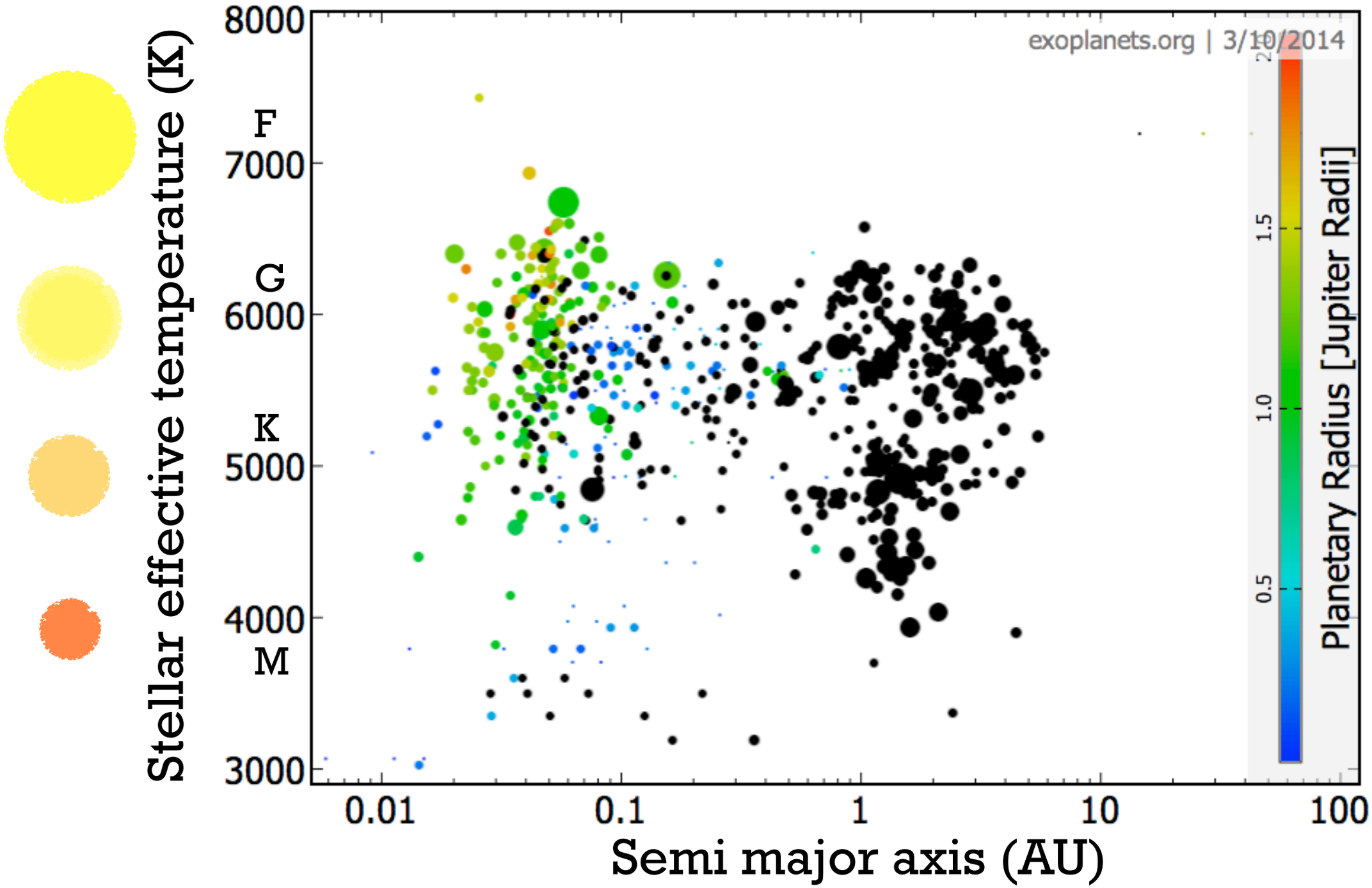
Exploring hot mini-Neptunes & EGPs atmospheres

