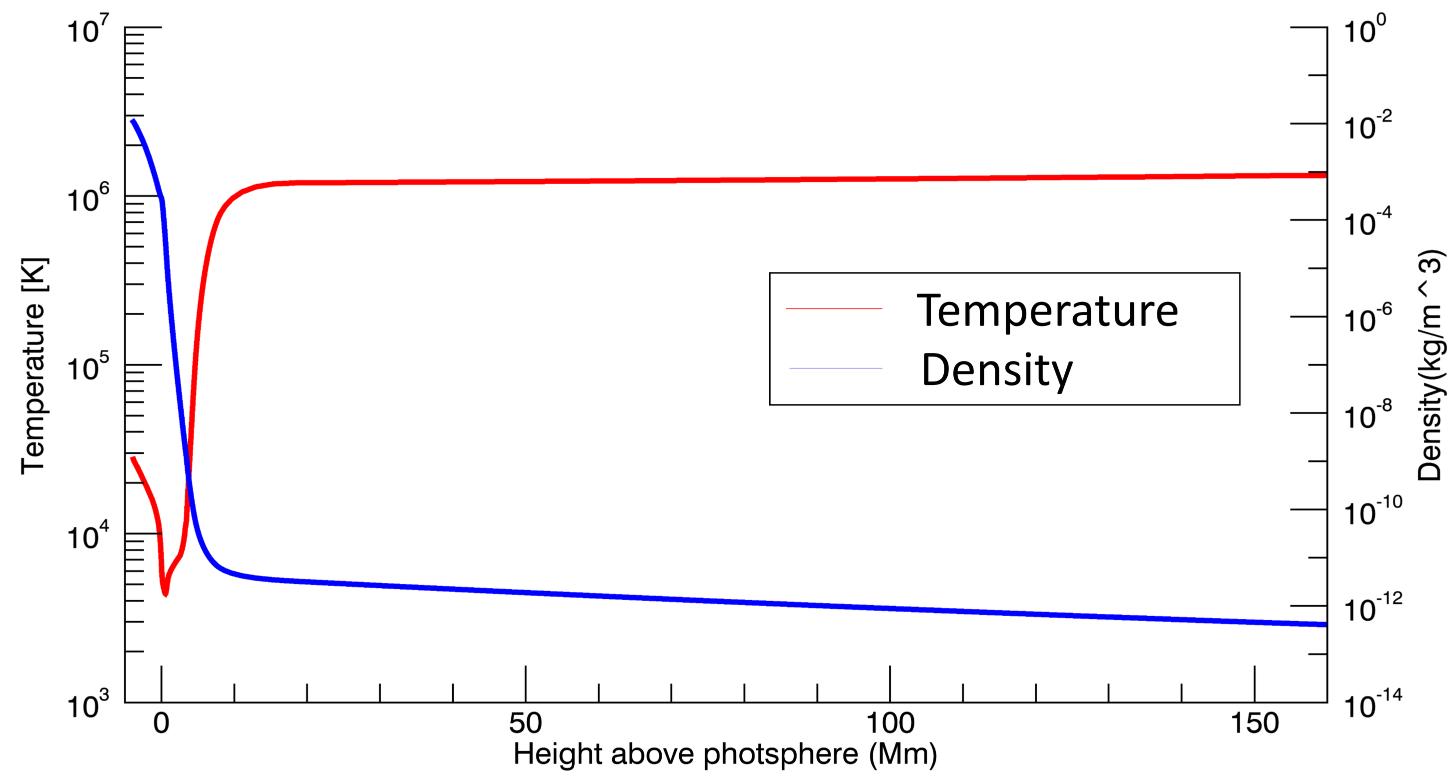
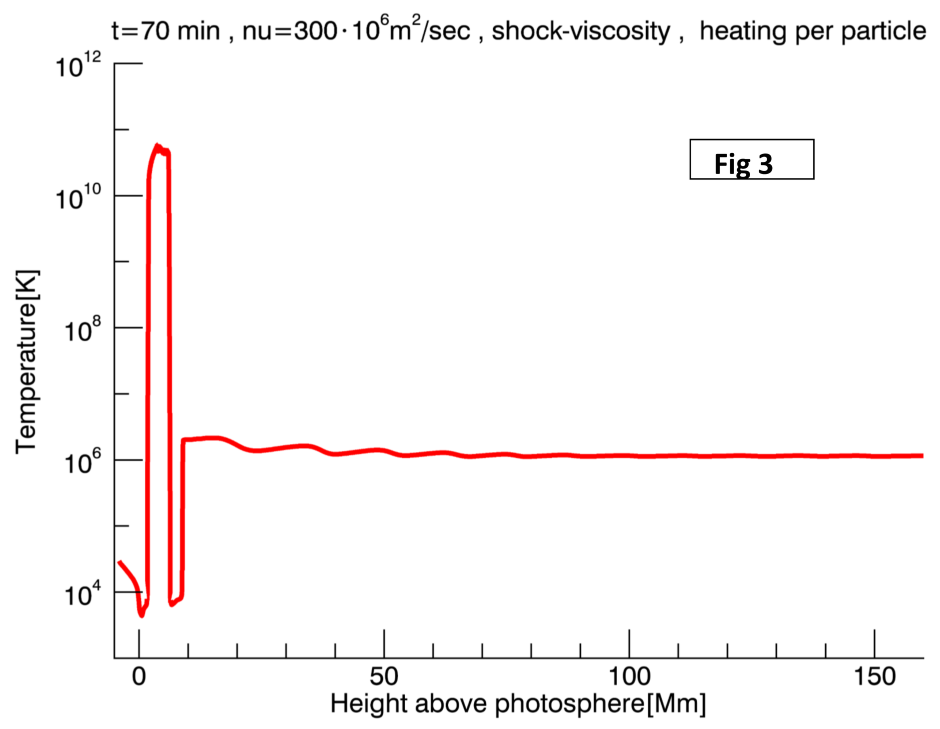


