COMMISSION H : Waves in Plasmas (Nov. '2001 - Oct. '2004)

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Based on the papers published from November of 2001 to October of 2004, we have compiled major achievements in the field of plasma waves and related studies made by Japanese scientists and their collaborators. We have categorized 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 three years covered by this report mark the start and growth of the ground-based remote-sensing of the magnetospheric plasma mass density by using ULF waves; from a geomagnetic field-line eigen-frequency, that is identified by applying method(s) in a group of methods called "gradient methods" to the data from two ground magnetometers separated in latitude by about 1 degree, one can estimate the plasma mass density at the equatorial point along the field line that runs through the midpoint of the two magnetometer sites. By applying this procedure to a chain of ground magnetometers, one can remote-sense the L-dependence of the magnetospheric equatorial plasma mass density. Kyushu University, Japan, having CPMN (Circum-pan Pacific Magnetometer Network; previously called 210MM), has been working along this line of research. Kawano et al. [2002] applied an improved method, called the "amplitude-phase gradient method" (APGM), to actually observed data for the first time, and proved its usefulness; they further improved APGM so that it can be applied to a chain of ground stations at once.

There exist papers on Pc pulsations: Matsuoka et al. [2002] studied high-latitude narrow-band Pc3 pulsations by using ground magnetometer arrays, SuperDARN radars, and the GEOTAIL satellite. As a result they found that, at times, there existed high coherence between the pulsations in the dawn magnetosheath and on the ground, from which fact they suggested that the driving source was located in the magnetosheath. Tanaka et al. [2004] statistically examined the longitudinal structures of coherence, amplitude, and phase of the Pc-3 H component by using three longitudinally separated sub-equatorial stations, and reported for the first time a nearly in-phase structure in the 0730-1700 LT sector and a nearly 180-deg phase jump across 0730 LT. Motoba et al. [2002; 2003; 2004] reported the existence of, and studied, Pc5-range magnetic-field oscillations on the ground that were actually caused by oscillations of a DP2-type current system.

Electric and magnetic field variations inside the plasmasphere associated with sudden commencements (SCs) are analyzed based on the Akebono satellite observations. Shinbori et al. [2004] showed that intense electric field disturbances with a bi-polar waveform associated with SCs are followed by a dumping oscillation with a period of Pc3-4 ranges. The dumping oscillation persisted for about 3-7 minutes in the equatorial region of the plasmasphere. The phase relation of Ex and Bz components of the oscillation reveals that there is a phase lag of about 90 degrees with compression nature. From this result, they concluded that the dumping oscillation generated by SC disturbances may be fast mode waves propagating in the plasmasphere.

The Hall-induced inductive shielding effect (ISE) of the ionosphere affects currents and electric fields that have impinged into the ionosphere from the magnetosphere. Yoshikawa et al. [2002] developed a new formula describing the inductive behavior of the magnetosphere-ionosphere-atmosphere-Earth system, and by using it, they investigated the ISE on geomagnetic pulsations. As a result, they found that dayside Pc 3-4 pulsations may be frequently affected by the ISE.

Many scientists worked on Pi2 pulsations: Yamaguchi et al. [2002] presented a case study in which a bursty bulk flow (BBF) in the plasma sheet started prior to the corresponding ground Pi2 onset, but was preceded by the corresponding Pi2 onset at GOES8. From this and another feature they suggested that the BBF was not the cause of the low-latitude Pi2. Shiokawa et al. [2002] examined 10s-resolution ground-observed auroral images at the times of Pi2s, but did not find an oscillation of the auroral luminosity synchronized with the oscillation of Pi2. Higuchi et al. [2002] presented a new method to identify the Pi2 onset time; the method is based on statistical science and uses, e.g., Akaike Information Criterion (AIC). Saka et al. [2002; 2004] suggested, mainly based on observations at the synchronous orbit, that impulsive dusk-to-dawn current near the nightside synchronous orbit, which current is closed by field-aligned currents, is a source of Pi2.

Nose et al. [2003] investigated a morning-side Pi2 using ground stations and the ETS-VI and EXOS-D satellites; from the dependence on (L,LT) of the observed waveform, period and phase, they concluded that the Pi2 was caused by the plasmaspheric cavity mode resonance and that its longitudinal structure was rather uniform. Uozumi et al. [2004] investigated propagations of high-latitude Pi2s observed by CPMN ground stations. With the aid of POLAR/UVI auroral images, they found that Pi2 was observed earlier (by about35s) in the polar cap than in the auroral region; thus, Pi2 in the polar cap is to be used to determine the substorm onset time. They also found the starting MLT of Pi2 to be 22.5 hr.

Fujita et al. [2001] numerically calculated how a Pi2 pulsation propagates in the magnetosphere-ionosphere system. They also showed its relation with the substorm current wedge [Fujita et al., 2002]. In recent years, a cavity resonance mode has been widely believed as the main mechanism of low-latitude Pi2 pulsations. Although it has been implicitly assumed that the frequency should be the same throughout different local time zones for cavity resonance mode, Kosaka et al. [2002] and Han et al. [2003] found a local time dependence of the dominant frequency. To explain their results, Fujita and Itonaga [2003] made a numerical simulation and showed that the frequency can be local time dependent in the longitudinally non-uniform plasmasphere. The propagation mechanism of Pi2 pulsations has also been investigated using satellite data by and Han et al. [2004]: They confirmed that the cavity resonance mode is the most plausible mechanism in low latitudes.

As regards Sudden Commencements/Impulses (SC/SI), Takeuchi et al. [2002a] reported that negative SIs are not caused by reverse shocks but by varied structures such as tangential discontinuities at high-low speed stream interfaces, front boundaries of interplanetary magnetic clouds, and trailing edges of heliospheric plasma sheets. Takeuchi et al. [2002b] reported that, for an SC with long rise time (30 min), the corresponding interplanetary shock, observed in the solar wind, was as sharp as usual SCs, but its normal was highly inclined duskward. Araki et al. [2004] statistically analyzed SCs, and reported that the rise time is essentially determined by time for an interplanetary shock to sweep geoeffective magnetopause length L, which they estimated to be about 30 Re.

Nakagawa et al. [2003] reported left-handed ULF waves with frequency of 0.3-1.1 Hz detected by GEOTAIL at 27 lunar radii upstream of the moon when GEOTAIL was located on field lines that ran through the lunar wake. They explained the observation by polarization-reversal of right-handed, sunward-propagating electron whistler waves with frequencies above 1.4 Hz in the solar wind rest frame, and suggested that the waves were excited by electron beams that had field-aligned-flowed anti-sunward through the lunar wake.

H1.2 Generation and Propagation of ELF/VLF Waves

The GEOTAIL spacecraft has observed Lobe Trapped Continuum Radiation (LTCR) in the Earth's distant magnetotail in the frequency range from several hundreds of Hz up to 8 kHz. Takano et al. [2001, 2004] have estimated the generation region of the LTCR by means of direction finding and three-dimensional ray tracing analyses. The direction finding analysis with the wave form data of the LTCR has shown that most of the LTCR propagates along the dawn-dusk direction. Comparing this result with the three-dimensional ray tracing analysis, the generation region of the LTCR has been estimated to be located around the plasma sheet boundary layer and the low latitude boundary layer of the distant magnetotail.

