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Characterizing the complex chemistry of exoplanet atmospheres with virtual laboratories and space telescopes

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Extrasolar planets are very diverse, ranging from rocky planets to ultra-hot gaseous giants. Ideally, one would like to use global parameters like orbital distance, planetary mass and the host star's effective temperature to characterize the planet as well as its atmospheric regimes remotely. Ultra-hot gas giants, however, defy this aim since their atmosphere exhibit a wide range of chemical conditions: The day side is sufficiently ionized to suggest a stratified magnetic coupling and the night side is so cold that clouds form. Warm, hot and ultra-hot gaseous exoplanets are the easiest to observe and therefore allow to characterize their complex chemistry and atmospheric regimes. Space missions like HST, CHEOPS, JWST, in the future also PLATO and Ariel enable unprecedented insight, for example: CHEOPS phase curves point to the presence of of atmospheric magnetic fields in
exoplanets, JWST provides the first proof of cloud particles in exoplanet atmospheres and the discovery of new gas-phase species like SO2 in combination with CH4 and H2O.

In this talk, I will demonstrate how virtual laboratories that combine detailed physical models are the base for interpreting observational findings, for putting them into a physical context. The focus of the talk will be our recent advances in cloud formation modelling combined with extensive studies of metal-oxide cluster formation, photo-chemical processes, and complex 3D atmosphere simulations.

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