CONNECTING JWST OBSERVATIONS TO CLOUD MICROPHYSICS

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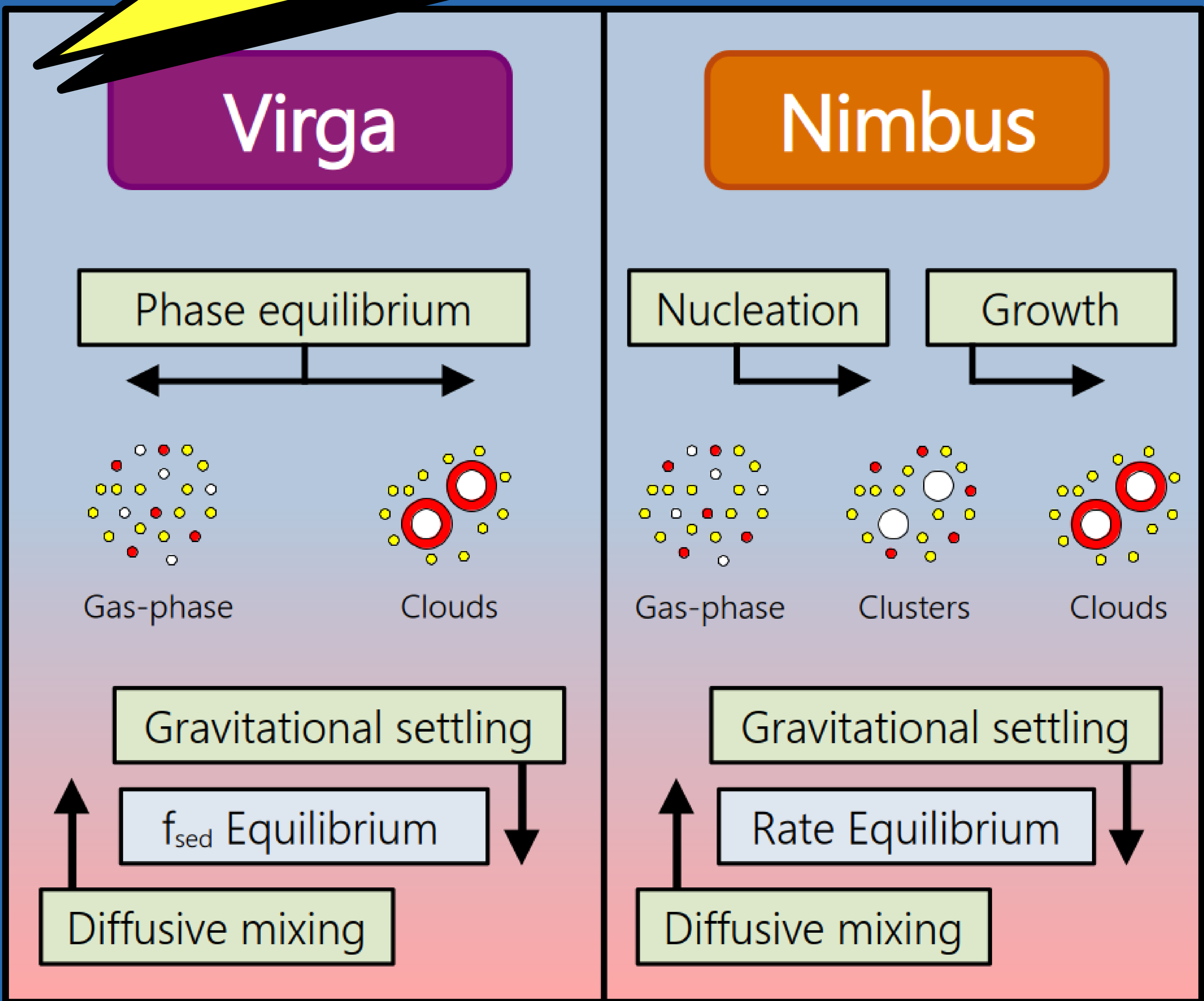
I NEED A CLOUD MODEL FOR MY OBSERVATIONS !!!