The low latitude boundary layer (LLBL) is a region where solar wind momentum and energy is transferred to the magnetosphere. Enhanced “broadband” electric plasma waves from <5 Hz to 105 Hz and magnetic waves from <5 Hz to the electron cyclotron frequency are characteristic of the LLBL. Tsurutani et al. [2003] reviewed wave-particle interactions, with focus on cross-diffusion rates and the contributions of such interactions toward the formation of the boundary layer and presented a scenario where the global solar wind-magnetosphere interaction is responsible for the auroral zone particle beams, the generation of plasma waves, and the formation of the boundary layer.

Shinbori et al. [2002] reported that plasma wave phenomena associated with sudden commencements (SCs) are analyzed by using the Akebono satellite observation data which have been carried out for more than 13 years since March 1989. The 719 cases of SC events showed an enhancement of plasma waves with one-to-one correspondence to the SC onsets measured at Kakioka in the inner magnetosphere, plasmasphere, and polar ionosphere. In the middle latitude and in the equatorial region of plasmasphere, electromagnetic whistler, LHR, and ion cyclotron mode waves are generated, while in the high latitude region, clear enhancements of electrostatic whistler mode waves with broad-banded spectra are observed.

From time difference between the onset times of SC on the ground and the plasma wave enhancements, Shinbori et al. [2003b] verified that the propagation nature of the SC disturbances deduced from these observations has shown two folding signatures; one route is crossing the equator regions with an average speed of 389.5 km/s, and the other route is passing the polar regions entering from the cusp region and propagating from the dayside to the nightside polar ionosphere with an average speed of 47 km/s.

Higashi et al. [2004] estimated the impedance of the wire dipole antennas onboard the Akebono satellite by using the electromagnetic field observations for Omega navigational signals. The estimated capacitance and resistance exhibit specific spin variation, which would be caused by the plasma sheath formation around the antenna wires depending on the angle between the antenna direction and the geomagnetic field line.

Imachi et al. [2004] studied the effective lengths of a wire dipole antenna onboard spacecraft and found the frequency dependence from DC (static) to AC (wave) electric fields by a “rheometry” experiment, where a scale model of the antenna is immersed in a water tank with two electrodes creating a quasi-static electric field in it.

The SS-520-2 rocket experiment was carried out over Ny-alesund, Svalbard, Norway, on Dec. 4, 2000, in the dayside polar region. With the onboard Plasma Wave Analyzer (PWA), Ueda et al. [2003] have observed impulsive packet-like waveforms with frequencies around 3 to 4 kHz as well as auroral hiss emissions. The packet-like waveforms were linearly polarized, and appeared for the duration of 100-500 ms, with their spectral peaks well below the lower cutoff of the auroral hiss emissions. The cross correlation obtained with the PWA interferometry system has estimated the phase velocity of the packet-like waves to be about 60 km/s. With the linear dispersion analysis they have shown that the most plausible wave mode for the packet-like waveforms is the lower hybrid wave excited by electron beams. On the other hand, the Electric Field Detector (EFD) onboard the SS-520-2 rocket was designed to observe DC electric fields and plasma waves with frequencies up to 50 Hz. Miyake et al. [2003] have analyzed EFD data, especially on natural DC electric fields observed in the noon polar region, by eliminating inductive electric fields with estimating several parameters. They have shown that natural DC electric fields were observed around the apogee and descending period of the rocket's trajectory, with their magnitudes of 20 - 40 mV/m, and with almost south-westward directions.

Two large scientific balloons (PPB: Polar Patrol Balloon) were launched on Jan. 13th, 2003 at Syowa Station in Antarctica. The balloons reached the altitude of 33 km, and observed important scientific data for about two weeks. Miyake et al. [2004] have participated in this project for observation of ELF/VLF electromagnetic waves. They developed a wide-band electromagnetic wave receiver EMW (ElectroMagnetic Wave receiver) onboard PPB, which can observe waveforms of ELF waves and power spectra of VLF waves. This EMW receiver worked properly, and succeeded in observing clear electromagnetic wave data.

Singh and Hayakawa [2001, 2003] examined the relative merits of ducted and non-ducted propagations of low-latitude whistlers critically in the light of works done mostly in the Asian countries. They found a growing consensus in favor of the non-ducted pro-longitudinal mode of propagation for nighttime whistlers, and ducted propagation for daytime whistlers. Hayakawa and Ohta, [2003] reviewed the direction finding systems and suggested the importance of the use of direction finding in VLF studies with a few experimental examples.

In an attempt to monitor subsurface VLF electric field changes associated with earthquakes, a borehole antenna has been installed at Agra, India. Some preliminary data analysis by Singh et al. [2003] has indicated penetration of ionospheric/magnetospheric VLF signals to large depths in the crustal region and caution for careful identification of seismogenic VLF signals.

Hayakawa and Nickolaenko [2001] reviewed lightning effects onto the mesosphere and lower ionosphere extensively in relation to the generation of sprites and elves and the associated ELF transients. Hobara et al., [2001, 2003] and Hayakawa et al, [2004b] have carried out the observation of sprites for the winter lightning in the Hokuriku area of Japan and found that sprites are really triggered mainly by +CGs whose charge moment change is exceeding the threshold of 200 ~ 300 C·km.

Otsuyama et al. [2002, 2003a, 2004a, 2004b] studied the VLF signature of ionospheric perturbations (Trimpis) associated with winter lightnings in the Hokuriku area. They found that there is no significant difference in the Trimpi occurrence rate between – and + CGs. Otsuyama et al.

[2002] also performed an FDTD computer simulation for VLF scattering in the Earth-ionosphere waveguide. Molchanov et al. [2001] investigated the modulation in the amplitude and/or phase of subionospheric VLF propagation. The result indicated the significant power in the frequency range of atmospheric gravity waves.

Hayakawa et al. [2004a] have presented the long-term observational results on the ionospheric Alfven resonance at middle latitudes on the basis of observation at Kamchatka and introduced a lot of resonance properties. Nickolaenko et al. [2004c] suggested an alternative mechanism due to the wave interference in the ionosphere and magnetosphere.

Ando et al. [2002] have theoretically investigated the penetrations of power line harmonics and compared with the previous satellite VLF observation. Soloviev and Hayakawa [2002, 2004] have proposed an algorithm to study the VLF scattering with taken into account a 3D local ionospheric irregularity over the ground of the solar terminator transition on the basis of a mathematical model, an asymptotic theory and an appropriate numerical method.

Hayakawa and Otsuyama [2002], Otsuyama et al. [2003b] and Otsuyama and Hayakawa[2004] have applied the FDTD method to the global Schumann resonances. They demonstrated that this application is expected to be very useful for the complicated ionospheric models (day/night asymmetry, local ionospheric perturbation etc.). Ando and Hayakawa [2004] have studied the inverse problem extensively for the Schumann resonance data observed at a few stations in the world and deduced the global distribution of background lightning activity. Nickolaenko et al., [2004a, 2004b] have developed an algorithm to accelerate the convergence of the time domain formal solution for the natural ELF transient pulses in the Earth-ionosphere waveguide.

