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Principal Investigators: Prof. A. Bhattacharjee
Prof. A. Hasegawa

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This is a Brief Smmary of the research completed under NASA Grant Nos. NAGW-894 and NAGW-1610. Details of the research are reported in the attached reprints/preprints.

1. Relaxation of magnetotail plasmas with field-aligned currents / 1, 2 /

We have developed a quasi-thermodynamic model for relaxation of magnetotail plasmas during substorms, followed by quiet times. We propose that the plasma relaxes to a state of low potential energy subject to a small number of global constraints. A variational principle which minimizes the free energy predicts the relaxed states. These relaxed states have the structure of flux ropes containing field-aligned currents. An interesting feature of these axisymmetric equilibria is that they contain a chain of magnetic islands along the tail axis. Theoretical results are compared with observations from ISEE 1 and ISEE 2 on flux ropes. A stability analysis of flux ropes is given.

2. The equilibrium dayside magnetosphere / 3 /

We present a method for computing the dayside global earth magnetic field which is in equilibrium with the plasma pressure based on satellite observations at a local region of the magnetosphere. The method involves an iteration beginning with dipole magnetic field and computes the global anisotropic plasma pressure profile based on the equatorial axisotropic pressure data only. The method is applied to AMPTE data, and the result of the computation is found to compare reasonably well with the observed magnetic field profile near the geomagnetic equator.

3. Macroscale particle simulation of kinetic Alfven wave physics / 4, 5 /

We have performed numerical simulations of the kinetic Alfven wave, which is well-known to have many applications in solar-terrestrial physics, such as particle acceleration on auroral field-lines, formation of auroral arcs and plasma heating in Jupiter. The code we have developed is novel in that both electron and ion dynamics are treated correctly on MHD-like spatial scales, i.e., spatial scales much larger than the Debye length. The dispersion properties and wave-particle interactions have been accurately modeled. The code base been used to study resonant mode conversion, longtidunal heating and particle acceleration.

4. Ballooning stability of plasmas with sheared equilibrium flows / 6, 7 /

Outer planetary magnetospheres, such as Jupiter's or Uranus', exhibit large plasma rotation velocities. Experimental observations of density depletions in Jupiter's magnetosphere by Voyager spacecrafts have been attributed by some (not without controversy!) to ballooning modes. We have, therefore, undertaken a careful theoretical study of ballooning modes in rotating plasmas. A WKB theory has been formulated for large-n ballooning modes. We find that rigid toriodal rotation, as usually occurs in Jupiter's inner magnetosphere, is destabilizing. A novel MHD resonant instabiltiy is also found in the presence of field-aligned flows. The effect of pressure axisotropies are included in the theory. Based on our calulations, we conclude that ballooning modes are an active instability in Jupiter (see, for additional details, C. Paranicas, Ph.D. Thesis, Columbia University, 1989)

5. Theory of the drift-mirror instability / 8 /

The drift-mirror instability is believed to play an important role in observations of "compressional waves" in the magnetosphere. We have developed a comprehensive theory of the instability, including the coupling to the shear Alfven wave in an inhomogeneous, axisymmetric plasma. It is shown that the mirror mode is coupled to the ballooning mode, and this coupling lowers the threshold conditions for the instability of the mirror mode. It is suggested that the new instability conditions are in closer accord with observations which have uncovered interesting discrepancies with theories which neglect the coupling between the mirror and ballooning modes.

6. Collisionless tearing instability in magnetotail plasmas / 9 /

The problem of the linear stability of collisionless tearing modes in the Earth's magnetotail is revisited. It is found that the collisionless tearing mode is linearly unstable with wavelengths of the order of 10 Re, and is therefore a viable candidate for observations on near-Earth reconnection events by AMPTE/ CCCE spacecrafts. It is shown that an important feature neglected in earlier theories is a non-zero By-field. The instability is treated in a sheared parabolic model which is representative of the magnetotail in which all three components of the magnetic field are non-zero. It is shown that the predictions of the theory are consistent with observations, both with repect to the range of unstable wavelengths, and the time-scale of the growth phase of a substorm.

7. Nonadiabatic behaviour of the magnetic moment of a charged particle in a dipole magnetic field and the development of stochastic webs

The non-adiabatic behaviour of the magnetic moment of a charged particle in a dipole magnetic field is studied both numerically and analytically in the presence of a low-frequency electrostatic wave. In particular, the breakdown of adiabaticity due to the bounce - E x B drift resonance is investigated. These studies have important implications for the confinement of charged particles in the earth's dipole field. In another study of fundmental theoretical interest, we consider the development of stochastic webs in a linear oscillator which is driven by a finite number of external waves. These stochastic webs represent "order" in chaos, and have interesting implications for the problem of intermittency.

8. Completion of the Book

As part of the educational contribution of the research effort supported by NASA, we are pleased to report completion and publication of the book "Space Plasma Physics, Volume 1" by T. Sato and A. Hasegawa (Springer-Verlag, 1989).

Reprints / Preprints (attached)

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