Exoplanet Detection and Characterization in the Ultraviolet using a Starshade Complement for Habitable Worlds Observatory

Zahra Ahmed[1*], Stuart Shaklan[2], Simone D'Amico[1]

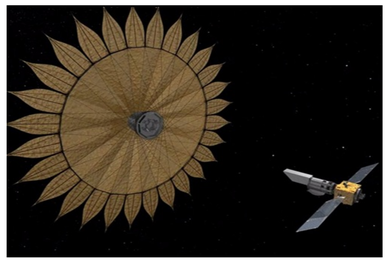
[1]Space Rendezvous Laboratory, Stanford University [2]Jet Propulsion Laboratory, California Institute of Technology

*zjahmed@stanford.edu

slab.stanford.edu

Why Starshades?

Achieving Habitable Worlds Observatory's goal of imaging and characterizing ~25 habitable worlds will require advancements in starlight suppression to achieve 10^{-10} contrast

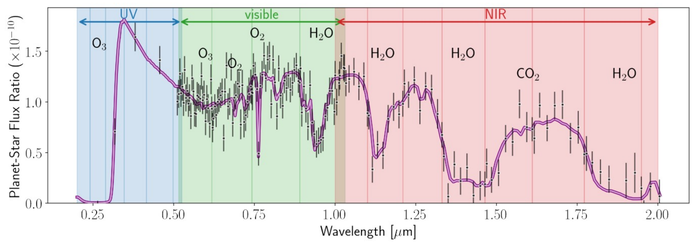


Rendering of starshade-telescope system. Source: Caltech/JPL.

Starshades' ability to achieve high contrast coupled with their small IWA and broad bandwidth make them a powerful characterization tool in the UV, complementary to coronagraphs.

Biosignatures in the Ultraviolet

The 0.25 μm ozone feature is a key biosignature both in modern and Proterozoic Earth-like atmospheres

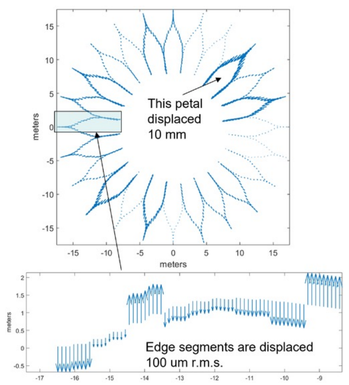


Key biosignatures in Modern Earth spectra. Source: Astro2020 Decadal Survey, Jacob Lustig-Yaeger

Ultraviolet Starshade Design

UV Starshade design introduced in Shaklan, S. et al. 2023 [1]

Starshade petals are deformed and displaced to demonstrate robustness to manufacturing and deployment defects far beyond what is expected based on laboratory experiments [2-4]



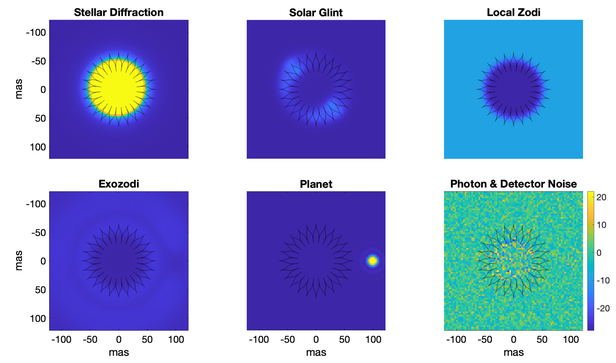
Source: Shaklan, S. et al. 2023 Proc. SPIE 12680

Project Objective

Investigate the ability to characterize Earth-like exoplanets using a starshade to constrain the 0.25 μm ozone feature with low resolution spectroscopy.

Starshade Simulations

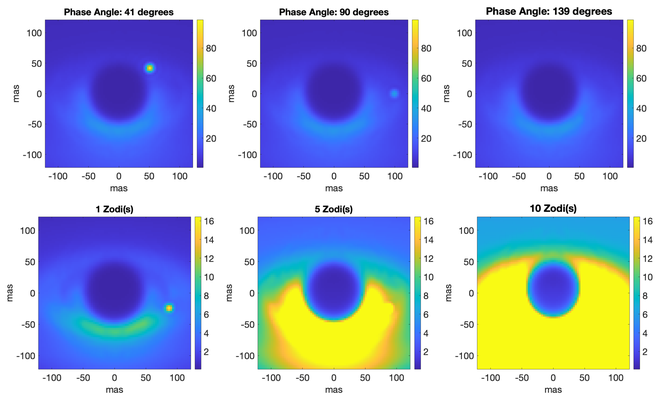
Data cubes simulated using the Starshade Simulation Toolkit for Exoplanet Reconnaissance (SISTER) [5]



Instrument and astrophysical components included in the data cubes, shown for 300-325 nm band. Scattered light exozodiacal dust images provided by Miles Currie [6] and based on n-body simulations developed by Chris Stark [7].

