Condensate Clouds of Cool Objects

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Clouds

on the way to meteor crater

Uniqueness of Low T Atmosphere

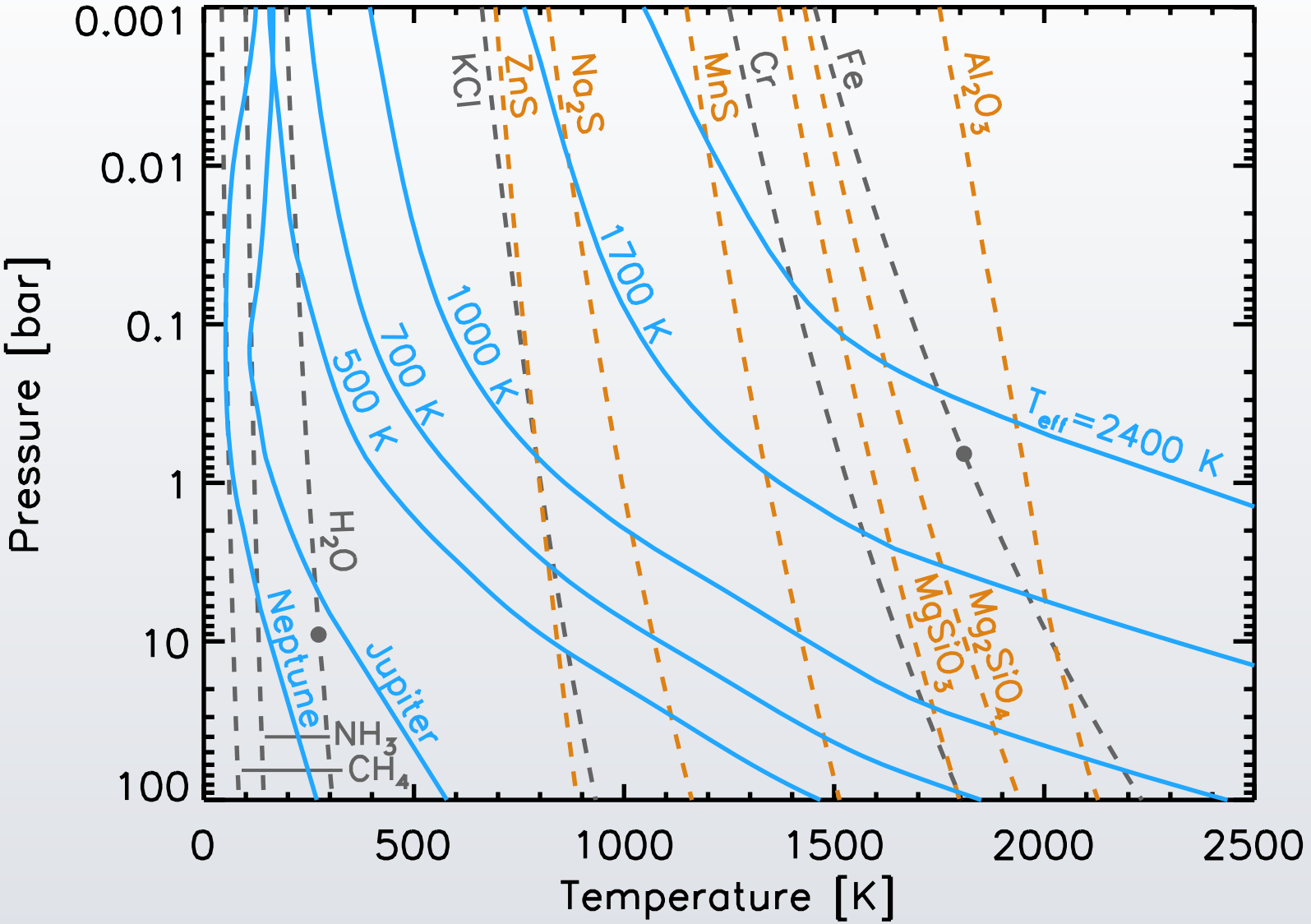
- Complex chemistry and molecules
- Alkali opacity
- **Condensation and cloud formation**
  Condensate species:
  $MgSi_3$, Mg_2Si_4, ...
  to H_2O, NH_3,...

