COMMISSION H: WAVES IN PLASMAS

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Based on papers published from November of 1998 to October of 2001, we compiled major achievements in the field of plasma waves and related studies made by Japanese scientists and their collaborators. We categorize the studies into two groups. One is based on observations and experiments, and the other is theories and computer simulations. Studies in each category are further divided into several sections. Each section provides a specific summary of important scientific achievements rather than a comprehensive report of the whole research activities of Japanese Commission H. On the other hand, the reference list attached at the end is intended to be used as a database of all papers we have collected from the Japanese Commission H members.

H1. Space Observation and Experiments of Plasma Waves

H1.1 Hydromagnetic and ULF Wave Phenomena

The magnetic field data from the Engineering Test Satellite -VI (ETS-VI) have been analyzed to investigate the occurrence distributions of pulsations in Pc3-5 frequency ranges in the magnetosphere. Although the azimuthal Pc4 pulsations on the nightside start at almost the same time as substorm onsets, they are different from Pi2 pulsations in the magnetosphere. Nose et al. [1998a] suggest that the azimuthal Pc4 pulsations on the nightside are excited through coupling to the fast mode Alfvén waves which were launched at substorm onset.

Using data from the polar orbiting Dynamic Explorer (DE)-1 and -2 satellites and a ground-based station, Nose et al. [1998b] investigated electron precipitation phenomena accompanying Pc 5 pulsations. They found that the resonance structure has a small scale comparable to the ion acoustic gyroradius, then kinetic Alfvén waves having electric fields parallel to the ambient magnetic field can arise.

Nose et al. [1999] investigated statistical characteristics of dayside Pi2 pulsations observed at Mineyama (25.5° geomagnetic latitude) from November 1994 through June 1996, using an algorithm to detect Pi2 pulsations which was introduced in [Nose et a., 1998c]. They found that the magnetospheric cavity model can explain most of observational results.

H1.2 Generation and Propagation of ELF/VLF Waves

Recent theoretical work has suggested that the energy release in magnetic reconnection is mediated by electrons in waves called ‘whistlers’ which move much faster for a given perturbation of the magnetic field because of their smaller mass. During reconnection the plasma forms a ‘magnetic nozzle’ like the nozzle of a hose, and the reconnection rate is controlled by how fast plasma can flow out of the nozzle. The whistler velocity and associated plasma velocity both increase as the ‘nozzle’ becomes narrower. A narrower nozzle therefore no longer reduces the total plasma flow – the outflow is independent of the size of the nozzle. Deng and Matsumoto [2001] reported observations demonstrating that reconnection in the magnetosphere is driven by whistlers, in good agreement with the theoretical predictions.

Many ELF chorus emissions were observed by the Plasma Wave Instrument (PWI) onboard

GEOTAIL spacecraft around the equatorial plane in the dayside outer magnetosphere. Along with the chorus observations, the pitch angle anisotropy of the cyclotron resonant electrons was measured by the Comprehensive Plasma Instrument (CPI). Yagitani et al. [1999] showed that the observed anisotropy was too small to generate simultaneously observed chorus emissions via linear cyclotron resonance. This is possibly caused by the pitch angle diffusion of cyclotron resonant electrons by the generated chorus emissions.

Electrons injected into the nightside magnetosphere during the expansion phase of a substorm generate whistler-mode waves near the equator which propagate downwards along field-aligned paths and through the ionosphere to be observed on the ground as substorm chorus evens. Smith and Nagano [2001] presented observations of such events recorded around Halley station (L~4) in Antarctica. Combined with a full-wave code to model the propagation of the waves through and under the ionosphere, the observations were used to estimate the apparent position and motion of the regions where the SCE waves enter the Earth-ionosphere waveguide during the substorm progress.

Rafalsty et al. [1999] studied penetration of electromagnetic waves into the seawater on the basis of wide-band synchronous measurements of ELF/VLF atmospherics on the sea surface and underwater. They found that the sea layer behaves as a spatial filter for modes in the Earth-Ionosphere waveguide.

