A SAG on Exoplanet Reflectance Spectroscopy for the Habitable Worlds Observatory

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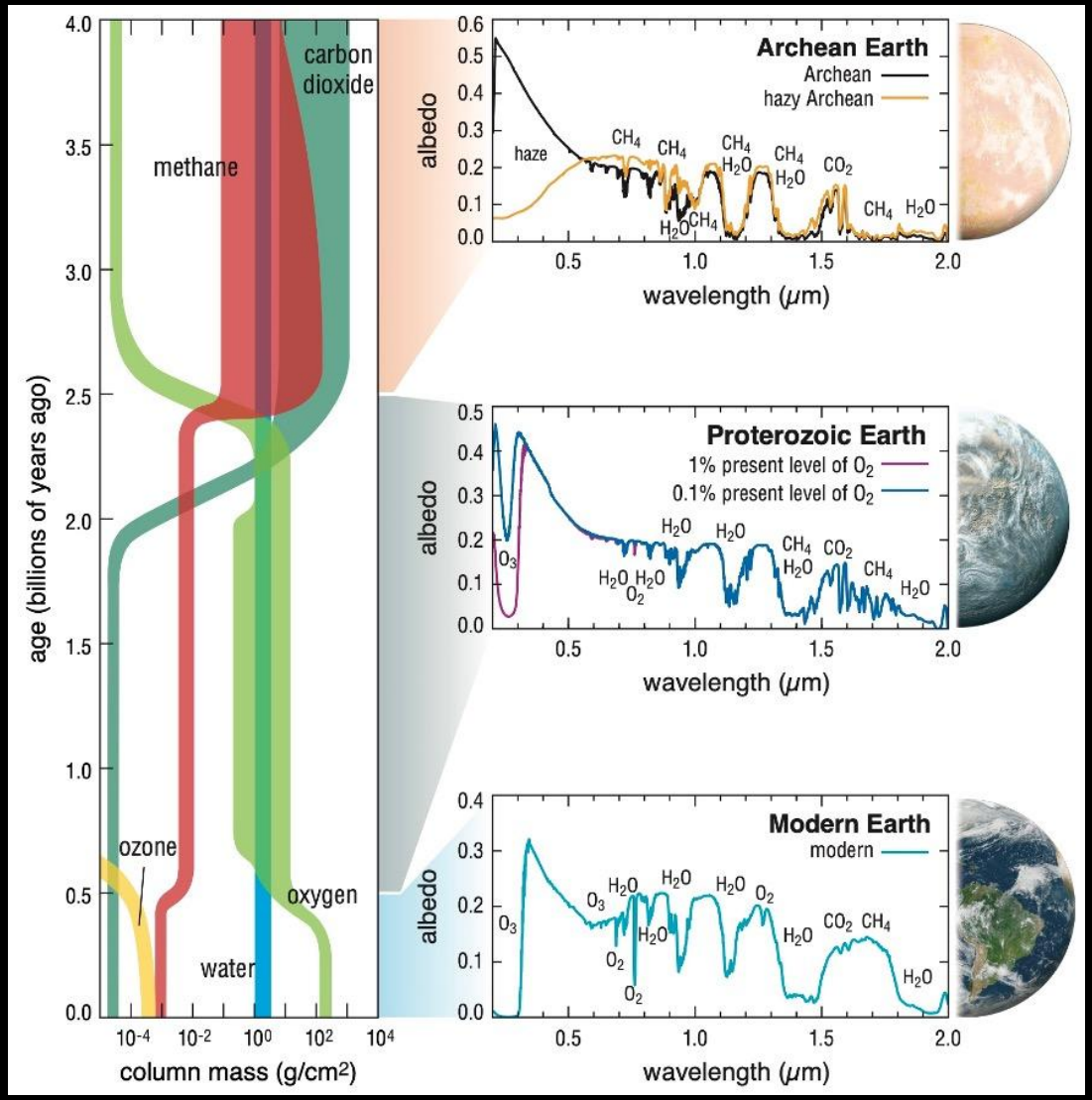
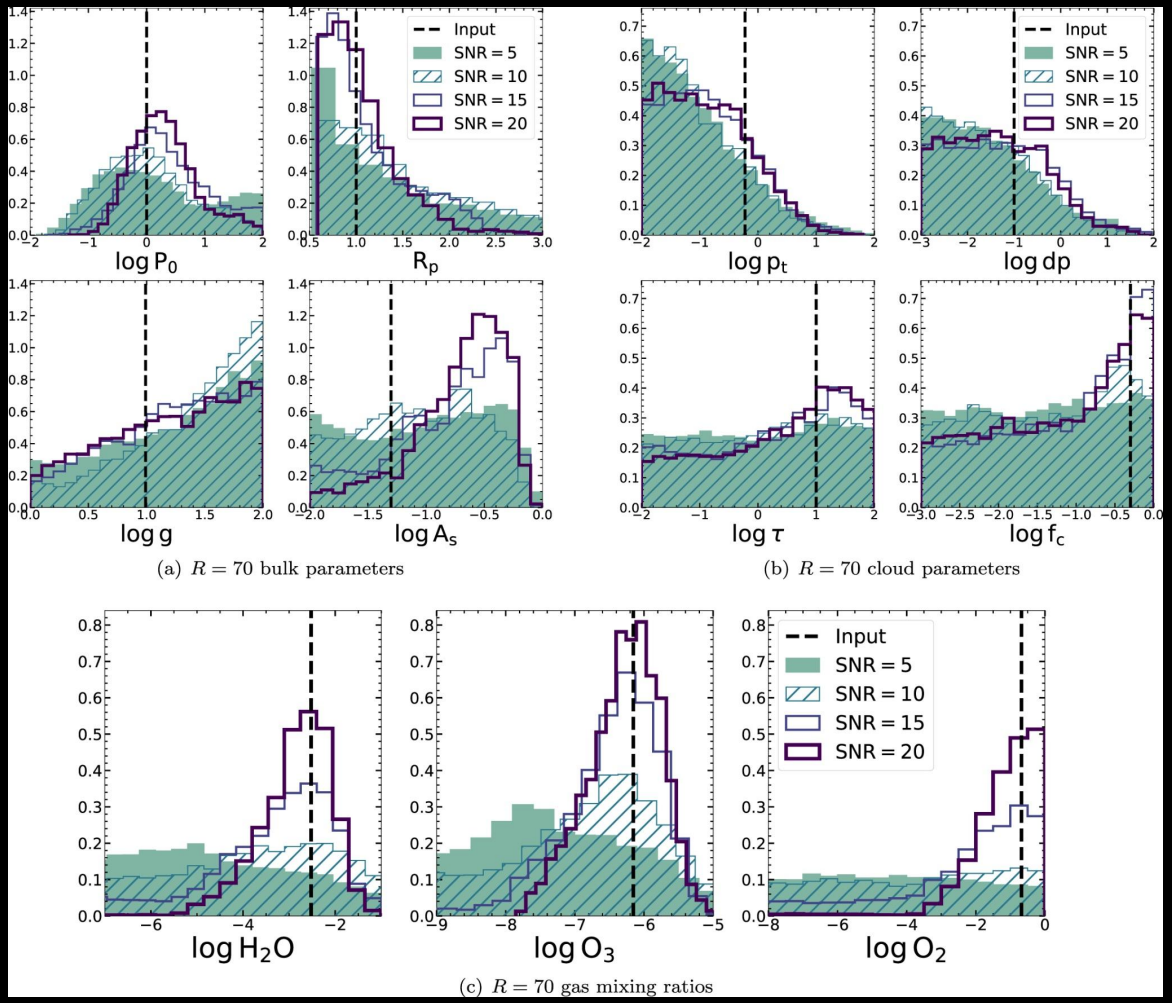
Motivations



