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Volatile-Rich Magma–Atmosphere Equilibria on Hot Rocky Exoplanets

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Highly irradiated rocky exoplanets are exposed to extreme temperatures that cause the presence of magma oceans on their surfaces. The direct exchange of material between these magma oceans and their overlying atmospheres offers a window into the planets' interiors. To understand how the properties of the magma shape atmospheric composition and observability, detailed chemical-equilibrium modelling is essential. Until now, however, most models have considered only refractory (non-volatile) components when simulating lava evaporation.

In this presentation, we examine how adding volatile species containing carbon, hydrogen, nitrogen, sulphur and phosphorus changes equilibrium vaporisation outcomes in vaporization codes and, in turn, the atmospheric makeup of hot rocky exoplanets.

In order to accomplish this, we modify our open-source code LavAtmos to be able to solve for the oxygen partial pressure that satisfies both mass-action and mass-conservation laws in a melt-plus-volatiles system. Coupling our code to the FastChem solver expanded the gas-phase network to 523 species. We used this scheme to compute “pure” atmospheres containing only one volatile element (C, H, N, S or P) and mixed atmospheres with all five, and we applied it to two literature scenarios for 55 Cnc e.

We show how introducing volatiles consistently raises the equilibrium partial pressures of rock-derived gases (SiO, SiO₂, Na and K) relative to volatile-free calculations. It also boosts the atmospheric oxygen inventory, altering key species such as CO₂ and H₂O. For 55 Cnc e, the model indicates that a low carbon-to-oxygen ratio could signal an exposed magma ocean beneath a volatile-rich sky on this ultra-short-period planet.