Japanese URSI Commission H (Waves in Plasmas)
Activity Report
December 2014 - March 2015

[1] Status of projects related with plasma wave observation

1. The ERG project
   http://ergsc.stelab.nagoya-u.ac.jp/index.shtml.en
2. BepiColombo/MMO
   http://www.stp.isas.jaxa.jp/mercury/p_mmo.html
3. STEL VLF/ELF observations are carried out in Canada and Japan.
   Details of the data are available at
   http://stdb2.stelab.nagoya-u.ac.jp/vlf/index.html

[2] Recent Meetings

1. Meeting on Waves in Plasmas 2014, “New Developments in Plasma Wave Theory”, Kyoto University, Uji, Kyoto, Japan, 5 December, 2014.
   https://sites.google.com/site/sgepsshadou/koremade/meeting141205
2. The Fifth Symposium on Polar Science, National Institute of Polar Research (NIPR), Tokyo, Japan, 2-5 December, 2014.
   http://www.nipr.ac.jp/symposium2014/e/
   The Fifth Symposium on Polar Science, National Institute of Polar Research
3. The 3rd Asia Oceania Space Weather Alliance (AOSWA) Workshop, The Luigans Hotel, Fukuoka, Japan, 2-5 March, Japan.
   http://aoswa.nict.go.jp/workshop_3/
4. Joint Symposium on Heliosphere, Solar-Terrestrial Environment and Cosmic Ray Modulation, Nagoya University, Nagoya, Japan, 4-6 March, 2015.
5. Meeting on Acceleration and Transport of Particle and Turbulence caused by Wave-Particle Interaction, Nagoya University, Nagoya, Japan, 5-6 March, 2015.
6. ERG Science Meeting, Nagoya University, Nagoya, Japan, 13 March, 2015.
   http://ergsc.stelab.nagoya-u.ac.jp/documents/science201503/
7. Japanese URSI Commission H (Waves in Plasmas) Meeting, Nagoya University, Nagoya, Japan, 13 March, 2015.
8. Inner Magnetosphere Coupling III, UCLA, U.S.A., 23-27 March, 2015.
   http://www.i-mp.org/conference/i-mp_2015/

[3] Future Meetings

1. ERG Mission Science Workshop, Taipei, 9-10 April, 2015.
2. European Geosciences Union (EGU) General Assembly 2015, Vienna, Austria, 12-17 April, 2015.
3. 4th International Symposium on the Arctic Research (ISAR-4), Toyama, Japan, 27-30 April, 2015.
4. Japan Geoscience Union Meeting 2015, Chiba, Japan, 24-28 April, 2015.
5. 42nd European Physical Society Conference on Plasma Physics, Lisbon, Portugal, 22-26 June, 2015.

   A plenary talk titled "*Generation mechanism of whistler-mode chorus emissions*" will be given by Y. Omura.
6. The 26th General Assembly of the International Union of Geodesy and Geophysics (IUGG) , Prague, Czech Republic, 22 June - 2 July, 2015.

   Sessions related to plasma waves:

   A17 The Earth's Plasmasphere: Remote Sensing and Modelling (Div. II-VERSIM)

   A19 ULF Waves: Space-Ground Coordination (Div. III)

   A20 ULF waves in the inner magnetosphere (Div. III)
7. The 12th International School/Symposium for Space Simulations (ISSS-12), Prague, Czech Republic, July 3-10, 2015.
8. Asia Oceania Geosciences Society (AOGS) 12th Annual Meeting, Singapore, 2-7 August, 2015.

   Sessions related to plasma waves:

   ST01 Energetic particle acceleration and transport in the geospace and interplanetary space (Co-convener: Y. Miyoshi)

   ST09 Sun-Earth system response to extreme solar and seismic events (Co-convener: Y. Omura)

   ST12-31 Observation, theory and modeling of ULF, ELF and VLF waves in geospace, and general session on magnetosphere (Main convener: M. Nosé, Co-convener: Y. Katoh)

   PS05 Solar wind interaction with planetary environments (Co-convener: Y. Kasaba)

[4] Recently Published Papers

1. **Kalaee, M. J., Y. Katoh, and T. Ono, Effects of the angle between the density gradient and the external magnetic field on the linear mode conversion and**

resultant beaming angle of LO-mode radio emissions, Earth Moon Planets, 114, 1-15, doi:10.1007/s11038-014-9448-4, 2014.

