The Interplanetary Plasma and the Heliosphere Report of IAU Commission 49

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Introduction

(B. Buti, President Commission 49)

The aim of the present report is to pinpoint the highlights of the scientific literature in the interplanetary and heliospheric plasma during the period 1990-1993. We have tried to cover these highlights in the following two reports: Nonlinear plasma processes in the Heliosphere and Plasma and MHD Phenomena in the Heliosphere. In order to manage within the allotted space, we have emphasized on a few hot and current topics in some details rather than just giving a bibliographical sketch of all the topics. The two reports are complimentary and two together hopefully cover most of the current topics.

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Nonlinear Plasma Processes in the Heliosphere

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Introduction

This review deals with a few nonlinear plasma processes which are essential to properly interpret some of the observations in the interplanetary medium, planetary atmospheres, comets, etc. The topics covered here are: nonlinear waves and turbulence, magnetic reconnection, magnetic substorms and chaotic dynamics.

Magnetic Reconnection

Magnetic reconnection is a fundamental plasma process which converts magnetic energy into the plasma kinetic and heat energy. The process results in the change of magnetic topology, and therefore requires some kind of dissipation in the system to initiate its onset. This process is mainly responsible for inhibiting build-up of excessive amount of magnetic energy in the current sheets occuring in astrophysical plasmas. Magnetic reconnection is believed to play an important role in many astrophysical phenomena, like solar and stellar flares, X-ray emmisions from stars, radio jets, magnetospheric substorms, etc.

The classical Petschek model is generalized to the nonuniform and curved field. The reason for the absence of fast scaling in Biskamp's model is explained (Priest and Forbes, 1992). Futher, in 3D reconnection can takes place on any singular field line where the nearby field has X- type topology, and an electric field parallel to the field line exists. In the absence of 3D null points, reconnection can still occur by a process of magnetic flipping where plasma crosses the flipping layer but field lines rapidly flip along them by diffusion (Priest and Forbes, 1992). A nonlinear stochastic MHD model for the magnetic reconnection process where the magnetic field line stochasticity resulting from the overlapping resonance surfaces provide the anomalous resistivity has been worked out (Tetreault, 1992a,b). Heating due to collisionless magnetic reconnection has been studied by Moses et al. (1993). It is shown that parallel electric field can arise from plasma flows which violate the frozen-in field condition, these fields can play an important role in cosmic particle acceleration (Schindler et al., 1991).

Magnetic Reconnection at Sun

It is suggested that the phenomena of X-rays corona is due to reconnection of the field lines deformed continuously by the subphotospheric motions. Similar processes may be responsible for the naoflares from the stars (Parker, 1992). In an other study, it is found that the magnetic reconnection and energy balance of the coronal magnetic field in response to prescribed motion of the photosphere footpoints could lead to coronal heating (Vekstein et al., 1991). Magnetic reconnection process may even explain the formation of post flare loops (Forbes and Malherbe, 1991). It is suggested that the spicules are generated during reconnection of the magnetic field of the supergranule boundary cylinder layer (Pataraya et al., 1990). On the other hand, the opening of new magnetic flux on the Sun can lead to magnetic disconnection above the helmut streamers (Linker et al., 1992).

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Magnetic Reconnection at Magnetopause

From the review of the reconnection versus viscous drag theory for solar wind interaction with the magnetosophere, it is concluded that steady state reconnections is highly unlikely, and that the relevant processes must be essentially time dependent, three dimensionsal and localized (Heikkila, 1990). Direct evidence for the reconnection of the open field lines of the tail lobe with Interplanetary Magnetic Field (IMF) in the vicinity of high latitude dusk magnetopause has been provided from the ISEE 2 data (Gosling et al., 1991). Further, the laboratory experiments on collisionless current sheet suggest that Flux Transfer Events (FTEs) may be formed because of 3D tearing at the magnetopause (Gekelman et al., 1991). Simulations using 2D MHD codes suggest that the ratio of magnetospheric to magnetosheath magnetic fields controls the excitation of different form of reconnection giving different signatures of FTEs (Ding et al., 1991). On the other hand, the particle simulations involving 2 1/2 D elctromagnetic codes predict that driven reconnection could occur in either of the two forms, a quasisteady single X line reconnection, and an intermittent multiple X line reconnection. The resulting heating leads to power law particle distributions (Ding et al., 1992a). The analysis of the tearing mode at the magnetopause has been extended to includes the effests of finite β, shear flow and the propagation at an arbitrary angle (Ding et al., 1992b; Wang and Ashour-Abdalla, 1992; Cao et al., 1991). It has been shown that the presence of background turbulence of lower hybrid or ion cyclotron type can act as external driver source which enhances the growth rate of the tearing instability (Das, 1992).

