電波望遠鏡と探査機Junoによる木星放射線帯のキャンペーン観測

Results from a 2024-2025 Observation campaign of Jupiter's radiation belts using radio telescopes and in-situ data

*北 元[1]、三澤 浩昭[2]、Bhardwaj Anil[3]、土屋 史紀[2]、和賀 正道[2]、藤沢 健太[4]、Santos-Costa Daniel[5]
*Hajime Kita[1], Hiroaki Misawa[2], Anil Bhardwaj[3], Fuminori Tsuchiya[2], Masamichi Waga[2], Kenta Fujisawa[4], Daniel Santos-Costa[5]

1. 東北工業大学　工学部　情報通信工学科、2. 東北大学大学院理学研究科惑星プラズマ・大気研究センター、3. Physical Research Laboratory、4. 山口大学、5. Southwest Research Institute
1. Tohoku Institute of Technology, 2. Planetary Plasma and Atmospheric Research Center, Graduate School of Science, Tohoku University, 3. Physical Research Laboratory, 4. Yamaguchi University, 5. Southwest Research Institute

Since its discovery in the late 1950s, Jupiter's radiation belt (JRB) has continuously presented surprising features and dynamical behaviors, yet to be understood from observational and theoretical studies. The objective of the present paper is to discuss our efforts regarding our understanding of JRB from improved empirical and physical models. The radiation-belt electrons are controlled by various physical processes, and these processes are energy-dependent. To constrain the energy spectrum and transport process of the relativistic electrons in the Jovian radiation belt, ground-based observations of Jovian Synchrotron Radiation (JSR) were carried out during close approaches of Jupiter by the Juno spacecraft (NASA).
On one hand, Jupiter's synchrotron radiation is emitted by relativistic electrons trapped in the radiation belt. The characteristic frequencies of JSR range from tens of megahertz to several gigahertz. This range corresponds to relativistic electrons with energies ranging from a few megaelectron volts to several tens of megaelectron volts. Consequently, multi-frequency observations of JSR are essential to constrain the energy spectrum of the radiation belt electrons. Previous spectral observations suggested that the spectrum hardening could be due to Coulomb scattering and/or energy loss by dust, although other mechanisms have been argued since. JSR observations are regarded as the most effective method to study remotely Jupiter's radiation belt.
On the other hand, Juno has been collecting in-situ and remote-sensing observations of the inner Jovian radiation belt for nearly 10 years. Juno is a NASA polar orbiter around Jupiter since Aug. 2016. During close approaches (or PeriJoves (PJ)), Juno passes through the inner belt region, thereby providing unique opportunities to carry out complementary Juno's in-situ measurements for several hours. Results from the first science orbit in 2016 showed that the electron fluxes derived from penetrating radiation are an order of magnitude lower than those derived from empirical and physics-based models. Given the above situation, we have performed a multi-frequency observation of JSR during certain Juno's PJs in 2024 and 2025. An analysis of the similarities and differences between in-situ measurement, remote sensing, and computational models is essential for understanding the physical processes occurring within Jupiter's inner electron belt.
The coordinated ground-based observations were made during PJ 65 (2024/9/20), 66 (2024/10/22), and 69 (2025/1/28). We observed Jupiter with the GMRT at 1000-1400 MHz (band-5) during PJ 65, at 125-250 MHz (band-2) and 550-900 MHz (band-4) during PJ 66. The additional observation with GMRT band-4 was made for PJ 69. We also observed Jupiter with Usuda 64m telescope at 3GHz during PJ 66. The Iitate Planetary Radio Telescope conducted observations at 325 MHz for PJ 66 and 69. Yamaguchi 32 m telescope completed our observations at 6.86 GHz and 8.45 GHz during PJ 69. Additional

ground-based observations were carried out with NenuFAR (10-85 MHz), MeerKAT (1750-3500 MHz), and the VLA (200-500 MHz and 1-2 GHz) as part of an international multi-frequency multi-interferometric campaign.
The GMRT data were calibrated using the SPAM pipeline, which corrects terrestrial ionospheric effects. The initial result of band-4 data for PJ 66 shows that the resulting band-4 wideband image is the best data product ever obtained from GMRT observations dating back from 2003. We can identify high-latitude emission regions as well as the equatorial spots. The reduced band 2 data for PJ 66, which clearly display the dawn and dusk equatorial spots, provide angular resolutions comparable to LOFAR observations at the HBA band. We will show an overview of these observation settings and present the initial results of the GMRT and single-dish data analysis, as well as our strategy to combine ground-based, remote sensing, and in-situ data to achieve our scientific objectives.

キーワード：木星、放射線帯、Juno、電波望遠鏡
Keywords: Jupiter, Radiation belt, Juno, Radio telescope