Nickolaenko and Hayakawa [1999] demonstrated that multiple electromagnetic pulses originating from staircase (multiply bent) strokes turn into a single pulse when propagation in the Earth-Ionosphere caving due to ELF radio wave dispersion and attenuation. Regarding the propagation mode of electromagnetic waves, Singh and Hayakawa [2001] critically examined the relative merits of ducted and non-ducted propagation of low-latitude whistlers in the light of work done mostly in the Asian countries.

Yoshida et al. [2000] investigated correlation between ion outflows observed by Akebono and EISCAT in the night side auroral region. They proposed that ELF waves were excited by a plasma instability due to upward thermal electron beam, and the wave caused transverse ion heating at the top of the ionosphere.

H1.3 Electrostatic Waves Excited by Electrons

Matsumoto et al. [1999] performed data analysis of electrostatic waves and plasma particles in the deep magnetotail respectively obtained by Plasma Wave Instrument and Comprehensive Plasma Instrument onboard the GEOTAIL spacecraft. When the GEOTAIL spacecraft experienced multiple crossings of the plasma sheet boundary layer, broadband electrostatic noise (BEN) and Langmuir wave were observed alternatively. The dynamic frequency spectra of BEN are very bursty in time, and their waveforms are a series of electrostatic solitary waves (ESW). The LW is observed when an enhancement of an electron flux is found on a high-energy tail of a relatively cold velocity distribution function of the major thermal electrons. The ESW, on the other hand, are observed in the presence of a hot thermal electron distribution function, in which electrons responsible for the ESW are embedded.

Omura et al. [1999a] studied waveforms of electrostatic solitary waves (ESW) and corresponding electron velocity distribution functions observed by the Geotail spacecraft.

When they observed a series of ESW in the plasma sheet boundary layer of the Earth's magnetotail, they found enhanced fluxes of high-energy electrons flowing along the ambient magnetic field. They found good correlation between the propagation direction of the ESW and the direction of the enhanced high-energy electron flux. This supports the model proposed by computer simulations that ESW are formed by the electrons modulated through the bump-on-tail instability. The enhanced electron flux is
regarded as the diffused electron beam after the saturation of the instability.

Kasahara et al. [2001] investigated waveforms of electrostatic broadband noise in ion heating region observed by Akebono. It is found that the waves can be classified into continuous noise and impulsive noise. They also showed the spatial distribution of the continuous noise statistically depending on local time, geomagnetic activity, and season.

Pickett et al. [1999] studied cusp energetic particle (CEP) events using simultaneous wave data from Polar and Akebono and magnetometer data from ground stations. They suggested presence of coherent electrostatic structures that were highly localized along the ambient magnetic field. Some of cusp waves may be indicators of the reconnection process taking place through the cusp.

Tsurutani et al. [2001a, b] made a statistical survey of the ELF/VLF electrostatic and electromagnetic plasma waves detected within the polar cap boundary layer, and found that two types of intense electric waves were present: solitary bipolar pulses (electron holes) and ~kHz electric turbulence. They argued that the PCBL waves were most likely a consequence of auroral zone field-aligned current instabilities, while the currents had in turn been ascribed to be due to magnetospheric convection driven by the solar wind.

Usui et al. [1999a, b] analyzed the electron environment associated with the TP emissions, intense bursts of ECH waves called TP emissions which occurred sporadically and intermittently in time in the dayside magnetosphere. Field analysis shows that, due to the occurrence of an intense Pc-5 pulsation, there was E × B drift flow which was switching its direction in time near the magnetopause. The GEOTAIL/CPI data shows the electron density fluctuated corresponding to the drift flow variation. Overall, TP emissions tend to occur during a transient time interval including a time when the density of cold electrons below 100 eV takes a minimum value. They concluded that the sporadic and intermittent signature of TP emissions can be due to the change of the electron environment driven by the intense field pulsation.

H1.4 Electromagnetic Waves Excited by Electrons

Hashimoto et al. [1999a,b] reported a new kind of terrestrial continuum that appears to be generated inside the Earth's plasmasphere. It has been detected by the Geotail satellite at an orbital distance of 10 to 30 Re in the dayside and evening sectors of the magnetosphere. This previously undetected emission, which will be called A kilometric continuum, is found to consist of slowly drifting narrowband signals at a frequency of 100 to 800 kHz, corresponding to the plasma frequency inside the plasmasphere at an altitude extending down to only a few thousand kilometers in the topside equatorial region of the Earth's ionosphere. Unlike normal continuum, kilometric continuum is found to occur only near the magnetic equator, where it appears to be unrelated to magnetic activity and is emitted within a well-defined beam within only ~10 of the magnetic equator.

