Characterizing exoplanets with low-frequency radio observations

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While characterization of individual exoplanets is often performed in the ultraviolet, optical, and infrared domains where the main observables are the atmospheric properties, low-frequency radio observations would serve as a complementary approach to characterize certain aspects of planets, mainly associated with the magnetospheric and ionospheric properties. With the Square Meter Array (SKA; around 0.1-10 GHz) being built, we explore the potential of SKA observations for characterizing various types of exoplanets as a part of SKA-JP science working group.

One of the recognized scientific goals of SKA is to search for the auroral emissions from exoplanets, which can constrain the planetary magnetic field strengths (e.g., Zarka 1997). A number of observations have been conducted so far, but no clear evidence has been obtained yet (e.g., Grießmeier et al., 2017 and references therein). We discuss the synergies with transit observations (due to the anisotropy of emission), direct imaging observations of young massive planets (for constraining the internal structure or the magnetic scaling laws by, e.g., Christensen et al., 2009), and gravitational microlensing observations (with the characteristic magnification curves; Shiohira et al., submitted). We also discuss the auroral radio generation by the pair of a close-in rocky planet and the host star via a mechanism similar to Io-Jupiter system as a probe of the planetary ionospheres.

A radio source observed through an exoplanet atmosphere (i.e., transmission observations in the radio domain) would be another opportunity to study the planetary magnetic fields as well as the surrounding plasmas, through the Faraday rotation and the time delay (Withers & Vogt 2017). This can be tested with Jovian magnetosphere passing in front of distant pulsars. We find that such events occur about 0.5 times/year on average, and SKA will have a sufficient sensitivity to detect the effects of Jovian magnetosphere.

Lastly, we argue that the gas-accreting proto-planets being formed in the protoplanetary disks emit the radio recombination lines (RRL) that are detectable with SKA, as estimated based on Aoyama et al., (2018). Compared with the tracers of the accretion processes at the shorter wavelengths (e.g., Hα; Haffert et al. 2019), RRL will be more sensitive to the (proto-)planets in young, optically thick disks, due to the reduced extinction efficiency. Detecting RRL would be critical to identify the very birthplace of the gaseous planets as well as to constrain the geometry and the rate of the planetary gas accretion at the early phase.

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