The Nimbus cloud model

Nimbus achieves computational efficiency by carefully selecting which micro-physical processes to consider. Currently, the model includes:

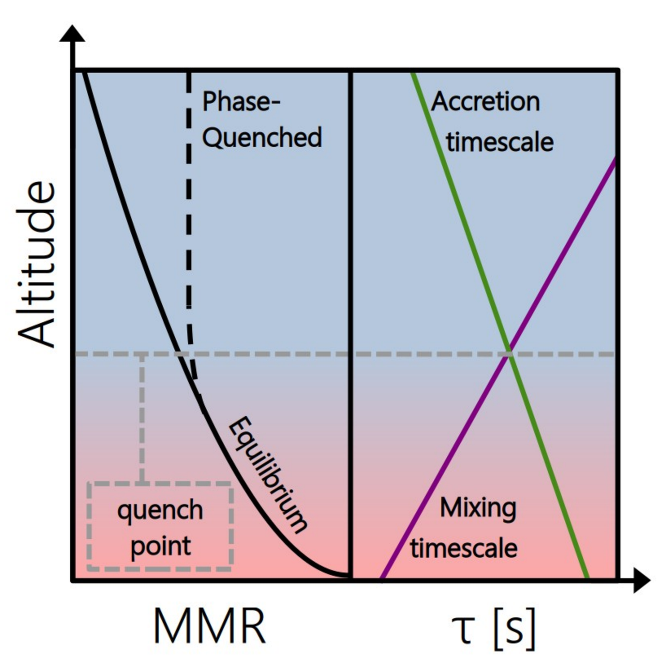
- Modified classical nucleation theory
- Condensation rates from vapor pressures
- Gas-phase and cloud particle diffusion via K_{zz}
- Gravitational settling of cloud particles

Simulations take 4 – 50 seconds and allow to determine where condensation, nucleation, and phase-quenching happens within an atmosphere. Nimbus is actively developed with these physical processes soon available:

- Physics and opacity of mixed cloud particles
- Material influx from (micro-)meteorites
- Time dependent temperature changes

WHY IS MICROPHYSICS IMPORTANT?

Microphysical processes determine the number density, radius, particle size distribution, and vertical extent of clouds. While equilibrium models work at high pressures, they cannot model the disequilibrium conditions at high-altitudes. Nimbus results show that equilibrium conditions break down around 0.01 bar, which is observable in transmission.



Cloud particle material start to quench at high altitudes, where accretion is inefficient.

TRY NIMBUS TODAY!

Download Nimbus from GitHub and follow the quick start tutorial from the documentation.