H1.3 Electrostatic Waves Excited by Electrons

Electrostatic waves associated with reconnection phenomena in the dayside magnetosphere region, were reported by Matsumoto et al. [2003] using the observation results by GEOTAIL skimmed along the dayside magnetopause. They confirmed the 3-dimensional multiple x-line magnetic reconnections take place in the same time period. The observed electrostatic waves are Electrostatic Solitary Waves (ESW) and Amplitude Modulated Electrostatic Waves (AMEW). They showed that the enhanced broadband electrostatic emissions associated with reconnection are not random noises but are nonlinear coherent structures which may provide important dissipation in the electron diffusion region during reconnection.

In the auroral zone and polar cap region outside the plasmapause, Shinbori et al. [2002, 2003b] reported that electrostatic whistler mode waves with broad-banded spectra suddenly appear below the local electron cyclotron frequency associated with SC onsets measured at Kakioka in the plasma wave data of the Akebono satellite. The ratio (E/H) of electric and magnetic field intensity of the plasma waves at 17.8 kHz obtained by the VLF instruments onboard the Akebono satellite is much larger than that of electromagnetic waves in vacuum. This result suggested electrostatic nature of the whistler mode waves. From simultaneous observation of low energy electrons by the Akebono satellite, Shinbori et al. [2003b] showed that the electrostatic whistler mode waves are excited by electron beams with an energy range of less than 100 eV.

Shin et al. [2004] showed the waveforms of the intense electrostatic waves observed in the downstream region are quasi-monochromatic. They named their waves Electrostatic Quasi-Monochromatic (EQM) waves. By comparing the plasma wave data with electron data, they found the good correlation of the observations of EQM waves with beam-like cold electrons. They suggested that the EQM waves are electron acoustic mode waves based on the preliminary linear dispersion analyses.

H1.4 Electromagnetic Waves Excited by Electrons

Using the Plasma Wave Instrument (PWI) data from the GEOTAIL satellite, Nagano et al. [2003a] showed that the angular intensity distribution of the Continuum Radiation (CR) received in the magnetotail regions changes from isotropic to anisotropic above a specific frequency. They interpret the transition as evidence of the magnetosheath cavity trapping of terrestrial radiation and that the magnetosheath plasma relaxes at the local Alfven speed, rather than the solar wind convection speed.

Kilometric continuum (KC) radiation was first identified from GEOTAIL plasma wave observations. This emission has a frequency range that overlaps that of the auroral kilometric radiation (AKR) but is characterized by a fine structure of narrow bandwidth with nearly constant or drifting frequency. Its source region is probably associated with the low-latitude inner magnetosphere. Menietti et al. [2003] reported new high-resolution electric and magnetic field observations of KC obtained by the Polar plasma wave instrument in the near-source region. These observations show intense electrostatic and less intense electromagnetic emissions near the magnetic equator at the plasmapause. Simultaneously, GEOTAIL, located at 20 to 30 RE in radial distance, observes KC in the same frequency range. These data support a possible mode-conversion source mechanism near a region of high-density gradient.

Green et al. [2004] compared a year's worth of observations of kilometric continuum (KC) from the plasma wave instrument (PWI) on GEOTAIL and extreme ultraviolet (EUV) images of the plasmasphere from IMAGE. KC was observed to be associated with density depletions or notch structures in the plasmasphere. IMAGE observations from the radio plasma imager (RPI) during passage through a plasmaspheric notch structure found that KC was generated in or very near the magnetic equator at steep gradients in density.

GEOTAIL and POLAR Plasma Wave (PWI) and WIND Radio Science (WAVES) experiments' detections from typically widely separated positions of emissions are compared and contrasted by

Anderson et al. [2001] in order to study the plasma characteristics near the sources and the generation mechanisms for 2fpe emissions, AKR, and other terrestrial wave phenomena. The GEOTAIL and POLAR Plasma Wave Instruments (PWI) both included sweep frequency receivers that had an upper frequency limit of 800 kHz and the WlND WAVES Thermal Noise Receiver (TNR) and Radio Receiver Band I (RAD1) went to 256 kHz and 1024 kHz, respectively. Anderson et al. [2004] have been able to observe the majority of the AKR spectrum in better detail than with earlier instrumentation and have made many important new discoveries concerning Terrestrial low frequency (LF) bursts, which are a part of AKR observed during strong substorms. Data from both satellite and ground-based experiments show that the LF bursts are well correlated with expansive phase onsets and occur during very geomagnetically-disturbed periods.

Imhof et al. [2003] compared simultaneous observations of bremsstrahlung X-rays above 2 keV from the Polar Ionospheric X-ray Imaging Experiment (PIXIE) on the POLAR satellite with the frequency distributions of AKR waves measured with the Plasma Wave Instrument (PWI) on the GEOTAIL satellite. Various AKR characteristics such as the low- and high- frequency cutoffs and the frequencies at peak intensity are compared with various X-ray parameters such as the magnetic local times of emission, the total intensities, and the spectral shapes. Imhof et al. [2004] further made comparisons between X-ray (>2 keV) emissions emanating from the Earth's Northern Hemisphere aurora observed on the Polar satellite and auroral kilometric radiation (AKR) plasma wave intensities detected on the GEOTAIL satellite. It is found that short time-scale variations of the LF-AKR activity often correspond to the temporal fine structure of the intensity (5-10 min) of X-ray auroral emissions. HF-AKR intensity enhancements generally precede enhancements of the X-ray emissions, while the LF-AKR intensity enhancements generally lag the X-ray enhancements.

The propagation characteristics of auroral kilometric radiation (AKR), the propagation mode, power flux as well as propagation direction, have been analyzed by applying the wave distribution function method to the Poynting flux measurement data of the Akebono satellite. Hosotani et al. [2001] showed that the power flux of O-mode waves was about 10% of the X-mode wave intensity in strong AKR emissions. The X-mode AKR waves tend to fill inside the radiation cone of an auroral field line, while the O-mode AKR waves showed two different propagation directions: one was directed to almost 90 degree with respect to the local magnetic field and the other showed the propagation angle of about 40 degree. From the above results, they concluded that the source locations of the O-mode AKR waves with the above propagation angle located close to the source of the intense X-mode AKR waves.

It is well known that auroral kilometric radiation (AKR) is intensified during substorms and has a good correlation with AE index. In the case of the magnetic storms, however, AKR characteristics have not been investigated. Morioka et al. [2003] report unexpected behavior of the storm-time AKR and its related particle precipitation: (1) AKR often disappears in the initial and main phases of the magnetic storms in spite of the large enhancement of AE index and field-aligned current, (2) At that time, the energy spectra of precipitating electrons do not show signature of the field- aligned acceleration but hot electron injection, (3) The radiation activates strongly in the recovery phase, and (4) AKR tends to disappear in larger storms. These results suggest that the field-aligned electric field which accelerates precipitating electrons and drives field-aligned currents is not formed in the initial and main phases of magnetic storms.