Cloud Keynotes

What does cloud mean?

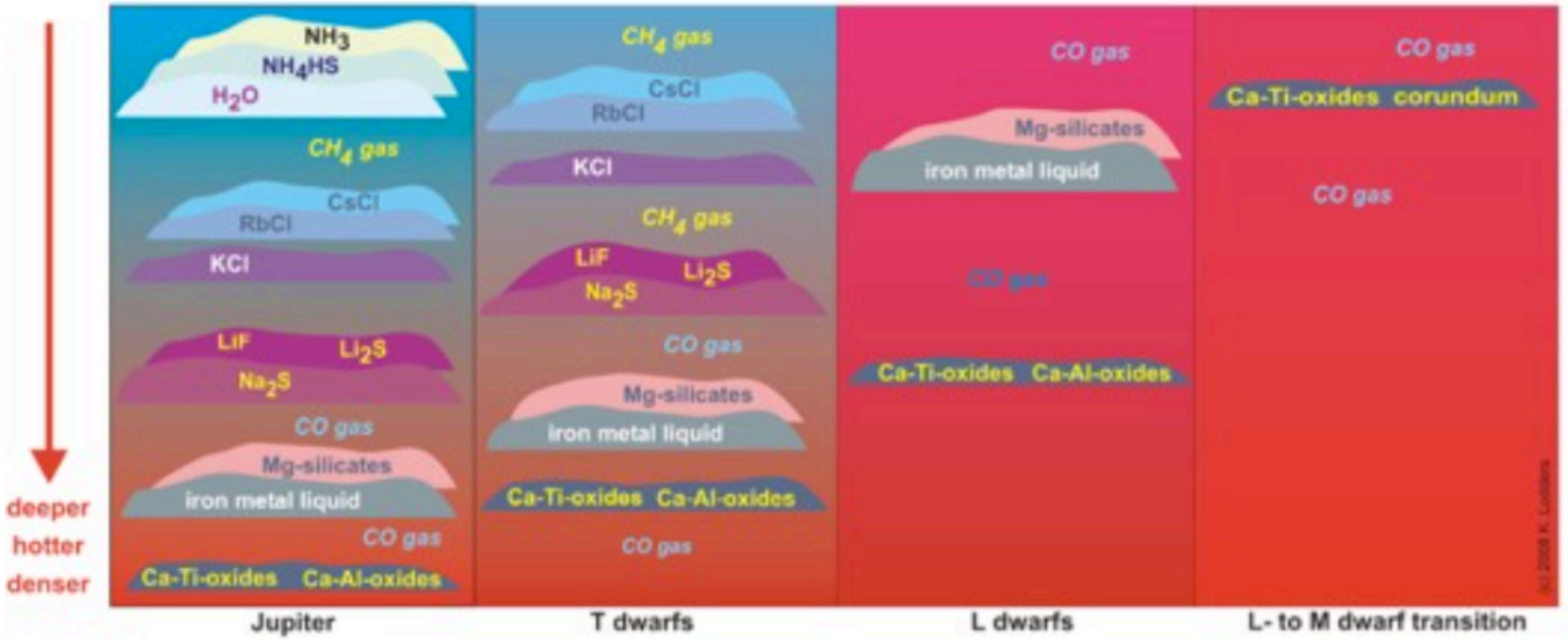
- solid/liquid particles formed by condensation

Cloud Keynotes



Marley & Robinson 2014

Cloud Keynotes



Cloud Keynotes

Physical processes

- dust particle formation
- the mixing of dust and gas
- dust growth and evaporation
- the feedback of condensation to chemical equilibrium.