Magnetic Reconnection in the Magnetotail

The results of collisionless tearing studied by 2D particle codes, suggest that the ion tearing mode is stabilized when the cyclotron frequency based on the B_z field equals growth rate of $B_z=0$ tearing mode. External pertubations can, however, drive the mode unstable (Pritchett et al., 1991). On the other hand 3D MHD simulations indicate that crosstail current diversion is mainly due to localization of reconnection in a 3D configurations. The onset of reconnection eventually leads to plasmoid formation and ejection. A new feature is reduction of B_y on reconnected dipole like field lines. The presence of pressure anisotropy tend to stabilize the resistive tearing mode instability in the magnetotail (Birn and Hesse, 1991a,b; Hesse and Birn, 1991, 1992) Fast reconnection is initiated by a localized resistivity causing plasma jets and plasmoids ejection, and redistribution of the overall current system (Ugai, 1991; Hoshino, 1991; Scholar and Hautz, 1991) Data from ISEE 3 and Geotail mission indicate that plasmoids are "open" magnetic structures (Moldwin and Hughes, 1992).

Structure of the X line during steady state reconnection is studied by analytical and numerical approach. It is found that no steady state reconnection is possible when the influx of plasma into the reconnection region exceeds some critical value (Burkhart et el., 1991a). Magnetic reconnection in collisionless field reversals and the universality of iontearing is discussed by Kuznetsova and Zelenyi (1991) A kinetic theory for driven reconnection in the magnetotail has been developed. Driven reconnection occurs in two modes, namely, the exponential mode reconnection which is similar to the ion tearing instability, and the bursty mode reconnection which is rather short lived but occurs at a much faster rate (Lakhina, 1992a). The widely believed qualitative picture of the "sling shot", i.e., plasmoid acceleration by the tension of the open interplanetry magnetic flux, is shown to be misleading. The spontaneous magnetic reconnection resulting in plasmoid formation and acceleration represents sufficiently fast process. Simulations using 2D implicit electromagnetic code VENUS, show that tearing develops if B_n is small enough and ion gyroradius is of the order of sheet thickness. In 1D the instability does not saturate, instead plasmoids continue to be formed, accelerated and ejected (Otto et al., 1990; Zwinmann et al., 1990) On the analysis side, it has been argued that the principal axis analysis (PAA) of magnetometer data from a single satellite pass is insufficient to differenciate between magnetic closed loops and flux ropes model (Moldwin and Hughes, 1991).

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Nonlinear Waves and Turbulence in the Interplanetary Medium

An over view of origin and evolution of the interplanetary MHD fluctuations observed in the solar wind including the turbulence due to cometary ion pick up processes is given by Roberts et al.(1991, 1992). A new model for SW turbulence is proposed by Lank and Matthaeus (1992). The importance of inwards propagating waves in transfering energy between different scale through nonlinear interaction with the outwards waves is discussed (Bavassano, 1992). Recently Buti (1991, 1992a) derived the evolution equation for the nonlinear Alfven waves in inhomogeneous plasmas and showed the effect of streaming on the solitary Alfven waves. In inhomogeneous but multispecies plasmas solitary Alfven waves have been investigated by Verheest and Buti (1992).

Using 2 and a 1/2 D fully relativistic PIC code, it is shown that electron acceleration by the lower hybrid waves excited by the ion rings can take place in the solar corona (McClements et al., 1990). During nonlinear evolution of parallel propagating waves, the wave steepening occurs due to beam ion bunching (i.e., nongyrotropic ions) caused by the trapping in the regions where waves have highest intensities (Akimoto et al., 1991). Quasi-linear evolution of ULF waves excited by cometary ions has been studied by Lee and Gary (1991). On the other hand, Huddleston et al. (1991) have used velocity diffusion due to observed level of turbulence to explain the development of the implanted ion distribution. The excitaion of lower hybrid instability by the pickup cometary ions (protons and water group) in the bow shock region and its quasilinear saturation has been discussed by Shapiro et al. (1993). Upper level of magnetic turbulence of nonresorant Alfven modes driven by multi ion beams is given by Verheest and Lakhina (1991). The results are found to be in good agreement with the MHD turbulence near comets. Large amplitude ion cyclotron wave could generate ion density holes which leads to the formation of intermittent double layers on the auroral field lines (Lakhina et al., 1992).

