ÖAW — AUSTRIAN ACADEMY OF SCIENCES

EXOPLANET WEATHER AND CLIMATE GROUP

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Webpage | YRP

The Exoplanet Weather and Climate group works to answer questions such as:

- **How diverse are exoplanets?**
- **Is our Solar System special or typical?**
- **How can we reliably infer exoplanet properties from observations?**

OUR RESEARCH

CLOUD FORMATION

New Cloud particles form when gases condense on small dust-sized particles. On Earth, these small particles can originate from the surface. However, on gas giant exoplanets there is no surface. These small dust-sized particles need to form from the gas. In the atmospheres of hot gas giant exoplanets, clouds which are formed from these particles are unlike anything seen in our Solar System. The high temperatures in the atmospheres allow materials such as minerals, metals, and metal oxides to condense into solid rock particles. Even though clouds block our view into the exoplanet's atmosphere, they hold the key to their understanding through observations with CHEOPS, JWST, and later also PLATO.

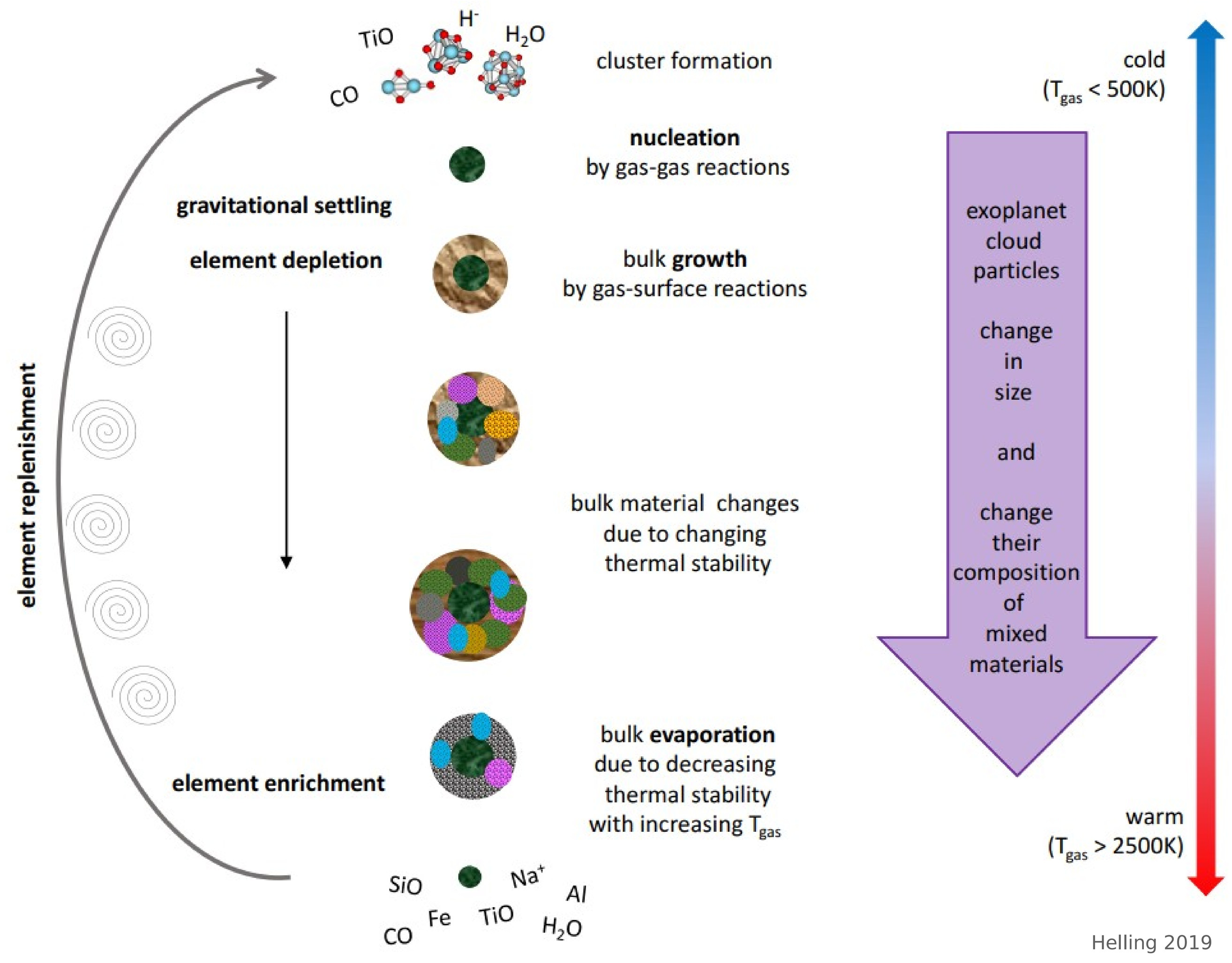


Fig.1: Cloud formation processes in exoplanet atmospheres. Certain gas phase species nucleate into dust-sized particles and condensable materials grow onto them. The cloud particles fall into dee-per, hotter layers where they evaporate. The freed species are brought back to higher layers through dynamical mixing.

