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飯舘・蔵王観測所を用いた低周波 VLBI 実験

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Low-frequency VLBI observation with Iitate and Zao observatories

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The detection and measurement of exoplanet magnetic fields greatly advances our understanding of planets. Planets with atmospheres and magnetic fields, such as Earth and Jupiter, have auroras, which emit radio waves originating from charged particles accelerated in the polar regions. From the information on auroral radio waves, not only the existence of intrinsic magnetic fields can be determined, but also rotation period, surface magnetic flux density, and magnetic moment can be derived, and planetary dynamo numerical experiments can provide insight into the internal structure of the planet. Furthermore, by clarifying various characteristic quantities of different planets, it will be possible to derive scaling laws, such as for the planetary magnetic field or radio emission power. Although there have been many observations of exoplanets using large radio telescopes, only one or two have been detected so far. We have also made observations using GMRT, but no detection has been made.

In previous studies, all circularly polarized components from planetary systems are assumed to be auroral radio waves from planets, but circularly polarized components are also emitted from the main star. VLBI is widely used in the GHz band, but VLBI observations in the MHz band have been not yet established as a stable method due to ionospheric fluctuations. VLBI is also effective for detecting exoplanet radio waves because the sensitivity can be improved by combining a large number of telescopes. Since the frequency of auroral radio waves is proportional to the strength of a planetary surface magnetic field, lower frequencies (several hundred MHz band) are suitable for observing more candidate planets. However, difficulties for observations in the MHz band are ionospheric fluctuations. The amount of delay in the ionosphere is larger at lower frequencies, and the phase rotates significantly in a few minutes, resulting in reduced sensitivity when integrated over a long period of time. Therefore, it is necessary to establish a method to compensate for the electron density fluctuations between the source and the antenna.

To evaluate the instrumental stability and ionospheric variability for future international VLBI observations, we conducted VLBI observations using the Iitate Planetary Radio Telescope (IPRT) at Tohoku University and the radio telescope at the Zao observatory. The baseline length between Zao and Iitate is 44.5 km, and the observation frequency is 325 MHz. Zao is equipped with a dual orthogonal polarization system, and IPRT is equipped with two systems of dual orthogonal polarization components. K5/VSSP sampler was used for data acquisition, and the correlation analyses were performed after the observations. The target was 3C48 passing near the zenith, and a drift scan was performed. 3C48 has an intensity of 42 Jy at P-band and can be regarded as a point source from the VLA calibrator manual. Since the baseline length between Zao and Iitate is approximately the maximum baseline length of the VLA A-configuration, it is also considered as a point source in this observation. The polarization of 3C48 is known to be close to zero above 1 GHz, and is assumed to have the same characteristics below 1 GHz.

The observations were made on September 29, 2021, using K5/VSSP32 sampler with 32 MHz, 8 bit, 1 channel. We successfully detected the fringe from this data. The fringe phase changed slowly during the 100 sec period. Both phase and group delays were examined, and the trends were consistent, indicating that the phase change found here is not of ionospheric origin. In the observation on December 21, 2022, all channels were measured at 32 MHz and 4 bits using K5/VSSP64 sampler. Fringes were also successfully detected except for some channels with no signal. We also conducted three consecutive days of observation from February 8 to 10 in 2023 using K5/VSSP64. From these data, we will investigate the relationship between the fringe phase and the ionospheric electron density.