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EFFECTS OF A LARGE M DWARF FLARE IN THE ATMOSPHERIC CHEMISTRY OF A POTENTIALLY HABITABLE PLANET

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We investigated the potential for a single large (≈10^{34} erg) stellar flare to generate a detectable O_2 or O_3 signature via UV-mediated photolysis of CO_2 in the atmosphere of an otherwise anoxic terrestrial exoplanet orbiting a main-sequence M star (M dwarf). A detectable quantity of O_2 or O_3 would constitute a false positive biosignature and potentially challenge the interpretation of future exoplanetary spectral observations.

From an observational point of view, M dwarfs and their orbiting planets have the following advantages for the characterization of potentially habitable planets: (1) M dwarfs constitute 70% of the main sequence stars in the solar neighborhood and therefore represent the greatest number of potential targets; (2) M dwarf planets and their atmospheres are more detectable in transit due favorable ratios of planet-star radii; (3) the low stellar temperature and luminosity of M dwarfs results in the habitable zone (HZ) lying much closer to the star than for Sun-like stars, which increases the geometric probability of transit for planets in the HZ (Shields et al. 2016).

A biosignature can be defined as a pattern, object, or substance that requires a biological origin and is separable from potential abiotic processes that may create it (Schwieterman et al. 2018). The search for and identification of remote atmospheric biosignatures demands a particular attention to the possible abiotic mechanisms that may produce similar observational signatures to those of life. For example, while atmospheric O_2 and O_3 are unequivocally products of life on Earth, it has been shown by many recent authors that there are potential abiotic pathways for generating these molecules in the atmospheres of terrestrial exoplanets (Meadows 2017).

We modified the *Atmos* photochemical model to receive flare input as outlined by Tilley et al. (2018). The simulated planets were located at a distance from the star such that the planet receives the same integrated (quiescent) flux as Earth receives from the Sun. The test atmospheres had surface pressures of 1 bar and CO_2 abundances of 3, 10, 30, 60, and 90% (N_2 was used as a filler gas).

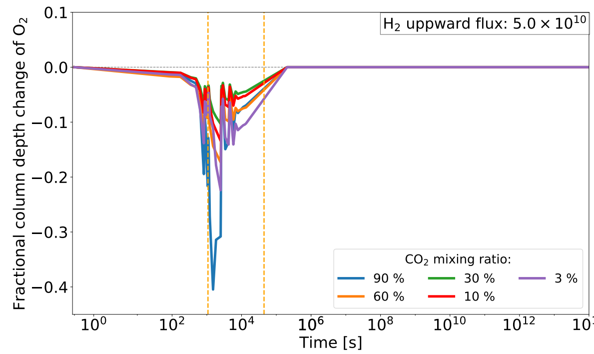

Fig. 1. O_2 column depth fractional changes during and after a big flare. Yellow lines indicate the peak and end of the flare.

For planets with H_2 volcanic fluxes of 5×10^{10} cm^{-1} s^{-1} the maximum column depth of abiotic O_2 is 1.99×10^{20} cm^{-2} for the atmosphere with 90% CO_2, much lower than present Earth's O_2 column depth of 4.65×10^{24}. During the flare, the small amount of abiotic O_2 generated in a quiescent state was destroyed and the atmosphere returned to its initial steady state O_2 column density within 1 year after the conclusion of the flare. Our preliminary results indicate that flares may not be a mechanism for generating false positives of O_2 in potentially habitable planets around M dwarfs.

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