Recent spacecraft's observations of kilometric continuum radiation showed that the observed beaming angle of radiations often deviates from the prediction of the linear mode conversion theory (LMCT). Satellite observations also show some local fluctuation in the density gradient. Kalaee et al. [2014] considered the mode conversion process from UHR- mode (slow Z- mode) to LO-mode (ordinary) waves, focusing on the effect of the angle between the density gradient and the external magnetic field on the efficiency of the LMCT and the resultant beaming angle of converted LO-mode waves; a comparison of the LMCT and simulation results are presented. They first consider a condition that the density gradient is perpendicular to the external magnetic field, corresponding to the condition assumed in the conventional LMCT. Next, they extend the discussion to the condition that the density gradient is oblique to the external magnetic field. Their aim is to investigate a condition where the efficient mode conversion can occur and to study the deviation of the beaming angle from that estimated by LMCT. From the results of analyses, for both perpendicular and oblique cases, the highest conversion efficiency is obtained for a certain value of the wave normal angle (critical wave normal angle) of the incident slow Z-mode waves, corresponding to the case when two mode branches are matched. The simulation results show in the perpendicular case that the beaming angle is consistent with the conventional LMCT; but in the oblique case a critical wave normal angle becomes different from the perpendicular case and the beaming angle is different from the LMCT prediction.

2. **Kasahara, Y., Y. Goto, and Y. Oike, Automatic calibration method for analogue wideband waveform receiver onboard the Akebono satellite, Journal of Space Science Informatics Japan, 4, 41-49, 2015.**

Akebono was launched in February, 1989 and has attained the 25 years of successful operation without major troubles. The VLF instrument onboard Akebono measures plasma waves below 20 kHz and plays an important role to study plasma physics in the Earth's magnetosphere. The VLF measures not only wave spectrum in digital format but also analogue waveform, and the analogue waveform data are transmitted via analogue telemetry. Huge amount of analogue data have been stored, but data analyses are not comprehensively performed so far because of the difficulties of their peculiar characteristics. In the paper, current status of data

analysis system developed for the VLF analogue waveform data and anticipated outcomes from these huge datasets are introduced.

3. **Koyanagi, J., A. Watanabe, N. Kawabata, T. Ozaki, K. Higuchi, K. Ishimura, and Y, Kasaba, Long-term durability of tri-axial woven CFRP tube structure extended along the spin axis of spinning platforms for the SCOPE mission, Adv. Composite Materials, 23, 2, 115-128, doi:10.1080/09243046.2013.835921, 2014.**

   This study investigates the strength and long-term durability of a spin-axis extensible rigid antenna element, made of tri-axial woven carbon fiber-reinforced polymer (CFRP), for a spinning spacecraft. Due to a slight deviation between the spin axis and antenna-extended axis with the spin, the antenna is subjected to centrifugal body force; the centrifugal force enhances the antenna deflection. A relationship between centrifugal force and antenna deflection is derived from beam theory. As the apparent material modulus decreases with time, the deflection increases simultaneously. The time dependence of mechanical properties of the tri-axial woven CFRP is hence examined by a creep test. The time-dependent failure criterion of the antenna is then examined using a flexural durability test. Based on the beam theory and experimental results, they examine the long-term reliability of applying the tri-axial woven CFRP to extensible rigid antenna for the spinning spacecraft, especially for SCOPE mission; it is verified that the current design tolerance for the mission assures certain durability for long-term usage.

4. **Martinez-Calderon, C., K. Shiokawa, Y. Miyoshi, M. Ozaki, I. Schofield and M. Connors, Polarization analysis of VLF/ELF waves observed at subauroral latitudes during the VLF-CHAIN campaign, Earth, Planets and Space, 67:21, doi: 10.1186/s40623-014-0178-7, 2015.**

   During the VLF Campaign observation with High-resolution Aurora Imaging Network (VLF-CHAIN) from 17 to 25 February 2012, several types of VLF/ELF emissions, including chorus, were observed at subauroral latitudes in Athabasca, Canada. There has not been any comprehensive study of the physical properties of such emissions at these latitudes. In this study, they calculate spectral and polarization parameters of VLF/ELF waves with high temporal resolution. They found that the polarization angle of several emissions depended on both frequency and time. They suggest that the frequency-dependent events, which usually last several tens of minutes, might be the consequence of the broadening of the ray path that the waves follow from their generation region to the ground. Furthermore,

time-dependent events, also lasting tens of minutes, have a polarization angle that changes from negative to positive values (or vice versa) every few minutes. They suggest that this could be due to variations of the wave duct, either near the generation region or along the wave propagation path. Using another ground station in Fort Vermillion, Canada, about 450 km northwest of Athabasca, they tracked the movements of the ionospheric exit point of three chorus emissions observed simultaneously at both stations. Although they found that movement of the ionospheric exit point does not follow a general direction, it is subject to hovering motion, suggesting that the exit point can be affected by small-scale plasma processes.