Spectroscopic measurement capabilities for identifying and characterizing potentially habitable exoplanets are of paramount importance to HWO, as they bear upon the trade and selection of an architecture for the flagship mission and for the maturation of some technologies

LUVOIR & HabEx final reports

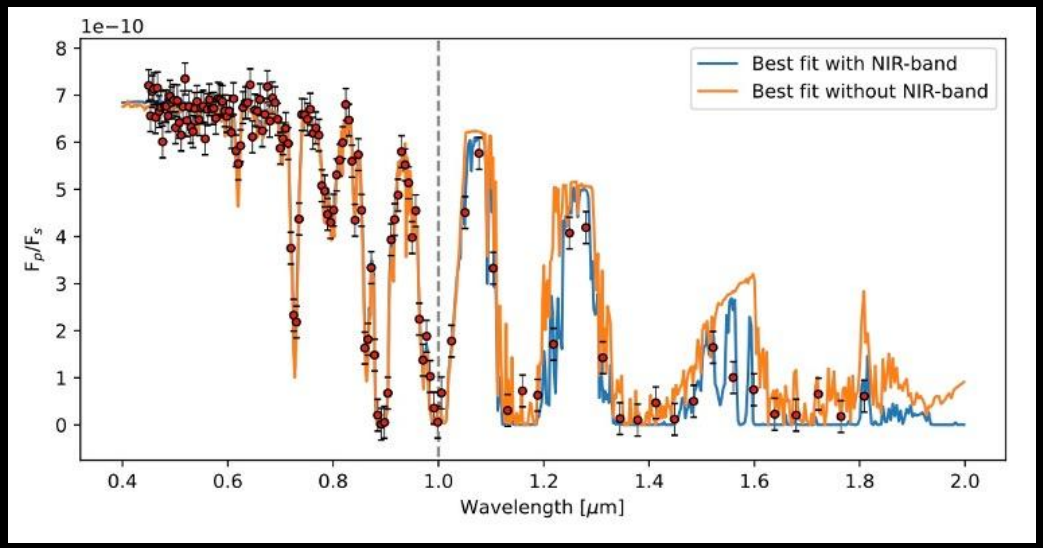
Recent Developments



- For a modern Earth analog, a R=70, S/N=15 spectrum between 0.4–1 μm would measure the atmospheric abundances of H_2O, O_2, and O_3
- The threshold S/N drops to 10 if R=140

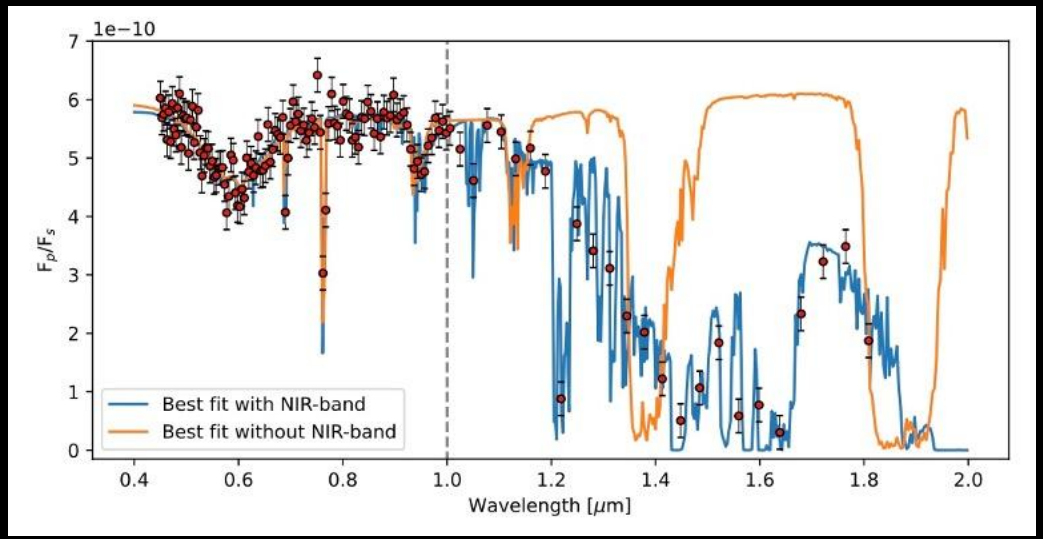
Feng et al. 2018

Recent Developments



- The NIR band (1.0–1.8 μm) is essential to characterize more types of terrestrial exoplanets