Cloud Keynotes

Lack of constraints

- degeneracy of spectroscopy

Model Approaches

Tsuji Model

- Precipitation described by critical temperature T_{cr}
- Cloud thickness varies with T_{cr}

Model Approaches

Allard settl model

- mixing, condensate, coagulation, and sedimentation time scales are bonded by particle size and condensate fraction
- particle size and condensate fraction are calculated to balance those time scales

Model Approaches

Ackerman & Marley

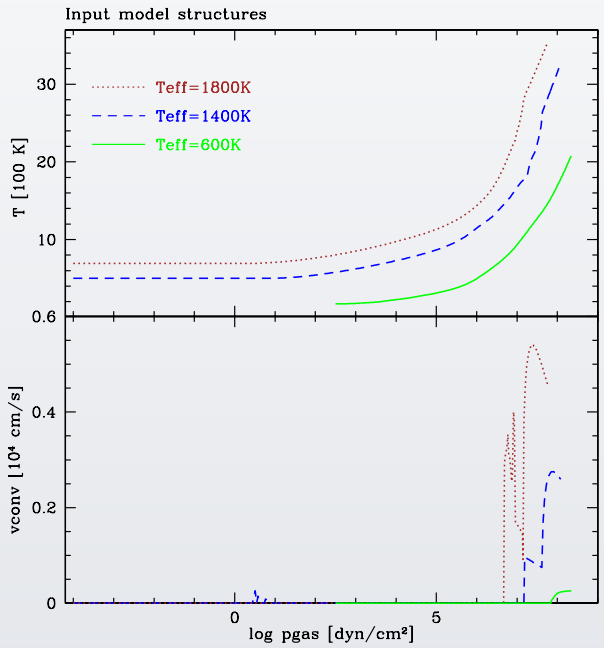
- using a scaling factor to describe the relationship of sedimentation velocity and turbulent mixing
- prescribing a particle size distribution

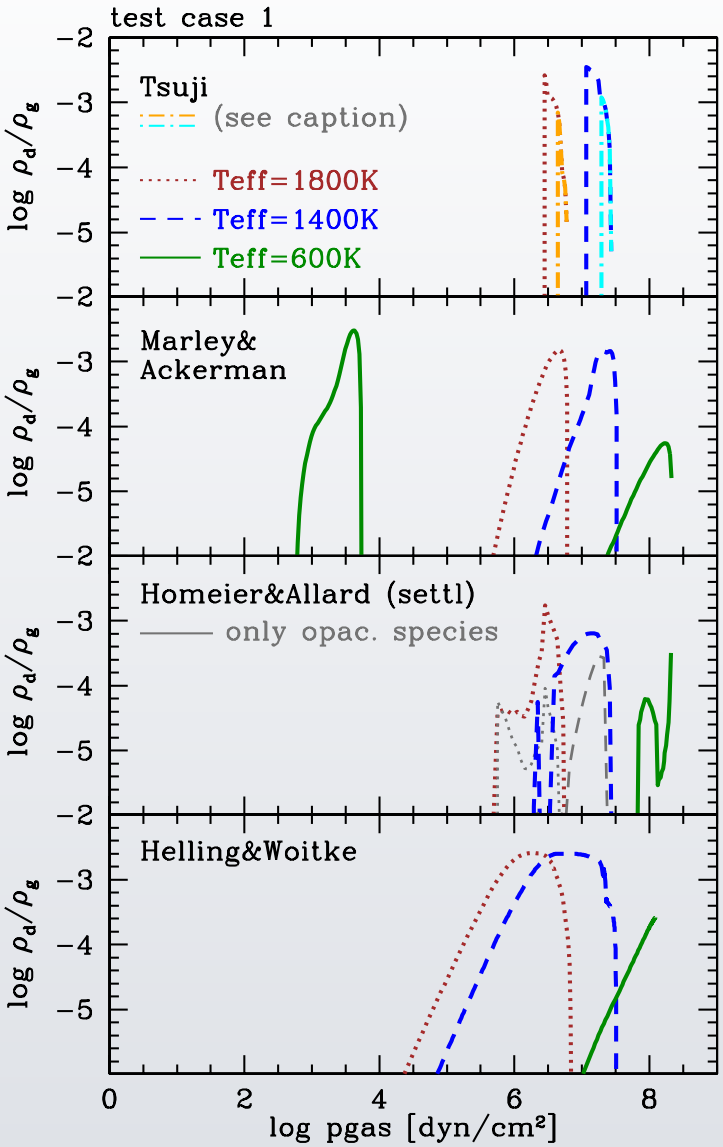
Model Approaches

Helling & Woitke

- Condensation starts with formation of seed particles
- seeds growing by gas-solid surface reaction

