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Generalizations of the theory of Goldreich and Sridhar and the theory of Boldyrev to incompressible MHD turbulence with cross-helicity

J.J. PODESTA, Los Alamos National Laboratory — A fundamental problem in the theory of incompressible MHD turbulence with cross-helicity, also called imbalanced MHD turbulence, is to understand how the energy cascade rate depends on the normalized cross-helicity σ_c. Solar wind observations indicate that in the inertial range σ_c is approximately constant, independent of wavenumber. For incompressible MHD turbulence with $Pr_m \equiv \nu/\eta = 1$, it is shown from first principles that if $\sigma_c = const$, independent of wavenumber, then the energy cascade times of the two Elsasser fields are equal to each other: $\tau^+ = \tau^-$. Using this result, the theory of Goldreich and Sridhar and the theory of Boldyrev are generalized to imbalanced MHD turbulence in such a way that the inertial range scaling laws of these two theories are both preserved. The functional dependence of the perpendicular energy spectrum on the normalized cross-helicity is determined by requiring that the energy cascade time at a given scale is equal to a particular correlation time determined by the second order Lagrangian structure function, a relationship that is shown to hold for hydrodynamic turbulence and for both the original Goldreich and Sridhar theory and the original Boldyrev theory for which $\sigma_c = 0$. The resulting generalizations to imbalanced MHD turbulence are characterized by perpendicular energy spectra that are independent of the normalized cross-helicity.

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