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Interaction of the Solar Wind with the Geomagnetic Field*

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The dynamical properties of the solar wind blowing past the geomagnetic field are investigated by considering the effective viscosity and the resulting transition layer thickness. The collision of ions in the solar wind produces a negligible viscosity in the flow past the geomagnetic field, but such an inviscid flow is shown to be unstable. The resulting disordered interface between the field and the wind yields Fermi acceleration of ions and consequently a not insignificant effective viscosity. The Fermi acceleration results in suprathermal ions which may have an energy spectrum like that observed for primary auroral protons.

The auroral zones and the agitated nature of the polar geomagnetic field are shown to follow from the depth of penetration of the solar wind into the geomagnetic field. The injection of gas into the geomagnetic field is studied. The effect at Earth of the distortion of the outer boundary of the geomagnetic field is computed; no matter how unevenly and anisotropically the outer field is distorted, the effect at Earth is a nearly uniform perturbation field which is closely parallel to the geomagnetic axis. Pushing in on the outer field increases the horizontal component at Earth, and pulling out decreases it; the total increase of the horizontal component is the algebraic sum of all the pushing and pulling. The simultaneous world-wide onset and the main phase of a geomagnetic storm follow.

The common tendency of large and/or violent bodies of plasma to produce suprathermal particles is noted and suggested to be a general dynamical property.

Phys. Fluids **1**, 171 (1958)

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MARCH 1968

Alfvén Waves in the Solar Wind

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(Received 14 August 1967)

Mariner II plasma and magnetic-field data are examined for explicit examples of low-frequency hydromagnetic waves. From the magnetic-field data, several sinusoidal waveforms are isolated. One of these clearly satisfies the hydromagnetic equations relating the magnetic-field variation to the ion-velocity perturbation for an Alfvén wave. This result is consistent with Barnes' theoretical prediction that only the Alfvén mode is not strongly damped in a plasma of moderate or high β .

Phys. Fluids **11**, 563 (1968)

Drift Mirror Instability in the Magnetosphere

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A new theory of the mirror instability is developed which includes the effects of ∇B and ∇n , finite Larmor radius, and a coexisting cold plasma. It is shown that the instability becomes overstable with a frequency equal to the drift wave frequency, which may be determined by the wave-number that gives the maximum growth rate. The theory is applied to explain the sudden kink in the increase (decrease) of proton flux (magnetic field) and the subsequent oscillations observed during a storm time on 18 April 1965 by detectors on the Explorer 26 satellite.

Phys. Fluids **12**, 2642 (1969)

Radiation from a strongly turbulent plasma: Application to electron beam-excited solar emissions

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The emission of radiation at the plasma frequency and at twice the plasma frequency from beam-excited strong Langmuir turbulence, for the case of low-density high-velocity warm beams, is considered. Under these conditions, Langmuir wave packets undergo (direct) collapse in a time short compared with one e folding of a beam mode. The wave packet energy density threshold for collapse depends only on the beam temperature and velocity, not on the beam density. Upper and lower limits on the volume emissivity for harmonic emission from these collapsing wave packets are found. Within most of this range, the emissivity is large enough to account for observations of second harmonic radiation during type III solar radio wave bursts. The radiation at the fundamental is many orders of magnitude larger than predicted by weak turbulence theory.

Phys. Fluids **23**, 388 (1980)

An electron cyclotron maser instability for astrophysical plasmas

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The electron cyclotron maser instability is analyzed for a plasma which consists of a suprathermal electron component characterized by velocity-space anisotropies in directions both parallel and perpendicular to the ambient magnetic field, as well as a high-density thermal plasma in which $\omega_e \sim \Omega_e$ (where ω_e and Ω_e are the electron plasma and cyclotron frequencies). The complete relativistic resonance condition is used and shown to result in a "resonance ellipse" in momentum space. The instability is considered for both cold and warm suprathermal electron distributions, and for frequencies $\omega \sim \Omega_e$ in the ordinary mode and $\omega \sim 2\Omega_e$ in the fast extraordinary mode. It is shown that the growth rates are comparable for these harmonics over a wide range of parameters which, since they are escape modes of the plasma, can lead to comparable radiation intensities.

Phys. Fluids 26, 2263 (1983)

Magnetohydrodynamic processes in the solar corona: Flares, coronal mass ejections, and magnetic helicity*

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The magnetized, million-degree solar corona evolves in cycles of about 11 years, in dynamical response to newly generated magnetic fluxes emerging from below to eventually reverse the global magnetic polarity. Over the larger scales, the corona does not erupt violently all the time. Violent events like the flares and episodic ejections of material into interplanetary space occur frequently, several times a day, but they often originate in long-lived magnetic structures that form continually throughout the solar cycle. In this paper, the creation, stability, and eventual eruption of these structures are discussed from basic principles, drawing on recent advances in observation and theory. A global view is offered in which different pieces of observation relate physically, with distinct roles for the conservation of magnetic helicity and the release of magnetic energy in dissipated and ordered forms.

