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Si chemistry in the atmospheres of extrasolar giant planets

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Abstract

The detection of Si^{2+} in the thermosphere of HD209458b is a surprising find given that silicon species are expected to condense in the tropospheres of these planets. Here, we use detailed photochemical models to describe the formation and evolution of silicon containing species in the atmospheres of extrasolar giant planets. We discuss the mechanisms affecting the production and evolution of different silicon containing species under different conditions. More specifically we investigate how the resulting abundances of the different Si species, are affected by the atmospheric vertical mixing and their condensation at pressure levels where this is permitted by the assumed temperature profile.

1. Introduction

The detection of ionized silicon (Si^{2+}) in the thermosphere of exoplanet HD209458b [1] has been an exciting surprise, because such a species is anticipated to condense deeper in the atmosphere in the form of forsterite or enstantite, and/or be diffusively separated at much higher pressure levels that those where it is observed. At the same time, current observations do not provide clear evidence for the detection of Si in the atmosphere of HD189733b. This divergence in the thermospheric composition of the observed exoplanets is a demonstration of the different chemical compositions possible, which in turn reflects the variability in the physical and chemical processes at play for each atmosphere.

2. Model description

In order to investigate the impact of chemistry, dynamics and condensation in the resulting abundance of the silicon species we use a photochemical model that is able to simulate the chemical processes from deep inside the planet's troposphere, where thermochemical equilibrium prevails, up to the thermosphere where the impacts of stellar radiation and atmospheric escape have an important contribution [2]. We include in the model the atmospheric eddy mixing profile derived by global circulation models [3] but also investigate the sensitivity of the model results to variations on the magnitude of the mixing assumed. In addition we include the loss of silicon species due to condensation and investigate the possible combinations of condensation rates and mixing efficiencies that allow significant amounts of silicon to remain in the gas phase.

3. Summary and Conclusions

Our model results show that the atmospheric mixing suggested by the general circulation models is strong enough to allow Si to remain in gas phase in the troposphere and the upper atmosphere of HD209458b. As a result silicon in different forms (mainly as SiO) survives in the troposphere and reaches up to 10^{-6} bar. At higher altitudes SiO dissociates to provide Si. Eventually Si is ionized providing the observed signature. These results verify our previous estimations [4]. The abundance of the Si reaching the thermosphere though, depends on the efficiency of condensation assumed in the model. We assumed in the calculations that condensation takes place at the surface of 1 micron size particles that act as condensation nuclei and facilitate the complex process for the formation of forsterite or enstatite. This size is supported by our aerosol microphysics simulations and is similar to the particle size observed in the hazes of the giant planets of our solar system. The condensation efficiency thus depends on the availability of these particles and therefore on the mechanisms that generate and sustain them in the atmospheres of exoplanets. The presence of aerosols in these atmospheres has been suggested by their possible detection in the atmosphere of HD189733b [5]. Nevertheless, the significantly lower temperature in the troposphere of this planet, enhances the condensation loss which in turn does not allow the survival of Si to lower pressure levels.

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