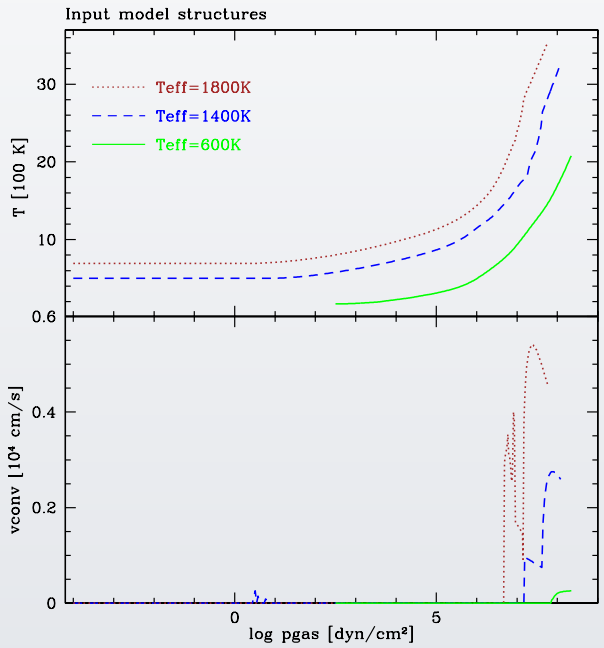
Comparison

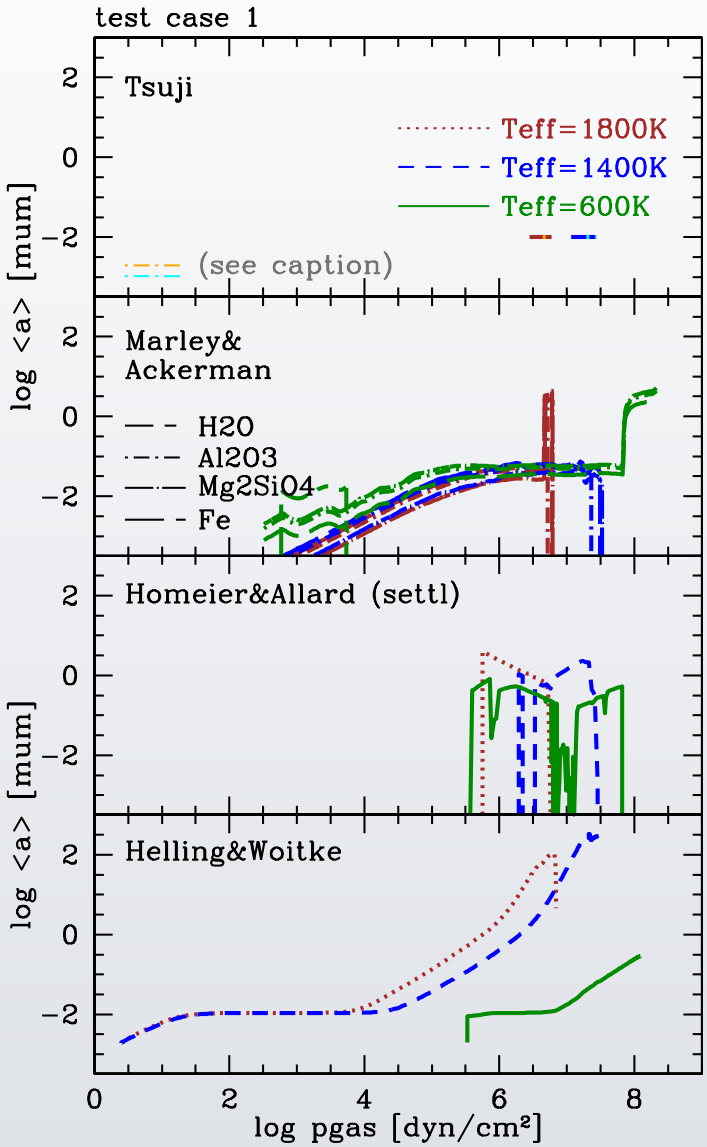




Helling et. al. (2008)

