SAG on Exoplanet Reflectance Spectroscopy for the Habitable Worlds Observatory

The Habitable Worlds Observatory (HWO), a flagship mission recommended by the Astro2020 decadal survey, would deliver transformative science capabilities for direct imaging and spectroscopic characterization of terrestrial exoplanets, expanding the horizons of human exploration to potentially habitable planets around Sun-like stars. The Astro2020 Decadal Survey stated that HWO should yield "a robust sample of ~25 atmospheric spectra of potentially habitable exoplanets," but it also left for the science community to decide what an adequate "atmospheric spectrum" would entail. This science requirement is of paramount importance as it bears upon the trade and selection of the architecture of the flagship mission, and also on the technology maturation programs that will ramp up in ~FY25. For example, whether HWO would have spectroscopic capabilities in UV or IR, the wavelength cutoffs, and whether HWO would include single or multiple parallel coronagraphs or a starshade, all hinge on the measurement requirements for identifying and characterizing potentially habitable exoplanets.

As HWO would push the frontier of exoplanet observations, the determination of its measurement requirements must be based upon the simulation of anticipated planetary spectra and statistical inference of planetary parameters from the spectra, i.e., the spectral retrieval. The notional specification of the wavelength coverage and spectral resolution of the LUVOIR and HabEx concepts, predecessors of HWO, were derived from a spectral retrieval exercise based on modern Earth's spectrum as a template. Multiple groups in the country and abroad have now built spectral simulation and retrieval tools, and substantial progress has been made recently on the potential need for a wide spectral coverage for habitable exoplanets beyond modern Earth analogs.

In this context, it is essential to have a common understanding between different research groups and models about exoplanet reflectance spectroscopy, and this would be best achieved by community intercomparisons and a data challenge that focuses on spectral retrievals, with the supervision of ExoPAG. We thus propose a community study to compare and converge on the practices of the simulation and retrieval of the exoplanet reflectance spectra, with a focus on terrestrial exoplanets relevant to HWO. We will aim to:

- compare and cross-validate spectral retrieval tools, including elements as central as opacities, radiative transfer routines, and statistical evaluation algorithms;
- compare and converge on appropriate levels of model complexities (such as the treatment of clouds and radiative transfer model sophistication) based on the expected data characteristics (e.g., wavelength, resolution, SNR);
- coordinate a blind retrieval challenge open to the entire community and focusing on reflectance spectroscopy of terrestrial exoplanets;
- achieve common understanding of how the wavelength range, spectral resolution, and prior constraints on the planetary mass impact the characterization of different types of terrestrial exoplanets;
- identify key areas of disagreement that could adversely impact HWO science and design; and

- identify the best practices for deriving atmospheric constraints from exoplanet reflectance spectra.

The SAG will provide useful tools and scientific inputs to HWO's Science, Technology, Architecture Review Team (START), who will study specific science cases for the mission.

This study will allow open participation from any group in the science community. We anticipate that the activities will commence by April 2024 and will continue for 1.5 years. We expect to report the progress and results of the study to ExoPAG and START. The study will result in a final report that summarizes the findings.