ÖAW — AUSTRIAN ACADEMY OF SCIENCES

EXOPLANET WEATHER AND CLIMATE

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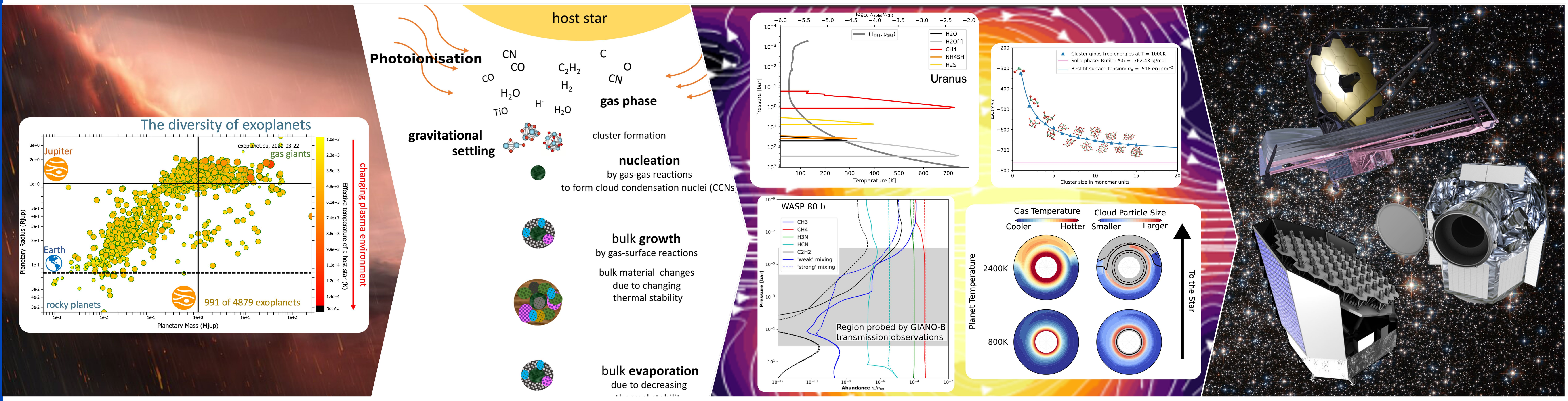


DIVERSE ATMOSPHERES | COMPREHENSIVE THEORY | DETAILED MODELLING | COMPARISON TO OBSERVATIONS

MAIN RESEARCH QUESTIONS

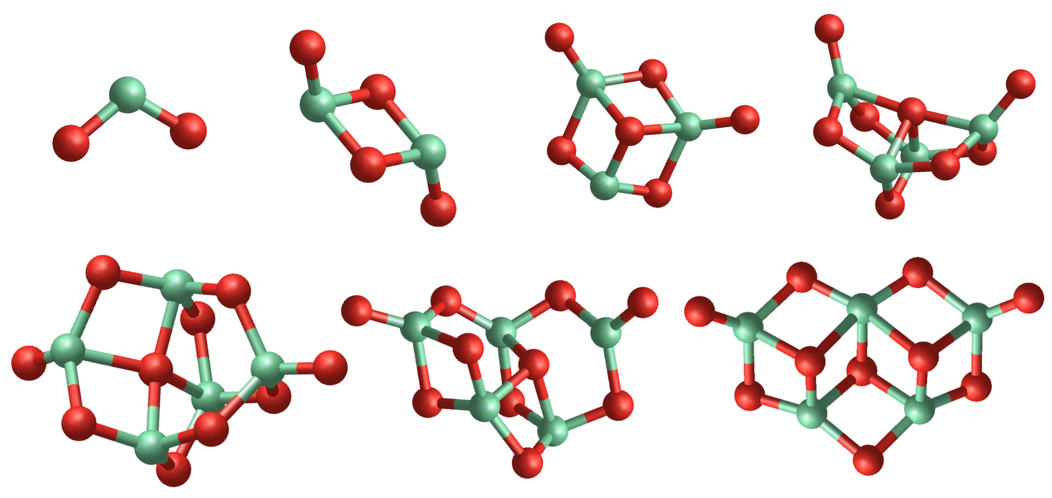
The IWF Exoplanet Weather and Climate group works on

- **Kinetic cloud formation in diverse atmospheres**
- **Gas-kinetic and photo-chemical processes in atmospheres of exoplanet that orbit different host star**
- **Ionisation, ionospheres, and lightning on extrasolar planets**
- **3D modelling of exoplanet climate regimes**

in order to understand the diversity of exoplanets orbiting different types of host stars.