5. **Matsuda, S., Y. Kasahara, and Y. Goto, M/Q = 2 Ion Distribution in the Inner Magnetosphere Estimated from Ion Cyclotron Whistler Waves Observed by the Akebono Satellite, J. Geophys. Res., doi:10.1002/2014JA020972, 2015. (accepted manuscript online 11 March, 2015).**

Matsuda et al.[2015] examined the spatial occurrence distributions of H^+, He^+, and M/Q = 2 ion band ion cyclotron whistler waves observed by Akebono below an altitude of 10,500 km. These waves are categorized as electromagnetic ion cyclotron (EMIC) mode waves with characteristic spectrum properties that depend on the ion composition in the plasma. Statistical study is important for clarifying the variation of ion composition in a plasmaspheric ion environment. In this study, essential differences were noted among the observed regions of each ion cyclotron whistler wave band. The statistical analysis showed that the generation of H^+ band ion cyclotron whistlers in the equatorial region is difficult, while M/Q = 2 ion band ion cyclotron whistlers are frequently observed near this region. A certain amount of M/Q = 2 ions are evident. To explain these statistical results, they proposed a model for generation of several bands of ion cyclotron whistlers along a propagation path. The magnetic local time dependence of the observed ion cyclotron whistlers was also examined. The spatial occurrence distribution of the M/Q = 2 ion cyclotron whistler waves is greatest inwards of L~2.4 in the local dayside; however, they extend to L~3.0 in the local nightside. The results suggest a density enhancement process of M/Q = 2 ions in the nightside plasmasphere, which is consistent with previous satellite observations. This study presents important knowledge on the effects of minor ion population on wave propagation and generation.

6. **Miyoshi, Y., S. Oyama, S. Saito, S. Kurita, H. Fujiwara, R. Kataoka, Y. Ebihara, C.**

Kletzing, G. Reeves, O. Santolik, M. Clilverd, C. J. Rodger, E. Turunen, and F. Tsuchiya, Energetic electron precipitation associated with pulsating aurora: EISCAT and Van Allen Probe observations, J. Geophys. Res., doi:10.1002/2014JA020690, 2015. (accepted manuscript online 16 March, 2015).

Pulsating auroras show quasi-periodic intensity modulations caused by the precipitation of energetic electrons of the order of tens of keV. It is expected theoretically that not only these electrons but also sub-relativistic/relativistic electrons precipitate simultaneously into the ionosphere owing to whistler-mode wave–particle interactions. The height-resolved electron density profile was observed with the European Incoherent Scatter (EISCAT) Tromsø VHF radar on 17 November 2012. Electron density enhancements were clearly identified at altitudes >68 km in association with the pulsating aurora, suggesting precipitation of electrons with a broadband energy range from ~10 keV up to at least 200 keV. The riometer and network of subionospheric radio wave observations also showed the energetic electron precipitations during this period. During this period, the footprint of the Van Allen Probe-A satellite was very close to Tromsø and the satellite observed rising tone emissions of the lower-band chorus (LBC) waves near the equatorial plane. Considering the observed LBC waves and electrons, they conducted a computer simulation of the wave–particle interactions. This showed simultaneous precipitation of electrons at both tens of keV and a few hundred keV, which is consistent with the energy spectrum estimated by the inversion method using the EISCAT observations. This result revealed that electrons with a wide energy range simultaneously precipitate into the ionosphere in association with the pulsating aurora, providing the evidence that pulsating auroras are caused by whistler chorus waves. It is suggested that scattering by propagating whistler simultaneously causes both the precipitations of sub-relativistic electrons and the pulsating aurora.

