An invited talk to be presented at the U. of California Astrophysics Conference, Feb 8-12, 2003.
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This talk is essentially the same one that was approved for presentation at Montana State University, on 11 October 2001 and Texas A&M University on 22 October 2001. The material to be presented has already been published externally by the speaker (*Physica D*, **37**, 173-191, 1989; *Physics of Plasmas*, **1**, 541-7, 1994; *Journal of Plasma Physics*, **56**, 419-427, 1996; *Physics Letters A*, **250**, 319-322, 1998; and as NASA TP-2002-210783.

The Statistical Mechanics of Ideal MHD Turbulence

John Shebalin, NASA Johnson Space Center, Houston, Texas, USA

Turbulence is a universal, nonlinear phenomenon found in all energetic fluid and plasma motion. In particular, understanding magnetohydrodynamic (MHD) turbulence and incorporating its effects in the computation and prediction of the flow of ionized gases in space, for example, are great challenges that must be met if such computations and predictions are to be meaningful. Although a general solution to the "problem of turbulence" does not exist in closed form, numerical integrations allow us to explore the phase space of solutions for both ideal and dissipative flows.

For homogeneous, incompressible turbulence, Fourier methods are appropriate, and phase space is defined by the Fourier coefficients of the physical fields. In the case of ideal MHD flows, a fairly robust statistical mechanics has been developed, in which the symmetry and ergodic properties of phase space is understood. A discussion of these properties will illuminate our principal discovery: Coherent structure and randomness co-exist in ideal MHD turbulence.

For dissipative flows, as opposed to ideal flows, progress beyond the dimensional analysis of Kolmogorov has been difficult. Here, some possible future directions that draw on the ideal results will also be discussed. Our conclusion will be that, while ideal turbulence is now well understood, real turbulence still presents great challenges.