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Reproducing the Solar Wind proton temperature profile via DNS of MHD turbulence

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Context: The Solar Wind proton temperature T_p shows a radial profile $R^{-0.9}$ significantly shallower than the adiabatic $R^{-4/3}$ profile [Totten et al 1996]. This temperature profile has been attributed to turbulent heating, which requires a dissipation rate equal to $Q = 3.6\,10^{-5} T_p U/R [J/(kg\,s)]$ (1) [Vasquez et al 2007]. The possibility of a turbulent heating large enough to modify the radial profile of the temperature has not been verified yet via direct numerical simulations.
Aim: We want to test if MHD turbulence developing in the range [0.2,1] AU is able to reproduce the observed $R^{-0.9}$ temperature profile.
Method: We use the expanding box model (EBM) [Grappin & Velli 1996] which incorporates the effects of expansion into the compressible MHD equations, and so allows to follow the evolution of the plasma advected by the solar wind between 0.2 and 1 AU. In the absence of turbulence, the $R^{-4/3}$ temperature profile is obtained. We start at 0.2 AU with mean field almost aligned with the radial and $k_\perp^{-1}$ spectrum perpendicular to the mean field [Verdini, Grappin 2016]. Simple phenomenology (Kolmogorov) suggests that the ratio between turbulent heating and the required heating (1) is close to M^2/ϵ, where M is the Mach number of the large eddies and ϵ is the nonlinear time normalized by the transport time of the plasma by the wind. We thus explore the (M, ϵ) parameter space and examine whether a large enough value of M^2/ϵ indeed allows to recover the temperature profile observed by Totten et al (1996).
Results: We have obtained significant slowing down of the adiabatic cooling by considering increasing Mach numbers and/or decreasing ϵ and approach in some cases the $R^{-0.9}$ temperature profile. The role of the compressibility in the cascade is examined.