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Impact of Clouds and Hazes on the Simulated JWST Transmission Spectra of Habitable Zone Planets in the TRAPPIST-1 System

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Abstract

The TRAPPIST-1 system will be a prime target for atmospheric characterization with JWST due to the small size of the host star, its relative proximity to the Earth and frequent transits of the seven planets . However, the detectability of atmospheric molecular species may be severely impacted by the presence of clouds and/or hazes in their atmosphere.

In this work, we performed 3-D Global Climate Model (GCM) simulations with the LMD Generic model supplemented by 1-D photochemistry simulations at the terminator with the Atmos model to simulate several possible atmospheres for TRAPPIST-1e, 1f and 1g: 1) modern Earth, 2) Archean Earth, and 3) CO_2 rich atmospheres. JWST synthetic transit spectra were computed using the GSFC Planetary Spectrum Generator (PSG).

We find that TRAPPIST-1e, 1f and 1g atmospheres, with clouds and/or hazes, could be detected with NIRSpec prism from the CO_2 absorption line at 4.3 μm in less than 15 transits at 3σ or less than 30 transits at 5σ assuming a 10 ppm 1σ noise floor. Those number of transits are reasonably achievable during JWST life time. However, our analysis suggest that other gas such as O_2, O_3, CO, CH_4 would require hundreds (or thousands) of transits to be detectable. The presence of hazes can be inferred by comparing wavelength regions where the haze opacity is high (shortwave) and low (longwave). We also find that H_2O, mostly confined in the lower atmosphere, is very challenging to detect for these planets or similar systems if the planets' atmosphere is not in a moist greenhouse state. This result demonstrates that the use of 3-D Global Climate Models, taking self-consistently into account the effect of clouds and sub-saturation, is crucial to evaluate the detectability of atmospheric molecules of interest as well as interpreting in a more global approach (and thus robust and relevant) future detections.

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