Fig. 1 : Initial temperature and density profiles.

Parameter studies on viscosity



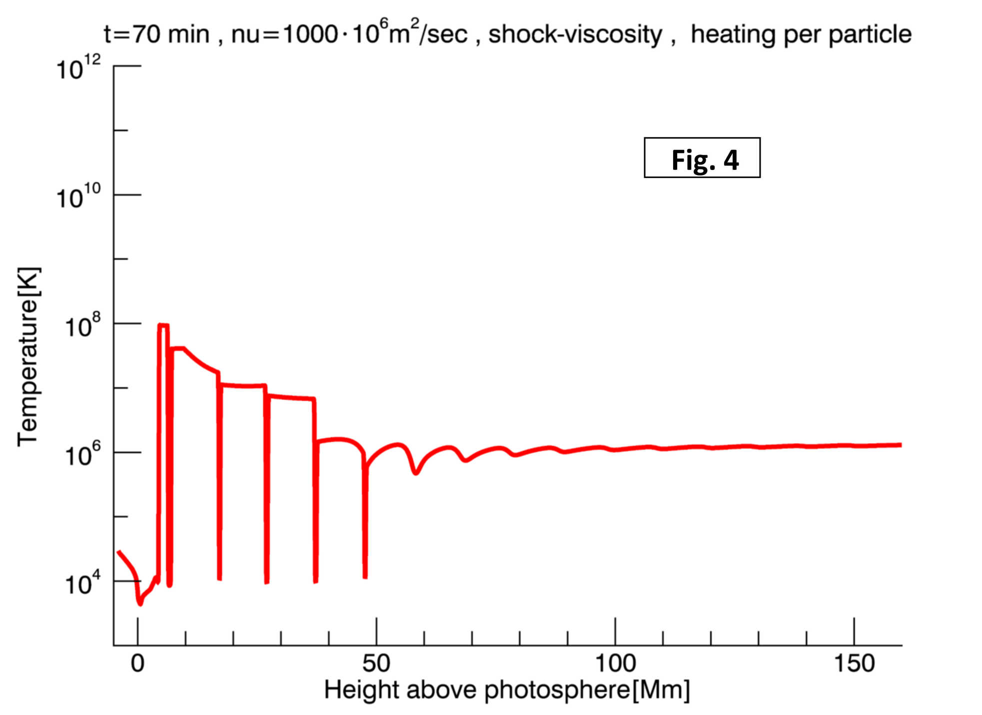
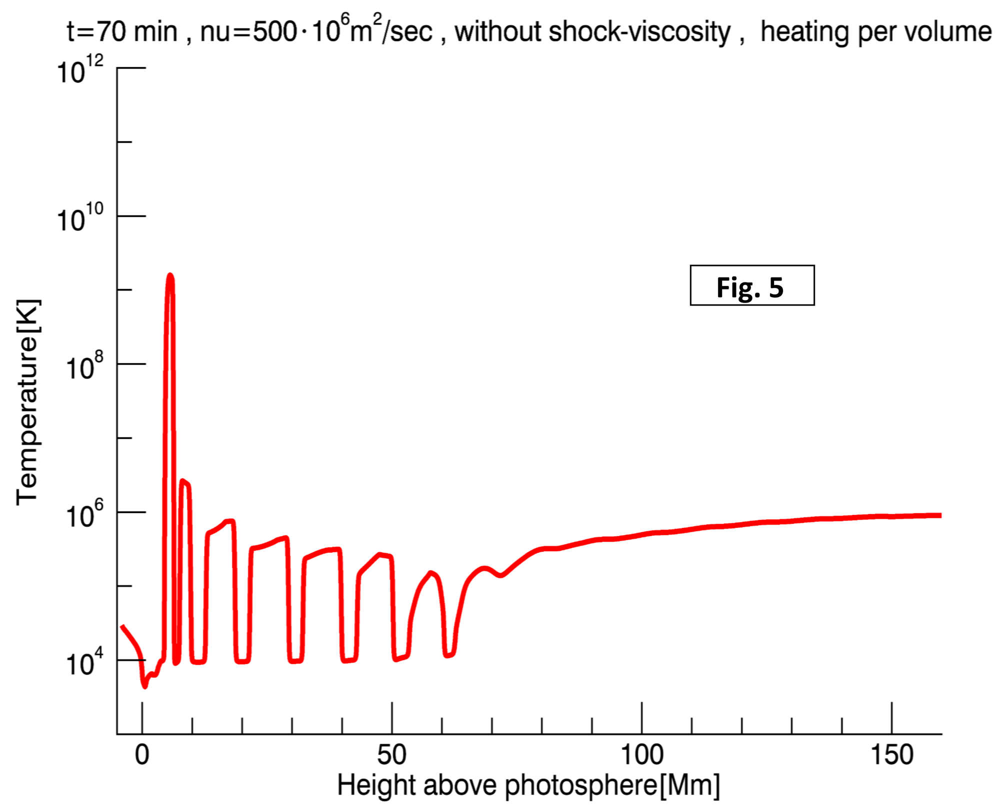