CHEMISTRY, IONIZATION AND LIGHTNING

Planetary atmospheres are the windows into exoplanets. Their chemical composition may be a fingerprint for the planet's evolutionary state, for the presence of clouds, and eventually, for the existence of breathable oxygen. But we need to be careful not to confuse disequilibrium chemistry with signs of life. Some of the observed exoplanets experience intense irradiation that leads to non-equilibrium photochemistry. Another process that may leave fingerprints is lightning which can form HCN and influences the NO_2 content.

MODELLING: VIRTUAL LABORATORIES

Computer models are crucial to understand current and future observations of exoplanet atmospheres.

- Exoplanets are diverse and very different to what we know from our Solar System.
- Our models act as virtual laboratories, in which we can simulate the physical and chemical processes that are not accessible by observations.

WEATHER, CLIMATE, AND CLOUDS

Clouds form around the globe of exoplanet atmospheres depending on a variety of global conditions, such as the temperature of the host star, how close the planet orbits to the star, and how fast the planet rotates. Our group maps the global cloud distribution of extrasolar planets based on 3D global circulation models. Our specific interest is to discern the local cloud properties applying our first-principle micro-physical modelling approach.

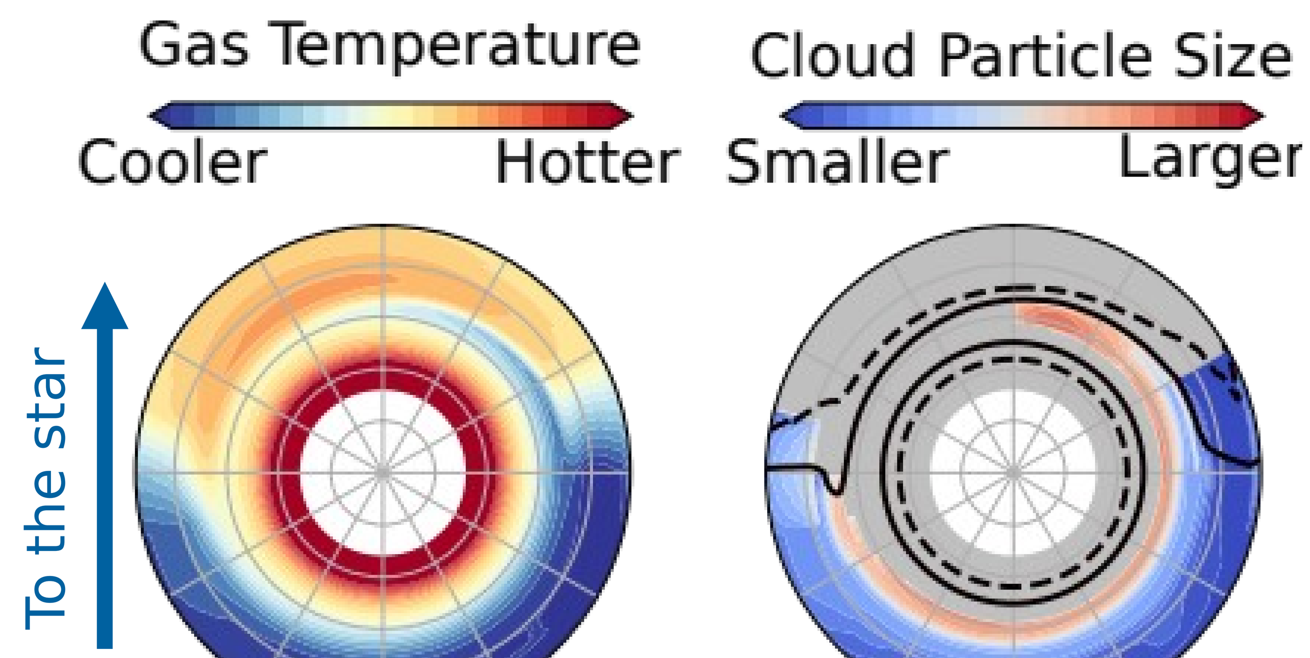


Fig.2: Cross-sections through the equator of a hot gas-giant planet showing the gas temperature and size of cloud particles forming in our models. These models allow us to explore the climates and cloud formation for exoplanets, and link these to observations.