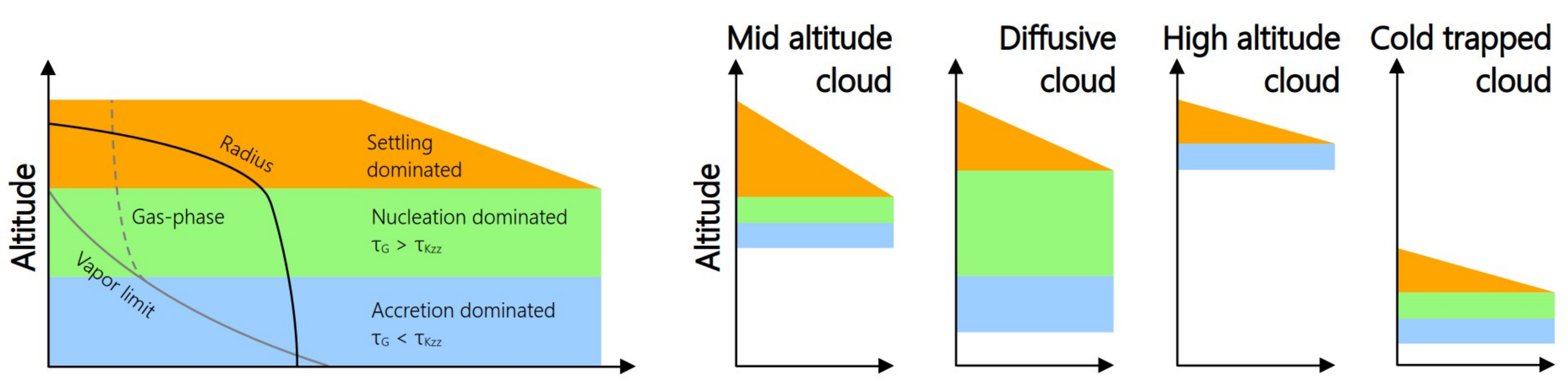
Documentation

GitHub

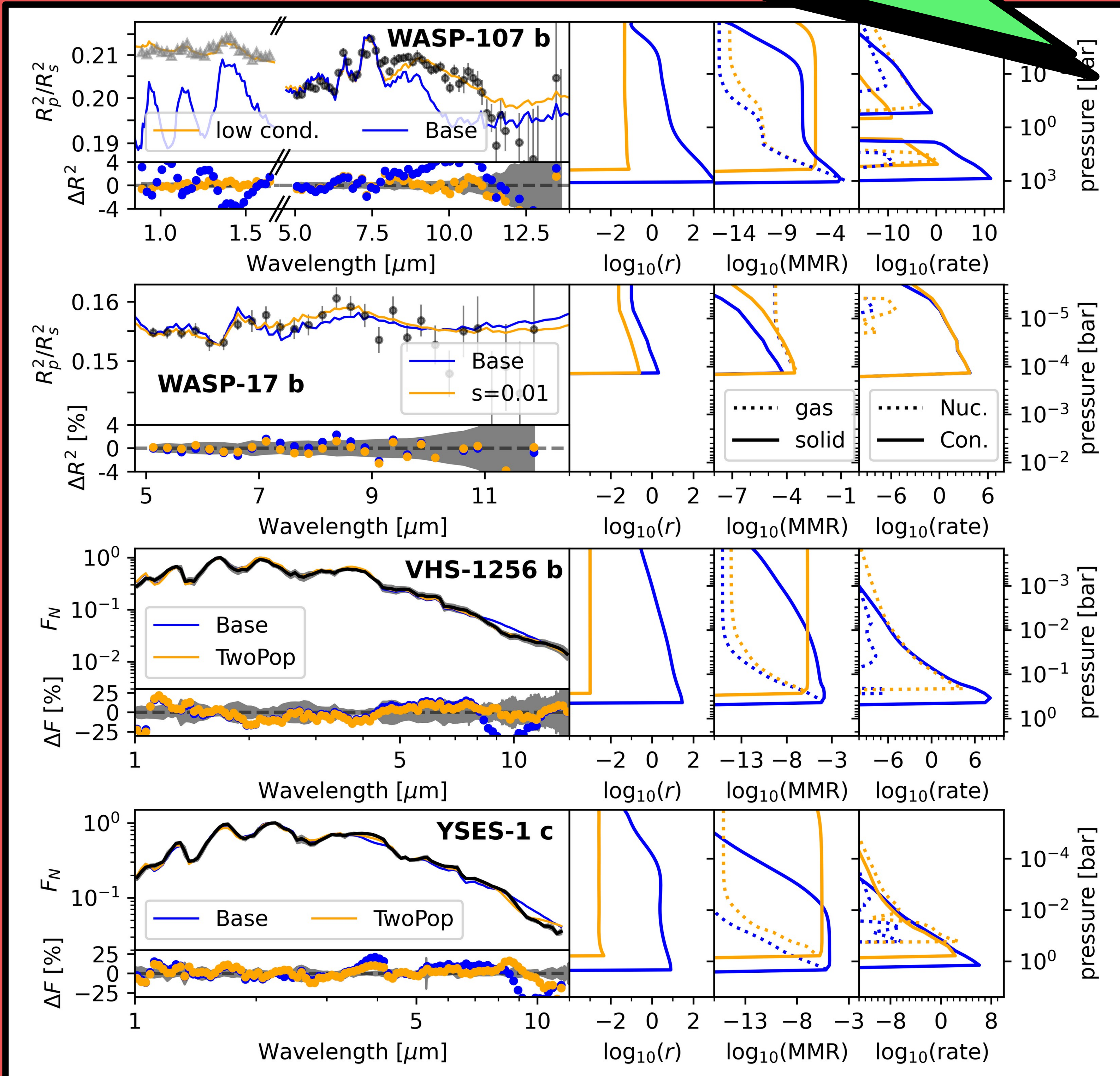
The diversity of cloud structures unveiled with Nimbus