Fig 3 and 4: The difference in output due to changed nu parameter.



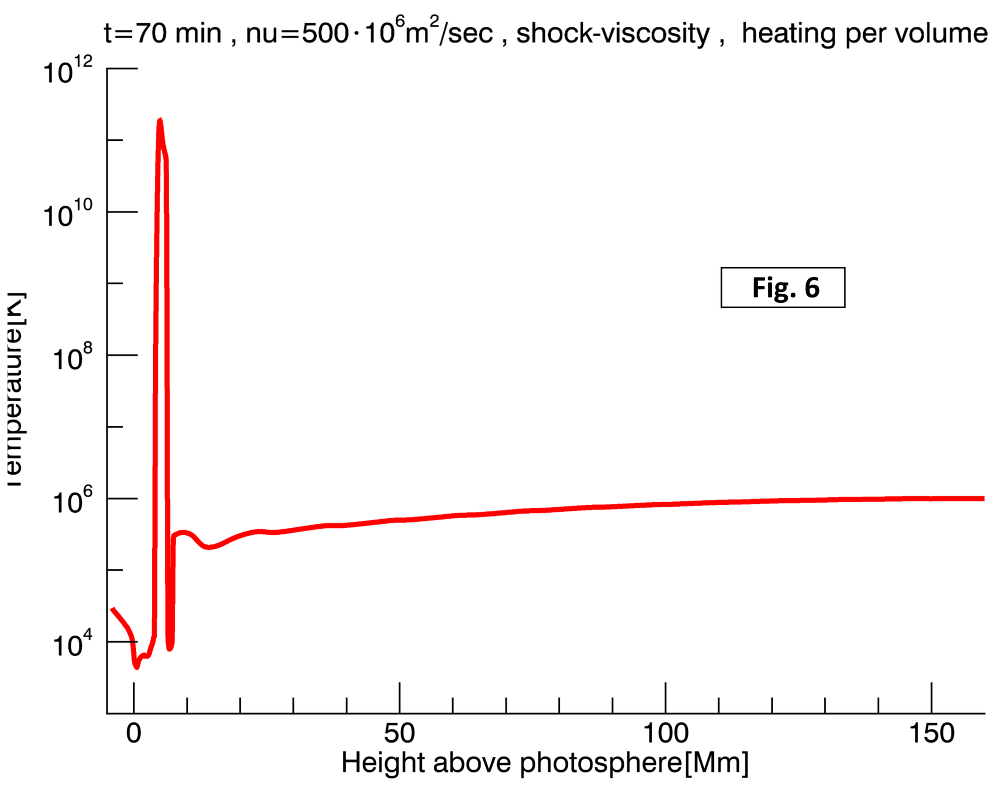


Fig 5 and 6: The difference in output due to the absence and presence of shock diffusion.

