Toward self-consistent 3D simulations of solar wind using compressible MHD

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The solar corona has 1 Million Kelvin plasmas while the photosphere underneath the corona only has 6,000 K. How to maintain the high temperature plasma against radiative losses and thermal conduction has been a big problem in solar physics. Moreover, the existence of super Alfvénic flows or the solar wind from the high temperature corona is also a long standing problem.

The ultimate energy source to maintain the high temperature corona and high speed solar wind is the photospheric convection motion. The kinetic energy of the convection is considered to be transported to the upper layer as Magnetohydrodynamic (MHD) waves generated by coupling between the convection and embedded magnetic field there.

Among the MHD waves, Alfvén waves are considered to be most important for the corona and the wind because Alfvén wave is basically incompressible so that Alfvén wave will not suffer shock dissipation even in the highly stratified layer between the photosphere and the corona.

One of the most plausible dissipation processes of Alfvén waves in the corona is Alfvén turbulence[1] driven by Alfven wave collisions, which is purely incompressible process. The current standard model of the solar wind is constructed assuming incompressible Alfvén turbulence[2].

On the other hand, the compressibility is often neglected in the solar wind model. However recent MHD simulations[3] reveal the importance of compressibility even in the solar wind. To improve the standard imcompressible solar wind model, we have conducted 3D simulations of solar wind using fully compressible MHD formulations. The hot corona and the solar wind can be reproduced simultaneously as a natural consequence of Alfven wave propagation and dissipation. In this talk, I will explain why the compressible effect is important in incompressibly heated solar atmosphere.

References
[1] Matthaeus et al., ApJL, **523**, L93 (1999)
[2] Cranmer et al., ApJS **171**, 520 (2007)
[3] Shoda et al., ApJ, **880**, 2 (2019)

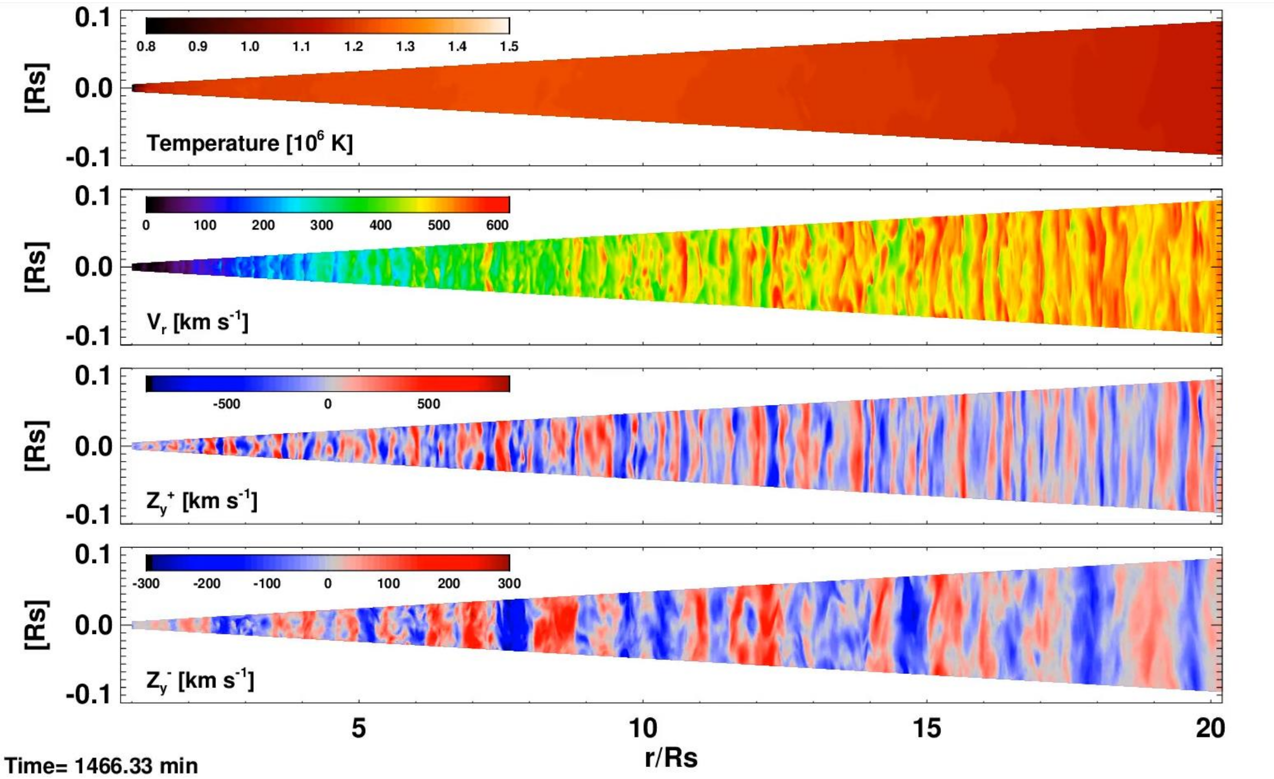

Fig. 1 Temperature, radial velocity, outwardly and inwardly propagating Elsässer variables (From top to bottom) in r-θ plane of 3D MHD simulation. The obtained quasi-steady state has both the high temperature corona and the high speed solar wind simultaneously as a natural consequence of Alfvén wave injection from the bottom.