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Potential Biosignatures in Super-Earth Atmospheres – Photochemical Responses

J. L. Grenfell (1), S. Gebauer (1), H. Rauer (1,2), R. Lehmann (3), P. von Paris (2), J. Cabrera (2), and M. Godolt (1)

(1) Technische Universität Berlin (TUB) (lee.grenfell@dlr.de), Germany, (2) Inst. für Planetenforschung, DLR, Berlin, (3) Alfred-Wegener Institut für Polar- und Meeresforschung, Potsdam, Germany

Abstract

We present modeled photochemical responses of potential biomarker species for Earth-like planets orbiting in the Habitable Zone of M-dwarf stars. Results imply that photochemical effects vary quite strongly with the class of the star and to a lesser extent with the assumed gravity of the planet.

1. Introduction

Spectral characterisation of Super-Earth atmospheres for planets orbiting in the Habitable Zone (HZ) of M-stars is a key focus in exoplanet science. A central challenge is to understand and predict the expected spectral signals of biomarkers (species associated with life). Our work assumes a planet with an earthlike biomass and planetary development. Following the approach of [1] we apply a coupled climate-photochemical column model, varying planetary gravity (from 1g to 3g) and the stellar spectral class (from M0 to M7).

2. Computational details

We employ a coupled radiative-convective-photochemical model updated from [2] and [3] as detailed in [1] The SQuIRRL (Schwarzschild Quadrature InfraRed Radiation Line-by-line) code [4] is used for high resolution radiative transfer modeling in a spherical atmosphere (for an arbitrary observation geometry and instrumental field-of-view and spectral response function). In addition, this work uses the Pathway Analysis Program (PAP) developed by [5] and applied by [6] to the Earth's atmosphere, in order to quantify and identify chemical pathways in Super-Earth atmospheres.

3. Results

We calculate a shift in the ozone photochemistry from mainly Chapman production (which dominates in Earth's stratosphere) to smog-dominated ozone production for scenarios modelling planets in the Habitable Zone (HZ) of (M5-M7)-class dwarf stars. This result was associated with the weaker UV-B output of such stars, hence slower planetary atmospheric photolysis of molecular oxygen, which slowed their Chapman ozone production.

4. Summary and Conclusions

Coupled, consistent climate-photochemistry calculations are potentially important when calculating spectral signals of potential biomakers of Super-Earth atmospheres. Improved knowledge of the UV-emission spectra of the parent M-dwarf stars is desirable.

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