Meetings

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Understanding Solar Wind and Magnetospheric Intermittent Turbulence

Turbulence and Multifractals in Geophysics and Space; Brussels, Belgium, 9–11 June 2010

Space plasmas exhibit intermittent turbulent fluctuations, i.e., randomly alternating quietness and bursts. Fractals (discussed by Benoît Mandelbrot in 1967) describe self-similar, irregular geometrical objects with fractional dimension. Self-similarity manifests as the recurrence of the same topology at all scales. Multifractals are a generalization of fractals and describe with geometric analogs dynamical processes whose self-similarity depends on scale. Intermittency is one possible key to understanding the energy transfer from large (magnetohydrodynamic (MHD)) scales to much smaller, kinetic scales. To review the current understanding of multifractals and intermittent turbulence in the solar wind and magnetosphere, the Belgian Institute for Space Aeronomy (BIRA-IASB) organized a workshop in Belgium.

During the workshop, Roberto Bruno showed that the intermittency of solar wind velocity and magnetic field is linked to waves and plasma discontinuities. The magnetic field dominates the energy transfer from medium scales (less than 3 hours) to microscopic scales; at larger scales, velocity is the dominant parameter, as pointed out by Luca Soriso-Valvo. One key question is how the energy cascade ends. Plasma waves with kinetic signature (kinetic Alfvén waves) are among the possible candidate mechanisms, as pointed out by Vincenzo Carbone and Yuriy Voitenko, sustained by observations at small scales.

Using a type of model known as a two-scale weighted Cantor set (TSC), Wieslaw Macek and Anna Wawrzaszek found multifractal scaling of solar wind magnetic fluctuations at scales from minutes to days; the degree of multifractality decreases with scale. Bogdan Hnat showed that self-similar probability distribution functions (PDFs) of solar wind magnetic fluctuations at solar maximum may be signatures of fractal configurations of the solar corona. Another analysis method, the rank-ordered multifractal analysis (ROMA), was invented in 2008 by T. Chang and C. C. Wu to avoid the problem of small-amplitude fluctuations altering the statistics of large-amplitude ones. At the workshop, Wu demonstrated how ROMA collapses the PDF of intermittent fluctuations at multiple scales on a single master curve. Hervé Lamy discussed possible crossovers between two different ROMA spectra computed for the high-altitude polar magnetospheric region (the terrestrial cusps).

Zoltan Voros linked magnetospheric intermittency in the central, equatorial magnetospheric regions (the plasma sheet) to interconnection of magnetic field lines (magnetic reconnection). Emiliya Yordanova showed how multispacecraft methods enable the investigation of anisotropic turbulence, as exemplified with data from the Cluster spacecraft at the interface with the solar wind (the magnetosheath). Marius Echim discussed dawn-dusk asymmetries of the magnetosheath intermittency revealed by Cluster and NASA's Time History of Events and Macroscale Interactions during Substorms (THEMIS) mission. Sunny Tam used rocket data to compute the ROMA spectrum of auroral electric fields, which identifies different regimes, from evolving turbulence to fully developed (MHD) turbulence. Similar features are seen in the ROMA spectrum of the auroral activity geomagnetic index *AE*, computed by Giuseppe Consolini, suggesting an intermittent dynamics of substorms, the magnetospheric processes entailing sudden release of energy on a global scale. Giga Gogoberidze reviewed turbulence due to waves and to strongly interacting structures (weak and strong MHD turbulence). Véronique Delouille showed examples of multifractals applied to processing images of the Sun, and Norma Crosby discussed the concept of self-organized criticality.

Tom Chang presented a theoretical overview stressing that intermittent space plasma turbulence is a hallmark of dynamical complexity, manifesting as the multiscale interaction between coherent structures of varied sizes in a stochastic medium. His talk triggered lively discussion on multifractals and the stochasticity of dynamical systems far from equilibrium. Participants concluded that the multifractal approach, including novel techniques like ROMA and TSC, reveals key aspects of space plasma turbulence, bridging gaps still existing in understanding the turbulent transfer of energy.

The workshop presentations are available at http://multifractal.aeronomy.be.

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