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Introduction: Growing number of exoplanets including those in the habitable zone have been discovered [e.g., 1]. However, a planet in the habitable zone does not necessarily mean that the planet is habitable. Thus, we need to make continuous efforts to characterize the planet as habitable. Polarimetric observations may be able to play an important role to approach the goal. Light emitted from a host star is virtually unpolarized, whereas reflection on a planet produces polarization. Degree and position angle of polarization are dependent with the planet's geometry and physical properties with regard to reflection. Therefore, polarimetric measurements can be used to characterize exoplanets in a coming age when direct polarimetry of exoplanets has been put into practical use.

In this presentation, we focus on potential of polarimetry for searching (1) planetary atmosphere with Earth-like optical thickness, and (2) liquid surface on planets, both of which are important information to discuss habitability of planets. To investigate the potential, we have carried out polarimetric observations of Earthshine on the Moon. Earthshine is Earthlight reflected from the lunar surface. It is commonly used by ground-based observers to obtain disk-integrated Earthlight and to extract observational signatures of the Earth.

Atmosophere with Earth-Like Thickness: Firstly, we summarize our optical spectropolarimetry of Earthshine for Earth phase angles ranging from 49° to 96°. Full description of this project can be found in [2]. This project aims to derive the phase variation of polarization spectra of the Earth to find a signature pointing toward a distinctive characteristic of the Earth. The observations were conducted on March 9-13, 2011 (UT). We utilized the spectropolarimeter HBS mounted on the 1.88 m telescope at the Okayama Astrophysical Observatory located in Okayama, Japan. The wavelength coverage is 450-850 nm with a resolution of 6 nm. We have found that the phase dependence differed with the wavelengths; the maximum polarization for the *V* band wavelengths occurred at a phase angle of near 90°, whereas that for longer wavelengths is reached at larger phase angles. This is interpreted as indicating that Earthshine polarization at shorter wavelengths is dominated by atmospheric Rayleigh scattering, whereas that at longer wavelengths has an increasingly effective contribution from the Earth surface reflection. The observed wavelength dependence in the phase angles of the maximum polarization for the Earth is suggested to be different from the other rocky planetary objects in the Solar System. Therefore our observational result might be a signature pointing toward atmosphere with Earth-like optical thickness: the atmosphere is scattering in the shorter wavelengths but transparent in the longer wavelengths.

Liquid Surface: Secondly, we describe our ongoing project of comparing polarization between Earthshine from land-dominant surface and that from ocean–dominant surface. Polarimetry may be a method to search a planet with a liquid surface because specular reflection from a liquid surface is expected to produce a greater polarization degree than reflection from a rough surface does [3]. This project aims to evaluate the difference between Earthshine polarization contributed by reflection at a land-dominant surface and that by an ocean-dominant surface. As viewing from Japan, we can observe Earthshine with contribution from a land-dominant surface in waxing phases of the Moon, whereas we can study that from an ocean-dominant surface in the waning phases. We utilized the 60 cm reflecting telescope at the Nishi-Harima Astronomical Observatory located in Hyogo, Japan and the simultaneous imaging/spectrometric polarimeter. In a series of observations from May 2010 to March 2012, twelve data sets were obtained for the waxing phases and seven data sets for the waning. The observations were conducted in *V* band. The measured polarization degrees increased as the Earth phase approaches a quadrature phase. The maximum polarization degree was roughly ~8 % for the both phases. Fitting with a function for Rayleigh scattering have yielded the polarization maximum of 7.7±0.4% and 8.4±0.7% for the waxing and waning phases, respectively. Although a larger value has been derived for the waning phases when the Earthshine is contributed by an ocean-dominant surface, the difference is not significant considering uncertainty of the result. Refinement of our observational system is currently underway.

References: [1] Borucki, W. J., et al. (2013) Science, 340, 587 -590. [2] Takahashi, J. et al. (2013) PASJ, 65, 38. [3] Zugger, M. E., et al. (2010), ApJ, 723, 1168