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Polarimetry for rocky exoplanet characterization

Daphne Stam (1) and Theodora Karalidi (2,3)

(1) Aerospace Engineering, Technical University, Delft, the Netherlands (d.m.stam@tudelft.nl), (2) SRON Netherlands Institute for Space Research, Utrecht, the Netherlands (t.karalidi@sron.nl), (3) Leiden Observatory, Leiden University, Leiden, The Netherlands

Since the first discovery of a planet around a solar-type star by Mayor & Queloz in 1995, several hundreds of exoplanets have been detected. Indeed, it appears that practically all Sun-like stars have planets. Inevitable, Earth-sized, rocky planets that orbit in their star's habitable zone, where temperatures could be just right to allow liquid water on a planet's surface, will be found. Liquid water is generally considered to be essential for the existence of life. Whether liquid water actually exists on a planet depends strongly on the atmosphere's thickness and characteristics, such as the surface pressure and composition. Famous examples in the Solar System are Venus and the Earth, with similar sizes, inner compositions and orbital radii, but wildly different surface conditions.

The characterization of the atmospheres and/or surfaces of exoplanets will allow a comparison with Solar System planets and it will open up a treasure trove of knowledge about the formation and evolution of planetary atmospheres and surfaces, thanks to the vast range of orbital distances, planet sizes and ages that can be studied. Characterization will also allow studying conditions for life and ultimately the existence of life around other stars. Information about the upper atmospheres of close-in, hot, giant exoplanets, can be derived from measurements of the combined flux of the star and the planet, in particular when the planet is transiting its star. This method has also provided traces of an atmosphere around a large solid planet orbiting red dwarf star GJ1214.

Detection and characterization of the atmospheres and/or surfaces of small, solid, Earth-like exoplanets in the habitable zones of Sun-like stars, is virtually impossible with transit observations. For these exiting planets, polarimetry appears to be a strong tool. Polarimetry helps the detection of exoplanets, because direct starlight is usually unpolarized, while starlight that has been reflected by a planet is usually polarized, especially at planetary phase angles around 90 degrees, that are favorable for observing exoplanets. Polarimetry thus improves the contrast between stars and their planets, and confirms that the detected object is indeed a planet. Polarimetry is also invaluable for the characterization of exoplanets.

This application is known from the derivation of the Venus cloud properties from the planet's polarized phase function by Hansen & Hovenier in 1974. Using numerically simulated flux and polarization phase functions and spectra for rocky exoplanets, I will discuss the added value of polarimetry for exoplanet characterization as compared to flux observations, in particular for the retrieval of properties of clouds and hazes. Special attention will be given to the features in polarized phase functions that reveal the existence of liquid water clouds in an exoplanet's atmosphere (rainbows), even in the presence of ice clouds. Using satellite data of the cloud and surface coverage of the Earth, calculated flux and polarization phase functions that should be observable from afar will be presented.