Summary. In situ observations indicate that the dynamical processes in the geoplasma environment generally entail localized intermittent processes and anomalous global transports. It was suggested by T. Chang that instead of considering the turbulence as a mixture of interacting waves, such type of patchy intermittency could be more easily understood in terms of the development, interaction, merging, preferential acceleration and evolution of coherent magnetic structures.

In this three-year project, we have used direct numerical MHD simulations to study some aspects of the MHD dynamics in Chang's model. Our large-scale numerical calculations and simulations have been supplemented by and coordinated with theoretical studies conducted by Chang and his colleagues. Major accomplishments are given below:

- Dynamical Evolution of Coherent Structures in Intermittent Two-Dimensional MHD Turbulence

Recent satellite observations indicate that the Earth's magnetotail is generally in a state of intermittent turbulence. A model of sporadic localized merging of coherent structures has recently been proposed by Chang to describe the dynamics of the Earth's magnetotail. In a series of papers [Wu and Chang, 200a,b, and 2001], we report the results of MHD simulations regarding the development and merging of 2D coherent structures. With a magnetic shear, such coherent structures are generated in alignment with the imposed current sheet. The calculated fluctuation spectra suggest long-ranged correlations with power-law characteristics.

- Preferential Acceleration of Coherent Magnetic Structures and Bursty Bulk Flows in Earth's Magnetotail

Observations indicate that the magnetotail convection is turbulent and bi-modal, consisting of fast bursty bulk flows (BBF) and a nearly stagnant background. We [Chang, Wu, and Angelopoulos, 2002] demonstrate that this observed phenomenon may be understood in terms of the intermittent interactions, dynamic mergings and preferential accelerations of coherent magnetic structures under the influence of a background magnetic field geometry that is consistent with the development of an X-point mean-field structure.

- Complexity" and Anomalous Transport in Space Plasmas

"Complexity" has become a hot topic in nearly every field of modern physics. Space plasma is of no exception. In a paper [Chang and Wu, 2002], it is demonstrated that the sporadic and localized interactions of magnetic coherent structures are the origin of "complexity" in space plasmas. The intermittent localized interactions, which generate the anomalous diffusion, transport, and evolution of the macroscopic state variables of the overall dynamical system, may be modeled by a triggered (fast) localized chaotic growth equation of a set of relevant order parameters. Such processes would generally pave the

way for the global system to evolve into a "complex" state of long-ranged interactions of fluctuations, displaying the phenomenon of forced and/or self-organized criticality. An example of such type of anomalous transport and evolution in a sheared magnetic field is provided via two-dimensional magnetohydrodynamic simulations. The coarse-grained dissipation due to the intermittent triggered interactions among the magnetic coherent structures induces a "fluctuation-induced nonlinear instability" that reconfigures the sheared magnetic field into an X-point magnetic geometry (in the mean field sense), leading to the anomalous acceleration of the magnetic coherent structures. A phenomenon akin to such type of anomalous transport and acceleration, the so-called bursty bulk flows, has been commonly observed in the plasma sheet of the Earth's magnetotail.

- Complexity, Forced and/or Self-Organized Criticality, and Topological Phase Transitions in Space Plasmas

An overall picture of complexity in space plasmas is given in a review paper [Chang, Tam, Wu, and Consolini, 2003]. There, we describe a theory of dynamical ``complexity" for space plasma systems far from equilibrium. We demonstrate that the sporadic and localized interactions of magnetic coherent structures are the origin of ``complexity" in space plasmas. Such interactions generate the anomalous diffusion, transport, acceleration, and evolution of the macroscopic states of the overall dynamical systems. Several illustrative examples are considered. These include: the dynamical multi- and cross-scale interactions of the macro- and kinetic coherent structures in a sheared magnetic field geometry, the preferential acceleration of the bursty bulk flows in the plasma sheet, the onset of ``fluctuation induced nonlinear instabilities" that can lead to magnetic reconfigurations.

Publications Supported by the Grant

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