COMMISSION H: Waves in Plasmas
(November 2020 – May 2023)

Edited by *Kojima Hirotsugu (Kyoto University, Japan) and Katoh Yuto (Tohoku University, Japan)*

1. Summary

The roles of the URSI Commission H are to promote and deepen studies of plasma waves by supporting related missions, coordinating science meetings, and enhancing the exchange of achievements among scientists. Japan's Commission H is continuing its activities in the present report period of November 2020 to May 2023. It is notable that the committee contributed to the success of the two milestone meetings of URSI-JRSM2022 and URSI-Japan Centennial Celebration Symposium 1922-2022. Activities of the missions related to Japan's Commission H are described in the following section of the activity report. During that period, while Japan's community has been holding a new space probe, JUICE, to Jupiter in 2023, the operation of the historic satellite, GEOTAIL, was terminated in the same year after 30 years of the operation.

2. Activity Report

1. BepiColombo/MMO

http://www.isas.jaxa.jp/en/missions/spacecraft/current/mmo.html

BepiColombo is a Mercury exploration project jointly planned by JAXA and the European Space Agency (ESA). Arrival at Mercury will be in Dec 2025. It consists of two orbiters: the Mercury Planetary Orbiter (MPO) and the Mio (Mercury Magnetosphere Orbiter, MMO). JAXA is responsible for the latter.

For the plasma wave, Plasma Wave Investigation (PWI, PI: Y. Kasaba [Tohoku Univ.]) is aboard this spacecraft. PWI will first observe electric field, plasma waves, and radio waves around Mercury, which were not covered by past missions. The PWI science team is now waiting for the deployment of electric-field wire antennas (15-m length x 4) just after the Mercury orbit insertion planned in 2025. Limited observation by non-deployed search coils is going in the cruise phase, with the development of the telemetry data pipelines and operation planning. Earth flyby was executed on 10-11 April 2020, and Venus flybys were on 15 Oct 2020 and 11 Aug. 2021. Two Mercury flybys were also executed on 1-2 Oct 2021 and 23 June 2022. Based on the Mercury flybys, one paper was published (Griton+ 2023, https://doi.org/10.1051/0004-6361/202245162) and another paper is under review. Mio will see additional 4 flybys (June 2023, Sep 2024, Dec. 2024, and Jan 2025) before the real arrival.

Mio also has two magnetometer sets, MGF-O (outbound) and MGF-I (inbound), organized by Magnetic Field Investigation (MGF) team (PI: W. Baumjohann [IWF, Austria]). With PWI and MGF, the wide frequency band of electromagnetic fields is first covered around Mercury. MGF-I is managed by Japan (Co-PI: A. Matsuoka [Kyoto Univ.]).

2. JUICE

http://www.isas.jaxa.jp/en/missions/spacecraft/future/juice.html

JUICE (JUpiter ICy moons Explorer) is the L-class mission of ESA, launched on 14 Apr. 2023. The arrival at Jupiter will be in 2031. It will make detailed observations of the Jovian system including Europa, Ganymede, and Calisto flybys in 2031-2034, and finally be in orbit around Ganymede in 2034-2035. For the plasma wave, Radio and Plasma Wave Investigation (PI: J.-E. Wahlund [IRF Uppsala, Sweden]) is aboard this spacecraft and covers the information of the exospheres, surfaces, and conducting subsurface oceans of icy satellites and their interactions with surrounding Jovian magnetosphere. For access to the conductive subsurface ocean, RPWI will first observe cold plasma and electric fields, to separate the global conductivity and current

from the ionospheres. As a byproduct, reflected Jovian radio emission can be expected from the boundary of crust (ice) and subsurface ocean (conductive water). From Japan, High Frequency part (RWI-Preamp and HF-Receiver) are supplied (Co-PI: Y. Kasaba [Tohoku Univ.]) and provides the highly resolved information of Jovian radiation emitted from Jupiter and Galilean moons by the first 3-axis E-field measurement on Jovian orbit. In 2023 Apr-June, the RPWI successfully deployed all booms and antennas and is doing the health checks in the Near Earth Commissioning Period.

