

UV SURFACE ENVIRONMENT OF EARTH-LIKE PLANETS ORBITING FGKM STARS THROUGH GEOLOGICAL EVOLUTION. S. Rugheimer^{1,2,3}, A. Segura⁴, L. Kaltenegger¹, and D. Sasselov³, ¹Institute for Pale Blue Dots, Astronomy, Cornell ²Center for Radiophysics and Space Research ³Harvard-Smithsonian Center for Astrophysics, ⁴Instituto de Ciencias Nucleares, Universidad Nacional Autónoma de México, México (srugheimer@cfa.harvard.edu, 304 Space Sciences Building, Cornell University, Ithaca, NY 14853).

Introduction: The UV environment of a host star affects the surface UV environment for Earth-like planets through geological time and therefore the conditions for the origin and evolution of life.

Depending on the intensity, UV radiation can be both useful and harmful to life as we know it. UV radiation can inhibit photosynthesis and cause damage to DNA and other macromolecule damage [1,2]. However, UV also drives several reactions thought necessary for the origin of life [3]. In this work, we model the UV surface radiation environments for both pre-biotic and post-biotic planets orbiting other stars.

Methods: We model the surface UV radiation environment for Earth-like planets orbiting FGKM stars corresponding to Earth through its geological evolution. To model the planetary atmospheres, we use a coupled 1D radiative-convective atmosphere code developed for rocky exoplanets [4,5] and a 1D photochemistry [6] to calculate the atmosphere transmission of UV fluxes to the ground.

We explore four different types of atmospheres corresponding to an early Earth atmosphere at 3.9 Gyr ago and three atmospheres covering the rise of oxygen to present day levels at 2.0 Gyr ago, 0.8 Gyr ago and modern Earth [7]. For each atmosphere type we model the planet orbiting a grid of host stars with observed UV radiation fields from IUE/HST from F0V to M8V (Teff = 7000K to 2400K) [8,9].

Results: We present the calculated UV fluxes at the surface of an Earth-like planet for a range of stellar types and four atmosphere models through geological time (See Fig. 1). In addition to calculating the UV flux on the surface of the planet, we model the biologically effective irradiance, using DNA damage as a proxy for biomolecular damage (See Fig. 2). We compare shortwave action spectra for different molecular damage and organisms.

A pre-biotic Earth (3.9 Gyr ago) orbiting an F0V star receives many times the biologically effective radiation as around the early Sun and thousands of times the modern Earth-Sun levels. A pre-biotic Earth orbiting GJ 581 (M3.5V) receives hundreds times less biologically effective radiation, a few times modern Earth-Sun levels.

The UV fluxes calculated here provide a grid of model UV environments during the evolution of an Earth-like planet orbiting a range of stars. These models can be used as inputs into photo-biological experi-

ments and for pre-biotic chemistry and early life evolution experiments [9].

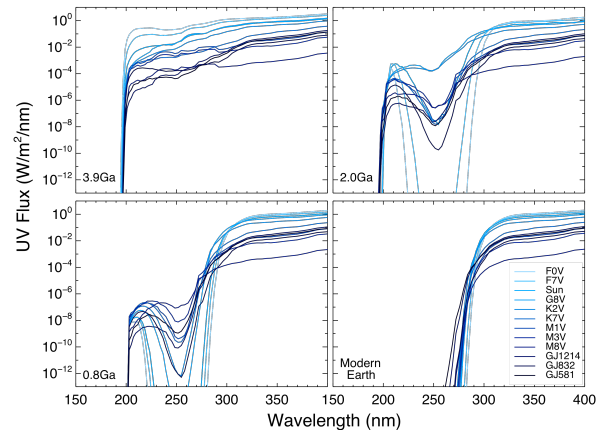


Fig. 1: Surface UV flux levels ($\text{W/m}^2/\text{nm}$) for an Earth-sized planet at four geological epochs orbiting F0V to M8V host stars.

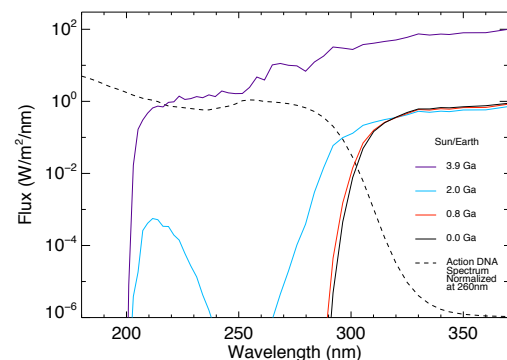


Fig. 2: UV fluxes at the surface for the Earth-Sun case through time and the DNA Damage Action Spectrum. The resulting biological effectiveness of UV damage is the convolution of the flux and action spectrum over wavelength.

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