High dynamic-range observation using a low-scattered light telescope PLANETS: feasibility study

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High dynamic-range (HDR) observation is one of the key technique to reveal composition, distribution and dynamics of plasma and neutrals in the vicinity of planets and their moons in our solar system, e.g. water plumes on Europa and Enceladus, volcanic plumes on Io, escaping plasma and neutrals from Venus and Mars, and so on. A low-scattered light telescope, PLANETS (Polarized Light from Atmospheres of Nearby Extra-Terrestrial Systems) would be an 1.8-m off-axis telescope on Mt. Haleakala, Hawaii under collaboration with Japan, USA, Germany, Brazil, and France. The off-axis optical system enables us to achieve HDR measurements without diffraction by support structure of secondary mirror. We present feasibility study of monitoring water plumes on Europa, neutral torus close to Enceladus, and ionosphere on Mars using PLANETS telescope.

To test feasibility of HDR under actual condition of wavefront error which includes by an optical system as well as by atmospheric turbulence, modeling the propagation of light though the system was made based on Fraunhofer (far-field) calculations with help from PROPER library (Krist 2007). The optical system consists of an entrance pupil (1.85 m), primary mirror, a deformable mirror, an occulting mask, a Lyot mask on a pupil, and a detector on image plane. We gave wavefront error made by atmospheric turbulence (typical Fried length is 15 cm) and the optical system represented with power spectral density. Then, dynamic range of point spread function was calculated for several cases of surface roughness of the primary mirror, 1 to 8 nm r.m.s., and number of control points for active wavefront compensation by a deformable mirror, 7 to 24. Finally we calculated brightness distribution of background continuum, and derived signal-to-noise ratio for each observing target assuming expected brightness and band-width of spectroscopy. For O_2^+ 561 nm and N_2^+ 391 nm emissions from Martian ionosphere and O 630 nm emission from Enceladus torus, sufficient signal-to-noise ratio is expected for 2-hour integration by employing wavefront compensation with 7x7 deformable mirror and small roughness of primary mirror, 2-nm r.m.s. Whereas for O 630 nm emissions from water plumes on Europa, wavefront compensation by 24x24 deformable mirror is needed to achieve sufficient signal-to-noise ratio for 2-hour integration. Now the primary mirror is waiting for final polishing. We will present required surface error of the primary as well as a concept design of an active support structure to fulfill the requirement.