The computational speed of Nimbus allows to explore how variations in the atmospheric mixing, condensation rate, nucleation rate, and composition can lead to different cloud structures:

- Mid altitude clouds are formed when condensation is efficient enough to form fast settling cloud particles. This limits the vertical extend and leads to a compact, optically thick cloud.
- Diffusive clouds from when condensation is inefficient and diffusion is efficient. Small particles are lifted to high altitudes, leading to extended clouds which can be observed in transmission.
- High altitude clouds are found in hot planets, where clouds only form in low pressure layers. These cloud structures are sensitive to the relative efficiency of nucleation and condensation.
- Cold trapped clouds are compact because of efficient condensation and form at high pressures. They are not observable in transmission or thermal emission spectra.



CLOUD MICROPHYSICS CAN BE OBSERVED ???



Connecting JWST observations to cloud microphysics

Transmission spectra probe high altitudes where nucleation and diffusive mixing of small particles dominate, allowing to constrain the gas-to-solid phase-transition, cloud vertical extent, and cloud particle material. Thermal emission spectra probe lower altitudes, allowing to constrain the structure of the base cloud, and the efficiency of condensation (see sticking coefficient!). The silicate absorption feature at 10 μm is produced by small particles above the main cloud layer.

STICKING COEFFICIENTS ARE OBSERVABLE!

The sticking coefficient describes the probability that a gas-phase molecule sticks to a cloud particle when the two collide. It limits the rate at which cloud particles can grow. Fast growth leads to flat clouds, quick grow leads to extended clouds. Direct imaging is sensitive to the extent of clouds in the photosphere, allowing to link the panchromatic shape of the emission spectrum to the sticking coefficient.

VHS 1256 b s = 0.24

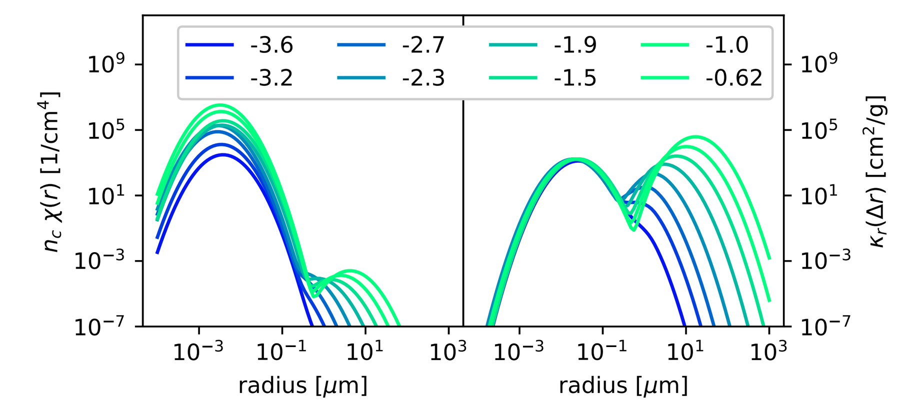
YSES-1 c s = 0.09

READ THE PAPER

TwoPop approach

GET A FIT WITH TWOPOP!

Clouds have two distinct effects on thermal emission spectra. First, they can dominate the photosphere, leading to a black-body-like emission profile. Second, cloud particles have characteristic absorption features around 10 micron. Using only a log-normal particle size distribution, it is not possible to account for both. We introduce the Two Population (TwoPop) approach, where we combine two cloud models to approximate a multi-modal size distribution. Even though particles producing the 10 micron feature outnumber the base cloud (left Panel), both have comparable opacities (right Panel).



Size distribution and opacities using our multi-modal cloud modeling approach, providing the best fit for observations.

Observed cloud structures of exoplanet atmospheres