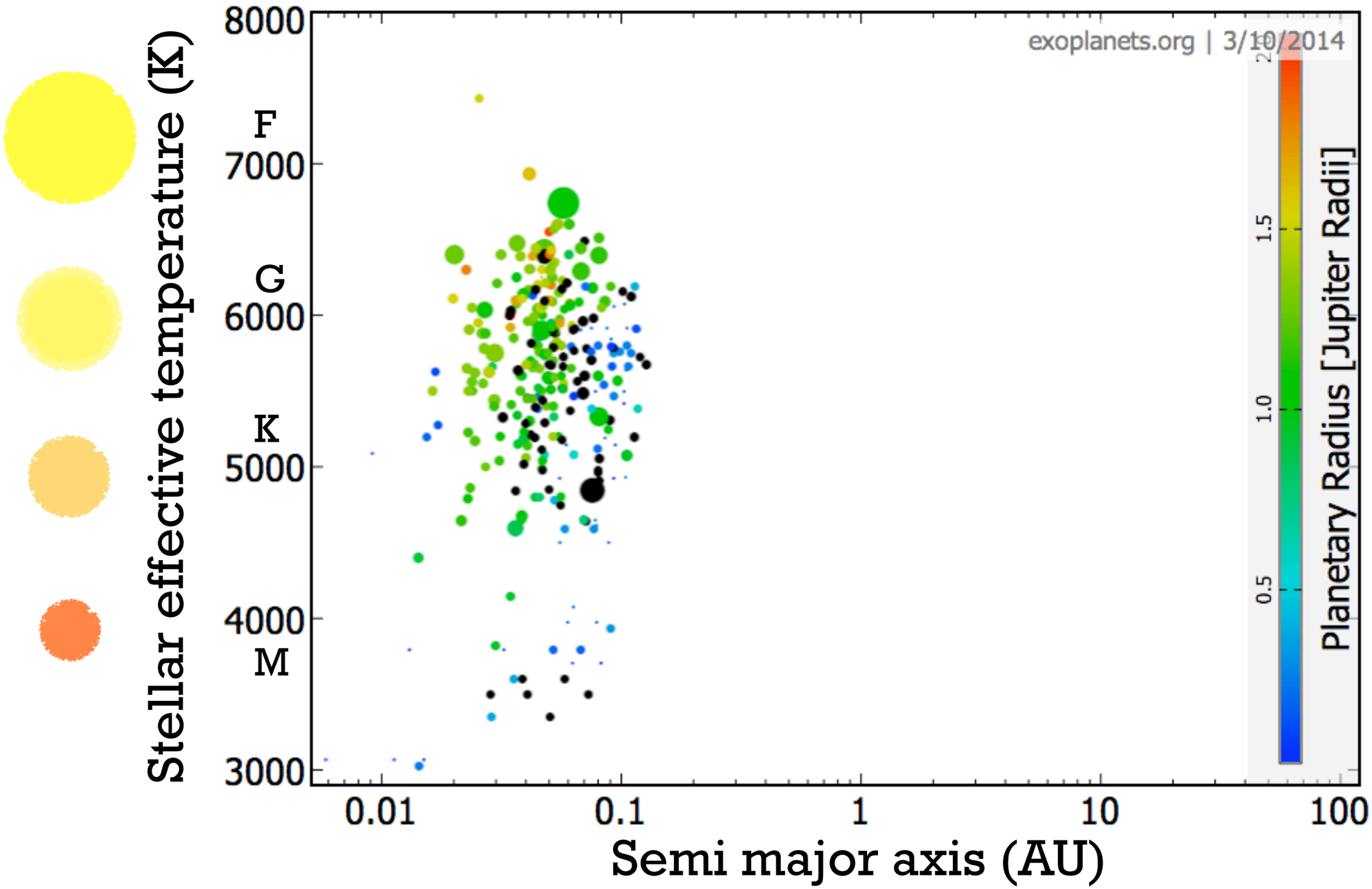
Lisa Kaltenegger,
Jim Kasting,
Ravi K. Kopparapu