Kumamoto et al. [2001] studied the seasonal variations of AKR activities and up-flowing ion (UFI) events based on long-term plasma wave and particle data obtained by the Akebono satellite. The analysis results suggested that field-aligned potential drops vary depending on the seasons and cause AKR seasonal variations. Furthermore, Kumamoto et al. [2003a] have investigated seasonal and solar cycle variations of AKR and UFI. In the summer polar region, the peak of the vertical distribution of the occurrence probability of AKR sources is at an altitude higher than 5000 km with a value of 10% in the solar maximum period and at an altitude of 5000-6000 km with a value of 40% in the solar minimum period. The AKR and UFI occurrence probabilities decrease with increasing solar EUV ionization in the ionosphere. Kumamoto et al. [2003b] have derived long-term variations of ambient plasma density in the auroral regions from whistler wave data, and discussed as a control factor of solar cycle variations of field-aligned potential drops and AKR sources. AKR occurrence maximum coincides not with solar wind dynamic pressure peak, but with sunspot number and F10.7 minimum. UFI events and ambient plasma density also show similar behavior.

Shinbori et al. [2003a] showed that the plasma wave data from 263 satellite passages covering the SC onsets included 85 cases of AKR enhancement within a frequency range from 100 kHz to 1.2 MHz. The start time of the AKR enhancements tended to occur after the SC onsets determined by using the geomagnetic records of the Kakioka Magnetic Observatory within a time range from 3 to 8 minutes. The averaged time is about 5.26 minutes. Based on the delay time feature, the magnetic disturbances associated with SCs were thought to propagate from the dayside magnetosphere to the nightside tail region where they compressed the plasma sheet.

The second harmonic wave properties of AKR were investigated by using the plasma wave data of the Akebono satellite. The statistical analysis results by Hosotani et al. [2003] showed that the probability of a harmonic event occurrence is more than 60% of all AKR events, whose relationship between the frequencies of the fundamentals and the second harmonics is exactly two times for the upper and lower cut-off frequencies of the spectra as well as the fine structures. They showed that the intensity ratio of the second harmonics to the fundamentals exhibits a two-fold nature, with both a linear and a quadratic relationship. Furthermore, the second harmonic waves of the X-mode of AKR are generated from a source which is identical to that of fundamental waves of the O-mode. These data analysis results suggest that possible generation mechanism of AKR harmonic structure should allow the coexistence of different AKR emission processes.

Characteristics of type III solar radio bursts are studied by Kasahara et al. [2001] using high-frequency resolution of the SFA of the PWI instrument on board the GEOTAIL spacecraft. Abnormal type III bursts which have separated frequency bands or have prolonged tails at particular frequencies are often observed. These observations provide observational clues to detect density inhomogeneities in the upstream interplanetary medium. They propose possible models of interplanetary density structures which can account for some type III structures observed.

Murata et al. [2004a] studied the Auroral kilometric radiation(AKR) occultations in the vicinity of the Earth using two observations by GEOTAIL and POLAR. They compared the dynamic spectra of both satellites for eight months paying attention to times and frequencies at which AKR is observed simultaneously. Then, we carefully examined the AKR illumination regions using the POLAR two-month orbit data. Two distinct regions where the AKR is occulted are found during the period. One is the region on the night side of the Earth, where the AKR does not propagate at frequencies > 400 kHz. The other region is in the vicinity of the plasmapause, on both the day and night side of the Earth.

Long-term data analysis results of the seasonal variations of AKR activity by Kumamoto et al. [2001] suggested that field-aligned potential drops varies depending on the seasons. The idea was supported by Kumamoto et al. [2001], which clarified the similar seasonal variations of upflowing ion (UFI) events. Furthermore, Kumamoto et al. [2003a] have discovered the solar cycle dependence of vertical distribution of AKR sources and UFI events: AKR and UFI are quiet during solar maximum while they become active during solar minimum. By Kumamoto et al. [2003b], long-term variations of ambient plasma density in the auroral regions has been derived from whistler wave data, and discussed as a control factor of solar cycle variations of field-aligned potential drops and AKR sources.

By using their model to explain the production of modulation lanes in the dynamic spectra of Jupiter's decametric emission and the analysis of the curvature of the modulation lanes, Imai et al. [2001] have obtained the cone half-angle of the emission for the Io-B source. Their results show that the value of the cone half-angle remains at a fixed value of 60 degrees for each of the storms analyzed and that the longitude of the intersection of the active magnetic flux tube with the equatorial plane increased linearly with time. Imai et al. [2002] used the model with newly available data to test the model and to measure emission source and beam parameters. This measurement is consistent with the long-held idea that the sources Io-B, Io-A, and non-Io-A are due to the same rotating hollow-cone beam and that the only difference between the latter two is the intensification of Io-A radiation by the connection with Io in comparison with that of non-Io-A.

The characteristics of the Jovian Anomalous Continuum (JAC) in interplanetary space and in the magnetosheath are investigated using Ulysses observation. Morioka et al. [2004] obtained some new source characteristics of JAC in addition to those found in previous works. They also evaluate possible sources of JAC and hypothesize that its origin is Langmuir waves excited at the magnetopause by energetic particles such as QP bursts ejected from the polar magnetosphere. The relation of magnetospheric disturbances to the generation of JAC is also discussed.

Morioka et al. [2002] investigated the persistence of the most intense Jovian decameter bursts observed during 17 consecutive years (1974 - 1990). The results showed that even the most intense group of decametric storms lasted only one-earth-day or less. When it is assumed that the persistence of the Jovian decametric radio storms indicate the duration of the Jovian magnetospheric disturbance, the result implies that even the large Jovian magnetospheric disturbance appears in a major singular event without sequential activities. From this argument, it would be supposed that the Jovian magnetosphere unloads the stored magnetospheric energy in a burst and has no geomagnetic storm-like disturbance.

The dynamic behavior of electrons with energies from a few tens keV to a few MeV and its relation to plasma waves were examined, using the data from the NOAA and EXOS-D satellites during the November 3, 1993 magnetic storm [Miyoshi et al., 2003]. After the late main phase, relativistic electron flux started to recover from the heart of the outer radiation belt, where the cold plasma density was extremely low and intense whistler mode chorus emissions were detected. The phase space density showed a peak in the outer belt, and the peak increased gradually. The simulation of the inward radial diffusion process could not reproduce the observed energy spectrum and phase space density variation. On the other hand, the simulated energy diffusion due to the gyroresonant electron-whistler mode wave interactions, under the assumption of the Kolmogorov turbulence spectra, could generate the relativistic electrons without the transport from the outer region.

Krasovsky et al. [2002] studied the dynamics of high energy electrons in gyroresonance with a quasi-monochromatic circularly polarized whistler mode tracing a geomagnetic field line are studied numerically. The space-time dependence of the electromagnetic field manifests itself in the existence of an approximate invariant of the electron motion. Under the conditions characteristic of the magnetosphere, this invariant is found to be conserved with very high accuracy even in the process of resonant wave-particle interaction, whereas the constancy of the electron magnetic moment is strongly violated in the resonance.

H1.5 Observational and Experimental Techniques

Ishisaka et al., [2004] investigated that the relationship between the GEOTAIL spacecraft potential and the electron number density determined by the plasma wave observations in the solar wind and broader magnetosphere (except for the high-density plasmasphere) and obtained an empirical formula shown by the relation between them. Using this empirical formula and plasma particle measurements, they have shown the distribution of low-energy plasma in the magnetosphere.