OUR EDUCATION

COURSES

Prof. Helling is teaching the course "Exoplanets and our place in the universe – an interdisciplinary approach" (PHT.525UF Special Topics of Technical Physics). This course can be taken by students from the TU Graz and the University Graz and hopes to attract students from outside natural sciences as well.

BACHELOR AND MASTER PROJECTS

3D Exoplanet Climate regimes throughout the galaxy

Background:

Exploring climate regimes requires substantial modelling efforts including the 3D atmosphere structure, cloud formation and atmospheric chemistry for planets orbiting different host stars throughout the galaxy where the element abundances may change.

Project:

Construct grids of 3D atmosphere models that span a sufficient parameter space in order to enable systematic data analysis to apply machine learning. This includes cloud modelling for exoplanets that orbit M, K, G, F, and A-type stars for:

- solar element abundance (or a subset of these).
- reduced mixing efficiencies (or a subset of these).
- reduced growth efficiency (or a subset of these).

This is a large-scale modelling effort which can involve several students, each studying the effect of their parameter (metallicity, mixing, growth efficiency). If time allows, observational signature like transmission spectra for JWST, Albedos for CHEOPS or photometric fluxes for PLATO can be derived.

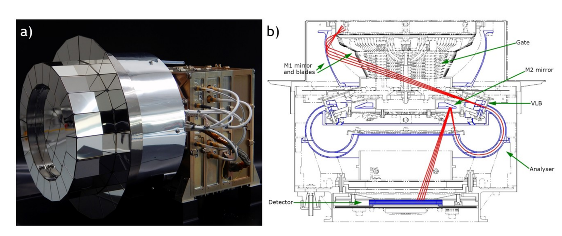
Ion trajectories simulation for the calibration of the PICAM instrument

Background:

The Planetary Ion CAMera (PICAM) is an ion analyzer onboard the ESA/BepiCOlombo mission to Mercury. The instrument uses electric fields to select incoming ions from the environments, and measures the Time-of-Flight of the particles in order to distinguish the various species (H+, He+, etc.). A precise understanding of the instrument performance is required to interpret the flight measurements.

Project:

The project aims at expanding the existing SIMION model which allows to calculate the trajectory of the ions inside the instrument. The goal is to derive the exact path length for all azimuth and elevation segments, as well as deriving the theoretical effectiveness of the gate voltage at stopping the incoming ions. The results will be compared to laboratory measurements performed on the spare model of PICAM installed in the IWF vacuum chamber.



Greenhouse Gases in Exoplanets

Background:

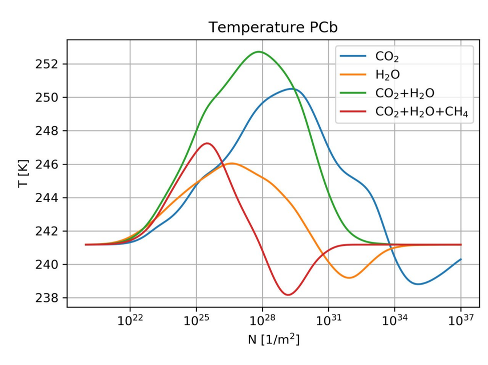
On Earth, the greenhouse effect is well known and the leading cause of global warming. Even though the greenhouse effect is bad for us, it can be favorable for exoplanets. The increased temperature caused by greenhouse effects can help to keep an otherwise cold planet warm enough for liquid water to exist.

Project:

Investigate the pressure dependence of various greenhouse gases in exoplanet atmospheres.

Requirements:

- Suitable for Bachelor in Physics and Astronomy.
- Basic knowledge of Python.



FURTHER PROJECTS

We offer various additional Bachelor and Master projects. Students are also welcome to join us at the Space Research Institute of the Austrian Academy of Science.

Projects:

- *Cloudy spectra of Exoplanet Atmospheres:* Studying the effect of size distributions on transmission spectra.
- *Exoplanet cloud formation modeling:* Forming cloud condensation nuclei from TiO_2-isomers.
- *Exoplanets in the galaxy:* The effect of the changing UV and CR galactic background on atmospheric C/N/O/H chemistry.
- *Impact of tidal deformation in 3D climates of ultra-hot Juptiers:* Explore and incorporate tides into the 3D climate code MITgcm/expeRT developed at IWF.
- *Magma ocean evolution on rocky exoplanets:* Improve VPLANET/MagmOcV2.0 to incorporate new volatile outgassing laws for H2O and CO2.

It is also possible to conduct projects together with the Planet-forming Disks and Astrochemistry group.

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Please contact us directly for further information.

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