Analysis of ISEE 1 and 2 data indicate that small-scale ULF fluctuations at magnetopause are possibly due to nonlinear Alfven modes (Rezeau et al., 1993). Upstream of the earth's bow-shock, the nonlinear strong turbulence effects cause soliton like coherent wave packets to form and decouple from incoherent background beam excited weak Langmuir turbulence. They collapse to scales of 100 m and electric field $E \sim 2$ V/m (Robinson and Newman, 1991).

Chaotic Dynamics

Chaotic processes in plasmas are being investigated to understand the nature of plasma turbulence. The fractal structure of observed fluctuations could possibly throw some light on the source of observed plasma turbulence. From the existence and evolution of the multifractal structure of velocity fluctuations in the recurrent streams at 1 AU and at ~ 6 AU, Burlaga (1991) concluded that the turbulence around 6 AU is intermittent. In the Voyager data of large-scale magnetic field fluctuations also, Burlaga (1993) found multifractals indicating intermittent turbulence. The transition from regular to chaotic motion of a particle in a sheared magnetic field due to loss of adiabaticity was shown by Büchner and Zelenyi (1991). Ion acceleration due to chaos has also been investigated by Büchner and Zelenyi (1990). Through two-time velocity correlations, Horton and Tajima (1991) showed that the chaotic motion of charged particles could be a potential source for the collisionless conductivity.

In solar wind, magnetosphere as well as cometary plasmas, there are more than 2 species e.g., solar wind besides electrons and protons has 5% of helium and comets Halley and Giacobini-Zinner were found to have water group ions. By using nonlinear dynamical techniques, Buti (1992b) showed that the presence of these heavy ions leads to the reduction of chaos in the system. There have been large number of attempts to study the chaotic behaviour of a variety of systems (cf. special section on Chaos and Stochasticity in Space Plasmas, Geophys. Res. Lett. 18, 1991; IAU Symposium 152 on Chaos, Resonance and Collective Dynamical Phenomena in the Solar System 1992).

Magentospheric Substorms and Nonlinear Dynamics

Several models of the substorm phenomena have been reviewed by Birn (1991), Fairfield (1992), and Lakhina(1992). It is generally concluded that near earth reconnection model provides the best frame work to fit in various observations of the substorms. That reconnection occurs is established, but the actual mechanism is yet to be worked out. Alternative view is to construct a coherent description of the substorm development by extracting some important components from various existing models. In this connection, the role of cross-field instability in substorm onset has been high lighted (Lui, 1991; Lui et al., 1991, 1992). Observations based on ISEE 1 and 2 data for energetic particles ($> 20keV$) and magnetic field, are found to be generally consistent with the predictions of the near earth reconnection model of substorm (Lin et al., 1991) Some recent studies also show that current disruption starts near-earth magnetotail $|X| < 20R_E$ and often within 15 R_E and the results are consistent with the near earth neutral model (Ohtani et al., 1992a,b). Furthermore observations from AMPTE IRM satellite (about 50,000 measurements) fit in the framework of near earth reconnection model (Baumjohann et al., 1992). However, there are some observations, like variations of plasma β values, which are thought to be consistent with ballooning instability model (Pu et al., 1992). However, it has been suggested that the ballooning modes can not affect the large scale 2d configuration (Lee and Wolf, 1992).

It is shown that development of ion Weibel instability can produce anomalous resistivity about 11 to 12 orders higher that the classical value (Lui et al., 1993).

Recent observations strongly indicate the formation of a thin current sheet at the center of plasmasheet during growth phase of the substorm (Mitchell et al., 1990; Pulkkinen et al., 1991; Sergeev et al., 1990). The stability of such forced thin current sheet agiainst ion tearing mode instability has been studied by Burkhart et al. (1992a,b) and Lakhina (1993). The trapped electrons have a strong stabilizing effect on the ion tearing instability. Formation of a thin current sheet and its stability against pressure anisotropy instabilty (kink type) is studied (Pritchet and Coroniti, 1992).

