Oxygen False Positives in Terrestrial Planetary Atmospheres: Taking a Closer Look at Proxima Centauri b.

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Introduction: The recent discovery of a terrestrial planet orbiting the nearest star to our solar system, Proxima Centauri b [1], will allow us to test our predictions of atmospheric composition for an alien world in the near future. On Earth, oxygen (O_2) and ozone (O_3) are byproducts of oxygenic photosynthesis coupled with organic carbon burial, and provide one of the strongest ways to remotely detect the life. No known terrestrial abiotic surface process would be able to generate an oxygen-dominated atmosphere for a planet within the habitable zone, and by extension, lifeless exoplanets are expected to be devoid of O_2. A number of authors have demonstrated the abiotic generation of molecular oxygen in a planetary atmosphere under oxidizing conditions [2], around an M star during its main sequence lifetime [3] and in its pre-main sequence lifetime [4], and for planets with low non-condensable inventories [5]. Attempts to reproduce these 'false positives' have met with mixed success [6,7]. If a terrestrial planet could build up abiotic oxygen to sufficient levels (e.g., above the biotic levels of oxygen suggested for the Proterozoic Earth [8], which is also above the detection threshold for a proposed next-generation TPF-style space telescope [9]), the detection of oxygen (and consequently ozone) would not mean the unequivocal detection of life. The presence of other distinguishing spectral signatures would be needed [10].

Results: We explore oxygen false positives with our 1-D photochemical model [7], updated from Segura et al. [8]. For M stars, the ratio of far-UV to near-UV (FUV:NUV) drives the photochemical steady state of the atmosphere, where substantial amounts of CO and O_2 accumulate. Whether these two gases remain in the atmosphere is dependent on the imposed lower boundary conditions, with low deposition velocities corresponding to higher mixing ratios in the lower atmosphere. For a realistic terrestrial planet, such low deposition velocities are incongruous, and reasonable choices for the deposition velocities draw oxygen down below the detection threshold for a next-generation TPF-style space telescope, as well as below the biotic oxygen levels seen following the first rise of oxygen on Earth.

Because Proxima Centauri is an M5.5 star with a FUV:NUV comparable to GJ 876, Prox Cen b may host an abiotic O_2-rich atmosphere. Here, we update our results with the Prox Cen spectrum, and show an expanded treatment of the dependence of abiotic O_2 on atmospheric CO_2, volcanic outgassing, and deposition velocities. The deposition velocities for CO and O_2 remain major players in determining the abundance of abiotic O_2. The largely unconstrained aqueous recombination of these species is a necessary next step in calculating the likelihood of Prox Cen b maintaining a abiotic O_2-dominated atmosphere.

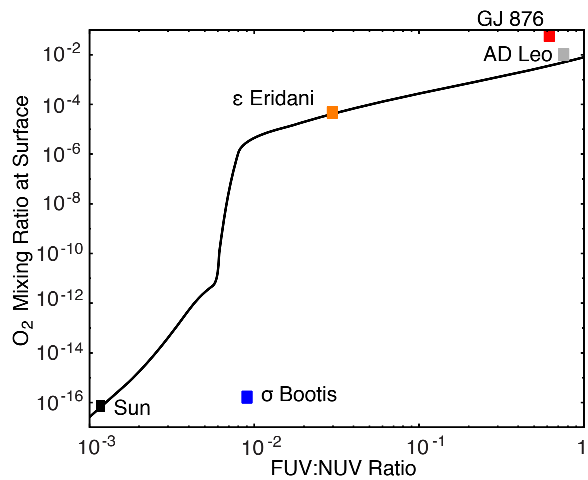

Figure 7 from Harman et al. [7], showing the dependence of abiotic O_2 in the worst-case scenario as a function of stellar FUV:NUV.

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