THE HABITABILITY OF HIGHLY UV-IRRADIATED SURFACE ENVIRONMENTS: ALTERNATIVE AND TEMPORAL BIOSIGNATURES. J. T. O'Malley-James[1] and L. Kaltenegger[1], [1]Carl Sagan Institute, Cornell University, Ithaca, NY 14853, USA.

Introduction: The nearest known habitable planets to Earth orbit red dwarf (M) stars in the solar neighborhood, such as *Proxima Centauri*[1] and *TRAPPIST-1*[2]. More nearby habitable worlds around similar stars will be uncovered in the near future. Therefore, it is very likely that the first habitable planets we will be able characterize will be orbiting nearby M stars. However, M stars present a challenge for habitability in the form of strong, frequent flares. These flares can cause surface ultraviolet (UV) radiation fluxes on habitable zone (HZ) planets to increase by up to two orders of magnitude[3], which would be harmful for any surface life. Even more intense UV surface regimes would exist on planets without protective ozone layers, or planets with thin atmospheres. Here we propose a UV-defense strategy that defines a new surface spectral biosignature: biofluorescence.

Biofluorescence is prevalent throughout Earth's biosphere. It involves the absorption of short-wavelength light and its re-emission at longer wavelengths. In this way, fluorescence in some corals is thought to protect against UV radiation damage, by up-shifting biologically damaging UV to harmless longer wavelengths[4].

Methods: We use terrestrial coral spectra as a basis for a simulated fluorescent surface biosphere, along with data on the spectral responses of coral fluorescent proteins[5]. We model these biospheres for planets orbiting in the HZs of active M dwarfs[5]. A coupled 1D radiative-convective atmosphere code developed for rocky exoplanets (EXO-Prime)[6] provides model atmospheres for these simulations. We then explore the remote detectability of surface biofluorescence by simulating the response of a fluorescent biosphere to an M star flare. We use the vegetation red edge feature as a comparison to assess the detectability of biofluorescence in each case.

Results: We find that bright biofluorescence can alter a planet's observable surface color for the duration of a flare.[5] This change is detectable and has a similar signal strength to that proposed for the vegetation red-edge biosignature. The change in surface color during biofluorescence is distinguishable from abiotic fluorescence, making biological fluorescence a novel temporal biosignature for habitable planets that experience highly fluctuating UV environments. Hence, high UV fluxes may not always be detrimental to life, but can make certain biospheres more detectable. This suggests that HZ planets bathed in high UV surface fluxes should not be ignored in the search for signs of life beyond Earth.

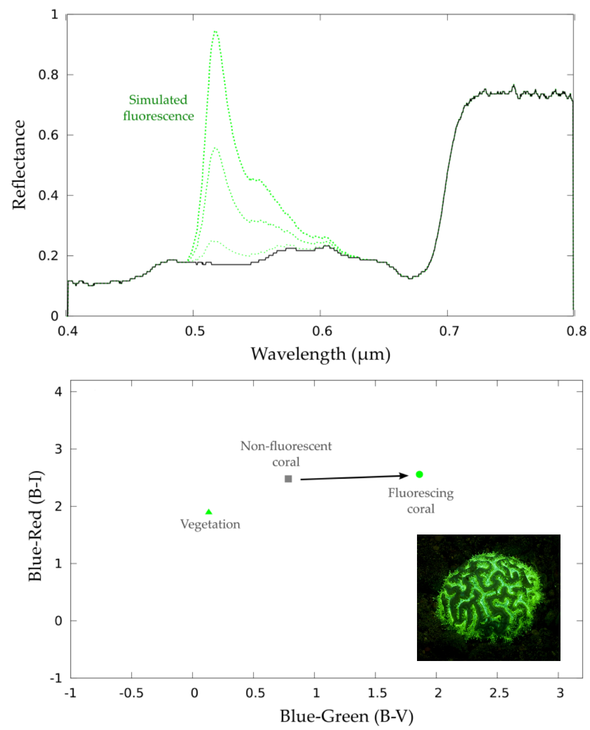

Figure 1: (Top) Simulated fluorescence is added to a coral reflectance spectrum. (Bottom) We use a standard astronomical tool, a color-color diagram, to show how the observed surface appearance of a planet would change before and during a flare event as a result of global biofluorescence (vegetation is plotted for comparison). This detectable temporary shift in color during a UV flare could indicate the presence of a biosphere. (Inset) An example of a fluorescing coral.

References: [1] Anglada-Escudé G. et al. (2016) *Nature* 536, 437 [2] Gillon M. et al. (2016) *Nature* 533, 221 [3] Segura A. et al. (2010) *Astrobiology* 10, 751 [4] Salih A. et al. (2000) *Nature* 408, 850 [5] O'Malley-James J.T. and Kaltenegger L. (2016) *Astrophs. J. Submitted* (arXiv:1608.06930) [6] Kaltenegger L. and Sasselov D. (2010) *Astrophys J* 708, 1162.