Many theoretical and numerical studies related to particle dynamics in the earth's magnetotail suggests that particle orbits can become chaotic. The effects of the chaotizations of the orbits on substorm process have been studied by several workers (Chen, 1992; Burkhart and Chen, 1992a,b; Pulkkinen et al., 1992). The collisionless conductivity using the chaotic single particle orbits has been calculated in the geomagnetic tail. The height integrated dissipative part of the collisionless conductivity governs the stochastic heating (Horton and Tajima, 1991). The effects of constant B_y on the collisionless conductivity produced by chaotic scattering and stochastic diffusion of particles in the current sheet for parabolic geometry is considered. The increase of B_y tend to strongly stabilize the tearing modes (Hermandez et al., 1993). Nonlinear particle dynamics in magnetotail gives rise to partitioning of phase space into different regions which are occupied by diffferent classes of orbits with separated time scales. This leads to differetial memory which affects the evolution of the particle distribution resulting in highly non-Maxwellian features (Burkhart et al., 1991).

The complexity of the solar-terrestrial phenomena such as solar wind magnetosphere coupling, solar activity, etc., can be viewed as the dynamical features of a nonlinear disssipative system. Such systems with complex behavior are known to have simple dynamical descriptions and are studied with a wide range of techniques. Among these techniques is the possibility of reconstructing the dynamics from experimental data and thus gaining insight into the complex nonlinear systems, independent of particular modeling assumptions. The analysis of the time series data of a single dynamical variable, using such techniques, can yield the characteristics quantities of the system, e.g., the fractal dimensions, Lyapunov exponents, etc. Therefore such studies have a lot of potential in exploring the processes connected with the substorms. Analysis of magnetospheic activity using time series data in the auroral electrojet indices (AE and AL) has shown low dimensionality (fractal dimension of 3.6) with a positive Lyapunov exponent. The dynamical equations may be constructed using the time series data of the variables obtained from the singular spectrum analysis. The key issues are the predictability of these dynamical models, and the relationship of the dynamical to the physical variables. (Sharma, 1992; Sharma et al., 1993; Vassiliadis et al., 1990, 1991).

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Plasma and MHD Processes in the Heliosphere

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Introduction

The study of plasmas is of the utmost importance due to their universal presence and the way to grasp the universe is through a detailed understanding of the all-encompassing dynamical processes observed to-date in the sun and its environs. The small and the large scale flow patterns, the unearthing of the outer planetary magnetic fields, the linear and the nonlinear electrostatic and electromagnetic waves, acceleration, heating and radiation through a host of plasma-magnetic kinetic processes and the ubiquitous shocks have all pointed towards their kinship with extra-solar system phenomena. For example, the large inclinations of the rotation axes to the magnetic axes in Uranus and Neptune are reminiscent of the oblique rotator model of the stellar and pulsar magnetic fields. The mechanism of magnetic reconnection believed to be responsible for solar flares as well as for transfer of mass, momentum, energy and magnetic flux in planetary magnetospheres is found to be equally good at accelerating cosmic rays and enhancing gravitational collapse. The physics of degenerate plasmas is as essential for Jupiter as it is for white dwarfs and pulsars. Flow patterns on the solar surface, in planetary magnetospheres and in the large scale structure of the universe may have more in common than we are willing to believe in (Lanzerotti 1990; Krishan 1991). Cylindrical plasma structures whether in the form of solar coronal loops, cometary tails, galactic loops or extragalactic jets pose common questions of their equilibrium and stability. Therefore, any investment of effort in the study of solar system structures promises good returns. The collisionless shocks proposed in most of the astrophysical systems can be modelled in every detail, thanks to the in-situ observation of planetary bow shocks. Thus the citation index of solar planetary and interplanetary and heliospheric plasma phenomena reads like the story of the entire universe. In the following sections, a brief account of the work done in some of the solar system plasma physical problems is given. The account is complete neither in content nor in references, as limited space allotted by IAU forbids anything more ambitious.

Solar Wind

The solar wind blows in two modes: the quasi-stationary and the transient. The density and the velocity structure of the quasi-stationary high speed wind is consistent with its origin from the coronal holes, where, it is accelerated by wave damping (Grappin et al., 1991; Coles et al., 1991; Zhang et al., 1991), superthermal electron heat flux, macrospicules or by the energy released through network and internetwork magnetic elements (Parker, 1991). The quasi-stationary slow speed flows, on the other hand, are believed to be associated with the coronal streamers, edges of coronal holes and the heliospsheric current sheet or sector boundaries (Neugebauer, 1991). However, the mechanisms that prefer to accelerate α particles and other heavy ions (Bogdan et alo., 1991) to protons have not yet been delineated in a satisfactory manner. The determination of the relative contributions of the various possible mechanisms occurring on a variety of spatial and time scales as well as the ways in which they cooperate to produce a rather smooth flow awaits more theoretical and observational inputs. Further, the correlation between the solar wind speed near the earth and the magnetic geometry of the corona can be used to deduce the latitudinal distribution of wind speed at different phases of the sunspot cycle. The fastest wind appears to be centred around the warps in the heliospheric current sheet (Sheeley et al., 1991).

