Abstract

Possible favored Great Oxidation Event scenario on exoplanets around M-Stars with the example of TRAPPIST-1e

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The Great Oxidation Event (GOE), which marked the transition from an anoxic to an oxygenated atmosphere, occurred 2.4 billion years ago on Earth, several hundreds of millions of years after the emergence of oxygenic photosynthesis. This long delay implies that specific conditions in terms of biomass productivity and burial were necessary to trigger the GOE. It could be a limiting factor for the development of oxygenated atmospheres on inhabited exoplanets. In this study, we explore the specificities of a terrestrial planet in the habitable zone of an M dwarf for a GOE. Using a 1D coupled photochemical-climate model, we simulate the atmospheric evolution of TRAPPIST-1e, an Earth-like exoplanet, exploring the effect of oxygen sources (biotic or abiotic). Our results show that the stellar energy distribution promotes O_3 production at lower O_2 concentrations compared to Earth, and the ozone layer on TRAPPIST-1e forms more efficiently. This lowers the threshold for atmospheric oxidation, suggesting that the GOE on TRAPPIST-1e would occur quickly after the rise of oxygenic photosynthesis, up to 1Gyrs earlier than on Earth, and would reach O_2 enabling oxygenic respiration and thus the development of animals. We may question whether this is a general behavior around several M-stars. Furthermore, we discuss how the overproduction of ozone could make O_3 detection possible using the James Webb Space Telescope, providing a potential method to observe oxygenation signatures on exoplanets in the near future. Previous studies predicted that for an Earth-like atmosphere O_3 would require over 150 transits for detection, but our results show that significantly fewer transits could be needed.