FIRST STEPS OF CLOUD FORMATION

Cloud particles form when gases condense on small dust-sized particles. On Earth these small particles can originate from the surface. On gas giant exoplanets there is no surface, so the small particles are formed directly from the gas.

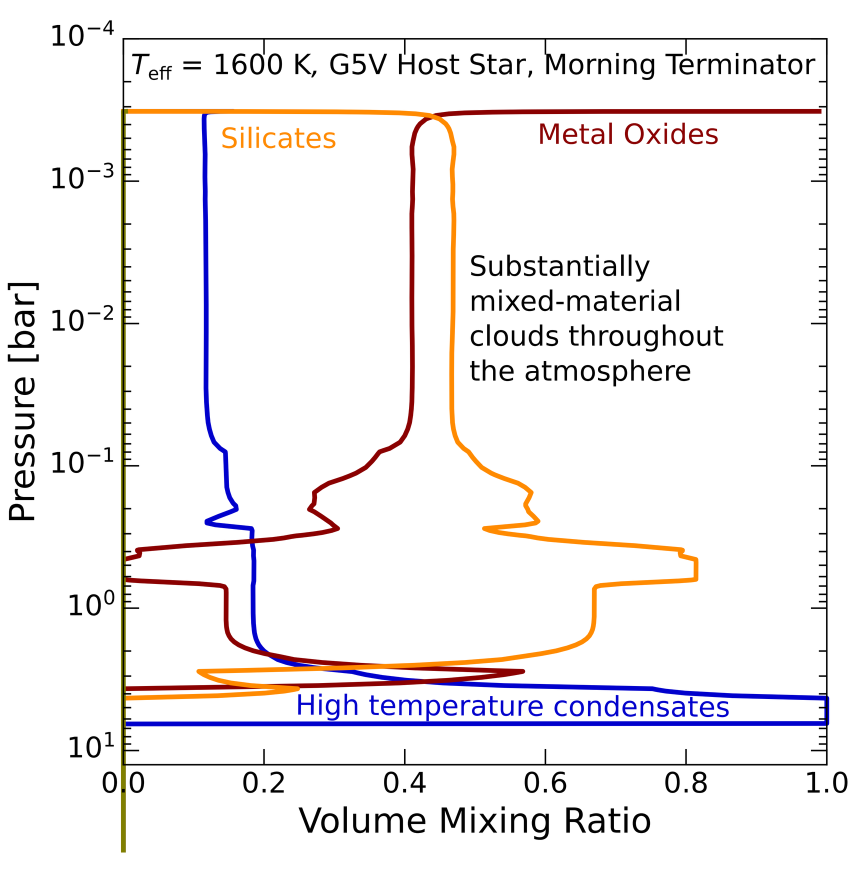


Optimal geometries of small TiO_2 molecular clusters (TiO_2 – Ti_5O_{10}) computed using quantum chemical calculations.

We model the cloud formation process from the bottom-up by considering the quantum and surface effects of the smallest nanoclusters, which are different from those of the bulk material. For this, we perform computational quantum chemistry calculations using Density Functional Theory (DFT). We optimize the geometries of the nanoclusters and calculate their thermochemical properties.

Sindel et al. 2022, A&A

DIVERSE CLOUDS ON EXOPLANETS



Mixed mineral clouds in a hot gas-giant exoplanet atmosphere.