A quasi-stationary flow, when interrupted by a transient event like a coronal mass ejection (CME's), acquires a transient character. Since CME's result when prominence supporting magnetic field structure turns unstable, most of the properties of the transient wind reveal the closed magnetic fields and flows (Veselovski, 1990), configuration (Svestka, 1991) e.g., the bidirectional electron heat fluxc and proton streaming. The detection of singly ionized He ions with an over abundance of 3 orders of magnitude was

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interpreted to be a straight signature of the presence of prominence material, which reached IAU without thermalizing on the way (Mullan, 1991). The exceptionally low temperatures of $7 \times 10^4 K$ indicate a large expansion that a transient flow undergoes after CME's generated shock heating. The many characteristics of the transient flows like the low level of wave activity (Velli et al., 1991) strong magnetic fields (Goldstein Jr., 1991), heavy ion ionization, abundances and velocities and the flux tube expansion factor, interaction of fast and slow streams (Fainshtein, 1991) remain to be cracked (Neugebauer, 1991). The MHD simulations of solar wind turbulence reflect upon the nature of interplanetary fluctuations and their generation mechanisms (Roberts et al., 1991; Dryer et al., 1991).

The Solar Probe expected to cruise at an altitude of 3 solar radii may settle many of these issues. To clarify the relationship of enhanced fluctuations with coronal structures, collaborative observations of Solar-A satellite with Kashima 34m antenna have been proposed. A magnetohydrodynamic along with a kinetic treatment (Moses and Kennel, 1991) including a self-consistent interaction between the flows and fields as well as the waves and the particles is a prerequisite to a complete appreciation of the richness of the solar wind phenomena. The reader is referred to the review articles by March (1991) and Fahr (1991).

Magnetospheric Convection

The magnetospheric convection i.e. a large scale plasma flow in planetary magnetospheres is driven either by the solar wind (SW) as in Earth and Mercury or by the planetary rotation as in Jupiter and Saturn or by both the solar wind and the planetary rotation as in Uranus and Neptune. The interaction of the solar wind with the atmospheres of Venus and Mars is more akin to SW-comet intraction. The merging of the planetary and the interplanetary magnetic field (IMF) at the magnetospause plays the most important role in the transfer of mass, momentum, energy and magnetic flux on to a planet in SW-driven convection. Whether the merging is steady or sporadic is an issue of live controversy (Lookwood et al., 1993; Smith et al., 1992; Lockwood and Smith, 1992); the resolution of which resides in the latitudinal and the transient structure of the ionospheric flows (Newell, 1992; Escoubet et al., 1992).

The issues in the case of rotation driven convection are the transport of mass, momentum, energy and magnetic flux through microscopic turbulent diffusion processes across Io-Jupiter magnetosphere region. Inclusion of microdiffusion processes leads to a Lorentz like strange attractor solution, indicating the chaotic nature of convection (Summers and Mee, 1992). The quadrupolar convective processes dominated by centrifugal and magnetic field effects, resulting in highly asymmetric flows to and from the planet in the Triton torus - Neptune magnetosphere region have been discussed by anumber of authors in GRL (1990). From the plasma flow perturbations, it has been shown that the signatures of cylindrical flux transfer events (FTE) and wavy magnetopause (MP) (Silbeck and Smith, 1992) with its unearthlike rotation and magnetic field relationship and an earthlike wind. The large inclination of the rotation axis to the magnetic dipole axis in Uranus and Neptune (Akasofu et al., 1991), the trapped radiation belt system enclosing the major satellites of Uranus and the formation and stability of self-gravitating dusty epitons of Neptune are some of the major excitements in this field. the Phobos-2 measurements suggest that the SW-Mars and SW-Venus interaction is cometary like with mass loading of the solar wind. The acceleration of the heavy Martian ions could be similar to the terrestrial-auroral acceleration along with the local action of pick-up processes. A recent review of the earthly magnetospheric processes can be seen in Saunders (1991).

