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Detectability of Atmospheric Features of Terrestrial Planets in the Habitable Zone around M-dwarfs

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Abstract

Small extrasolar planets around M-dwarfs are prime targets in the search for habitable surface conditions and biosignatures with current and near-future telescopes like JWST and E-ELT. For the characterization of their atmosphere, model calculations are needed to predict and interpret potential planetary conditions. Especially the UV Spectral Energy Distribution (SED) is crucial for the photochemical processes in the atmosphere which would e.g. impact the signals from a potential biosphere or cause false positive biosignatures. Here we investigate the atmospheric conditions and spectral appearance of virtual Earth-like exoplanets in the Habitable Zone (HZ) of different observed M-dwarf stars. As input for our coupled one-dimensional climate-chemistry-model we use spectra of 10 observed M1V to M5.5V stars, which differ in the UV SED by several orders of magnitude. With a line-by-line radiative transfer model we calculate synthetic emission and transmission spectra using the resulting atmospheric composition and temperature profiles. We furthermore discuss which biomarker and bioindicator absorption bands are potentially detectable by space-borne JWST or the ground-based E-ELT. Due to weak stellar UV emissions at wavelengths higher than 0.2 μm, planets orbiting M-stars show an increase in the abundance of certain biomarkers and bioindicators (CH_4, H_2O, N_2O) compared to the Earth around the Sun. Therefore the transmission spectra show strong absorption features for these species. The ozone profiles show a high dependency on the UV radiation below 0.2 μm. High UVC radiation can increase the ozone mixing ratio in the stratosphere by several orders of magnitude in comparison to a low UVC environment. The profiles of many biosignatures however lack a strong dependency on the stellar spectral type, hence planets around cool and warm M-dwarfs can have a similar chemical composition if their SED show minor differences in the UV. To investigate the impact of these photochemical responses upon the spectroscopic detectability of absorption bands with JWST and E-ELT we calculate Signal-to-Noise-Ratios (SNR) including photon and instrument noise for all the modelled atmospheric scenarios. We show that for transmission spectra even higher abundances of e.g. O_3 or CH_4 produce a small SNR for warmer M-dwarfs because of the lower ratio between planetary and stellar radius.