Yamila Miguel
Max Planck Institute for Astronomy

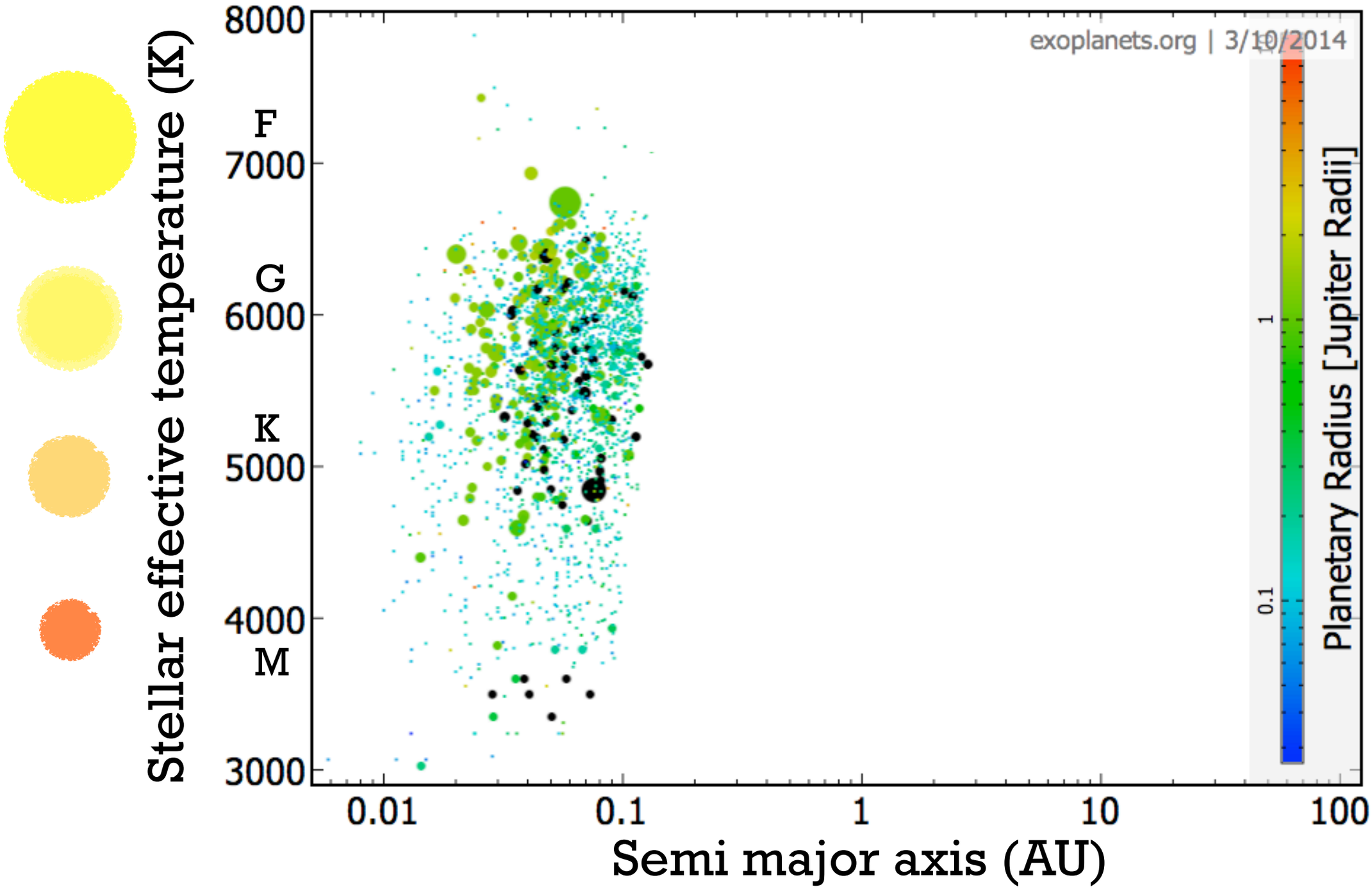
Introduction: exoplanets detected



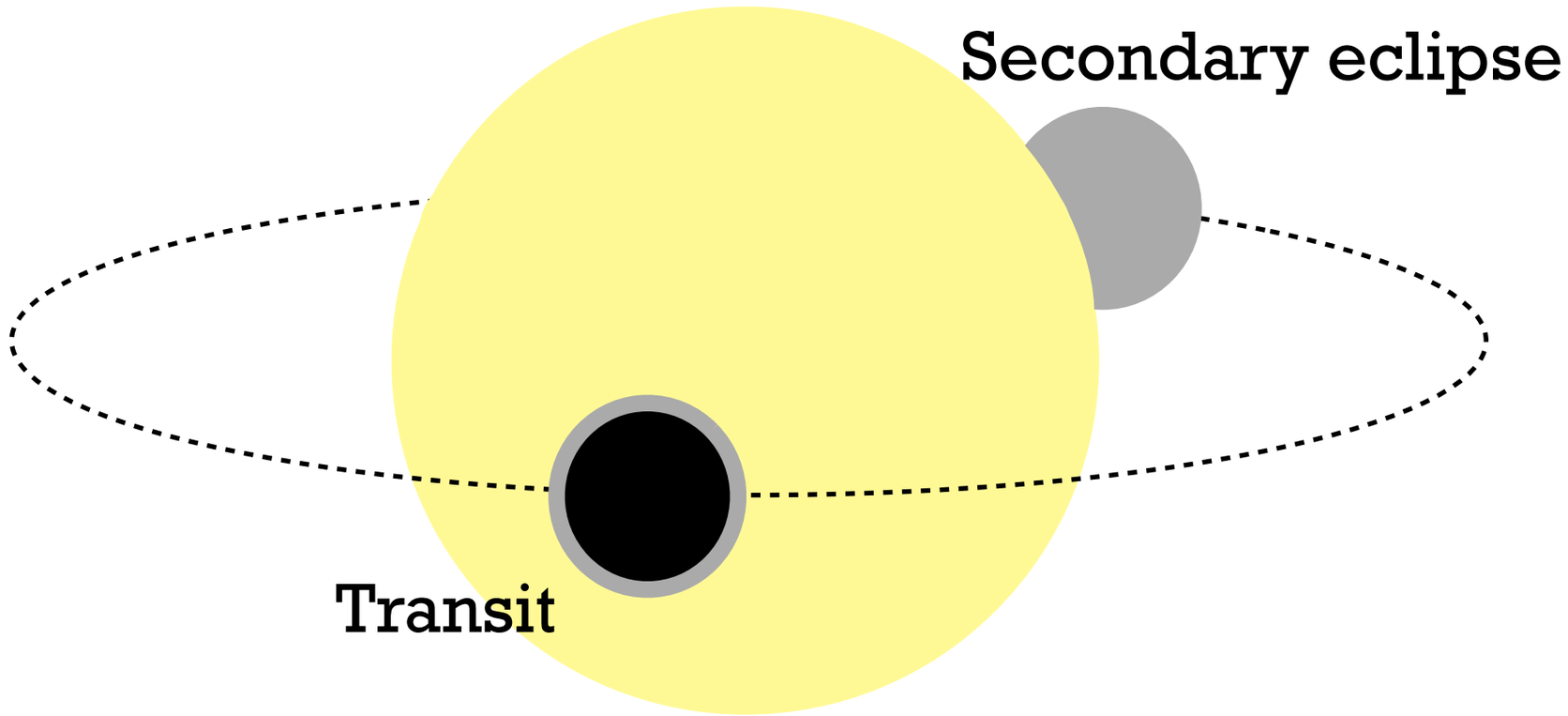