Dusty Plasmas

Dust particles acquire electric charge in the presence of a plasma, though it can also happen through photo-electron emission or absorption processes. The properties of dust particles then begin to depend strongly on their new status as charge carriers. For example, in the interstellar medium, charged dust grains when subjected to supernova associated shock waves may undergo significant changes in their destruction rate and overall dynamics. In the solar system, this new degree of freedom of the dust particles enables them to experience electromagnetic forces in addition to the gravitational forces, thus facilitating explanations of many an otherwise unexplained phenomena (Horanyi and Mendis, 1991). The electrostatically supported planetary dust rings are found to oscillate with 3 times the local Kepler frequency. The oscillation frequency structure of a dense ring is more complex. The lack of azimuthal symmetry in the co-rotating magnetospheric plasma can lead to a coupling with the vertical dust profile oscillations of orbiting dust rings (Melandso and Havens, 1991). The major properties of the spokes in Saturn's rings can be identified with those of magnetosonic waves which have group velocities larger than the Alfven speed. The magnetosonic waves can be driven in a fluid composed of small charged grains and ambient plasma. The impulse given to small grains by an electron beam or a meteor is enough to induce by collisions with large grains, the formation of a spray of dust. Dust rings around planets need to be continuously replenished since they lose particles due to several dynamical effects (Grun, 1991). Grain charge variations due to the modulation of photo electron current caused as the grain enters or exists the planetary shadow, are determined. The electromagnetic perturbation resonates with the orbital period and can modify the orbits size and eccentricity (Horanyi and Burns, 1991). The spatial and temporal variations of the plasma parameters and magnetic field, factors, which govern the charging of the dust and its subsequent motion, were included while developing numerical models to predict the dust distributions in P/Halley (Ellis and Neff, 1991).

Ulysses at Jupiter

During the seventeen day long encounter, Ulysses highlighted the intimate relationship between the solar wind and the Jovian magnetosphere by cruising through the previously unexplored dusk sector of the magnetosphere, where the magnetric field was found to be bent out of the meridian planes associated with the corotating planetary field. This was caused by the intense sweeping of the field into the magnetospheric tail by the solar wind as also indicated by the observed temporal variation of the trapped particle fluxes. Large fluxes of counter-streaming electrons and ions observed in the high latitude dusk side may be responsible for auroras in the earth-like polar caps of the planet. However, the density of the energetic particles suddenly dropped to solar wind values near 15 RJ, indicating the presence of open field regions. the Ulysses trajectory passed through the Io plasma torus, facilitating the electron density distribution measurements. The need for more detailed models of the magnetodisk current system including the effects associated with its inclination to the rotation axis and warping due to the solar wind stresses has been acknowledged while trying to model the Ulysses data. For preliminary results of the Ulysses encounter of Jupiter; papers describing volcanic activity on Io; observations of polar regions, magnetic fields, plasmas and waves, radio emission, energetic particles, their composition and energies, dust and highly configured plasma boundaries, see Science 257, 1992.

The Solar-Polar Expectations from Ulysses

After amply fulfilling the expectations of the planetary scientists, Ulysses now hurls towards the solar-polar regions to provide an out of the ecliptic view of the Sun. The curtain will rise in June, 1994. The complexities associateds with the looped and rotating equatorial magnetic fields are believed to be absent in the polar regions. Therefore, one expects to observe the low energy cosmic rays and be able to trace back clues to their origin which are otherwise lost in the labyrinth of the equatorial fields. For the same reason, it becomes possible to follow the polar-solar wind back into the Sun. Essentially Ulysses will observe from the poles what has been observed to-date from the equator. The list includes solar flares, radio waves, the extra solar system dust and gas, the polar heliosphere, the interstellar helium, the ubiquitous γ-ray bursts and even gravitational waves in addition to the direct measurements of the polar magnetic fields to confirm their simplicity (Wentzel and Smith, 1991; Appenzeller, 1992).

SOHO and Cluster Missions

SOHO - the Solar and Helioscopic Observatory and cluster consisting of a set of four spacecracfts are scheduled to be launched in the second half of 1995. SOHO has been planned to study the solar interior through helioseismology and solar irradiance variations as well as to delineate the heating and acceleration of the solar corona and the solar wind through spectroscopic measurements. Cluster, on the other hand, promises three dimensional time dependent measurements of the fields and flows and the associated current densities and vorticity in the near earth space plasma. A dream comes true for the plasma modeler! (Domingo Schmdt, 1991).