Goto et al., [2002] proposed a method to determine the global plasma profile in the plasmasphere from the satellite observation data. They adopted a stochastic model to represent the distribution of plasma. In the model, the parameters were determined by ABIC (Akaike Baysian Information Criterion) deduced from observed wave data. The validity of our method was evaluated using simulated data and it was found that the given distributions were successfully reconstructed by smoothing the observation data appropriately.

A determination method of plasmaspheric electron density profile has been developed by using OMEGA signals observed by the Akebono satellite. The wave parameters of the signals reflect the density along the propagation paths and can be calculated theoretically by ray tracing if the density profile is given. Thus the profile is reconstructed by model fitting so that the observed and theoretical wave parameters are consistent with each other. A novel algorithm based on this method was proposed, in which stochastic factors were taken into account. Goto et al., [2003] proposed a technique to separate the effects of ionosphere and plasmasphere to the wave parameters in this algorithm and apply it to some observational data of Akebono. The result for a recovery phase of a geomagnetic storm reveals the global compression and refilling clearly. In the other example, the method is applied to examine the symmetry of the plasmaspheric profile. Then Goto et al., [2004] have improved the method in order to deal with nonducted whistlers which are one of the most typical VLF wave in the plasmasphere. The nonducted whistlers originate from atmospherics, and the occurrence probability at an observational satellite is higher than that of Omega signals.

In order to determine the propagation mode of Jovian decametric radiation (DAM), Nakajo et al. [2001] instrumented the long range baseline interferometer and examined the stability of the phase information to the interferometry system. In the long baseline interferometer observation, it has been well known that the observed fringe phases are fluctuated by the temporary variation of TEC (Total Electron Contents). The dual frequency interferometer method is a powerful method to eliminate the influence of TEC; however, the problem caused by the dependence of the linear equations must be considered in the case of the observation of Jovian decametric radiation.

S-burst phenomena of DAM are investigated by Oya et al. [2001a], who reported that dynamic spectra of the S-bursts are obtained by using a high time resolution radio spectrograph with a time resolution of 2 ms and a bandwidth of 2 MHz. Within the occurrence feature of 65 S-burst events observed in the period from 1983 to 1999, 26 events have been identified as the S-N burst events, which are characterized by the interaction between the S-burst emissions and the Narrow band emissions.

Oya et al. [2001b] have developed array antenna system and multi-frequency interferometer network to investigate the electromagnetic radiation process in the Jovian magnetosphere. To understand the energy source and the radiation process of DAM with correlation to the Jovian auroras, ionosphere-magnetosphere couplings and interactions with satellite Io, it is important to obtain the information on the source location and the polarization of DAMs. The array antenna system consists of 9 antennas covering a frequency range from 20 MHz to 30 MHz. The new long baseline interferometer system employs the multi-frequency interferometer method by which ionosphere scintillation effect can be largely reduced.

In the dynamic spectra of the S-N burst, Oya et al. [2002] found the trend of emissions with negative and slower frequency drift named as "Trailing Edge Emission (TEE)", which are often observed shortly after the appearance of the S-burst. Detailed analyses of these phenomena revealed that the TEE is not a manifestation of S-burst with slower drift rate but a variation of N-burst. The results suggested that S-burst and the associated TEE are formed simultaneously started from a common region with different drift rates.

Oya and Iizima [2003] proposed a new method for detecting the phase difference of cesium frequency standards facilitated at coupling stations of an interferometer of 100km range baselines for observations of decameter wavelength radio waves. The feasibility of the proposed method has been verified by applying the method to observations of a 100km range baseline interferometer for decameter wavelength radio waves at Tohoku University selecting the radio-wave sources in the Cassiopeia A supernova remnant as the objective.

Hashimoto et al., [2003] developed a software wave receiver utilizing a programmable down converter (HSP50214B) and a digital data processor (TMS320C31) to obtain the spectra and waveform of plasma waves in wide frequency ranges of ELF, VLF and LF bands with high frequency and time resolution. They reported the successful flight test by using the SS520-2 rocket experiment on Dec. 2000 launched from Ny-Alesund in Svalbard in Norway, which indicates that the new plasma wave receiver to be used for future planet explorers and space observation missions.

Tsutsui [2002] developed a newly developed system for measuring electromagnetic (EM) environment in the earth to detect the earth-origin electric pulses which were leaking out of the ground. The author reported that intensity of the electric pulses detected above the ground was weaker than those in the earth.

H2. Theory and Computer Experiments on Plasma Waves

H2.1 Wave Instabilities

Computer simulations of the self-consistent nonlinear evolution of electrostatic and electromagnetic $2f_p$ waves excited by electron beams with electromagnetic particle code have been carried out by Kasaba et al. [2001]. Their results showed that in both one- and two-dimensional periodic systems an electrostatic $2f_p$ wave is generated at twice the wave number of forward propagating Langmuir waves by wave-wave, while the electromagnetic $2f_p$ wave is only excited in two-dimensional systems.

Kasaba et al. [2004] studied several topics related to the 2fp radiation generated in the terrestrial electron foreshock. They present a summary of the generation mechanism of electrostatic and electromagnetic 2fp waves and the electron acceleration at the quasi-perpendicular shock.

Omura et al. [2003] have studied the response of thermal plasmas to an induction electric field via one-dimensional particle simulations. Because of acceleration of electrons and ions in the opposite directions, there arise counter streaming electrons and ions that cause the Buneman instability. hey found that the induction electric field can form an electron beam along the magnetic field line.

Matsukiyo et al. [2004] succeeded in reproducing the high-frequency electric wave spectra observed in the auroral upward current region by one-dimensional particle-in-cell simulations. Using distribution functions suggested by the measurements, they found that in the nonlinear state, ion acoustic waves and electron two-stream (Langmuir) waves dominate the spectrum. In the absence of cold electrons, electron acoustic waves are not excited initially but appear only at a late time. This is due to the result of the formation of a two-temperature electron plasma by nonlinear interactions when all other instabilities have saturated.

Deng et al. [2004] have provided possible evidence of multiple X lines collisionless reconnection in the magnetotail at the microscopic level by combining the observations of plasma, magnetic field, particles, and waves. On 11 December 1994 the GEOTAIL spacecraft encountered an active reconnection diffusion region around the X line in the Earth's magnetotail. Three interesting features were observed. One is quadrupole pattern of the out-of-plane By magnetic field component during the passage of magnetic islands and the crossing of the neutral sheet. The second is a direction reversal of the electron beams in the vicinity of the separatrix of the magnetic topology of reconnection. The third is a clear plasma flow reversal.

Whistler-mode wave-electron interactions constitute an important physical mechanism in the Earth’s magnetosphere and the radiation belts of the magnetized planets. Omura and Summers [2004] performed an electromagnetic particle simulation to confirm analytical results for the growth rate of whistler-mode waves in a relativistic bi-Maxwellian plasma with given temperature anisotropy.

H2.2 Wave Propagations

Okada et al. [2001] evaluated the propagation characteristics of ELF and VLF electromagnetic waves in the Martian ionosphere, and discussed the possibility for the detection of Martian atmospherics by NBOZOMI observation.

