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Cascade rate and 3rd order structure functions in anisotropic turbulence

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The measure of the third-order structure function, Y, is employed in the solar wind to compute the cascade rate of turbulence. In absence of a mean field $B_0 = 0$, Y is expected to be isotropic (radial) and independent of the direction of increments, so its measure yields directly the cascade rate. For turbulence with mean field, as in the solar wind, Y is expected to become more two dimensional (2D), that is, to have larger perpendicular components, loosing the above simple symmetry. To get the cascade one should compute the flux of Y, which is not feasible with single-spacecraft data, thus measurements rely upon assumptions about the unknown symmetry. We use direct numerical simulations (DNS) of magneto-hydrodynamic (MHD) turbulence to characterize the anisotropy of Y. We find that for strong guide field $B_0 = 5$ the degree of two-dimensionalization of Y depends on the relative importance of shear and pseudo polarizations (the two components of an Alfvén mode in incompressible MHD). The anisotropy also shows up in the inertial range. The more turbulence is 2D the more the inertial range extent differs along parallel and perpendicular directions. We finally test the two methods employed in observations and find that the so-obtained cascade rate may depend on the angle between B_0 and the direction of increments. Both methods yield a vanishing cascade rate along the parallel direction, contrary to observations, suggesting a weaker anisotropy of solar wind turbulence compared to our DNS. This could be due to a weaker mean field and/or to solar wind expansion.