Shocks

Collisionless shocks have been observed by spacecrafts throughout the solar system. The physics of shocks depends on the inclination of their normal to the magnetic frield. This has given rise to the terminology of quasi-parallel and quasi-perpendicular shocks. In a collisionless plasma, particles communicate through electromagnetic fields. The collisionless coupling can take place through the electric field resulting due to the pressure gradient forces associated with intense electron heating and magnetic compression. This process is known as Laminar Coupling and is operative in quasi-perpendicular shocks. The Larmor Coupling is due to motion of ions in a magnetic field; the resulting inductive electric field couples the plasma particles. This is operative when a perpendicular shock is formed by the reflected ion beams or strong ion heating. The parallel shocks involve turbulent coupling which arises from the electric fields produced by the nonthermal particle distribution functions which form due to an impulse or a piston (Cargill, 1991). The quasi-parallel shocks involve all the three types of coupling. The decoupling of the piston and the shock has been questioned in the case of quasi-parallel and parallel shocks. Hybrid numerical simulations for hot plasmas indicate (i) parallel shock formation with hot electrons with no separation from the piston, (ii) no parallel shock formation with hot ion pistons, (iii) a quasi-parallel shock formation with severe coupling with the piston. These results emphasize a strong interaction between the driver and the consequent processes of particle acceleration and heating (Cargill, 1991). The collisions between pairs of quasi-parallel shocks is studied using hybrid numerical simulations. The two shocks are found to go through each other leaving behind a hot energetic plasma. The energization is more efficient for quasi-parallel shocks of comparable strengths (Cargill, 1991).

During an encounter of the AMPTE/CCE spacecraft, the earth's bow shock was seen to pass back and forth over the spacecraft with a typical period of oscillationof 20 seconds along with an upstream wave of the similar period propagating in the solar wind just before the multiple shock crossings. The magnetic field rotated through 360^o for each pair of shock crossings. It is suggested that the plasma displacement associated with the upstream wave activity is the cause of the oscillating shocks (Strangeway and Zanetti, 1991). The quasi-parallel shocks are associated with a variety of magnetic field structues including the low amplitude, nearly sinusoidal, low frequency waves observed far upstream to the large amplitude, turbulent pulsations which are usually associated with the shock itself. Low frequency magnetric field turbulence is described in terms of a gas of Alfven solitons. An analysis of electric field turbulence does not play a significant role in the energetics of the quasi-parallel shocks. The plasma data from Giotto shows that both the inbound and outbound crossings of the cometary bow shock fulfilled the shock conditions and supports the observation that the normal component of the solar wind flow becomes subsonic at a point close to the shock transition. All these topics are covered in Adv. in Space Res. 11 (1991). For the inbound crossing of Comet Halley's bow shock, it is found that the transmission of the sunward-streaming hydromagnetic waves through the bow shock could lead to the enhancement of its wave amplitude by a factor of 2-3 and the generation of Alfven waves with the opposite helicity (Ip and McKenzie, 1991). Plasma and magnetic field observations from crossings of the Martian bow shock by the Phobos-2 spacecraft and the pioneer venus orbiter at Venus are compared with data from bow shocks of other planets and the AMPTE lithium release. It is found that the shock spectra of the inner planets are very similar in shape and their wave energy densities, when normalized to the upstream electron thermal energy density, are comparable. However, the Martian shock spectrum is more like the spectrum from AMPTE indicating the role of pick-up ions and their large gyro-radii (Dubinin et al., 1991; Moses et al., 1991). The Voyager data on Uranus's magnetic field in the vicinity of the shock reveal a series of whistler wave events, believed to be analogous to those whistler waves upstream of the Earth's bow shock that are driven by stream of electrons (Smith et al., 1991).

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Shocks accelerate particles. The evolution study of ion distribution functions in the quasi-parallel bow shock, using the data from Prognoz-10 satellite shows that there exist many different plasma fluxes in the foreshock region. The foreshock consists of many shock-like structures which are caused by large amplitude MHD waves. Interaction of solar wind with these structures creates the beam ion distribution which gradually develops into the diffuse distribution. The 3-D ion distributions from the AMPTE-UKS ion instrument associated with magnetic field structures near the Earth's bow shock have been examined to search for origins of the observed ions from four source populations: reflected conserving magnetic moment, specularly reflected, magnetosheath leaked particles conserving magnetic moment and magnetosheath leaked particles accelerated parallel to the shock normal. The statistical analysis of the correlation of solar wind parameters with variations of the ion energy spectra shows that the differential particle fluxes in the energy range from 10-30 KeV correlate with the solar wind density thus supporting a solar wind source and that the spectral slope correlates with the solar wind velocity. For discussion of these topics, see Adv. in Space Res. 11 (1991). McKee and Draine (1991) have raised several issues crucial to the understanding of collisionless shocks e.g. the relative temperatures of the electrons and the ions; structgure of a quasi-parallel shock with a substantial amount of energy in accelerated particles, role and type of interstellar shocks responsible for accelerating the cosmic rays, the dependence of efficiency of acceleration on the inclination of the shock normal to the magnetic field and more. Computer simulations and observations of spectral lines by space telescopes at different electromagnetic bands should be able to answer some of these questions.

