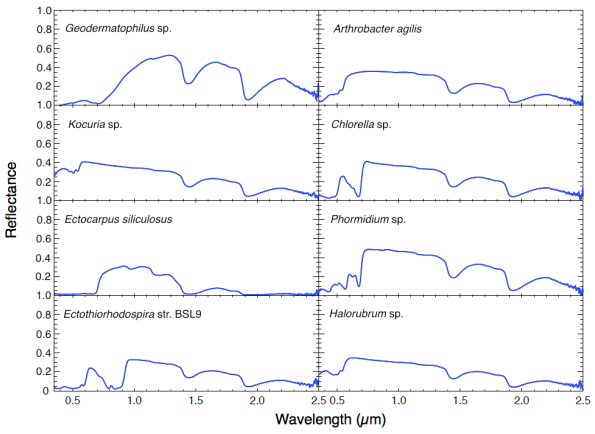
Surface biosignatures of exo-Earths: Remote detection of extraterrestrial life. Siddharth Hegde[1,2], Ivan G. Paulino-Lima[3], Ryan Kent[4], Lisa Kaltenegger[1,2], and Lynn Rothschild[5], [1]Max Planck Institute for Astronomy, [2]Institute for Pale Blue Dots, Department of Astronomy, Cornell University, [3]NASA Postdoctoral Program Fellow, NASA Ames Research Center, [4]UCSC University Affiliated Research Center, NASA Ames Research Center, and [5]NASA Ames Research Center.

Abstract: Exoplanet discovery has made remarkable progress, with the first rocky planets having been detected in the central star's liquid water habitable zone. The remote sensing techniques used to characterize such planets for potential habitability and life rely solely on our understanding of life on Earth. The vegetation red edge from terrestrial land plants is often used as a direct signature of life, but it occupies only a small niche in the environmental parameter space that binds life on present-day Earth and has been widespread for only about 460 My. To more fully exploit the diversity of the one example of life known, we measured the spectral characteristics of 137 microorganisms containing a range of pigments, including ones isolated from Earth's most extreme environments. Our database covers the visible and near-infrared (VNIR) to the short-wavelength infrared (SWIR) (0.35-2.5 µm) portions of the electromagnetic spectrum [1].

Our results show how the reflectance properties are dominated by the absorption of light by pigments in the visible portion and by strong absorptions by the cellular water of hydration in the infrared (up to 2.5 µm) portion of the spectrum. Our spectral library provides a broader and more realistic guide based on Earth life for the search for surface features of extraterrestrial life [2]. The library, when used as inputs for modeling disk-integrated spectra of exoplanets, in preparation for the next generation of space- and ground-based instruments, will increase the chances of detecting life.



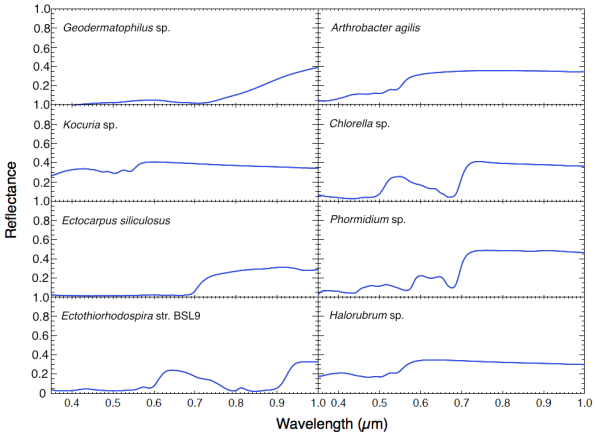


Fig. 1: Diversity in reflectance spectra for eight sample organisms for (top) the entire measured spectral range (0.35-2.5 µm) and (bottom) only the VNIR portion (0.35-1.0 µm) of the spectrum. Spectral characterizability between microorganisms is best observed in the VNIR portion of the spectrum where absorption is primarily due to pigments. At longer wavelengths, the spectral features are from weak absorptions by biomolecular components and strong absorptions from water in its free and bound states. The features in the infrared look quite similar for all our sample microorganisms with variations seen only in the relative strengths and depths of individual absorption features, which may be due to differences in cell composition and constituent concentrations. Note that the reflectance characteristics for *Kocuria* sp. (isolated from Sonoran desert in Arizona) look quite similar to *Halorubrum* sp. (isolated from evaporitic salt crystal, Baja California, Mexico) despite originating from very different environmental conditions, highlighting our aim to explore the spectra of a diverse range of pigmented organisms.

References: [1] Hegde S. et al. (2015) *Proc Natl Acad Sci USA,* in press. [2] Hegde S. and Kaltenegger L. (2013) *Astrobiology, 13,* 47-56.