Turbulence and Energy Dissipation in the Interplanetary Medium: Theory, Simulations and Spacecraft Observations

N. Andrés[1,2], F. Sahraoui[3], M. Brodiano[1], S. Huang[4], L.Z. Hadid[3], S. Galtier[3], P. Simon[3], P. Dmitruk[1]
[1] Physics Department, University of Buenos Aires (UBA), Buenos Aires, Argentina
[2] Institute of Astronomy and Space Physics, UBA-CONICET, Buenos Aires, Argentina
[3] Laboratoire de Physique des Plasmas, CNRS-Ecole Polytechnique-Sorbonne Université-Paris-Saclay-Observatoire de Paris-Meudon, Palaiseau, France
[4] School of Electronic Information, Wuhan University, Wuhan, People's Republic of China
e-mail (speaker): nandres@df.uba.ar / nandres@iafe.uba.ar

A long-established challenge in the solar-wind community is the so-called heating problem. It is manifested by the fact that the solar wind's proton temperature decreases slowly as a function of the radial distance from the Sun, in comparison to the prediction of the adiabatic expansion model of the solar wind (e.g., Marsch et al. 1982). While several scenarios have been proposed to explain those observations, the main candidate is certainly local heating of the solar wind plasma via the turbulent cascade (e.g., Matthaeus & Velli 2011). In this picture, the energy that is injected at the largest scales in the solar wind will cascade within the inertial range until it reaches the dissipation scales, where it is eventually converted into thermal heat of the plasma particles (see, Kiyani et al. 2015). This framework has led to several investigations to estimate the energy cascade rate in the solar wind at different scales and different heliocentric distances using theoretical, numerical, and observational strategies.

During this talk, we will discuss our recent theoretical results using two particular compressible models. Specifically, we have derived exact relations for fully developed homogeneous isothermal and polytropic magnetohydrodynamic (MHD) turbulence (see, Andrés & Sahraoui, 2017; Simon & Sahraoui, 2021). Using the incompressible (Politano and Pouquet *et al*., 1998) and the compressible exact relations, we will present our observational results at different heliocentric distances using the recent NASA's mission Parker Solar Probe (Figure 1). Finally, we will summarize and discuss the main numerical and observational results and its implications in the solar wind heating problem.

References
Marsch et al. JGRA, **87**, 52 (1982)
Matthaeus & Velli. Spa. Sci. Rev. **160**, 145 (2011)
Kiyani *et al.* Philos. Trans. Royal Soc. **373**, 2041 (2015)
Andrés & Sahraoui. Phys. Rev. E, **96**, 053205 (2017)
Simon & Sahraoui. ApJ, **916**, 49 (2021)
Politano & Pouquet. Phys. Rev. E, **57**, R21 (1998)

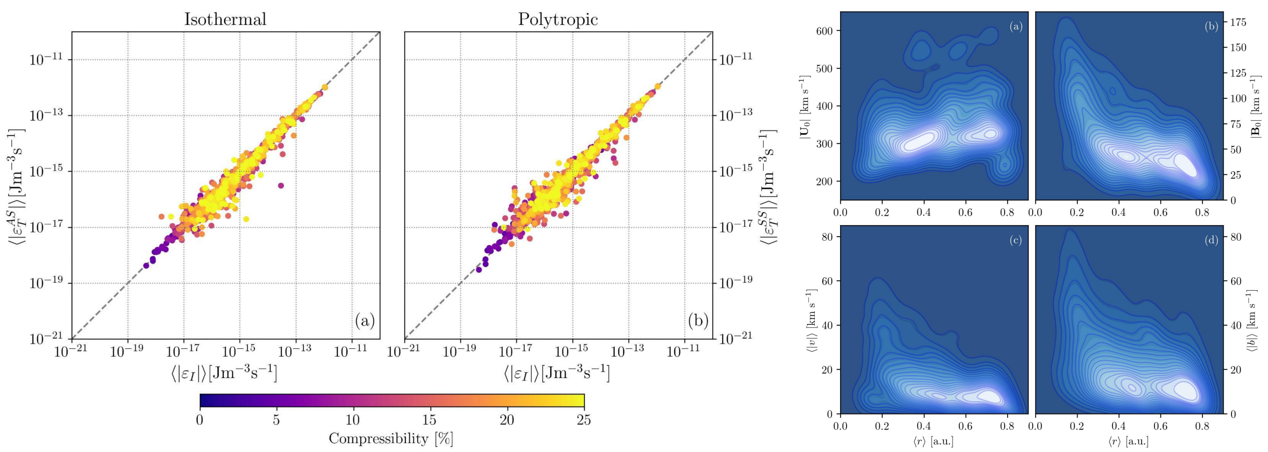

Figure 1: Total compressible energy cascade rate (absolute values) in the solar wind MHD scales as a function of the incompressible ones in the case of using an isothermal (AS) and polytropic (SS) model, respectively (left). Bivariant kernel density estimation for the mean (a and b) and fluctuating (c and d) velocity and magnetic field absolute values as a function of the heliocentric distance (right).