To investigate the occultation of auroral kilometric radiation (AKR) in the vicinity of the Earth, the dynamic spectra from GEOTAIL and POLAR satellites are compared by Murata et al. [2004a]. They reported two distinct regions of AKR occultation, where are the night side of the Earth and vicinity of the plasmapause.

In collision-free magnetized plasma the solution of the wave equation becomes singular and unstable. To cope with this problem, Takano et al. [2003] developed an integral approximation method. By applying this technique to the mode coupling from a Z mode to an L-O mode in space plasma, they evaluated the mechanism of wave energy absorption at the resonance point.

In order to investigate detailed space and time evolution of elves, Nagano et al. [2003b] computed rigorously propagation in a magnetized ionosphere of EM pulses radiated by lightning current strokes, by using a full-wave analysis. Computed results showed that an optical ring is created at the altitudes of 85-100 km above the lightning, quickly expanding horizontally over 200 km within < 1 ms, which is consistent with the actual observation of elves.

Ozaki et al. [2004] computed rigorous wave intensities on the ground surface and in the ionosphere caused by earthquakes, by using the full-wave analysis. The computed results in the frequency range from 10 Hz to 10 kHz showed the difference in spatial distributions of the wave intensities due to the whistler-mode propagation in the ionosphere.

Hikishima et al. [2004] investigated the cyclotron resonance and pitch-angle diffusion of the resonant electrons, to analyze the generation mechanism of the chorus emissions. Their results indicated that the initially large pitch-angle anisotropy of the resonant electrons is rapidly pitch-angle diffused by a generated whistler mode wave, and the pitch-angle anisotropy decreases down to the small anisotropy which saturates wave growth.

Ikeda [2002] examined the possibility of the sideband wave generation in whistler-mode via a non-linear Doppler-shifted cyclotron resonant interaction between untrapped electrons and the whistler mode carrier signal by using a new equation system. The untrapped electrons resonant with the quasi-monochromatic whistler mode signal are phase-bunched with the trajectory gap, just outside the separatrix, on the phase space in the frame of electron of the Doppler-shifted cyclotron resonance with the carrier. Then, they may be able to radiate the whistler mode sideband waves with frequencies of fundamental, second and third harmonics, whose currents may never be zero because of strong non-linear interaction. It is imagined that, at the same time, two kinds of plasma may interact with the carrier signal to form the broadening, and with the sideband waves showing frequencies of fundamental, second and third harmonics. The fundamental, second and third harmonics sideband wave frequencies may be related to the saturated amplitude of the carrier signal.

H2.3 Shocks and Particle Acceleration

Nishimura et al. [2002] studied the acceleration and heating of electrons at quasi-parallel shock waves by means of a one-dimensional full particle computer simulation. Their simulation shows that the ion beam instability due to the anomalous cyclotron resonance excites whistler mode waves in the upstream region. The electron acceleration parallel to the magnetic field results from the parallel electric fields caused by both the whistler mode waves and the electrostatic shock potential.

They found that the contribution of the whistler waves to the parallel acceleration is as important as that of the electrostatic shock potential below the critical Mach number.

The properties of reformation in perpendicular collisionless shocks were investigated by Nishimura et al. [2003] using one-dimensional particle-in-cell simulation. The reformation is known to be associated with ion reflection at the shock ramp and subsequent ion gyromotion in the upstream region. However, it is also known that the shock reforms intermittently at sufficiently high Mach number if ions are reflected continuously at the ramp. The simulations were performed to investigate this issue and they found that the shock potential changes dramatically through the re-formation cycle, so that the potential variation leads to the intermittent response of the shock.

Hada et al. [2003] analyzed the shock front nonstationarity of perpendicular shocks in super-critical regime by examining the coupling between "incoming" and "reflected" ion populations. For a given set of parameters including the upstream Mach number and the fraction alpha of reflected to incoming ions, a self-consistent, time-stationary solution of the coupling between ion streams and the electromagnetic field was sought. The analytic results were in good agreement with full particle simulations for low beta case.

Futaana et al. [2003] studied the nonthermal ions which were measured by Particle Spectrum Analyzer/Ion Spectrum Analyzer (PSA/ISA) on board the Nozomi when the spacecraft was very close to the Moon. It was found that the nonthermal ions were protons and had a partial ring structure in the phase space. By conducting particle tracing calculation, their source location was found to be the dayside of the Moon, and the nonthermal ions seem to have large velocities when they were generated. It was proposed that the electromagnetic field in the vicinity of the Moon must have a dynamic structure, possibly a miniature bow shock associated with a local magnetic anomaly, where some of the solar wind protons are deflected to forms a partial ring structure in the velocity phase space.

Cross field diffusion of energetic particles (cosmic rays) in a two-dimensional static magnetic field turbulence is studied by Otsuka and Hada [2003] by performing test particle simulations. Qualitatively different diffusion processes were observed depending on the ratio of Larmor radius to the correlation length of the magnetic field fluctuations. The diffusion was found to be composed of several regimes with distinct statistical properties, which can be characterized using Levy statistics.

Lembege et al. [2004] published a review to address a subset of unresolved problems in collisionless shock physics from a theoretical and/or numerical modeling point of view. The topics are the nonstationarity of the shock front, the heating and dynamics of electrons through the shock layer, particle diffusion in turbulent electric and magnetic fields, particle acceleration, and the interaction of pickup ions with collisionless shocks.

Supra-thermal particle acceleration for a perpendicular magnetosonic shock was discussed by Hoshino [2001] by focusing on the interaction of particles with a large amplitude solitary wave formed in the shock front region/shock transition layer. The author showed that the shock surfing acceleration in a relativistic electron-positron shock occurs under the interaction of the trapped particles by the magnetosonic solitary wave with the shock motional electric field, and that the trapped particle can be efficiently accelerated up to the shock potential energy determined by a global shock size.

Hoshino and Shimada [2002] studied the suprathermal electron acceleration mechanism in a perpendicular magnetosonic shock wave in a high Mach number regime by using a particle-in-cell simulation, and found that shock surfing/surfatron acceleration producing suprathermal electrons occurs in the shock transition region, where a series of large-amplitude electrostatic solitary waves (ESWs) are excited by Buneman instability under the interaction between the reflected ions and the incoming electrons.

Hoshino and Mukai [2002] found that the energy spectrum of electrons in magnetic reconnection has a suprathermal population above a few keV, and more importantly the higher energy spectrum can be fitted by exp(- α v). A simple model to explain the suprathermal electrons based on a Fermi acceleration process was proposed.

Shimada and Hoshino [2003] investigated the electron-ion coupling process under Buneman instability between inflow electrons and reflected ions in the shock transition region. The study examined how electron holes affect the ions and interact with them. This study may provide a first indication of what regulates strong electron heating in the shock transition region through the coupling process between the electrons and ions. Shimada and Hoshino [2004] evaluated the effect of the frequency ratio omega(pe)/Omega(ce) on the electron energization in the shock transition region by using periodic simulations with realistic mass ratio. Their results showed that when omega(pe)/Omega(ce) is less than or equal to 1 no electron phase space hole is generated and when omega(pe)/Omega(ce) is greater than or equal to 10 a clear series of electron phase space holes is generated.