Introduction: hot exoplanets detected



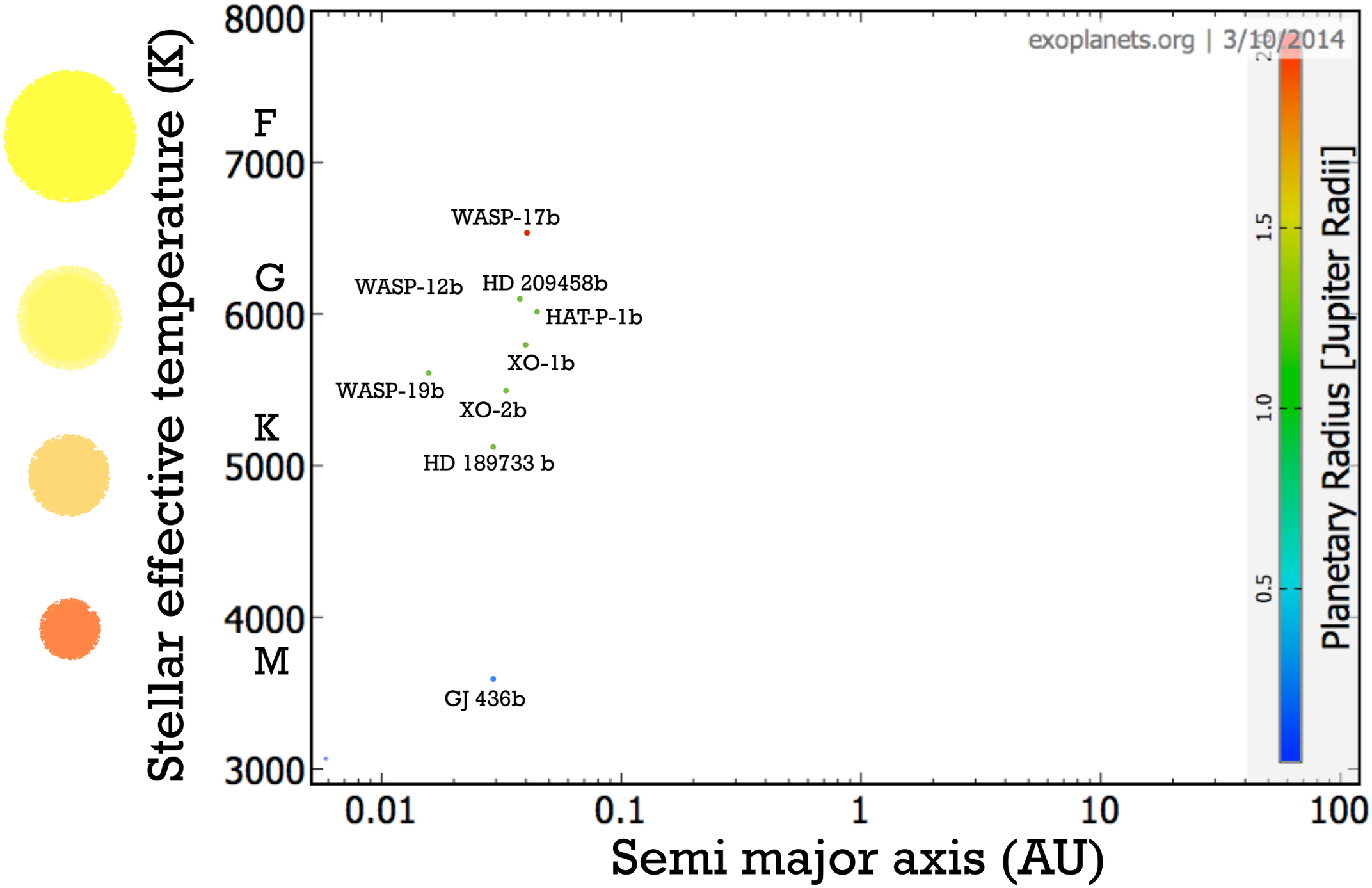
Introduction: hot exoplanets + Kepler candidates