Lobe-trapped continuum radiation (LTCR) has been observed in the distant magnetotail regions by GEOTAIL spacecraft. On the basis of the statistical analysis with the spectrum and waveform data of the LTCR, Takano et al. [2000] suggested that the LTCR source regions are located around the plasma sheet boundary layer (PSBL) of the tail region.

Through Geotail observations Matsumoto et al. [2000] have revealed that the terrestrial continuum radiation observed in the magnetotail consists of several components that are generated at different locations through different processes. "The continuum-like radiation" is classified into the following components: classical nonthermal continuum radiation generated in the dawnside and dayside plasmapause, short-lived enhancement of the nonthermal continuum radiation generated at the nightside plasmapause, auroral myriametric radiation generated at the auroral plasma cavity, lobe-trapped continuum radiation generated at the plasma sheet boundary layer (PSBL), and narrowband 2fp radiation generated through beam-plasma instability at the PSBL.

Kasaba et al. [2000] performed statistical studies of the direction finding of 2fp radiation and the spatial distribution of plasma waves and energetic particles in the terrestrial electron foreshock observed by Geotail. The "2fp radio source" is likely to be in the leading region of the electron foreshock where the most intense Langmuir waves are observed. The Langmuir wave activities and the population of energetic electrons gradually decrease in the region beyond 10 RE from the contact point between the tangential IMF lines and the bow shock. They also investigated the influence of the solar wind conditions on the activities in the electron foreshock. A positive correlation of the 2fp radio activity is confirmed with the solar wind kinetic energy flux and a decrease of 2fp radio activity with decreasing IMF cone angle resulting in IMF lines tangent to the far flank of the bow shock. The 2fp radio activity is more affected by both parameters than the amplitude of Langmuir waves is affected.

Morioka et al. [2001] found the unexpected dumbbell type pitch angle distribution of relativistic electrons in the inner radiation belt from the observation of the Akebono (EXOS-D) satellite. They investigated the spatial distribution of pitch angle anisotropy, and revealed that the dumbbell distribution exists only around the magnetic equator. They also found that the dumbbell distribution appears almost concurrent with the strong UHR emissions, which have been known as Equatorial Plasma Wave Turbulence (EPWAT) phenomena generated at the magnetic equator. Though the mechanism for sustaining unstable pitch angle distribution has not been clear, they suggested the relationship between the EPWAT emissions and the dumbbell distributions.

Plasma wave observation by the Akebono satellite contributed to the modeling of the plasmaspheric plasma distribution. Kimura et al. [2001] reviewed the modeling method using propagating wave characteristics obtained by the satellite and ray tracing. This method can be applied to get a long period variation of plasmaspheric density profile for one solar cycle.

H1.5 Observational and Experimental Techniques

Electron density measurements in the lower ionosphere were carried out during 1975-1992 by using sounding rockets launched at KSC (Kagoshima Space Center in Japan). Nagano and

Okada [2000] estimated low electron densities in the D-region, by comparing the intensity of ground-based VLF and MF radio signals observed by the rockets in the ionosphere, with that calculated by a full wave treatment.

Fukami and Nagano [2000] analyzed the height pattern of an HF radio wave intensity received by a sounding rocket in the daytime ionosphere about 1000 km away from the transmitter. The step-like damping structures of the HF wave observed at about 170 km and 200 km altitudes were found to be caused by reflections of one-hop and two-hop modes of an ordinary wave. By using these reflection heights, they estimated the lower ionospheric electron density profile, which was consistent with the ionogram traces actually measured at the rocket launching site.

Very long (several tens of meters) wire dipole antennas have been used to observe low-frequency (< MHz) AC electric field onboard spacecraft. Accurate measurements of the electric field require the accurate evaluation of the effective length of a wire dipole immersed in space plasmas. By using the whistler-mode wave observations with GEOTAIL spacecraft, Imachi et al. [2000] demonstrated that the effective length is almost a half of the dipole's tip-to-tip length at ELF/VLF frequencies, as conventionally assumed in the past studies.