7. **Nosé, M., S. Oimatsu, K. Keika, C. A. Kletzing, W. S. Kurth, S. De Pascuale, C.W. Smith, R. J. MacDowall, S. Nakano, G. D. Reeves, H. E. Spence, and B. A. Larsen, Formation of the oxygen torus in the innermagnetosphere: Van Allen Probes observations, J. Geophys. Res., 120, 1182-1196, doi:10.1002/2014JA020593, 2015.**

Nosé et al. [2015] studied the formation process of an oxygen torus during the 12-15 November 2012 magnetic storm, using the magnetic field and plasma wave data obtained by Van Allen Probes. They estimate the local plasma mass density (ρ_L) and the local electron number density (n_{eL}) from the resonant frequencies of

standing Alfven waves and the upper hybrid resonance band. The average ion mass (M) can be calculated by $M \sim \rho_L / n_{eL}$ under the assumption of quasi-neutrality of plasma. During the storm recovery phase, both Probe A and Probe B observe the oxygen torus at L=3.0-4.0 and L=3.7-4.5, respectively, on the morningside. The oxygen torus has M=4.5-8 amu and extends around the plasmapause that is identified at L~3.2-3.9. They find that during the initial phase, M is 4-7 amu throughout the plasma trough and remains at ~1 amu in the plasmasphere, implying that ionospheric O^+ ions are supplied into the inner magnetosphere already in the initial phase of the magnetic storm. Numerical calculation under a decrease of the convection electric field reveals that some of thermal O^+ ions distributed throughout the plasma trough are trapped within the expanded plasmasphere, whereas some of them drift around the plasmapause on the dawnside. This creates the oxygen torus spreading near the plasmapause, which is consistent with the Van Allen Probes observations. They conclude that the oxygen torus identified in this study favors the formation scenario of supplying O^+ in the inner magnetosphere during the initial phase and subsequent drift during the recovery phase.

8. **Ozaki, M., S. Yagitani, K. Takahashi, T. Imachi, H. Koji, and R. Higashi, Equivalent Circuit Model for the Electric Field Sensitivity of a Magnetic Search Coil of Space Plasma, IEEE Sensors Journal, 13(3), 1680--1689, doi:10.1109/JSEN.2014.2365495, 2015.**

An equivalent circuit model for the electric field sensitivity of an magnetic search coil (MSC) in a collisionless isotropic cold plasma is developed by Ozaki et al. MSCs are sensitive to both magnetic and electric fields, but detecting electric fields is unnecessary for magnetic observations of plasma waves. It is important to evaluate both sensitivities for different geometries and electrostatic shields to avoid electric field pickup. The electric field sensitivity is defined by a relationship between the MSC impedance and the sheath capacitance. To confirm the validity of the circuit model, the sensitivity to an electric field was measured by imposing an external electric field using charged parallel metallic plates in laboratory experiments. The coupling capacitance between the MSC and charged plates is equivalent to the sheath capacitance in a space plasma. The measured results showed good agreement with an approximate expression deduced from the equivalent circuit model. This agreement supports the validity of the proposed equivalent circuit model. An electrostatic shield having slits is often used to reduce eddy current

losses in the shield. It has been found, however, that such slits result in a deterioration of the electric field sensitivity by exposing a part of the sensor coil to the plasma sheath. These results will be useful in evaluating the electric field sensitivity of an MSC covered by an electrostatic shield.

9. **Kasaba, Y., C. Tao, T. Kimura, M. Fujimoto, and W. M. Morooka, Planetary plasma world: Magnetospheres of giant planets, J. Plasma Fusion Res., 90(12), 769 - 774, 2014.**

10. **Saito, Y., H. Kojima, Y. Kasaba, T. Abe, S. Kasahara, and A. Matsuoka, Observational technique of the solar system plasma: In-situ observation, J. Plasma Fusion Res., 90(12), 780 - 785, 2014.**

11. **Sato, Y., A. Kadokura, Y. Ogawa, A. Kumamoto, and Y. Katoh, Polarization observations of 4fce auroral roar emissions, Geophys. Res. Lett., 42, 249-255, doi:10.1002/2014GL062838, 2015.**

    Sato et al. [2015] reported on the first polarization measurement of auroral roar emissions near 4 times the ionospheric electron cyclotron frequency (4fce). A ground-based passive receiver that uses orthogonal loop antennas, installed in Iceland, revealed the sense of polarization of 11 events of 4fce roar emissions. In 9 of 11 cases, 4fce roar was left-handed elliptically polarized, namely, O-mode waves. The O-mode 4fce roar was observed under both sunlit and dark ionospheric conditions during geomagnetic storms. For O-mode 4fce roar generation, satisfaction of the matching condition where upper hybrid frequency (fUH) equals 4fce requires a high-density, F region ionosphere, even during darkness, which might be attributed to auroral precipitation or tongue of ionization. In two cases, right-handed elliptically polarized 4fce roar was observed during darkness hours and the main phase of a geomagnetic storm. This polarization indicates that nonlinear coupling of two upper hybrid waves may also work to generate X-mode 4fce roar.