Comparison





Helling et. al. (2008)

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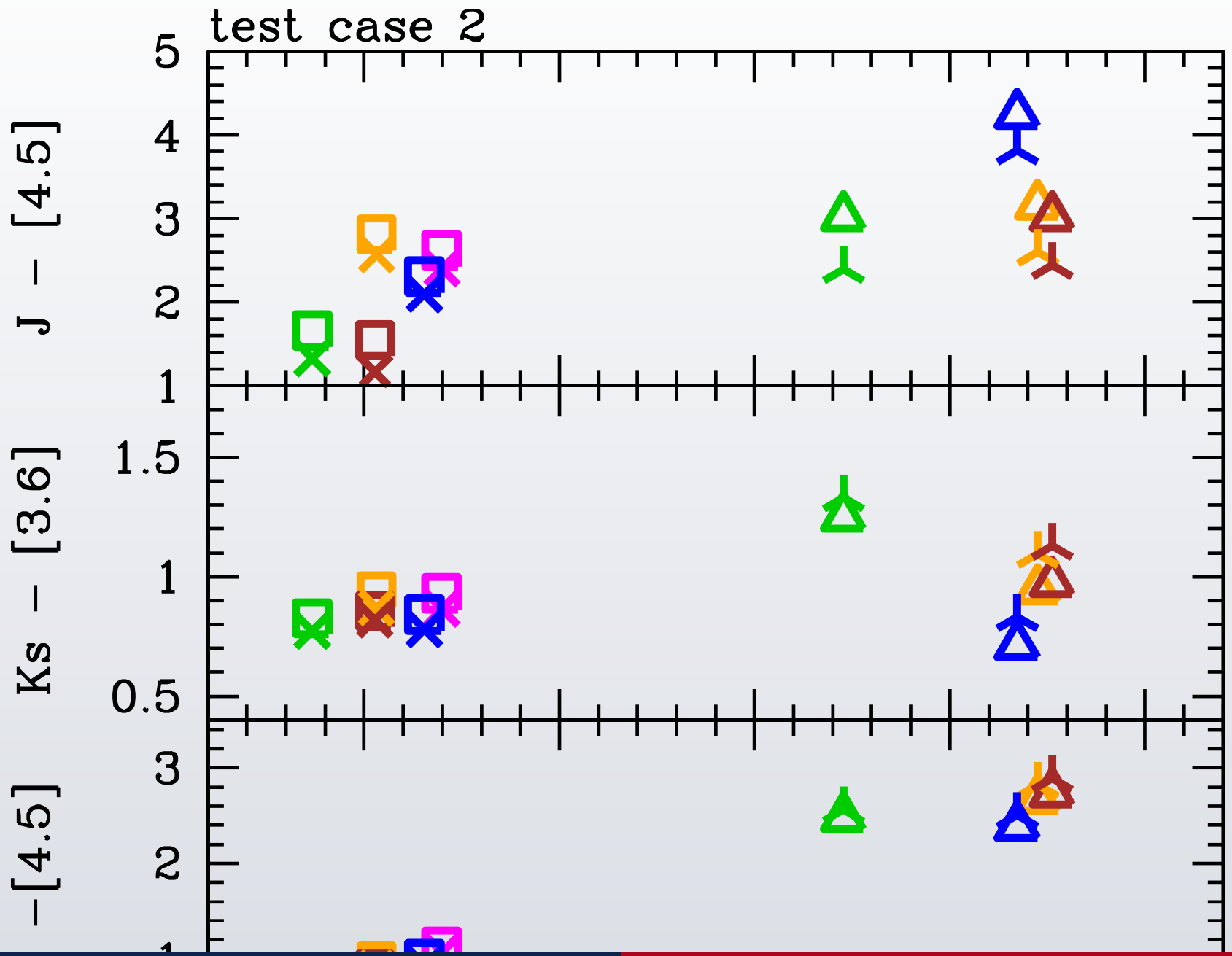
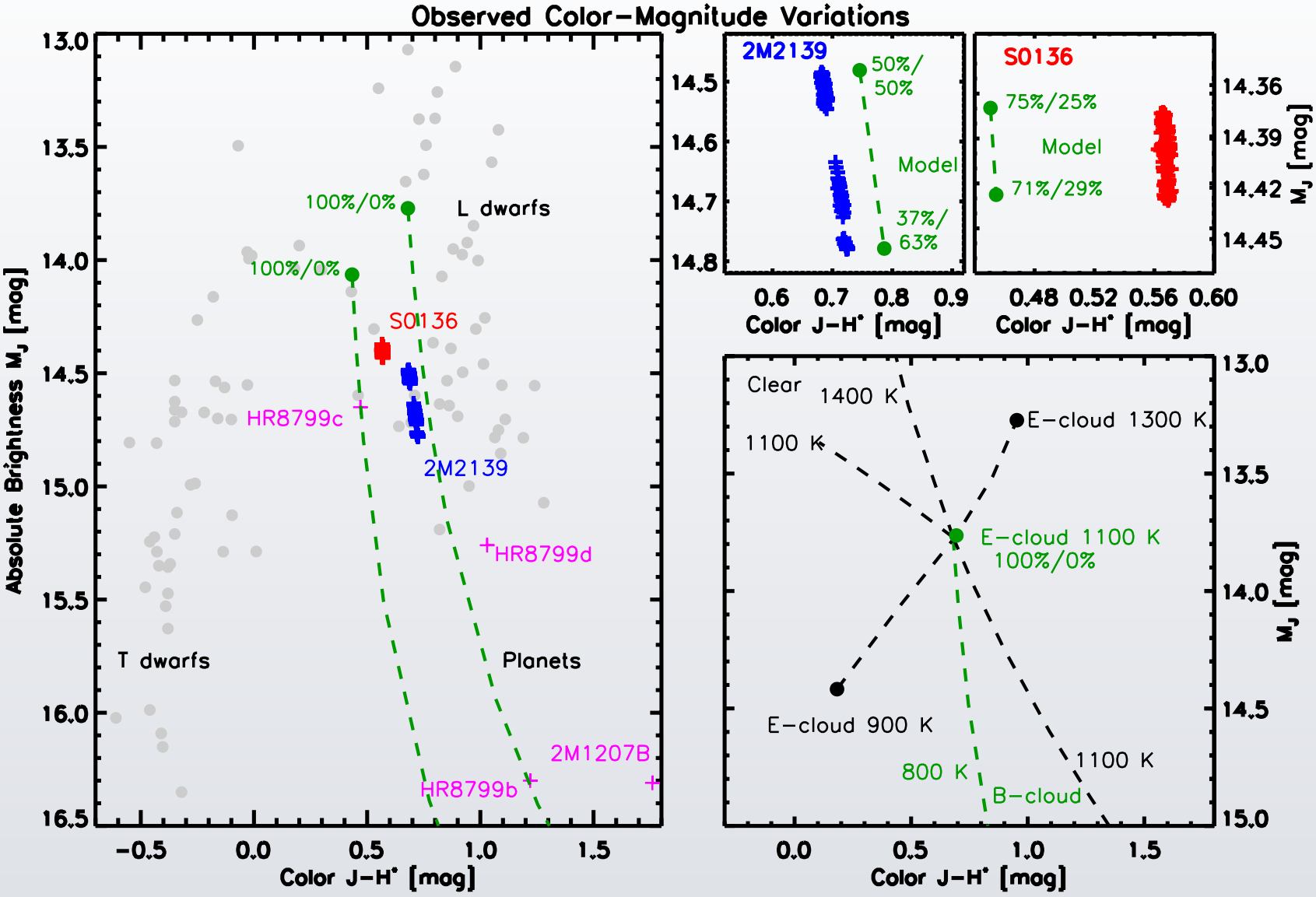