Heating/Cooling Terms

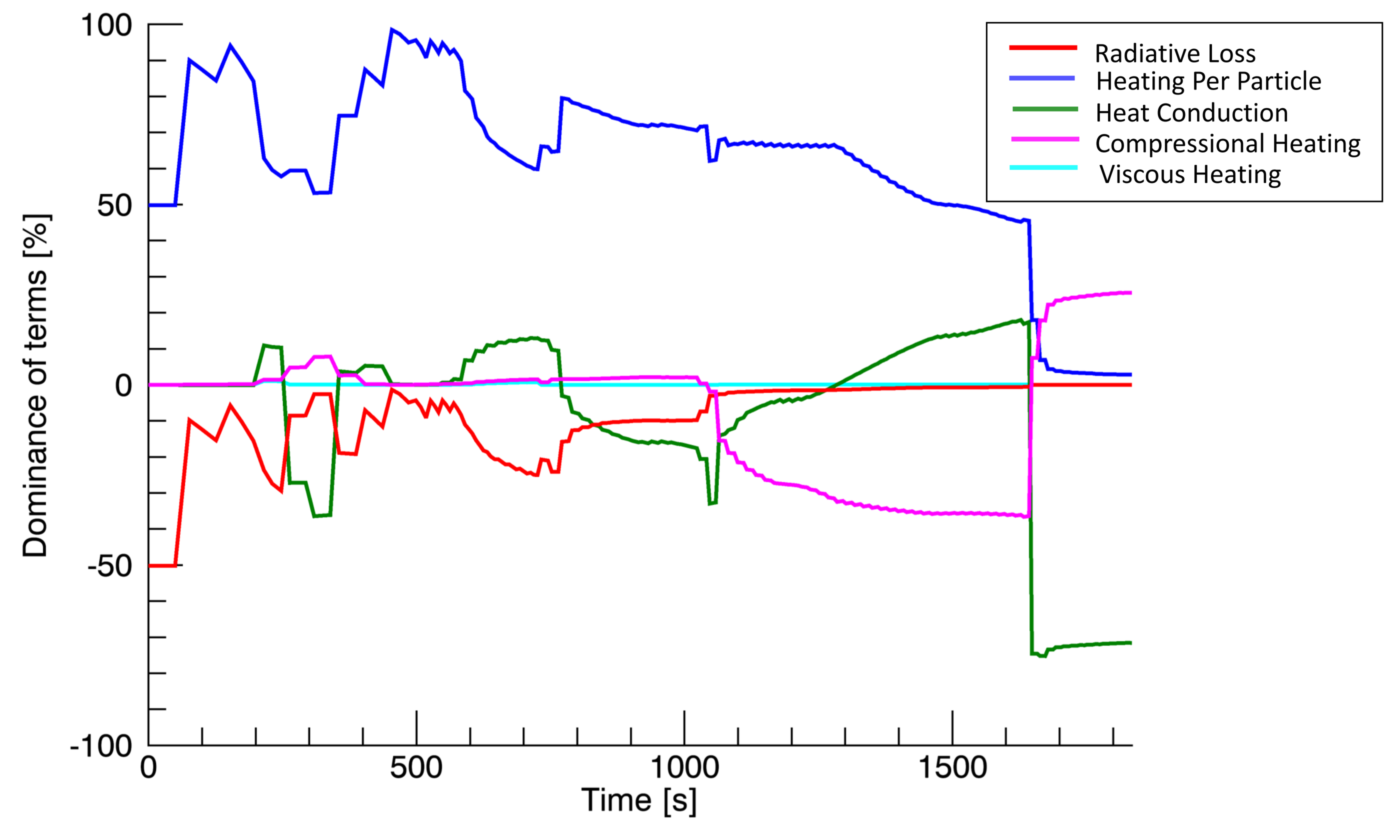


Fig. 2. The figure shows the percentage of heating caused by various heating terms in our simulation

Conclusion and outlook

- We can sustain the high temperatures in the corona with our artificial heating function but still need to work on the disturbance due to steep density gradient at transition region.
- Neither heating per particle nor heating per volume is an exact solution.
- Currently we are working on improving our heating function to limit the heat input.
- We are also working on to get the simulation boundaries as close as real.
- Currently we don't include magnetic field in our model but once the system gets under control we will add average magnetic pressure and stabilise it again.
- Our aim is getting the final vertical velocities lower than 3km/sec.
- Once this is done we can use the hydrodynamically settled stratifications as initial conditions in the production run for reproducing solar coronal structures with different magnetic activity levels.

References

- Bourdin, P.-A. 2014, Central Eur. Astrophys. Bull., 38, 1
- Bourdin, P.-A., Bingert, S., & Peter, H. 2013, A&A, 555, A123
- Bourdin, P.-A., Bingert, S., & Peter, H. 2014, PASJ, 66, 1
- Bourdin, P.-A., Bingert, S., & Peter, H. 2015, A&A, 580, A72
- Cook, et. Al., 1989, ApJ, 338, 1176
- Parker, E.N. 1972, ApJ, 174, 499
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