JUICE has magnetometer sets, organized by the JMAG team (PI: M. Dougherty [ICL, UK]). Some scientists from Japan also commit to this team. With RPWI and JMAG, wide band electromagnetic field will be covered around Jupiter.

3. Arase (ERG)

http://www.isas.jaxa.jp/en/missions/spacecraft/current/erg.html
http://ergsc.isee.nagoya-u.ac.jp/index.shtml.en

The Arase (ERG; Exploration of energization and Radiation in Geospace) project is a mission to study acceleration and loss mechanisms of relativistic electrons around the Earth. The Arase (ERG) was launched in Dec., 2016. After successful operation during the prime mission from March 2017 to October 2018, the JAXA has approved the mission extension of Arase until the end of March 2022. The Plasma Wave Experiment (PWE, PI: Y. Kasahara [Kanazawa Univ.]) measures DC electric field and plasma waves in the inner magnetosphere covering a wide frequency range from DC to 10 MHz for electric field and from a few Hz to 100 kHz for magnetic field. The Software-Wave Particle Interaction Analyzer (SWPIA) (PI: H. Kojima, [Kyoto. Univ.]) is equipped to realize direct measurements of interactions between energetic electrons and whistler-mode chorus in the Earth's inner magnetosphere. Varieties of wave phenomena such as chorus, EMIC, ULF pulsations, and lightning whistlers have been successfully observed by the PWE. We have also conducted cooperative observations with the ground-based stations, Van Allen Probes and the DSX satellites in the magnetosphere. We intensively conducted the PWE burst mode operations, by which waveforms were continuously captured. The science data files for wave spectrum and waveform are available from the ERG Science Center http://ergsc.isee.nagoya-u.ac.jp/index.shtml.en

All science instruments are still in good condition. JAXA has approved the extension of the operation period by the end of the 2032 fiscal year.

4. Hisaki and LAPYUTA

http://www.isas.jaxa.jp/en/missions/spacecraft/current/hisaki.html
https://www.darts.isas.jaxa.jp/stp/hisaki/

Hisaki satellite with the EUV spectrometer (Extreme Ultraviolet Spectroscope for Exospheric Dynamics: EXCEED) is the EUV space telescope dedicated to planetary sciences.

Hisaki has provided continuous observations of Jovian system in UV aurora total flux and EUV Io torus plasma distributions and plasma diagnostics, which connected the solar wind information and ground-based radio (Decameter [aurora] - VHF [radiation belt]) and IR (aurora and airglows) observations. From July 2016, NASA Juno orbiter started the observation around Jupiter. Hisaki's priority is on the support observation for this mission. The HISAKI mission will be terminated by the end of Mar. 2024.

LAPYUTA (Life-environmentology, Astronomy, and PlanetarY Ultraviolet Telescope Assembly) is proposed as the next Earth-orbiting ultraviolet space telescope led by Japan. It has been selected as one of candidates for 6th ISAS/JAXA M-class mission. Target launch year of LAPYUTA is 2032.

5. GEOTAIL

http://www.isas.jaxa.jp/en/missions/spacecraft/current/geotail.html

GEOTAIL spacecraft was terminated on November 28th, 2022, by sending the command that turns off the onboard transmitter. GEOTAIL had been operating and observing the Earth's magnetosphere for 30 years since its launch in 1992. The Plasma Wave Instrument (PWI) had completed collecting the high-resolution waveform data as well as the spectrum data to the end. The color plots of the observed wave spectrum data have been opened in the PWI website http://space.rish.kyoto-u.ac.jp/gtlpwi, and http://www.stp.isas.jaxa.jp/geotail. One can easily also

make the color spectrum plots in flexible time scales at https://geotail.nict.go.jp/.

