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Turbulence in the Solar Wind (Lecture Notes in Physics)

Roberto Bruno, Vincenzo Carbone

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This book provides an overview of solar wind turbulence from both the theoretical and observational perspective. It argues that the interplanetary medium offers the best opportunity to directly study turbulent fluctuations in collisionless plasmas. In fact, during expansion, the solar wind evolves towards a state characterized by large-amplitude fluctuations in all observed parameters, which resembles, at least at large scales, the well-known hydrodynamic turbulence.

This text starts with historical references to past observations and experiments on turbulent flows. It then introduces the Navier-Stokes equations for a magnetized plasma whose low-frequency turbulence evolution is described within the framework of the MHD approximation. It also considers the scaling of plasma and magnetic field fluctuations and the study of nonlinear energy cascades within the same framework. It reports observations of turbulence in the ecliptic and at high latitude, treating Alfvénic and compressive fluctuations separately in order to explain the transport of mass, momentum and energy during the expansion. Further, existing models are compared with direct observations in the heliosphere.

The problem of self-similar and anomalous fluctuations in the solar wind is then addressed using tools provided by dynamical system theory and discussed on the basis of available models and observations. The book highlights observations of Yaglom’s law in solar wind turbulence, which is one of the most important findings in fully developed turbulence and directly related to the long-lasting and still unsolved problem of solar wind plasma heating.

Lastly, it includes a short chapter dedicated to the kinetic range of fluctuations, which has recently been receiving more attention from the space plasma community, since this is inherently related to turbulent energy dissipation and consequent plasma heating. It particularly focuses on the nature and role of the fluctuations populating this frequency range, and discusses several model predictions and recent observational findings in this context.

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