Interaction of Turbulent Fluctuations and Interplanetary Shocks: Observations and Theoretical Aspects

A. Pitňa*(1), Gary P. Zank(2), L.-L. Zhao(2), L. Adhikari(2), M. Nakanotani(2), J. Šafránková(1), and Z. Němeček(1)
(1) Charles University, Prague, Czechia, e-mail: alex@aurora.troja.mff.cuni.cz
(2) The University of Alabama in Huntsville, Huntsville, USA

Throughout the solar wind and other space plasmas, one can frequently observe collisionless magnetohydrodynamic (MHD) shocks. These shocks serve as natural sites for plasma heating, propelling charged particles to energies beyond the thermal range through various Fermi acceleration mechanisms. The involvement of upstream and downstream fluctuations is pivotal in these processes, acting as scatter centers. Unraveling the intricacies of how fluctuations traverse the shocks offers invaluable insights into a myriad of shock-related studies. From both the theoretical and observational perspective, our understanding of the complex interaction between the fluctuations and shocks is poorly understood, owing to the fact that both the exact nature of turbulent plasma fluctuations and the processes at/around the shock front are generally not known.

In this paper, we investigate the interaction of fast shocks with solar wind turbulent fluctuations in two scenarios. First, employing a large set of fast forward (FF) shocks observed by the Wind spacecraft with varying upstream conditions and Mach numbers [1]; second, we exploit a simultaneous observations of upstream and downstream plasma of the Earth's bow shock. We estimate upstream and downstream power spectra within one-hour intervals adjacent to the shock front and we calculate theoretically predicted downstream power spectrum employing a recently developed framework of the Zank et al. (2021) [2] transmission model. We discuss the accuracy of the model and the role of various uncertainties in the analysis. Our results suggest that the turbulent fluctuations decay as they propagate further downstream of the IP shock front and that this decay can be connected to the increase of temperature in the downstream region as reported by Pitňa et al. (2024) [3].

1. A. Pitňa, G. P. Zank, M. Nakanotani, L.-L. Zhao, L. Adhikari, J. Šafránková, Z. Němeček, "Transmission of Magnetic Island Modes across Interplanetary Shocks: Comparison of Theory and Observations" *Journal of Physics: Conference Series*, **2544**, 1, July 2023, 012009, doi: 10.1088/1742-6596/2544/1/012009.

2. G. P. Zank, M. Nakanotani, L.-L. Zhao, S. Du, L. Adhikari, H. Che, J. A. le Roux, "Flux Ropes, Turbulence, and Collisionless Perpendicular Shock Waves: High Plasma Beta Case" *The Astrophysical Journal*, **913**, 2, June 2021, 127, doi: 10.3847/1538-4357/abf7c8.

3. A. Pitňa, J. Šafránková, Z. Němeček, G. Pi, G. P. Zank, L.-L. Zhao, L. Adhikari, M. Nakanotani, "Turbulent Heating of Solar Wind Plasma Downstream of Magnetohydrodynamic Shocks", 2024, accepted for publication in *The Astrophysical Journal*