Planetary Radio Emission

Jupiter emits at radio waves in a variety of forms through thermal and nonthermal processes. A new mechanism whereby plasma waves at the local upper hybrid resonance frequency with anomlous dispersion are generated through Cherenkov instability of an electron beam and then converted into electromagnetic waves by scattering of inhomogeneities, has been proposed to account for most of the properties like conical beam pattern and frequency drift of the decameter S-radio emission of Jupiter (Boev et al., 1991). The radial profiles of Jupiters nonthermal emission at 6, 20 and 90 cm show the presence of a shoulder or flattening in the intensity at 2, 5 RJ due to absorption effects by the satellite Amalthea (Peter, 1991). In order to determine the sources of hectometer emission, a ray tracing study including refraction effects has been done with the conclusion that the hectometeric source locations at high magnetic altitudes in both the hemispheres fit best the emission pattern as observed by the Voyager space craft. The polarization properties of the hectometric emission can be explained by simultaneous radiations from two independent 100% oppositely polarized sources. A global model for the hectrometric (HOM) and decametric (DAM) Jovian emission in which the left and right HOM components are identified with the left and right non-Io DAM components, respectively, is outlined (Ortega-Molina et al., 1991). The origin of the nearly unique 100% elliptical polarization of Jupiter's decameter radio emission along with the polarization of cyclotron maser radiation, the dispersion relation of the rarefied plasma composed of energetic anisotropic electrons the growth rate of the maser and the brightness temperature are determined by Melrose and Dulk (1991). A qualitative model is proposed which invokes the observed HOM polarization characteristic and continuously radiating sources on field lines having footprints at all longitudes along a narrow band of high magnetic latitudes close to the northern and southern auroral zones. The study of Faraday effect on Jovian emission shows that the usual simple approximation where the rotation of the polarizaztion plane varies as the inverse of the frequency squared has to be modified to include a term which goes as the inverse of the fourth power of frequency in order to explain the recent observations. The additional frequency dependence arises from the path difference between the ordinary and the extra-ordinary waves and the high density gradient of the ionosphere (Boudjada et al., 1991). For millimeter wave emission and Bremsstrahlung X-rays from Jupiter, see J.G.R. 96, (1991). Lakhina et al. (1990) gave a model which is applicable for radio emissions from planetary magnetospheres. This model is based on calculations of radiation from accelerated Alfven solitons in homogeneous plasmas.

Auroral Hiss

A review of auroral hiss emissions observed at ground based stations and in the magnetosphere is presented. The most likely energy source of these emissions lies in the electrons and energies below 100 eV precipitating to the auroral ionosphere. The incoherent Cerenkov radiation amplified by the beam-plasma instability may provide a good interpretation of the auroral hiss emissions (Sazhim et al., 1993). The secular variation of the aurora is examined and compared, where possible, to sunspot data and magnetic activity data. The data provide confirmation of the anti-correlation of auroral occurrence in the polar regions with sunspot activity as a result of displacement of the auroral oval with changes in solar and magnetic activity (Silverman, 1992). The average response to an electron drifting through randomly fluctuating double layers aligned parallel to the ambient magnetic field is calculated and the thickness of the visual auroral arc is estimated to be $\sim$ 2.5 km with fine structure $\sim$ 250 m at electron energy of $\sim$ 350 eV (Prakash and Lysak, 1992). The effects of stochastic motion of the ions on the westward cross-tail current at the earthward edge of the plasma sheet is studied for the formation of stable inverted -V's and arcs in the night sector (Galperin et al., 1992).

In addition to the phenomena discussed above, the study of various plasma kinetic and MHD waves and instabilities in dusty and otherwise media is being pursued in an attempt to grasp the detailed workings of the radiation, heating and acceleration processes on the one hand and the equilibrium and stability of the hot and energetic plasmas on the other. The field of Interplanetary plasma and the Heliosphere with its insitu observations has been raising questions which challenge the versatality of a plasma physicist and stimulate the curiosity of an astrophysicist.

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