12. **Teramoto, M., N. Nishitani, V. Pilipenko, T. Ogawa, K. Shiokawa, T. Nagatsuma, A. Yoshikawa, D. Baishev, and K. T. Murata, Pi2 pulsation simultaneously observed in the E and F region ionosphere with the SuperDARN Hokkaido radar, J. Geophys. Res. Space Physics, 119, 3444–3462, doi:10.1002/2012JA018585, 2014.**

    Teramoto et al. [2014] investigated Pi2 pulsations in the nightside ionosphere that

began at 14:15 UT (2315 LT) on 11 July 2010 observed with high-temporal (8 s) resolution by beam 4 of the Super Dual Auroral Radar Network (SuperDARN) Hokkaido radar. These pulsations were simultaneously observed in both the ground/sea scatter echoes reflected from the F region height and in ionospheric echoes from field-aligned irregularities in the sporadic Es region. They had the same period of 110 s and approximately no phase lag. From the radar observations and the International Geomagnetic Reference Field model, the amplitude of the eastward (EEW) component of the electric field of the Pi2 pulsations in the ionosphere was estimated ~8.0 mV/m in the F region and ~2.0 mV/m in the E region. Corresponding Pi2 pulsations appeared dominantly in the horizontal northward magnetic field component (H) at nearby ground stations, Moshiri (MSR), St. Paratunka (PTK), and Stecolny (STC), with amplitudes ranging from 6 nT (MSR) to 10 nT (STC). At the dominant frequency of 8.8 mHz, the coherences between H and EEW were high (>0.9), the cross phases of EEW relative to H were −56 deg and −45 deg, and the amplitude ratios were 2.7×105 m/s and 8.4×105 m/s, in the E and F regions, respectively. Based on a comparison of these results with theoretical predictions, they suggest that the concept of a pure cavity mode is not sufficient to explain the combined observations for midlatitude Pi2 waves and that the contribution of an Alfvén waves must be taken in account.

13. **Tsugawa, Y., Y. Katoh, N. Terada, H. Tsunakawa, F. Takahashi, H. Shibuya, H. Shimizu, M. Matsushima, Harmonics of whistler mode waves near the Moon, Earth Planets Space, 67, 36, doi:10.1186/s40623-015-0203-5, 2015.**

Tsugawa et al. [2015] investigated harmonic spectral features of electromagnetic waves identified by Kaguya in the frequencies of several Hz around the Moon. The waves have steepened waveforms peculiarly in the compressional component. The fundamental waves have almost the same properties as narrowband whistler-mode waves with the frequencies near 1 Hz, which have been observed around the Moon. The waves are observed around the terminator region in the solar wind near the lunar magnetic anomalies at the altitudes under 120 km. Tsugawa et al. suggest that the harmonic spectra are a result of the nonlinear steepening of narrowband whistler-mode waves. Although the narrowband whistler-mode waves have been observed in the upstream region of many planetary bow shocks, such harmonics have rarely been observed there. Since the harmonics are more frequently observed at lower altitudes of the Moon, Tsugawa et al. [2015] suggested that these waves are possibly caused by lunar intrinsic environments including lunar dusts and local

structures of lunar magnetic anomalies.

14. **Yagi, D., Ken T. Murata, and Y. Kasahara, Evaluation of parallel distributed processing of NICT science cloud for data analysis of waveform obtained by spacecraft, Journal of Japan Society of Information and Knowledge, 25(1), (in press), 2015.**

    Easy and effective parallel processing technique is required to analyze scientific big data without heavy programming. Yagi et al. [2015] analyzed a set of waveform data measured by the WFC-L receiver onboard "KAGUYA" for 9 months using their original program. The practical issue is that it is not easy for many space scientists to rewrite a program via parallelization library such as MPI (message passing interface). In the present paper, they import their original program, without rewriting, on a science cloud system on which a task manager is ready for use for development and management of parallel data processing. They demonstrated that easy task scheduling and parallel processing is effective and practical for big data analysis even in case that the data set is heterogeneous.