Phys. Plasmas 1, 1684 (1994)

Phenomenology for the decay of energy-containing eddies in homogeneous MHD turbulence

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We evaluate a number of simple, one-point phenomenological models for the decay of energy-containing eddies in magnetohydrodynamic (MHD) and hydrodynamic turbulence. The MHD models include effects of cross helicity and Alfvénic couplings associated with a constant mean magnetic field, based on physical effects well-described in the literature. The analytic structure of three separate MHD models is discussed. The single hydrodynamic model and several MHD models are compared against results from spectral-method simulations. The hydrodynamic model phenomenology has been previously verified against experiments in wind tunnels, and certain experimentally determined parameters in the model are satisfactorily reproduced by the present simulation. This agreement supports the suitability of our numerical calculations for examining MHD turbulence, where practical difficulties make it more difficult to study physical examples. When the triple-decorrelation time and effects of spectral anisotropy are properly taken into account, particular MHD models give decay rates that remain correct to within a factor of 2 for several energy-halving times. A simple model of this type is likely to be useful in a number of applications in space physics, astrophysics, and laboratory plasma physics where the approximate effects of turbulence need to be included. © 1995 American Institute of Physics.

Phys. Plasmas 7, 2886 (1995)

A new view of the solar corona from the transition region and coronal explorer (TRACE)*

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The TRACE Observatory is the first solar-observing satellite in the National Aeronautics and Space Administration's (NASA) Small Explorer series. Launched April 2, 1998, it is providing views of the solar transition region and low corona with unprecedented spatial and temporal resolution. The corona is now seen to be highly filamented, and filled with flows and other dynamic processes. Structure is seen down to the resolution limit of the instrument, while variability and motions are observed at all spatial locations in the solar atmosphere, and on very short time scales. Flares and shock waves are observed, and the formation of long-lived coronal structures, with consequent implications for coronal heating models, has been seen. This overview describes the instrument and presents some preliminary results from the first six months of operation. © 1999 American Institute of Physics. [S1070-664X(99)91805-0]

Phys. Plasmas 6, 2205 (1999)

Magnetohydrodynamic modeling of the global solar corona*

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A three-dimensional magnetohydrodynamic model of the global solar corona is described. The model uses observed photospheric magnetic fields as a boundary condition. A version of the model with a polytropic energy equation is used to interpret solar observations, including eclipse images of the corona, Ulysses spacecraft measurements of the interplanetary magnetic field, and coronal hole boundaries from Kitt Peak He 10 830 Å maps and extreme ultraviolet images from the Solar Heliospheric Observatory. Observed magnetic fields are used as a boundary condition to model the evolution of the solar corona during the period February 1997–March 1998. A model with an improved energy equation and Alfvén waves that is better able to model the solar wind is also presented. © 1999 American Institute of Physics. [S1070-664X(99)94805-X]

Phys. Plasmas **6**, 2217 (1999)

Magnetohydrodynamic turbulence in the solar wind

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Low frequency fluctuations in the solar wind magnetic field and plasma velocity are often highly correlated, so much so that the fluctuations may be thought of as originating near the Sun as nearly perfect Alfvén waves. Power spectra of these fluctuations from 10^{-7} Hz to several Hz suggest that the medium is turbulent. Near 1 AU, fluctuations below 10^{-5} Hz have a relatively flat slope (~ -1) and contain most of the energy in the fluctuating fields. From 10^{-5} Hz to ~ 0.1 Hz, the spectra exhibit a power law inertial range similar to that seen in ordinary fluid turbulence. At the highest frequencies, the rapid fall-off of the power suggests that strong dissipation is occurring. From *in situ* measurements, it is clear that the fluctuations emanate from the solar corona. The turbulent cascade appears to evolve most rapidly in the vicinity of velocity shears and current sheets. Numerical solutions of both the compressible and incompressible equations of magnetohydrodynamics in both Cartesian and spherical geometry corroborate this interpretation. There are conflicting interpretations of observations suggesting that much of the power in magnetic field fluctuations resides in quasi-two-dimensional structures and simulations have helped to elucidate some of these issues. [S1070-664X(99)02811-6]

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Evidence for intermittency in Earth's plasma sheet and implications for self-organized criticality

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It has been proposed recently that a description of the magnetosphere as a system in a state of self-organized criticality would be fruitful for understanding (and predicting) the global response to solar wind input. In this paper it is shown that the proposed description fits the characteristics of magnetotail plasma flows and their variability. According to observations, the magnetotail is in a bi-modal state: nearly stagnant, except when driven turbulent by transport-efficient fast flows. The distributions of flows are in agreement with sporadic (intermittent) variability in the magnetotail. The variability may resemble hydrodynamic turbulence around a jet. The presence of turbulence alters the conductivity and the mass/momentum diffusion properties across the plasma sheet and may permit cross-scale coupling of localized jets into a global perturbation. Bursty-flow-driven turbulence is a physical process that may have an important role to play in the establishment of a state of self-organized criticality. © 1999 American Institute of Physics.

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