Introduction: molecular & atomic detections in the atmosphere of hot exoplanets



Introduction: hot exoplanets with molecular & atomic detections in the atmosphere



Aim: characterization of hot exoplanets

Which atmospheric features can we find in hot exoplanets?

- Hot rocky planets (Miguel + 2011)
- Mini-Neptunes & EGP
  - Which parameters affect these atmospheres?
    - Semimajor axis + Stellar flux (Miguel & Kaltenegger, 2014)
    - Stellar UV flux + composition (Miguel + 2014, in preparation)

Aim: characterization of hot exoplanets

Which atmospheric features can we find in hot exoplanets?

Hot rocky planets (Miguel + 2011)

Mini-Neptunes & EGP

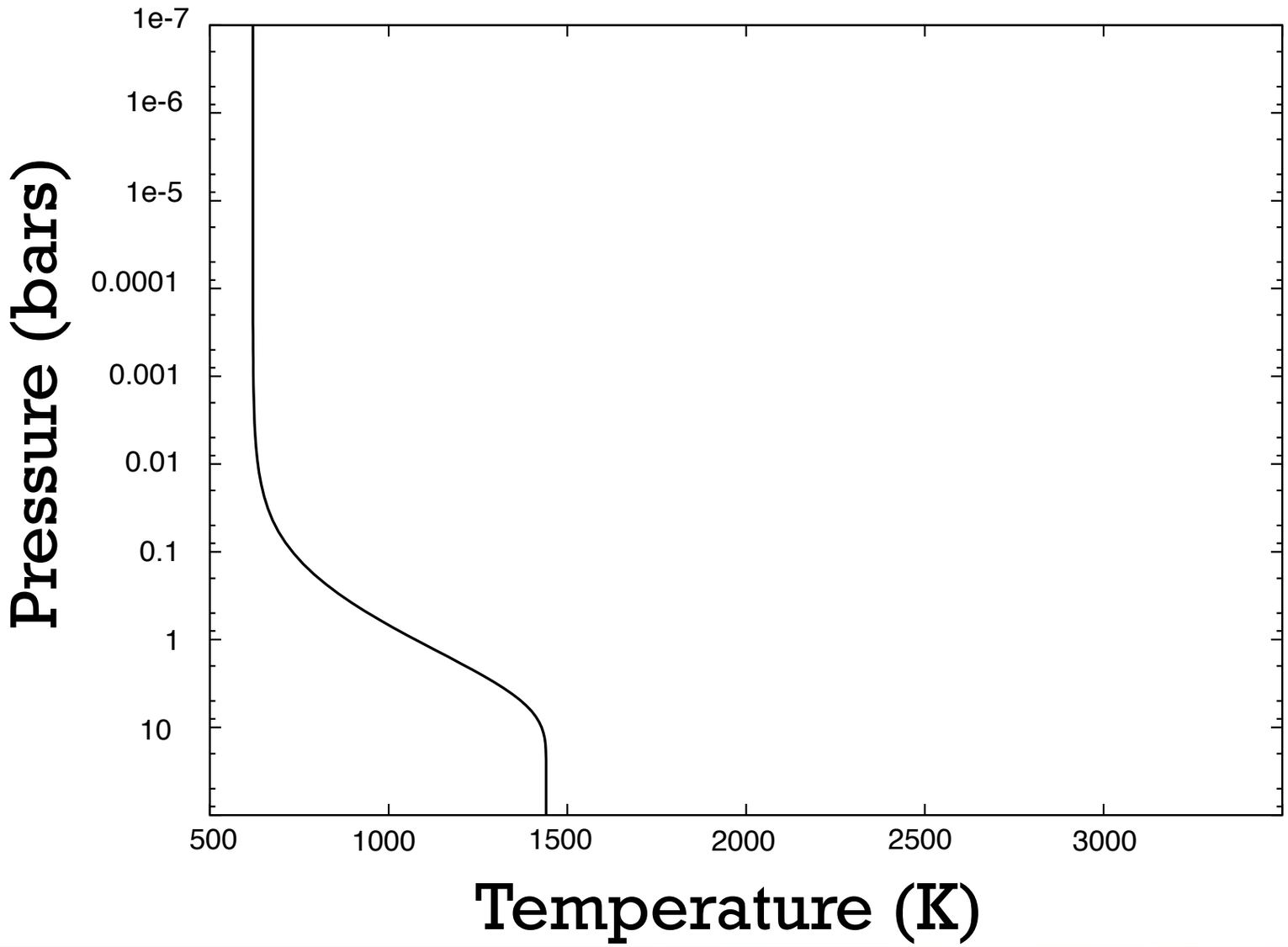
Which parameters affect these atmospheres?