Wavelet analysis is suitable for investigating waves, such as Pi2 pulsations, which are limited in both time and frequency. Nose et al. [1998c] have developed an algorithm to detect Pi2 pulsations by wavelet analysis. They tested the algorithm and found that the results of Pi2 detection are consistent with those obtained by visual inspection. The algorithm is applied in a project which aims at the nowcasting of substorm onsets.

Elie et al. [1999] proposed use of neural network on the forthcoming satellite DEMETER to identify the coherent VLF signal like whistlers.

Goto et al. [2000a, 2000b, 2001] proposed a direction finding method based on the wave distribution function (WDF) by using the concept of the energy function. The method was applied to the Akebono data and the derived results were in the acceptable range from theoretical viewpoints.

Kasahara et al. [2000] proposed a new computational technique for extracting particular wave phenomena from enormous data sets. Applying this method to the Akebono VLF wave data, some kinds of plasma waves were automatically classified and the spatial distribution of chorus emission was revealed.

Kojima et al. [2000] developed an Automatic Waveform Selection (AWS) method for identifying the electrostatic solitary waves observed by Plasma Wave Instrument (PWI) onboard the Geotail spacecraft. They defined an ESW index using the AWS method. The ESW index allows us to perform statistical analyses by calculating it from a huge amount of Geotail data sets.

In order to measure the Martian plasma waves in the frequencies from dc to 32 kHz, the low frequency plasma waves analyzer (LFA) onbaord the PLANRT-B (NOZOMI) spacecraft has been developed. The scientific objectives and system configuration of LFA are comprehensively presented [Matsumoto et al.,1998].

Ishisaka, et al., [1999a, b; 2001] have derived an empirical relation to estimate the very low electron density in the magnetosphere ranging from 0.001 to 50 /cc by coordinating the spacecraft potential and the plasma wave such as the continuum radiation observed by GEOTAIL.

H2. Theory and Computer Experiments on Plasma Waves

H2.1 Wave Instabilities

Ueno [2001] derived a dispersion relation for the lower-hybrid-drift instability including the effects of magnetic curvature associated with transverse electromagnetic perturbations. To account for the curvature drift, an alternative method proposed by Nakamura [1997] was applied to obtain the perturbed distribution function. The previous treatment, i.e., simulating the curvature drift by a virtual gravitational drift, was found to be considerably inaccurate. When an ambient magnetic field has a curvature so that the curvature drift is directed opposite the grad-B drift, the maximum growth rate increases as long as the radius of curvature is larger than a certain value, while the rate decreases for a sharper magnetic field curvature.

Kono and Tanaka [2000] has formulated a theory of spiral structure formation to show that spiral structures are rather basic entities in magnetized rotating plasmas subjected to various kind of instabilities such as collisional drift wave instability, flute mode instability due to centrifugal force, and Kelvin-Helmhotz instability. The characteristic features of spiral structures observed experimentally in ECR plasmas are reproduced by our theory.

A new analytical approach to cyclotron instability of electron beams with sharp gradients in velocity space is developed by Trakhtengerts et al. [1999] , with taking into account magnetic field in- homogeneity and non-stationary behavior of the electron beam velocity. Under these conditions, the conventional hydrodynamic instability of such beams is drastically modified and second-order resonance effects become important. Hobara et al. [1999, 2000] and Demekhov et al.[2000] studied the properties of electron beams formed by cyclotron interactions between radiation belt electrons and a quasi-monochromatic whistler wave packet from a ground VLF transmitter. The beams are formed due to trapping of the electrons at the forward edge of the wave packet, their acceleration inside the wave packet, the escape of the accelerated electrons from the moving backward edge of the wave packet, and their following free motion in an in homogeneous magnetic field. A combination of these processes provide the main features of the spatial-temporal evolution of the beams, which are investigated both analytically and numerically.

