Constraining Oxygen False Positives for Terrestrial Planets around F, G, and K Stars

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Abstract

On the Earth, oxygen represents a dramatic disequilibrium fueled by photosynthesis that has lasted for billions of years. Since oxygen is so pervasive and persistent here, is it safe for us to extrapolate? Oxygen as a remotely detectable biosignature has been knocked down, amended, and resurrected several times during the last 50 years. Recently, a number of authors have weighed in and come to very different conclusions – some pointing to a potential false positive, while others failing to reproduce those results. The problem of false positives has recently become more difficult, as new estimates of Proterozoic O2 levels on Earth put this value at 0.001 PAL (times the Present Atmospheric Level). Any abiotic O2 concentration above this value could potentially constitute a false positive for life. We have used our 1-D photochemical model to calculate abiotic O2 concentrations for rocky planets with CO2-rich atmospheres orbiting G, K, and M stars. For late-K and M stars, the ratio of far-UV to near-UV (FUV/NUV) increases, changing the production and loss rates of CO and O2. The fate of CO and O2 is strongly dependent on the assumed lower boundary conditions. These boundary conditions, in turn, depend on how fast O2 and CO react in solution with each other and with other dissolved species that may be present in the ocean. Faster chemical reactions in the ocean correspond to higher deposition velocities and lower concentrations of these gases within the model atmosphere. Reliable predictions of deposition velocities may require laboratory investigations of aqueous chemical reaction rates, particularly the reaction between dissolved CO and O2. Work on this problem should proceed well before spectroscopic data on Earth-like exoplanets become available.

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