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ATMOSPHERIC CHEMISTRY IN A HABITABLE PLANET WITH A RICH CO_2 ATMOSPHERE UNDER THE EFFECT OF A STELLAR FLARE

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Main sequence M stars are the most abundant stars in our galaxy, they have features that make them an attractive target for Astrobiology, but their strong chromospheric activity produces high energy radiation and charged particles that may be detrimental to life. We study the impact of a strong flare from the M dwarf, AD Leo, on the atmospheric chemistry of a hypothetical Earth-like planet located in the habitable zone. The simulations were performed using a 1-D photochemical model. We simulated six atmospheres with high concentrations of CO_2 and CH_4.

The response of atmospheric chemistry to the variation of the ultraviolet (UV) radiation from its star, in cases where the atmosphere contains a high concentration of oxygen has been studied by Segura et al. (2010). However is likely that potentially habitable planets around other stars have an atmosphere with high concentrations of carbon dioxide (CO_2) similar to early Earth's atmosphere. The goal of this research is to analyze the response of atmospheric chemistry of potentially habitable planets to short-term variability of UV radiation produced by a stellar flare. We focus on planets around stars of spectral type M of the main sequence (M dwarfs) because they show intense chromospheric activity that may be detrimental for planetary habitability. The results of this work will be particularly useful for planning the Terrestrial Planet Finder missions for NASA and Darwin of the ESA. We use an M dwarf star of spectral type dM3.5V, AD Leonis (Gl 388), located at 4.85 pc from the Sun. Because of its proximity, AD Leo is a relatively bright star, with a visual magnitude $V = 9.43$. As a consequence of its brightness and its high flare rate, it is one of the most observed flare stars. We use a 1-D photochemical code detailed in Segura et al. (2007) to simulate the time-dependent atmospheric effects of an energetic stellar flare on an Earth-like planet located within the habitable zone of AD Leo. The characteristics of the flare are described in Segura et al. (2010). The code includes 73 chemical species that are linked by 359 chemical reactions and spanned the region from the planetary surface up to 70 km in 1-km steps. We simulated six planetary atmospheres with constant atmospheric surface pressure of 1 atm. We set up different mixing ratios of CO_2 and CH_4 (Table 1). On the simulated atmospheres, O_2 is produced by CO_2 photolysis and O_3 is the result of O_2 photolysis, the column depths (cm^{-2}) listed in Table 1 are calculated at steady state before the flare. Our results show that the amount of oxygen formed before the flare (steady state) is 2–3 orders of magnitude larger than what is generated on similar atmospheres around the Sun (Segura et al. 2007). During the flare the concentrations of O_2 are slightly modified, the atmosphere that presents more changes is the one with 0.02 bar CO_2 where oxygen is depleted by 0.3%. Methane concentrations do not change during the flare. Ozone changes during the flare are being analyzed. Our preliminary analysis shows that the atmospheric chemistry, except for ozone, of the simulated planets does not change significantly by a stellar flare.

TABLE 1

CHEMICAL COMPOSITION OF THE SIMULATED ATMOSPHERES

CO_2	CH_4	O_2 (cm^{-2})	O_3 (cm^{-2})
2×10^{-1}	1×10^{-4}	3.2×10^{21}	7.0×10^{17}
···	1×10^{-5}	2.3×10^{21}	1.3×10^{16}
···	1×10^{-6}	6.0×10^{21}	1.4×10^{18}
2×10^{-2}	1×10^{-4}	4.5×10^{19}	2.5×10^{15}
···	1×10^{-5}	2.4×10^{21}	6.5×10^{17}
···	1×10^{-6}	3.6×10^{21}	1.0×10^{18}

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