Simulation Parameters

Parameter	Value(s)
Imaging Bandpass	250 - 500 nm with 25 nm bands
System Distance	10 pc
Target Star	Solar-type star
Planet	Modern Earth-twin in a circular 1 AU orbit
Planet Orbital Position	0, 30, 60, 90, 120, 150, 180 degrees
Disk Inclination	0, 30, 60 degrees
Exozodi Density	1, 5, 10, 20, 50, 100 zodi

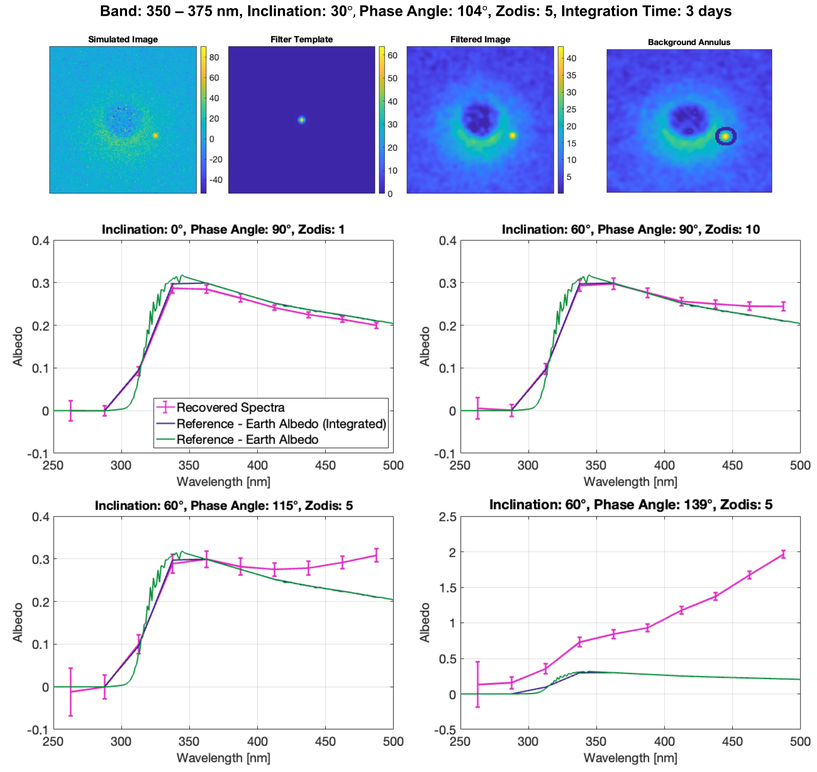


Noiseless images shown for 300 – 325 nm band for a 60° inclined system. (*Top)* Varying phase angle with 5 zodis. (*Bottom)* Varying zodis for a planet with phase angle of 115°.

Spectral Extraction

Matched Filtering: Assuming the planet location and type is known, the data cubes are passed through a matched filter with a template defined by the planet PSF.

Background Estimation: The average background from a 5-pixel annulus around the planet is subtracted from the extracted spectra.



Recovered albedo spectra after matched filtering and background estimation. All simulations use an integration time of 3 days per observation.

Conclusions and Next Steps

- Assuming a known planet location, the spectra can be extracted from the starshade simulations using a simple matched filter and background estimation, even for an unfavorable planet phase of 115° with significant exozodiacal dust
- Next steps: Perform retrieval on extracted spectra to constrain the 0.25 $\boldsymbol{\mu m}$ ozone feature under various observing conditions

References

1. Shaklan, S. et al. 2023 Proc. SPIE 12680
2. Arya, M, et al. 2021 JATIS
3. Webb, D. et al. 2019 Proc. SPIE 9912
4. Shaklan, S. et al. 2017 Proc. SPIE 10400
5. Hildebrandt, S. et al. 2021 JATIS
6. Currie, M. et al., 2023 AJ
7. Stark, C. 2011 AJS

This material is based on work supported by the National Science Foundation Graduate Research Fellowship under Grant No. DGE-1656518.