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The case for spectropolarimetry with SPEX on EJSM

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Abstract

We present SPEX, our Spectropolarimeter for Planetary EXploration, and its application as science payload for EJSM. SPEX' novel spectropolarimetry method allows to simultaneously measure radiance spectra (with a resolution of 2 nm) and polarization spectra (with a resolution of 20 nm) from 0.4 to 0.8 μm. Thanks to this novel method, SPEX is small and robust.

Strengths of polarimetry

Light is fully described by its radiance and degree and direction of polarization. Direct sunlight is unpolarized (when integrated over the solar disk), but sunlight that has been scattered in a planetary atmosphere and/or that has been reflected by a planetary or lunar surface will usually be (linearly) polarized. The degree of polarization of this light is very sensitive to the microphysical properties (size, shape, composition) of the scattering particles and/or to the reflection properties of the surface (i.e. its roughness, and characteristic particle size). The degree of polarization is also sensitive to the vertical distribution of the atmospheric particles, such as cloud top altitudes. In addition, the degree of polarization varies with wavelength and the illumination and viewing geometries.

Because the degree of polarization of the scattered and reflected sunlight has a different, and usually higher sensitivity to the characteristics of a planetary atmosphere and/or surface than the radiance, polarimetry is a powerful and often the only tool for disentangling the many parameters that describe planetary atmospheres and surfaces, in particular in combination with radiance measurements.

The strengths of polarimetry for studying planetary atmospheres and surfaces have long been recognized. As an early example, Hansen and Hovenier [1] successfully derived the composition and size of Venus' cloud particles from Earth-based polarimetry at several wavelengths and a range of phase angles. Earth-based polarimetry of the outer planets has not been very popular, because at the small phase angles under which these planets can be seen, the observable degree of polarization is always very small. However, there have been many planetary missions to these planets that carried instruments with polarimetric capabilities, such as the Pioneers 10 and 11, the Voyagers, the Galileo and Cassini missions, and the Huygens lander.

Spectropolarimeter SPEX

Polarimetry on the above mentioned missions was done by combining two or three radiances measured through (broadband) polarization filters. This method provides little spectral information, and usually results in a low accuracy. We present SPEX, our Spectropolarimeter for Planetary EXploration, as science payload for the orbiters of the EJSM mission. SPEX has been designed to measure the radiance, degree and direction of linear polarization of scattered and reflected sunlight from 0.4 μm to 0.8 μm with resolutions of 2 nm (radiance) and 20 nm (polarization).

SPEX uses a novel method for its spectropolarimetry (a preliminary patent has been granted): through a series of birefringent crystals the radiance of the observed sunlight is spectrally modulated, such that the modulation amplitude yields the degree of (linear) polarization and the modulation phase the direction of polarization. SPEX measures two modulated, high-spectral resolution radiance spectra, with a phase shift between their modulations. The sum of these spectra yields the high-spectral resolution radiance spectrum of the observed sunlight without the modulation. SPEX thus simultaneously measures the radiance, the degree, and the direction of polarization of the reflected light over a continuous, broad spectral range. For a detailed description of the method see [2].

References

[1] Hansen, J.E., and Hovenier, J.W. (1974) *J. Atmos. Sci.*, 31, 1137–1160.

[2] Snik, F., Karalidi, T., and Keller, C.U. (2009), *Appl. Opt.*, 48, 1337–1346, doi:10.1364/AO.48.001337.