Ishiguro et al. [1999] developed a 2-1/2-dimensional open boundary particle simulation model and studied the current-driven electrostatic ion-cyclotron instability and related D.C. potential difference. Fresh streaming electrons are injected smoothly from th boundaries at each time step, avoiding unphysical accumulation of charged particles in front of the boundaries. As a current-driven electrostatic ion cyclotron instability grows, a d. c. potential difference along the magnetic field lines is created.

Ishiguro and Sato [1999] investigated formation of dc potential structure due to current-driven electrostatic ion-cyclotron instabilities by means of an open boundary two-and-a-half dimensional electrostatic particle cell (PIC) simulation model. A dc potential difference in built up as a fluctuation associated with an ion-cyclotron wave induced by streaming electrons grows. A V-shaped dc potential structure is created for a bell-shaped electron stream, while the dc potential does not have a structure across the magnetic field for a uniform electron stream.

According to the recent observations by several satellites, FAST satellite observed very strong solitary waves in the downward current regions of the mid-altitude auroral zone, and Polar spacecraft also succeeded in detecting solitary waves in the polar region. These solitary waves are reported to have isolated two-dimensional structures. Miyake et al. [2000] studied the formation mechanism of the isolated two-dimensional solitary waves via two-dimensional electrostatic particle simulations. They demonstrated that such isolated two-dimensional solitary waves can be generated by a simple electron two-stream instability.

Kasaba et al. [2001] performed computer simulations of the self-consistent nonlinear evolution of electrostatic and electromagnetic 2fp waves excited by electron beams with electromagnetic particle code. In both one- and two-dimensional periodic systems an electrostatic 2fp wave is generated at twice the wave number of forward propagating Langmuir waves by wave-wave coupling. This wave grows with the forward propagating Langmuir wave in the nonlinear stage of the simulations. The electrostatic 2fp wave in the simulations is saturated at about -20 ~ -30 dB of that of the Langmuir waves. It is larger than the value expected from observations in the terrestrial electron foreshock. The electromagnetic 2fp wave is only excited in two-dimensional systems. The magnitude of the electromagnetic 2fp wave is correlated with the backward propagating Langmuir wave, not with the electrostatic 2fp wave. This result suggests that the electromagnetic 2fp wave is excited by the wave-wave coupling of forward and backward propagating Langmuir waves.

Matsukiyo et al. [1999] compared the relativistic electrostatic beam instabilities driven via the Landau and the cyclotron resonances. The linear theory predicts that, when the electron beams are non-relativistic or only weakly relativistic, the waves are generated predominantly via the Landau interaction for a wide range of plasma parameters, except for a limited parameter regime at oblique propagation angles. However, when the beam electrons are highly relativistic, the cyclotron interaction becomes dominant. They discussed implications on plasma processes in astrophysical environments.

H. 2.2 Wave Propagations

Ohta and Hayakawa [2000] performed three-dimensional ray-tracing taking into account the latitudinal and longitudinal gradients of the ionosphere in order to explain the occurrence of echo-train whistlers at very low latitudes.

From the analysis of the plasma wave observations by the Ulysses spacecraft, Nakagawa et al. [2000] have investigated the dynamics of the Jovian Hectometric Radio Emissions (HOM), which have been thought to be Jovian auroral radio emissions. They revealed that the HOM can be classified into two components, which have different occurrence characteristics with respect to Jovian System III longitude; (i) amplitude of emissions is related to the variation of the solar wind pressure (sw-HOM), and (ii) amplitude of emissions is independent of solar wind parameters (nsw-HOM). They suggested that the source locations of sw- and nsw- HOM emissions are L > 30 and L~12 respectively.

Misawa [2000] performed a 3D ray-tracing analysis on Io-related Jovian decametric radio emission (Io-DAM) to investigate the condition for generation of Io-DAM emissions. The ray tracing was calculated for the case of both R-X and L-O mode emissions using the most recent Jovian global magnetic field model (VIP4). He compared the simulated occurrence probability of observable Io-DAM waves at ground with observations, and concluded that the observed occurrence probability is not explained only by the initial wave condition at the source region (magnetoionic wave mode, ray direction, and source position), but additional conditions which restrict the wave generation must be required.

A feasibility study of LFA plasma wave analyzer onboard NOZOMI spacecraft was made on the detection possibility of Martian atmospherics during large dust storms. By the full wave calculations using the realistic Martian ionospheric model and crustal magnetic anomalies, Okada et al. [2001] showed the conditions for the LFA remote-sensing of the Martian atmospheric discharge.