Semimajor axis + Stellar flux (Miguel & Kaltenegger, 2014)

Stellar UV flux + composition (Miguel + 2014, in preparation)

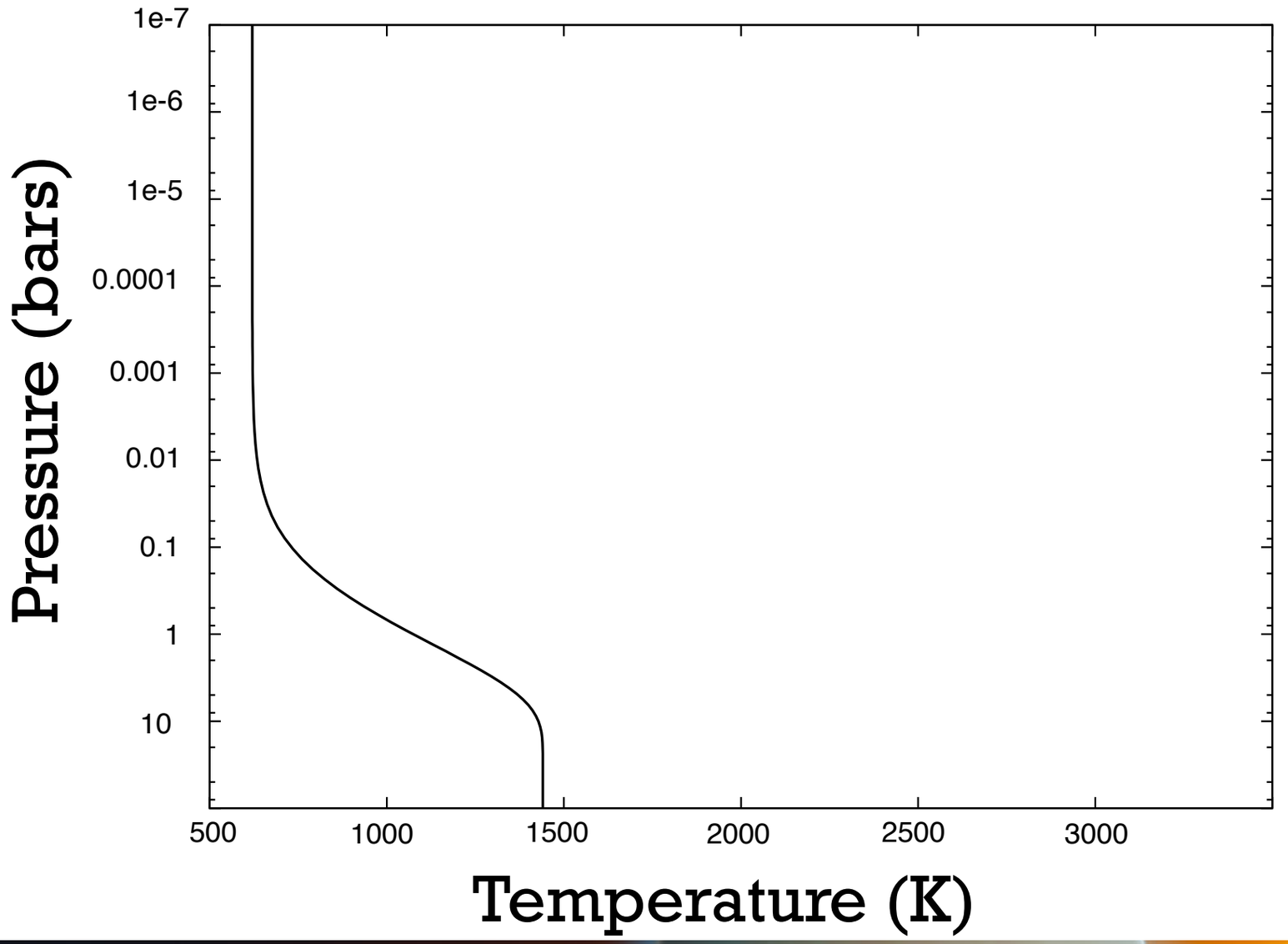
Modeling T-P of hot Mini-Neptunes and EGPs with H/He dominated atmosphere