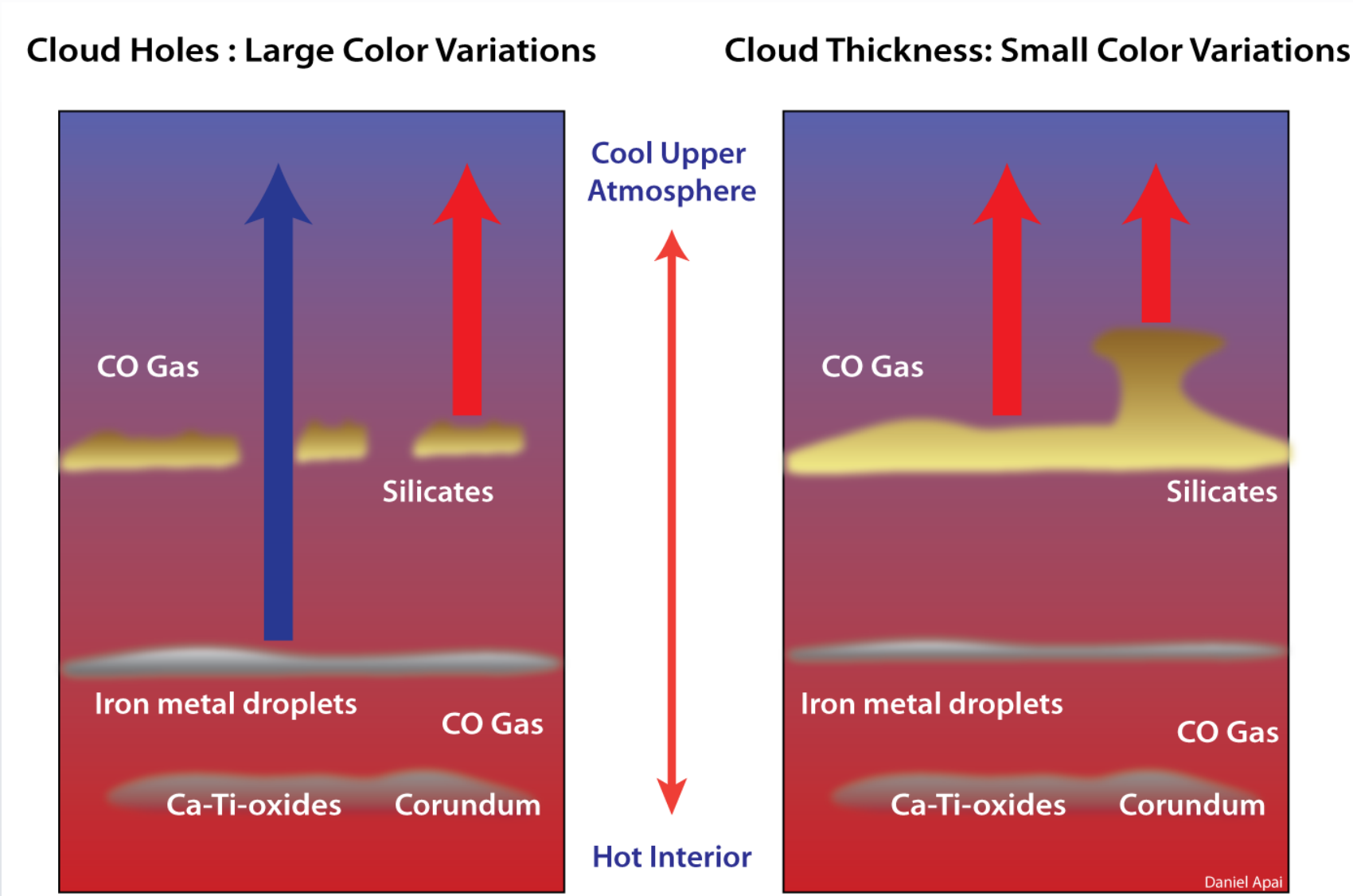


Time resolved observation



Apai et. al. (2013)


Cloud Holes : Large Color Variations
Cloud Thickness: Small Color Variations
Cool Upper Atmosphere
Hot Interior
CO Gas
Silicates
Iron metal droplets
CO Gas
Ca-Ti-oxides
Corundum
CO Gas
Silicates
Iron metal droplets
CO Gas
Ca-Ti-oxides
Corundum
Daniel Apai