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Modelling Mineral Snowflakes in the Atmospheres of Gas-Giant Exoplanets

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Exoplanets provide excellent laboratories to explore novel atmospheric regimes; using observations coupled with microphysical models we can probe our understanding of the formation and evolution of planets beyond those in the Solar System. However, clouds remain a key challenge in observation of exoplanet atmospheres, both altering the local atmospheric composition and obscuring deeper atmospheric layers. Currently, most observed exoplanet atmospheres are tidally locked gas-giants in close orbit around their host star. These hot and ultra-hot Jupiters have day-side temperatures in excess of 2500 K, and still above 400 K on the night-side, thus they form solid clouds made of minerals, metal oxides and metals. These clouds may form snowflake like structures, either through condensation or by constructive collisions (coagulation).

We explore the effects of non-compact, non-spherical cloud particles in gas-giant exoplanet atmospheres by expanding our kinetic non-equilibrium cloud formation model, to include parameterised porous cloud particles as well as cloud particle growth and fragmentation through collisions. We apply this model to prescribed 1D temperature - pressure Drift-Phoenix atmospheric profiles, using Mie theory and effective medium theory to study cloud optical depths, representing the effects of the non-spherical cloud particles through a statistical distribution of hollow spheres.

Finally, we apply our cloud formation model to a sample of gas-giants as well as ultra-hot Jupiters, using 1D profiles extracted from the 3D SPARC/MITgcm general circulation model. In particular, we take the example cases of gas-giant WASP-43b and the ultra-hot Jupiter HAT-P-7b, where we find dramatic differences in the day-/night-side distribution of clouds between these types of exoplanets due to the intensity of stellar irradiation for HAT-P-7b. Further an asymmetry in cloud coverage at the terminators of ultra-hot Jupiters is observable in the optical depth of the clouds, which affects the observable atmospheric column and thus has implication for detection of key gas phase species. Clouds also enhance the gas phase C/O which is often used as an indicator of formation history. With next-generation instruments such as the James Webb Space Telescope

(JWST) such details will begin to be examined, but we find that a detailed understanding of cloud formation processes will be required to interpret observations.