H2.3 Shocks and Particle Acceleration

Terada and Machida [1999] studied supercritical perpendicular shock waves propagating in a plasma containing electrons and two positive ions (i.e., protons and alpha particles), using a one-dimensional electromagnetic hybrid code. It is found that the shock with moderately high Mach number becomes dynamic and changes its structure periodically, as the number density ratio of heavy ions to protons is increased.

Particle acceleration processes at quasi-parallel shocks have been already widely discussed, however, the very initial injection from thermal to supra-thermal energies is still controversial. Sugiyama et al. [2001] showed that a non-linear wave-particle interaction at quasi-parallel shocks results in quick injection and quick further acceleration of ions to non-thermal (NT) energies. Instead of an ensemble of small amplitude random waves, a large-amplitude monochromatic upstream wave is set to propagate into the shock transition layer and test particle orbits are deterministically calculated. The resultant energy spectrum has the exponential slope extending up to 70 times the upstream bulk flow energy with the characteristic energy being 7 times the upstream bulk flow energy. They have compared this energy spectrum with self-consistent hybrid simulation results and with Geotail satellite observations in the upstream region to find reasonably good agreements.

Motivated by the observational evidences that large amplitude MHD waves in space often have spatially correlated wave forms, Kuramitsu and Hada [2000] discussed energy diffusion and acceleration of charged particles due to such waves, by performing test particle simulations. It was found that, in a presence of locally correlated waves, charged particles can be efficiently accelerated as they are successively mirror reflected by oppositely propagating wave packets, a process analogous to the Fermi acceleration. Statistical properties of the acceleration were discussed in detail.

In a similar context, Krasnoselskikh et al. [1999] analyzed the acceleration and heating of charged particles in a turbulence field with prescribed statistical properties, and identified the relationship between the statistics of the field and that of the diffusion scaling law. The results were discussed for possible applications in several branches of astrophysics and space physics. Some of these theoretical expectations are analyzed by making comparison of observations and test particle simulations of pitch angle diffusion and the parallel transport of energetic solar wind helium ions by Tsurutani et al. [2000]. It was emphasized that the pitch angle diffusion across the 90 degrees was a qualitatively different process from the diffusion at different angles, and that inclusion of finite wave amplitude effect was essential.

H2.4 Nonlinear Effects

Traktengerts et al. [1999, 2001] estimated the role of the second-order cyclotron resonance effect in the self-consistent approach to the problem of triggered VLF emission is estimated. The self-consistency includes the calculation of energetic electron beams produced by a quasi-monochromatic whistler wave packet and the analysis of secondary whistler wave generation by this beam, with the magnetic field inhomogeneity taken into account, and we have estimated the maximum amplification of secondary waves, as well as the dynamic frequency spectrum of a triggered emission.

Krasovsky et al. [1999] studied an elementary event of interaction of two weak electrostatic solitary waves associated with a deficit of the electrons trapped in the self-consistent potential well. Consistent perturbation theory descriptive of the interaction dynamics is developed which is based on the smallness of the trapped electron holes as compared with the length of their shielding by plasma. It is shown that a violation of the adiabaticity of the particle motion and phase mixing process entail an irreversible deformation of the hole structure, effective heating of the holes and the corresponding losses in the mechanical energy of the system. As a result of the peculiar irreversibility, the "collisions" of the solitary waves take the character of inelastic impacts, explaining the general tendency to merging of the phase density holes.

Shinohara et al. [2001] reported that rapid large scale magnetic field dissipation is observed in a full kinetic simulation of cross-field current instabilities in a collisionless plasma current sheet even when the thickness of the current sheet is at ion-scale. The Kelvin-Helmholtz instability caused by the velocity shear between the current-carrying ions and the cold background ions excites lower hybrid drift instability at the edges of the undualated current sheet. They showed that non-linear coupling between these two instabilities is responsible for the observed rapid dissipation. The simulation result clearly illustrates the importance of non-linear coupling between MHD and electron scale instabilities.