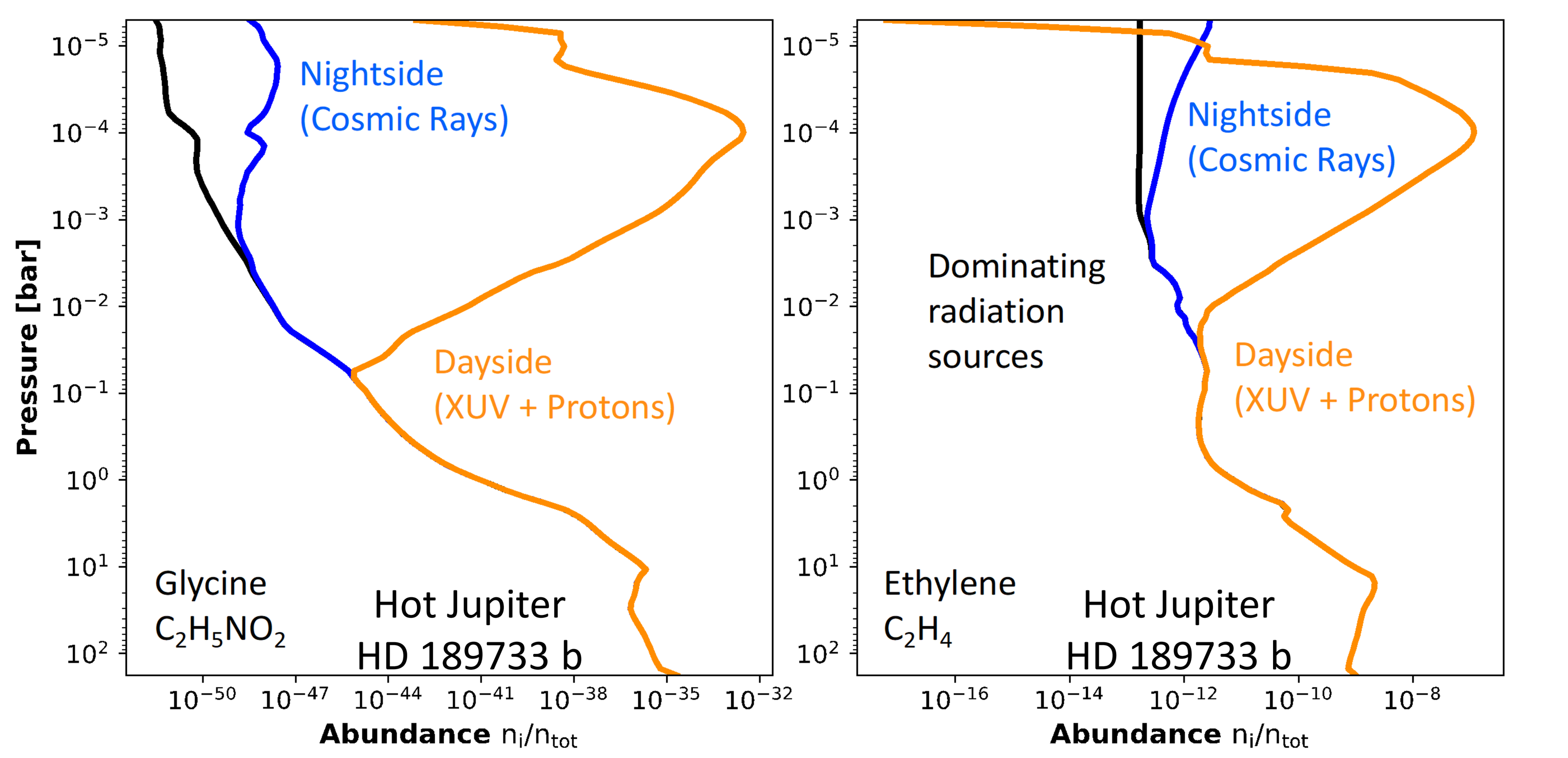
The high temperatures in gas giant exoplanet atmospheres allow for materials such as minerals, metals, and metal oxides to condense into solid particles. With our models we study the microphysics of these cloud particles, their material and spectral properties, and how they form. Understanding these processes is important for interpreting observations with CHEOPS, JWST, and later also PLATO.

Helling et al. 2023, A&A

NON-EQUILIBRIUM CHEMISTRY

With the photochemistry and diffusion code ARGO and the chemical-kinetics network STAND2020, we simulate the effect of external high-energy radiation and lightning on the atmospheric chemistry of exoplanets. We are interested in the effect on prebiotic chemistry and to identify observable signatures of such high-energy processes. Simulations of the hot Jupiter HD 189733 b showed that stellar protons and XUV-radiation as well as galactic cosmic rays can enhance the abundance of important prebiotic molecules such as the ethylene (C_2H_4) and glycine ($C_2H_5NO_2$) in the atmosphere.

