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Impact of photochemical hazes on the thermal structure of exoplanet atmospheres

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Transit observations reveal that a significant population of the detected exoplanets has hazy atmospheres (Sing et al. 2016). Although the relative contribution of clouds and photochemical aerosols is not yet fully clarified, the impact of haze particles on the thermal structure could be significant, as such particles can efficiently scatter and absorb radiation over a large part of the electromagnetic spectrum. Particularly, photochemical aerosols are anticipated to be present at pressures lower than those of cloud formation. The transit observations of HD 189733 b indicate that the haze opacity responsible for the UV-Visible slope is located at pressures between 1μbar and 1 mbar. As such low pressures, the presence of hazes could allow for strong temperature inversions due to the low atmospheric density. We investigate here the implications of such hazes on the exoplanet atmospheric thermal structure.

We simulate the atmospheric thermal structure using a 1D radiative-convective model. The model utilizes non-equilibrium chemical composition results (Lavvas et al. 2014) for the gas phase composition, and haze particle size distributions calculated from an aerosol microphysical growth model (Lavvas & Koskinen 2017, Lavvas et al. 2019). We do not yet consider the non-LTE effects for the gases, but we do take into account the impact of temperature disequilibrium between the particles and the gas envelope that can strongly affect the heating efficiency of the particles. We consider various gas phase opacities from atomic and molecular contributions calculated through correlated-k coefficients.

Our results demonstrate that in the lower atmosphere the simulated temperature profiles provide emission spectra that are in good agreement with the eclipse observations for the simulated targets (HD 209458 b and HD 189733 b). In the upper atmosphere of the hazy HD 189733 b the simulated haze distribution, which fits the transit observations, results in a strong temperature inversion. On the contrary, the upper atmosphere of the clear HD 209458 b, is significantly colder compared to previous evaluations based on equilibrium chemistry assumption. The implications of these results on the chemical composition will be discussed, as well as results from other exoplanet cases.