In usual MHD, it is assumed that a plasma is both isotropic and gyrotropic at any instant of time. Noting that these are not always justified for applications in space plasmas which are essentially collisionless, Hada et al. [1999] proposed a new model to describe evolution of the plasma, by introducing externally two relaxation time scales, one for isotropization and another for gyrotropization. This model includes both the MHD and the CGL formulations as limiting cases of strong coupling limits of the relaxation time scales. Linear wave dispersion relations within the model are discussed.

In a dusty plasma with streaming ions, it is known that a wake potential is produced downstream of a dust particle due to ion-sound waves. The wake potential is a possible candidate for producing attractive force between the dust particles. Nambu et al. [2000]

discussed the effect of the external magnetic field imposed on the dusty plasma, and showed that the amplitude of the wake potential was significantly reduced because the over-shielding by streaming ions was inhibited by the presence of the external magnetic field.

Buti et al. [2000] studied nonlinear dynamics of large amplitude circularly polarized Alfvenic wave packets using a hybrid model. They discussed the spatio-temporal evolution of the waves including the collapse of the magnetic structures, the polarization switching from the LHP to RHP, and the broadening of the wave packet. These theoretical results in mind, large amplitude Alfven waves and structures were analyzed using the Ulysses data by Tsurutani et al. [2001c]. Discussed herein were the rotational discontinuities, the phase-steepened Alfven waves, and the magnetic field decreases (MD's) bounded by discontinuities. Hybrid simulation results suggest that MDs may be a product of the evolution of nonlinear Alfven waves.

H2.5 Active Experiment and Spacecraft-Environment Interaction

Shklyar and Nagano [1998] developed a systematic approach to the problem of wave scattering on plasma density irregularities. Treating the scattering process as a wave field spatial evolution while crossing the scattering region, they showed that a spatial modulation of the wave packet amplitude caused by spectral broadening in k space is a general consequence of wave scattering. As an example of applications of theoretical consideration, they discussed the relation between amplitude modulation and the apparent spectral broadening of VLF transmitter signals observed by the Akebono satellite in the upper ionosphere.

Usui et al. [1999c] performed computer experiments on the measurement of reentry plasma with radio waves with an electromagnetic particle code. They propose a remote measurement of the reentry plasma with the reflectmetry method which uses radio wave emission from the vehicle. In the experiments, we emit a pulse wave with no DC component from a vehicle antenna toward a Gaussian reentry plasma put in front of the vehicle surface. The obtained phase difference between the emitted and reflected waves is used in the reflectmetry to estimate the spatial density profile. The spectrum of the reflected waves which has a cut-off frequency at the maximum plasma frequency is used to estimate the maximum density in the plasma layer. The results of the computer experiments revealed that the plasma parameters estimated with the reflectmetry agree very well with the ones actually used in the experiments.

H2.6 Te chniques of Data Analysis and Computer Experiments

Umeda et al. [2001] developed a new scheme to mask electromagnetic fields for absorbing boundaries used in electromagnetic particle codes. The conventional masking method can suppress reflection of various plasma waves by assigning large damping regions for absorbing boundaries. It requires substantial computer memory and processing time. They introduced two new parameters to control absorption of outgoing electromagnetic waves. The first parameter is a damping parameter to change the effective length of damping regions. The second parameter is a retarding parameter to change phase velocities of electromagnetic waves in the damping regions. As a new masking method, we apply both damping and retarding factors. They also found that the best absorption of outgoing waves is realized with a combination of a smaller damping factor and a larger retarding factor. The new method allows us to reduce the size of damping regions substantially.

A two-dimensional (2d) relativistic electromagnetic PIC code called XOOPIC

(Object-Oriented Particle-in-Cell code for X11-based Unix workstations) has been developed since the early 1990s by PTSG (Plasma Theory and Simulation Group) in the University of California at Berkeley. In order to minimize the redundancy in one-dimensional simulations, Usui et al. [2000] developed a 1d-XOOPIC in which 1d arrays are used for field components as well as particle positions. The formulations are also simplified for Maxwell's equations and current deposition to the grid in the 1d code. To verify the function of the 1d code, we performed simulations with typical models such as the Child-Langmuir current model and electromagnetic wave propagation in plasma.

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