Barth et al. 2021, MNRAS

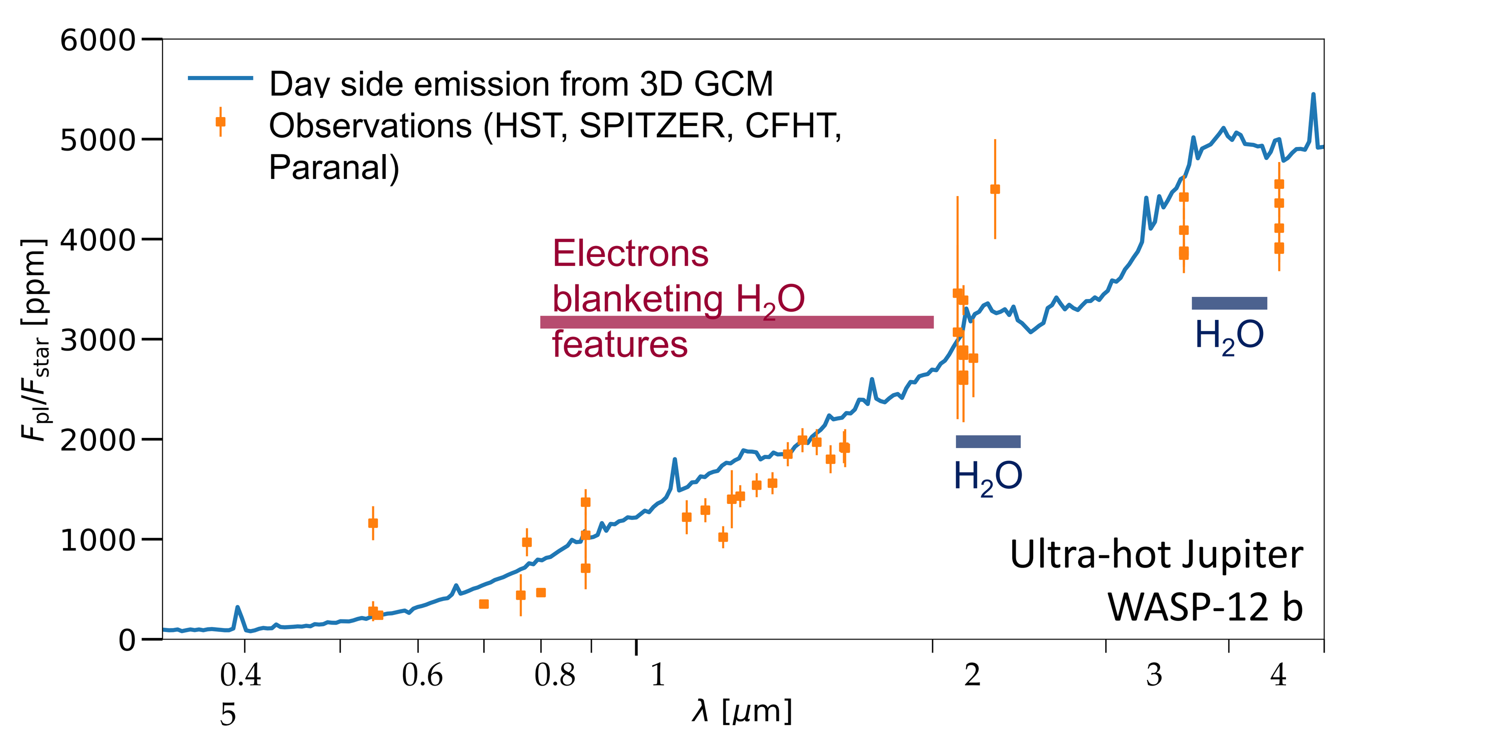


High-energy stellar radiation and cosmic rays may trigger the formation of biologically relevant complex molecules like glycine (left) and ethylene (right).

CLIMATE MODELS & OBSERVATIONS

Ultra-hot Jupiters like WASP-12 b have such hot day sides (more than 3000 K) that molecules in their atmosphere like H_2O are partly thermally ionized and species that are only expected on stars like H, H^- and electrons are foreseen to appear on the day side of these planets. Comparison with emission spectra derived from a theoretical 3D climate model that reproduces the steep horizontal temperature gradient at the day side and self-consistently calculates the abundances of ionized species show qualitative good agreement with observational data. In the future we will use our models to interpret observations from missions like CHEOPS, JWST, and PLATO.

Carone et al. 2020, MNRAS; Schneider, Carone et al. 2022, A&A



Day side emission spectrum for the ultra-hot Jupiter WASP-12 b as result of our 3D climate model compared to observations.

2023

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