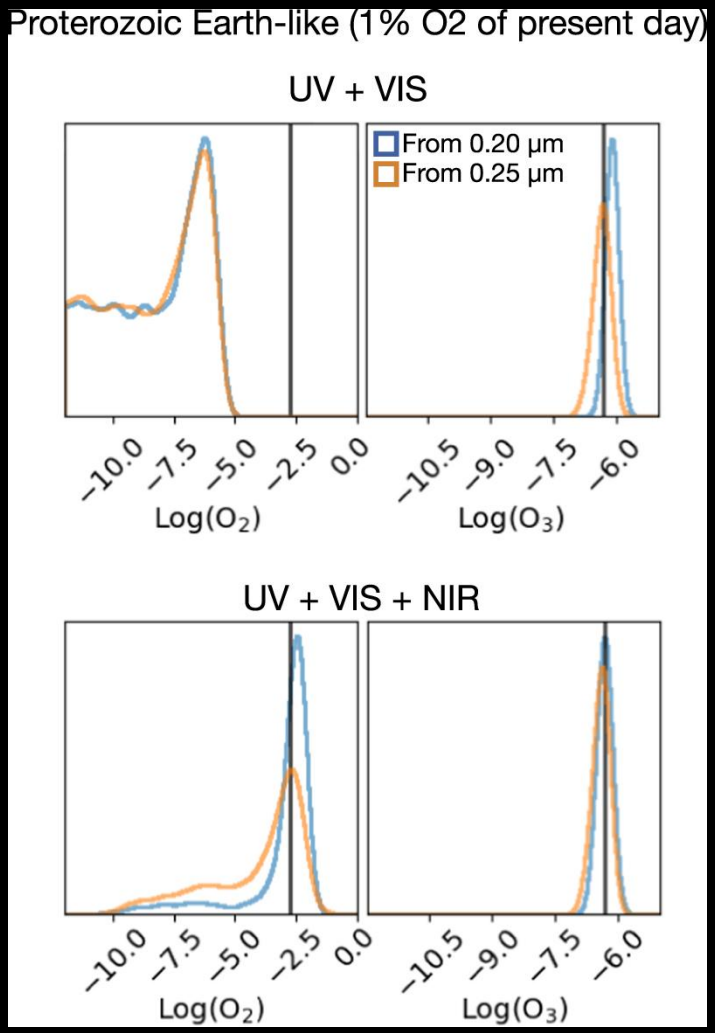
Archean Earth



Habitable Venus

Damiano & Hu 2022

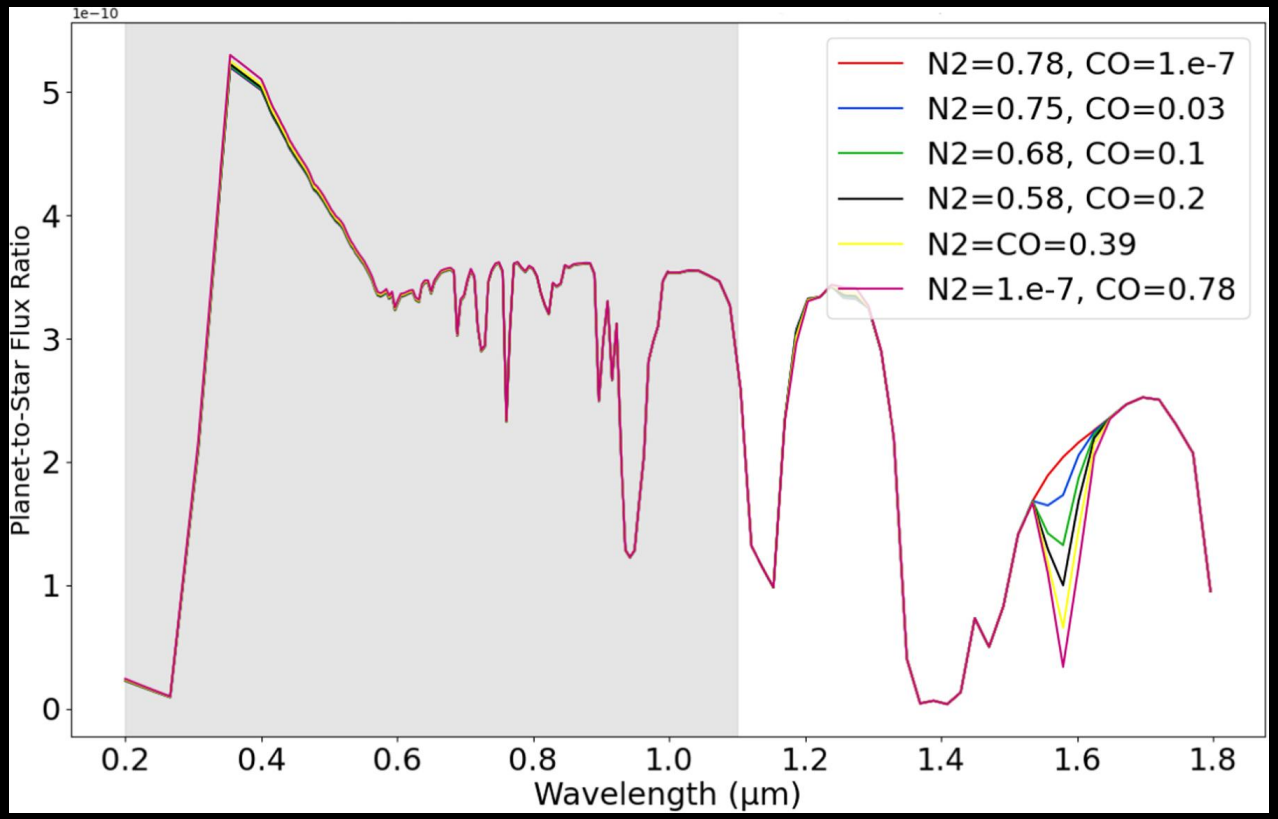
Recent Developments



Damiano et al. 2023

- The UV spectral coverage between 0.25 and 0.4 μm, in addition to the optical band, would measure the atmospheric O_3 corresponding to the Proterozoic Earth level
- A modest spectral resolution (R=7) and S/N=10 is necessary
- The O_3 detection is robust against other potential gases absorbing in the ultraviolet (e.g., H_2S and SO_2)