Trakhtengerts et al. [2002] developed the kinetic theory for runaway electrons in a stochastic electric field. The general kinetic equation for the isotropic part of the electron distribution function was derived and was simplified to the differential form for a particular case of electric field spectral intensity. The stationary analytical solution and numerical dynamic solutions were obtained and were discussed in connection with the problem of energetic electrons in a thunderstorm cloud.

Electron acceleration by a stochastic (in space) electric field in the atmosphere was considered by Trakhtengerts et al. [2003a] taking into account limited scales of the acceleration layer. Stationary solutions of the kinetic equation in a finite layer were analyzed numerically in the presence of source of energetic electrons. These solutions were discussed in connection with γ - and x-ray emissions observed inside thunderclouds.

A role of the second-order cyclotron resonance effect in the self-consistent approach to the problem of triggered ELF/VLF emissions was estimated by Trakhtengerts et al. [2001].The main and general conclusions are: (1) The second-order cyclotron resonance effects give an important contribution to triggered ELF/VLF emissions. (2) The short pump whistler wave packets generate fallers, while the long packets generate predominantly rising tones. (3) There are critical maximal and minimal values for the pump wave pulse duration.

Trakhtengerts et al. [2003b] considered the effect of initial phase bunching of energetic electrons on the generation of triggered ELF/VLF emissions in the magnetosphere. They focused on a phase-bunched beam in the velocity space, which serves as a traveling-wave antenna emitting secondary waves, and showed that the antenna field is significant as the seed wave which is further amplified by the same beam via the cyclotron resonant mechanism.

Electron accelerations in the outer radiation belt was investigated based on the Akebono observations by Obara et al. [2001]. Increase of the electron flux occurred in low L region and in low energy. Phase space density for MeV electrons had a peak around the center of the outer radiation belt. This means the internal acceleration took place in the outer radiation belt during the storm recovery phase.

Obara and Li [2003] showed that MeV electrons moved Earthward quickly with a sudden commencement, filling the so-called the slot region, and that the electron flux decayed slowly, forming the slot structure again. Time constant of the decay was studied.

Miyoshi et al. [2003] examined the dynamic behavior of electrons with energies from a few tens keV to a few MeV and its relation to plasma waves, using the data from the NOAA and EXOS-D satellites during the November 3, 1993 magnetic storm, and then numerically investigated the electron acceleration process at the storm. Their study suggested that the acceleration by whistler mode chorus via gyroresonant wave-particle interactions outside the plasmapause could play an important role to generate the storm-time relativistic electrons.

Katoh et al. [2003] studied particle acceleration processes due to wave particle interactions by employing numerical simulations based on a hybrid algorithm in order to investigate the merging process of cometary oxygen ions into the solar wind and verify a elementary process of energizing mechanism of relativistic electrons in the outer radiation belt during a geomagnetic storm recovery phase.

H2.4 Nonlinear Effects

Krasovsky et al. [2003] studied the electrostatic pulses recorded by the GEOTAIL spacecraft and labeled electrostatic solitary waves (ESW) within the framework of Bernstein-Greene-Kruskal (BGK) solitons. The general approach developed in the article applies to arbitrary particle distributions of the background plasma, velocities of the BGK solitons and wide variety of the recorded ESW waveforms. The new models and physical interrelations reveal universal features of the BGK soliton structure and allow a direct juxtaposition with the observations. The established interconnections between the physical characteristics of the waves agree well with the GEOTAIL data on ESW waveforms. Krasovsky et al. [2004] clarified the qualitative differences between the actual three-dimensional (3-D) perturbations and the well-known 1-D Bernstein-Greene-Kruskal (BGK) modes of the electron hole type. They showed that the anisotropy caused by the geomagnetic field is a decisive factor and the hole-like structures is closely connected with the quasi-one-dimensional nature of the electron motion, predominantly along the external magnetic field.

The formation process of ESW was studied by Umeda et al. [2002]. They conducted one- and two-dimensional electrostatic particle simulations with open boundaries. In the open system, spatial structures of electron holes vary depending on the distance from the source of the electron beam. A lower hybrid mode is excited locally in the region close to the source of the electron beam through coupling with electron holes at the same parallel phase velocity. The lower hybrid mode modulates electron holes excited in later phases, resulting in formation of modulated one-dimensional potentials.

Umeda et al. [2004] extended the previous electrostatic particle model to an electromagnetic particle model. In the present two-dimensional simulations of an electron beam instability, electromagnetic field components are enhanced around two-dimensional electron holes. They found that the enhancement of electromagnetic fields is due to a current formed by electrons undergoing the $E \times B_0$ drift, where the electric field is a perpendicular electrostatic field at the edge of a two-dimensional electron hole. An electromagnetic beam mode is excited by the current due to the drifting electrons moving with the electron hole.

Generation of electrostatic multiple harmonic Langmuir modes during beam-plasma interaction process has been observed in laboratory and spaceborne active experiments, as well as in computer simulation experiments. Despite earlier efforts, such a phenomenon has not been completely characterized both theoretically and in terms of numerical simulations. Yoon et al. [2003] found analytic expressions for harmonic Langmuir mode dispersion relations and compared their results with numerical simulation results. Gaelzer et al. [2003] developed generalized weak turbulence theory in which multiharmonic Langmuir modes were included and the self-consistent particle and wave kinetic equations were solved. The result shows that harmonic Langmuir mode spectra exhibit a quasi-power-law feature, implying multiscale structure in both frequency and wave number space spanning several orders of magnitude. The generation of harmonic Langmuir modes during beam plasma interaction was studied by Umeda et al. [2003] with nonlinear theoretical calculations and computer simulations. In their Vlasov simulation code, multiple harmonic Langmuir modes up to 12th harmonics can be included in contrast to previously available simulations which were restricted to the second harmonic only. The frequency-wave-number spectrum obtained by taking the Fourier transformation of simulated electric field both in time and space showed an excellent agreement with the theoretical nonlinear dispersion relations for harmonic Langmuir waves. The saturated wave amplitude features a quasi-power-law spectrum which reveals that the harmonic generation process is an integral part of the Langmuir turbulence.

A linear analysis and 2-1/2dimensional electromagnetic full-particle simulations were performed by Fujimoto and Machida [2003] to investigate mechanisms of an electron heating due to an intense Hall current, which is caused by a large velocity difference between electrons and ions in the outflow region inside the diffusion region of the magnetic reconnection.

Shklyar and Matsumoto [2002] studied the initial problem of plasma wave dynamics in the presence of a sharp density jump that divides the space into transparent and opaque regions. A wave packet was assumed to be initially localized in the transparent region. The transient process of field penetration beyond the density barrier during the wave packet reflection from the density jump was investigated.

In order to self-consistently study the kinetic processes at the Venus ionopause, Terada et al. [2002] calculated the Venus ionopause-solar wind interaction region kinetically, including the ionosphere, ionopause transition layer, magnetosheath, and solar wind, by applying boundary-fitted coordinates to the particle-in-cell code. They found that the distribution of ionopause surface waves generated by the Kelvin-Helmholtz (K-H) instability exhibits a clear asymmetry between hemispheres of upward and downward solar wind motional electric fields. Accordingly, the asymmetrical momentum transport across the ionopause yields an asymmetrical convection pattern of the ionosphere. Terada et al. [2004] extended their work to study a viscous process associated with the K-H instability around the ionopause, which is less well understood compared to the pickup process of exsospheric ions and electrons. They studied the relative importance of the escape processes for the case of low solar wind dynamic pressure as well as for the high dynamic pressure case, and showed the viscous removal process occurring at the ionopause plays a significant role in the ion escape from Venus.