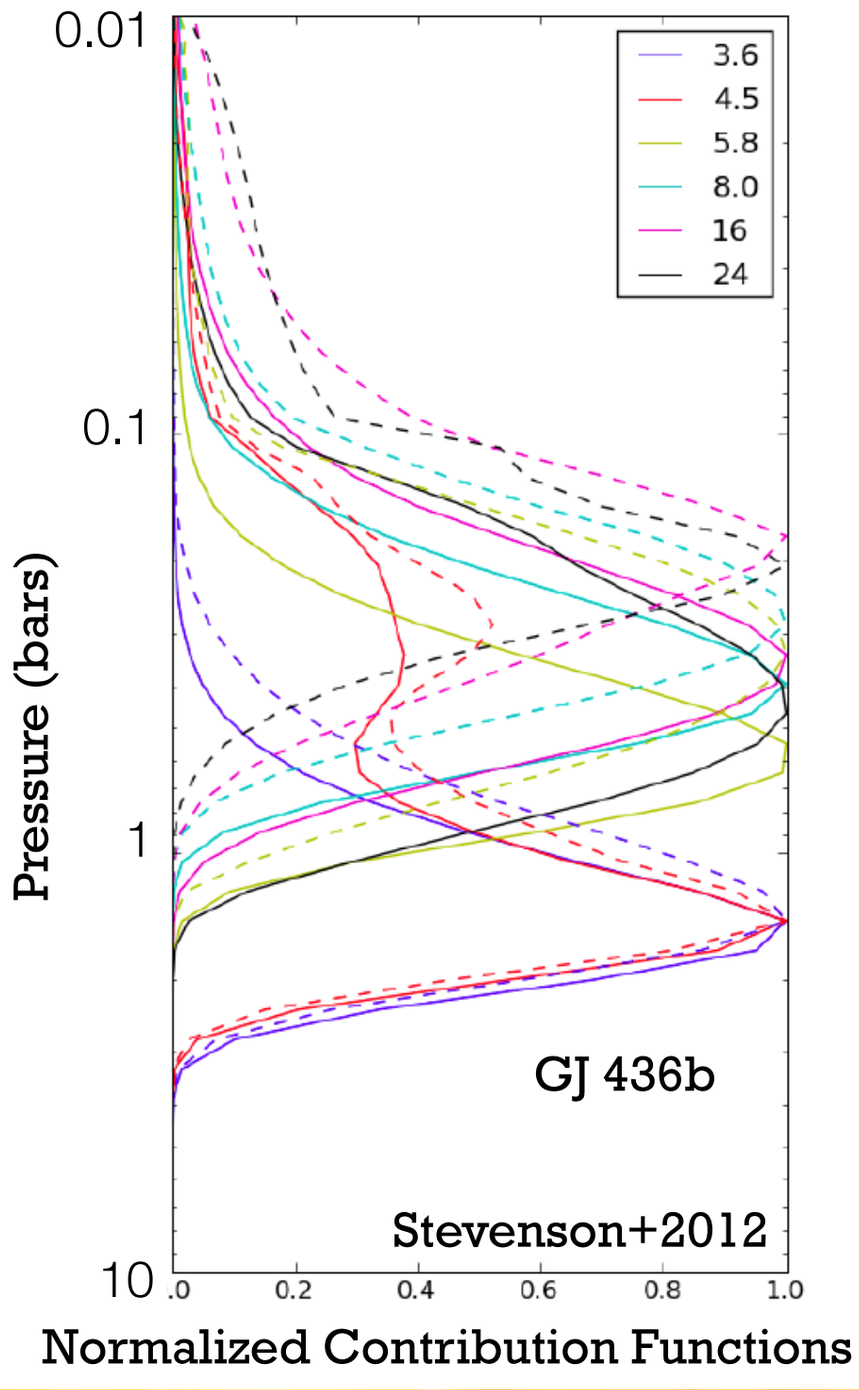
Thermal profile (Guillot 2010), $T(\tau,\gamma,T_{in},T_{irr})$



