FALSE POSITIVES FOR LIFE: A NEW METHOD FOR ABIOTIC OZONE ACCUMULATION IN EXOPLANET ATMOSPHERES. S. D. Domagal-Goldman[1] and V. S. Meadows[1], [1]Virtual Planetary Laboratory, UW Astronomy, Box 351580, University of Washington, Seattle, WA 98195, USA, sgoldman@astro.washington.edu.

Introduction: The search for life on extrasolar planets will be done remotely, via spectroscopic identification of biosignature gases. Chief amongst these biosignatures are methane (CH_4), molecular oxygen (O_2), and the photolytic by-product of O_2, ozone (O_3) [1]. We have discovered a way for atmospheric ozone (O_3) to accumulate in an atmosphere that does not require O_2 production from oxygenic photosynthesis. Our 1-D (altitude) photochemical simulations predict that reducing atmospheres receiving low amounts of UV radiation will have decreased O_3 destruction rates, and thus higher amounts of atmospheric O_3.

Method: We used a 1-D (altitude) photochemical code to simulate the composition of potential early Earth-like planetary atmospheres [2] and a spectral mapping model to predict the spectra for planets with the predicted atmospheric composition [3]. In our simulations, we used a constant deposition velocity for O_2 and O_3 to account for oxidation reactions with surface materials. We implemented three different stellar spectra: that of the Sun, the M Dwarf AD Leo, and a model star with a temperature of 3100K and no chromosphere. The latter star represents an end-member case, and is not physically realistic.

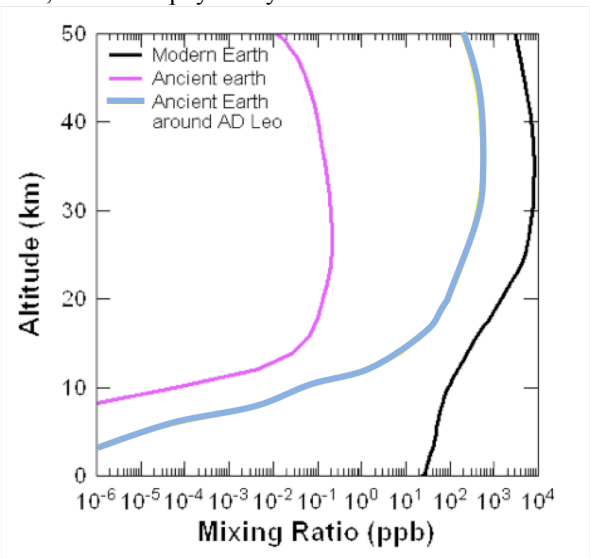

Figure 1: This figure shows three O_3 mixing ratio profiles: that of the modern day Earth (black), and model predictions the O_3 profiles of an early-Earth like planet around the Sun (pink) and around AD Leo (blue).

Results: Our results (Figure 1) suggest that some planets orbiting M dwarfs such as AD Leo may contain detectable amounts of O_3 even without biological O_2 production. This O_3 accumulation is a result of lower amounts of the UV photons and the atmospheric radical species that destroy O_3. The radical species are in turn produced by UV radiation. The low incident UV radiation from AD Leo, combined with the formation of UV-reflective organic hazes, greatly reduce UV fluxes to the lower atmosphere. This drastically slows the two major sinks for O_3: UV-driven photodissociation and reactions of O_3 with UV-dependent radicals.

We also predict that a planet orbiting AD Leo – a particularly active M dwarf with frequent, severe flares – should contain more O_3 than a planet orbiting an M dwarf with no chromosphere, no flares, and a resulting UV-deficient spectrum. This seemingly counter-intuitive result occurs because UV radiation is required for both the destruction and production of O_3. The main source of O_3 is the reaction of O_2 with O atoms, and the main source of O atoms is photolysis of O_2 by photons with wavelengths < 183 nm. The main difference between AD Leo and an M dwarf with no chromosphere (and no flares) is the production of photons at wavelengths < 183 nm from stellar flares. These photons will lead to the production of O and O_3. Thus, our results suggest that it is both the abundance and energy of photons that determines O_3 concentrations in the atmosphere. High abiotic O_3 concentrations require sufficient amounts of short-UV radiation for O_3 production but low total UV radiation for radical production and O_3 photodissociation.

Discussion: This discovery of an abiotic source of O_3 represents a potential false positive for life on exoplanets. However, this false positive should only pose a problem to missions that attempt to detect life exclusively through a search for O_3 absorption features. The presence of detectable O_3 concentrations on exoplanets without oxygenic photosynthesis is requires an organic haze in the upper atmosphere of the planet. This haze will only be present if organic compounds such as ethane are also abundant in the atmosphere. Missions that include a wavelength range wide enough to detect the spectral features of these organic compounds will avoid mis-interpreting the presence of O_3.

References:

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