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Power spectral density of magnetic field and ion velocity fluctuations from inertial to kinetic ranges

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The solar wind is a unique laboratory to study the turbulent processes occurring in a collisionless plasma with high Reynolds numbers. A turbulent cascade—the process that transfers the free energy contained within the large scale fluctuations into the smaller ones—is believed to be one of the most important mechanisms responsible for heating of the solar corona and solar wind. The paper analyzes power spectra of solar wind velocity, density and magnetic field fluctuations that are computed in the frequency range around the break between inertial and kinetic scales. The study uses measurements of the Bright Monitor of the Solar Wind (BMSW) on board the Spektr-R spacecraft with a time resolution of 32 ms complemented with 10 Hz magnetic field observations from the Wind spacecraft propagated to the Spektr-R location. The statistics based on more than 42,000 individual spectra show that: (1) the spectra of both quantities can be fitted by two (three in the case of the density) power-law segments; (2) the median slopes of parallel and perpendicular fluctuation velocity and magnetic field components are different; (3) the break between MHD and kinetic scales as well as the slopes are mainly controlled by the ion beta parameter. These experimental results are compared with high-resolution 2D hybrid particle-in-cell simulations, where the electrons are considered to be a massless, charge-neutralizing fluid with a constant temperature, whereas the ions are described as macroparticles representing portions of their distribution function. In spite of several limitations (lack of the electron kinetics, lower dimensionality), the model results agree well with the experimental findings. Finally, we discuss differences between observations and simulations in relation to the role of important physical parameters in determining the properties of the turbulent cascade.