6. Ground-based observation of solar and planetary radio waves

https://pparc.gp.tohoku.ac.jp/research/iprt
https://pparc.gp.tohoku.ac.jp/about-us/observatory/?lang=en
http://adrastea.gp.tohoku.ac.jp/~jupiter/

Ground-based observation of solar and planetary radio waves is performed using IPRT (Iitate Planetary Radio Telescope) and HF antenna array developed by Tohoku University. IPRT has been operated at the Iitate observatory in Fukushima Japan since 2000. IPRT measures meter to decimeter natural radio waves at fixed frequencies of 325 MHz using a low noise amplifier (LNA) and from 150 to 500 MHz using a wide-band receiver. The primary purposes of the telescope are to investigate the dynamic behavior of Jupiter's synchrotron radiation and solar radio emissions in the low-frequency range. In addition to this, IPRT has the capability to observe weak radio sources in the low-frequency range such as pulsars. The low frequency very long baseline interferometer (VLBI) observations at 325 MHz were performed with ISEE (Nagoya University) since 2020 and Ooty radio telescope (India) in December 2021. HF antenna at the Iitate observatory has been operated since 1996 for ground-based observation of Jovian decametric radiation (DAM; 15-40MHz). Wide-band spectrum monitor, waveform receiver with a single antenna, and long-baseline interferometer (LBI) with 3 station's antennas (Kawatabi, Zao, and Yoneyama) are in operation. For observation of Jovian DAM including weak events, a short-baseline interferometer (SBI) with six antennas is also operated. In 2022, 42 Jovian DAM events could be observed by the SBI.

7. SS-520-3 sounding rocket

SS-520-3 sounding rocket aims at the investigation of energy sources that provide outflow energies to escaping ionospheric ions at the Cusp region. Low frequency plasma waves are one of the plausible candidates of the energy sources. The LFAS (Low frequency analyzer system) onboard the rocket observes electric field components of plasma waves including global electric fields in the frequency range below 10kHz. The rocket was launched at Ny Alesund, Norway on November 4th, 2021, during a geomagnetic storm. The LFAS operated as expected. Two electric field components in the rocket spin plane were successfully acquired, and the waveforms near the rocket's apex height are now under investigation. In addition to the LFAS, the NEI/PWM (Ne measurement by impedance probe / Plasma wave monitor) successfully observed electron number density and plasma wave spectra in a frequency range from 300 Hz to 20 MHz.

8. PWING Project

The ground-based observation of cosmic noise absorption, Pc1 geomagnetic pulsations and ELF/VLF waves by the PWING project are automatically carried out at 6 stations at subauroral latitudes at Athabasca and Kapuskasing (Canada), Gakona (Alaska), Zhigansk/Maimaga and Istok (Russia), and Husafell (Iceland). The data in CDF format are available from the ERG Science Center at https://www.isee.nagoya-u.ac.jp/dimr/PWING/en/.

9. Bilateral project between JSPS and CAS

The bilateral project between Japan and Czech has worked for multi-satellite data analysis about various plasma waves and inter-calibrations for receivers using Arase, Van Allen Probes, Cluster etc. The project also studies the tweek atmospherics by investigating the regional lightning activities at Europe and Japan.

10. Japan-Norway Partnership for computing in Space Science

A new six years' program is initiated in the Japan-Norway partnership in 2021. This program aims to enhance activities in research and research-based education for computing in space science. Kobe University and Kyoto University collaborate with the University of Oslo and exchange students under the supervision of the staff members. Students will learn space science and acquire expertise in computational science. Schools and workshops on space science will be held in both countries.

11. A high-speed data file transfer technique

High-speed data transfer is one of the crucial factor to share large-scale plasma data. We have been developing a network transfer protocol named as "HpFP" and an application to use this

protocol named as "HCP tools". The performance of them are being examined on the JGN and SINET5 in Japan that provide 10Gbps bandwidth.

12. **Space Experiment on Effects of High-Power Microwave Radiation on Ionospheric Plasma for Solar Power Satellite**

    Space experiment of energy transmission by microwaves will be conducted by the combination of a small satellite(mother) and a microsatellite(daughter) that is released from the mother satellite. Both satellites carry Impedance probe, Langmuir probe, and Plasma wave receiver. They are dedicated to measuring plasma response to the radiated intensive microwaves from the mother satellite to the Earth or the daughter satellite. It will be launched in 2025.