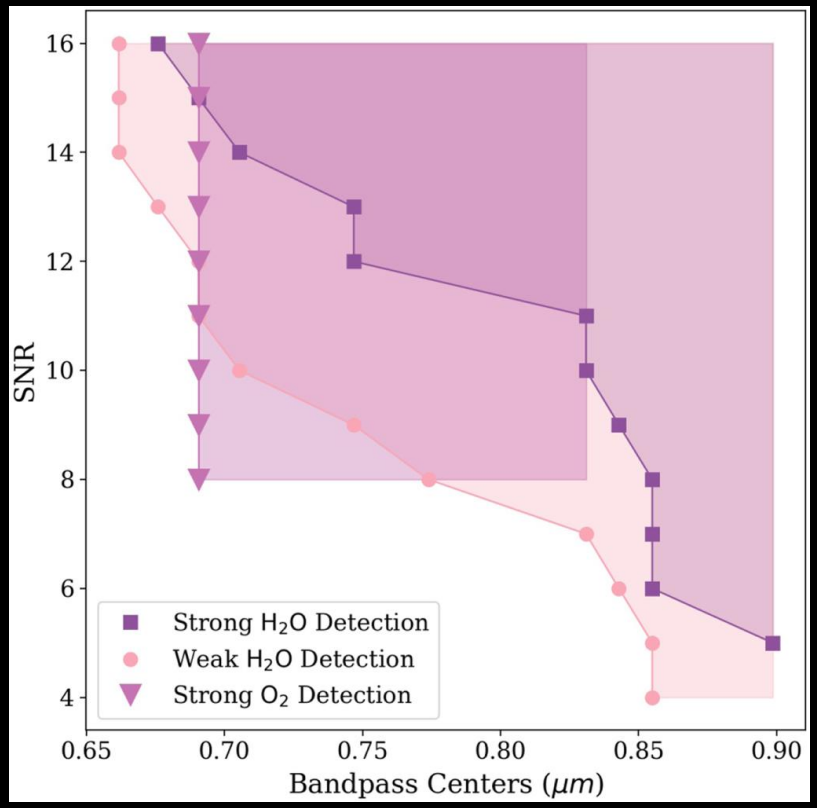
Recent Developments



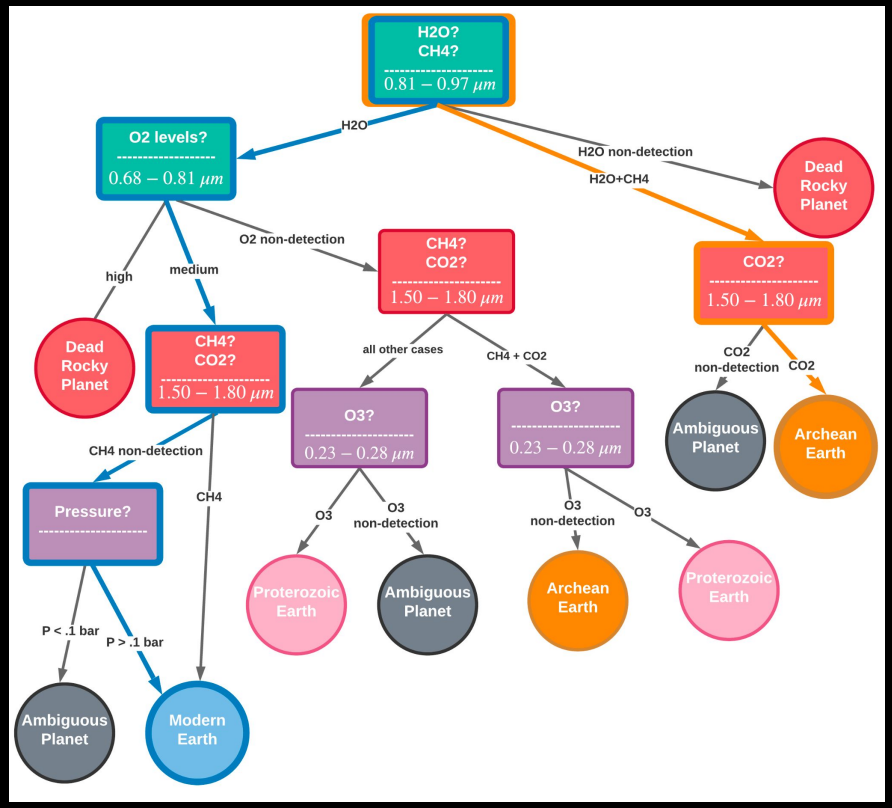
Hall et al. 2023

- A spectrum that extends beyond ~1.6 μm and with S/N~20 would distinguish N_2- versus CO-dominated atmospheres
- S/N~40 may be necessary to totally rule out O_2-dominated atmospheres