A merging process of cometary oxygen ions into the solar wind particle was studied by Katoh et al. [2003] employing numerical simulations based on a hybrid algorithm. The results of one-dimensional hybrid simulation shows that a spatial extent of interaction region surrounding comet nucleus is deeply related to the ion beam instability driven by a field aligned motion of picked-up ions. Katoh and Omura [2004] studied resonant interaction between relativistic electrons and whistler mode waves excited by a temperature anisotropy using the hybrid simulation. The simulation shows that selected resonant electrons are effectively accelerated in a homogeneous system where both forward and backward traveling waves interact with the relativistic electrons.

Matsukiyo and Hada [2002] studied a long time evolution of cyclotron maser instability at null wave number (k=0) which is destabilized by relativistic ring distribution of plasma through the cyclotron resonance. They performed particle simulations using a plasma which consists of gyrotropic or nongyrotropic relativistic ring electrons, background positrons, and background electrons. The linear theory predicts that, when the initial ring energy is strongly relativistic, there appears a critical initial ring momentum at which the system is marginally stable. Numerical simulations show, however, that the system is nonlinearly unstable even when the initial ring momentum exceeds the critical momentum.

Matsukiyo and Hada [2003] examined the dispersion relation and nonlinear evolution of the parametric instabilities of circularly polarized Alfven waves in a relativistic electron-positron plasma. First, the nonlinear dispersion was solved in a nonrelativistic limit, then the weakly relativistic effect was examined. The one-dimensional full particle simulation and bicoherence analysis of the simulation result suggest that successive decay via the interaction between the parallel propagating Langmuir-like wave and antiparallel propagating Alfven-like wave can efficiently generate a continuum of low frequency electromagnetic waves, which can interact with energetic particles.

H2.5 Active Experiment and Spacecraft-Environment Interaction

Using topside sounder data obtained by the Ohzora (EXOS-C) satellite, Uemoto et al. [2004] investigated the structure and dynamics of the ionization ledge in the equatorial topside ionosphere. They found that the ionization ledge observed in the local noon time period shows similar nature as it has been theoretically predicted for the F3 layer. Also they indicated that the seasonal dependence of the occurrence probability of the ionization ledge has a tendency contrary to that of the F3 layer.

Usui et al. [2004a, 2004b] for the first time applied electromagnetic PIC (Particle-In-Cell) computer simulations to analyze the antenna characteristics in magnetized plasma. They particularly examined the electron kinetic effects on the antenna impedance. It is confirmed that the most obvious resonance point is the local Upper Hybrid Resonance frequency. As the electron temperature increases, the resonance frequency also increases in accordance with the modification of dispersion relation for the UHR branch.

Numerical simulations on active perturbation of space environment by microwave power transmission (MPT) and plasma beam emission for the spacecraft charging control have been performed. Usui et al. [2002] studied a three-wave coupling process occurring in an active experiment of MPT in the ionospheric plasma by performing one dimensional electromagnetic PIC (Particle-In-Cell) simulations. Continuous emission of intense electromagnetic waves from an antenna located at a simulation boundary excites a low-frequency electrostatic wave as the result of a nonlinear three-wave coupling. Usui et al. [2004c] also studied the basic process of the spacecraft charging and its neutralization using dense plasma emission by performing PIC simulations. They particularly examined the electron/ion flux to the charged body and the corresponding potential variation. It is shown that the negatively charged body is neutralized mainly by the enhancement of ion flux of the emitted plasma In the transient process of the charge neutralization, they found very turbulent current variation at the emitted plasma cloud region, which may cause electromagnetic perturbation in the vicinity of the body.

H2.6 Techniques of Data Analysis and Computer Experiments

One of the most important methods for the studies of plasma waves observed by spacecraft is to compare them with other observations either with same spacecraft or with other spacecraft. Simultaneous ground-based observations also help our understandings of the plasma wave generation mechanisms. Murata [2003] and Murata et al. [2002a] have constructed a software system (STARS) to gather observation data files individually managed at several organizations. It also provides a variety of functions to plot and analyze the data. For 3-dimensional data analyses of the observation data, a virtual Earth's magnetosphere system (VEMS) is produced by Murata et al. [2004b]. Murata et al. [2002b], Murata et al. [2002c], Murata [2002d] and Murata et al. [2002e] have developed systems to achieve high-performance computing and to support computer simulations for plasma particle simulations.

Akimoto et al. [2003] developed a new general-purpose computational technique for classifying the plasma waves in a systematic way from database of scientific satellite. Firstly, they propose a two-step cluster analysis for the classification. Applying this cluster analysis to the key parameters of the Akebono wave data, they could make some representative classes of wave phenomena with a small amount of calculation time. In order to determine the suitable number of representative class, they propose an evaluation function with AIC. Finally, they discriminated to the representative classes and exception.

Kasahara et al. [2002] introduced new computational techniques for extracting the attributes and/or characteristics of the plasma waves and particles from the enormous scientific database. These techniques enable us to represent the characteristics of complicated phenomena using a few key-parameters, and also to analyze large amount of datasets in a systematic way. These techniques are applied to the observational data of the ion heating/acceleration phenomena in the auroral region obtained by the Akebono satellite.

Tanaka et al. [2004] developed a general-purpose system which manages and provides various kinds of information accumulated in their university. One of the most important points in the design of the system is management of the enormous amount of data, which comes up to several tera-bytes in the field of natural science in some cases. They constructed a database system on the geospace radio environment obtained by the Akebono satellite.

The lunar radar sounder (LRS) experiment onboard SELENE (SELenological and ENgineering Explorer) has been planned for observation of the lunar surface and subsurface structures. The computer simulation of the LRS observations and development of data analysis method have been performed by Kobayashi et al. [2002a] using newly developed simulation code, Kirchhoff approximation sounder simulation (KiSS) code. It has been shown by the simulation that the subsurface echoes are detectable by using data stacking technique. Kobayashi et al. [2002b] has also performed the simulation of the LRS observations in the lunar highland regions, where subsurface echoes are severely masked by confusing surface echoes. The application of the synthetic aperture radar (SAR) method for subsurface echo analysis in the lunar highland region has been proposed based on the simulation results.

As for the effective method for EMC of spacecrafts in space plasma, Okada et al. [2004] demonstrated the sheilding effects of the conductive hood covering the solar sensor onboard NOZOMI spacecraft by performing a series of FDTD simulations with different configurations of a conductive hood.

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Acknowledgements

We would like to thank the following persons for their contributions to this national report of Japanese Commission H: Masashi. Hayakawa, Hideaki Kawano, Toshihiko Iemori, Shinobu Machida, Yasumasa Kasaba, Akira Morioka, Takayuki Ono, Hirotsugu Kojima, Kozo Hashimoto, Hideyuki Usui, Tadasu Nakamura, Yoshiya Kasahara, Satoshi Yagitani, Takeshi Murata, and Taketoshi Miyake.