Recent Developments



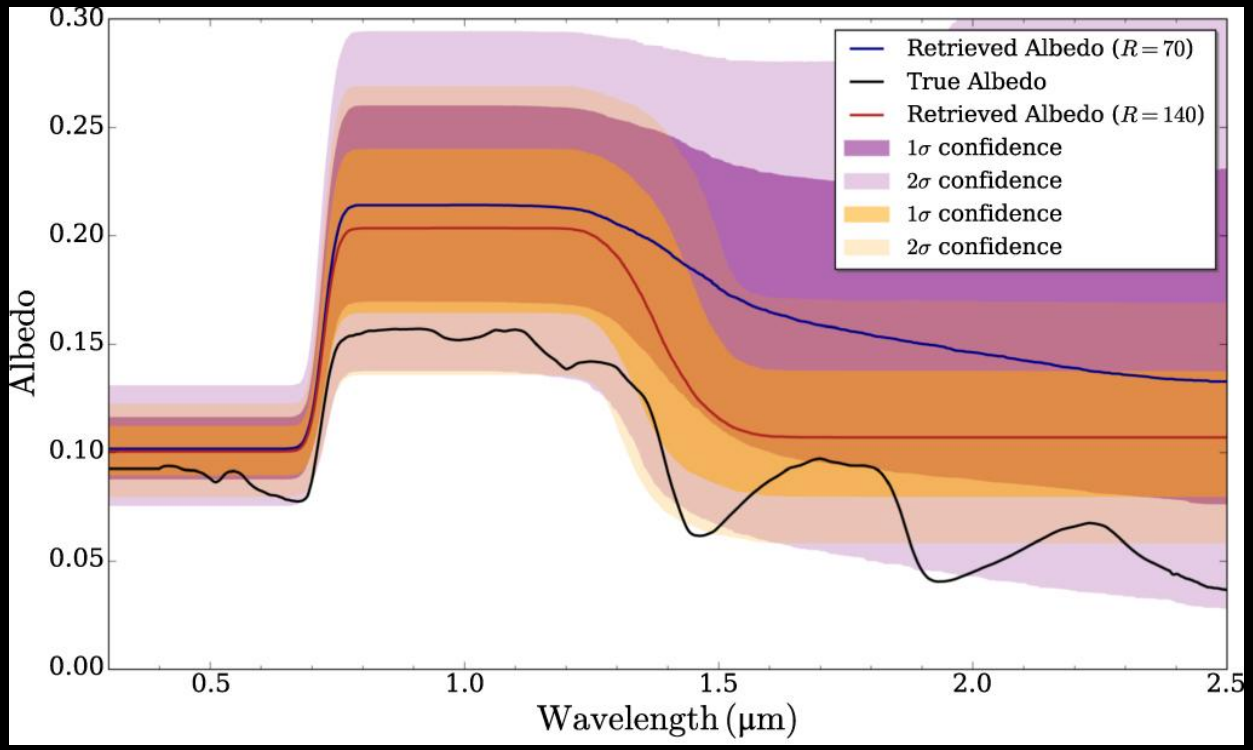
Latouf et al. 2023a, b



Young et al. 2023

- Narrow (~20%) band observations can detect single gases
- Multiple bands from UV to NIR are likely necessary for planet characterization

Recent Developments



- The surface albedo could be measured from a modern Earth analog
- Cloud is an interfering factor

Barrientos et al. 2023; also Wang et al. 2022

SAG on Exoplanet Reflectance Spectroscopy

- It is essential to have a common understanding between approaches and models for exoplanet reflectance spectroscopy
- The SAG will bring together multiple groups in the community to compare and converge on the practices for simulation of, and retrieval on, exoplanet reflectance spectra, with a focus on terrestrial exoplanets relevant to HWO
- The SAG will incorporate START members and bridge ExoPAG and START working group goals
- The SAG will leverage currently funded efforts:
    - Astrophysics Decadal Survey Precursor Science teams (Turnbull, Krissansen-Totton)
    - CUISINES model intercomparison framework (Fauchez)
    - ExoSpec ISFM Work Package (Mandell)

Detailed Objectives

- 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)
- Organize 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 characterization of different types of terrestrial exoplanets
- Identify key areas of disagreement that could adversely impact HWO science and design
- Identify the best practices for deriving atmospheric constraints from exoplanet reflectance spectra

Timeline and Participating Teams

- We anticipate that the activities will commence by Feb 2024 and will continue for 1.5 years

- This study would allow open participation from any group in the science community. Confirmed participants include:
    - Renyu Hu, Mario Damiano, Armen Tokadjian (JPL)
    - Tyler Robinson (University of Arizona)
    - Vikki Meadows, Jacob Lustig-Yaeger (University of Washington, JHU/APL)
    - Avi Mandell, Geronimo Villanueva, Amber Young, Thomas Fauchez, Eleonora Alei, Natasha Latouf (NASA GSFC)
    - Margaret Turnbull (SETI)
    - Lisa Kaltenegger (Cornell)
    - Sascha Quanz (ETH Zurich)
    - Laura Kreidberg (MPIA)

- Other potential participants include Heike Rauer (DLR Berlin), Patrick Irwin (University of Oxford), as well as from the brown dwarfs/transit communities

Early Career Exoplanet Astrobiologists:

Join the **Habitable Worlds Observer Exoplanet Data Challenge**

In 2024, SETI Institute and NASA Goddard collaborators will begin tutorial workshops and a blind data challenge for participants to extract habitable zone planet characteristics from spatially unresolved UVOIR spectra acquired by a future flagship, the Habitable Worlds Observatory. This challenge will inform the design of HWO, and prepare the next generation to use it.

Add your email to our contact list to receive more information as it becomes available! We hope to see you there.

https://forms.gle/qJtcH7f9h2oqv6sK9

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