Modeling T-P of hot Mini-Neptunes and EGPs with H/He dominated atmosphere

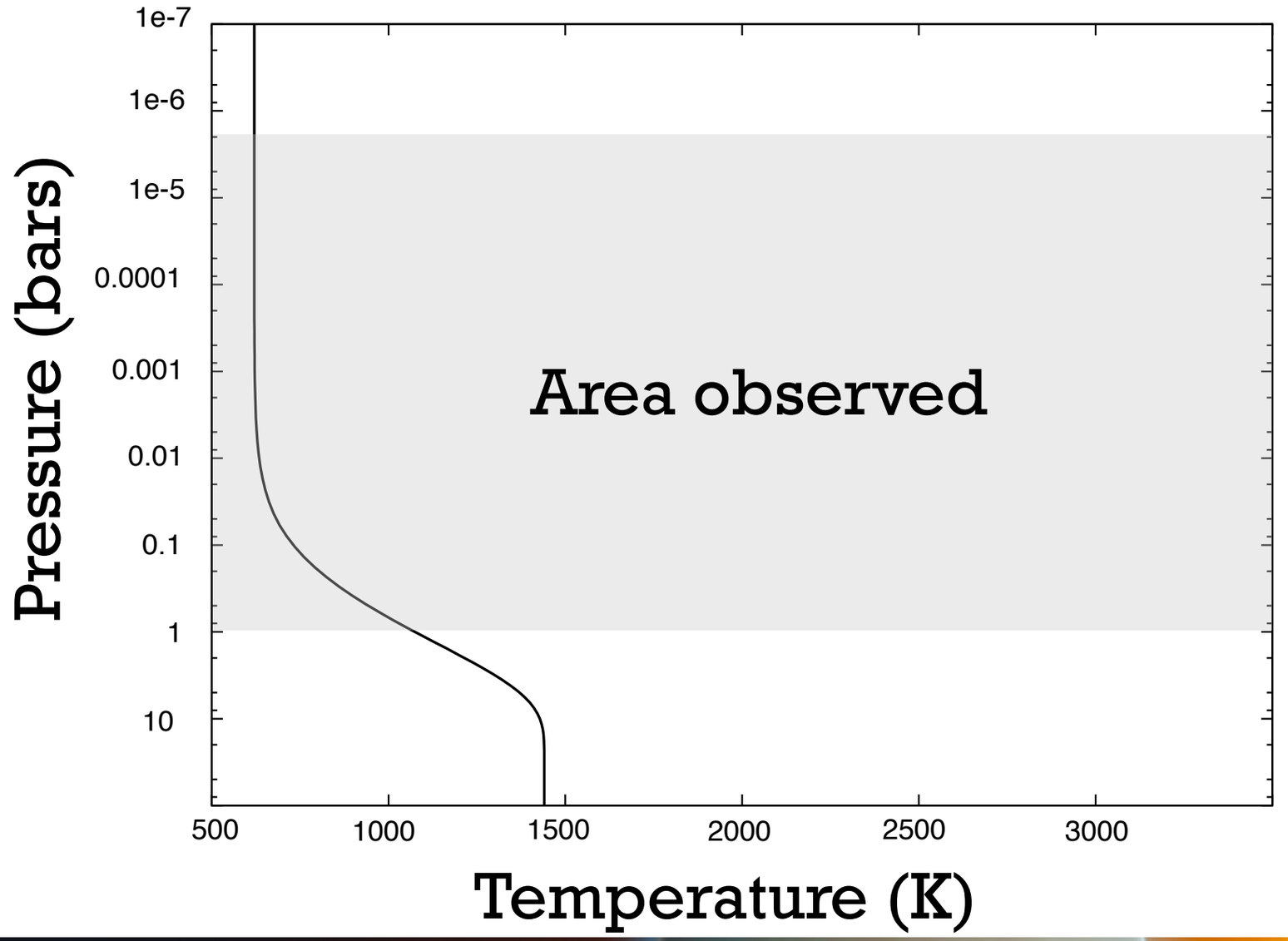
Thermal profile (Guillot 2010), $T(\tau,\gamma,T_{in},T_{irr})$

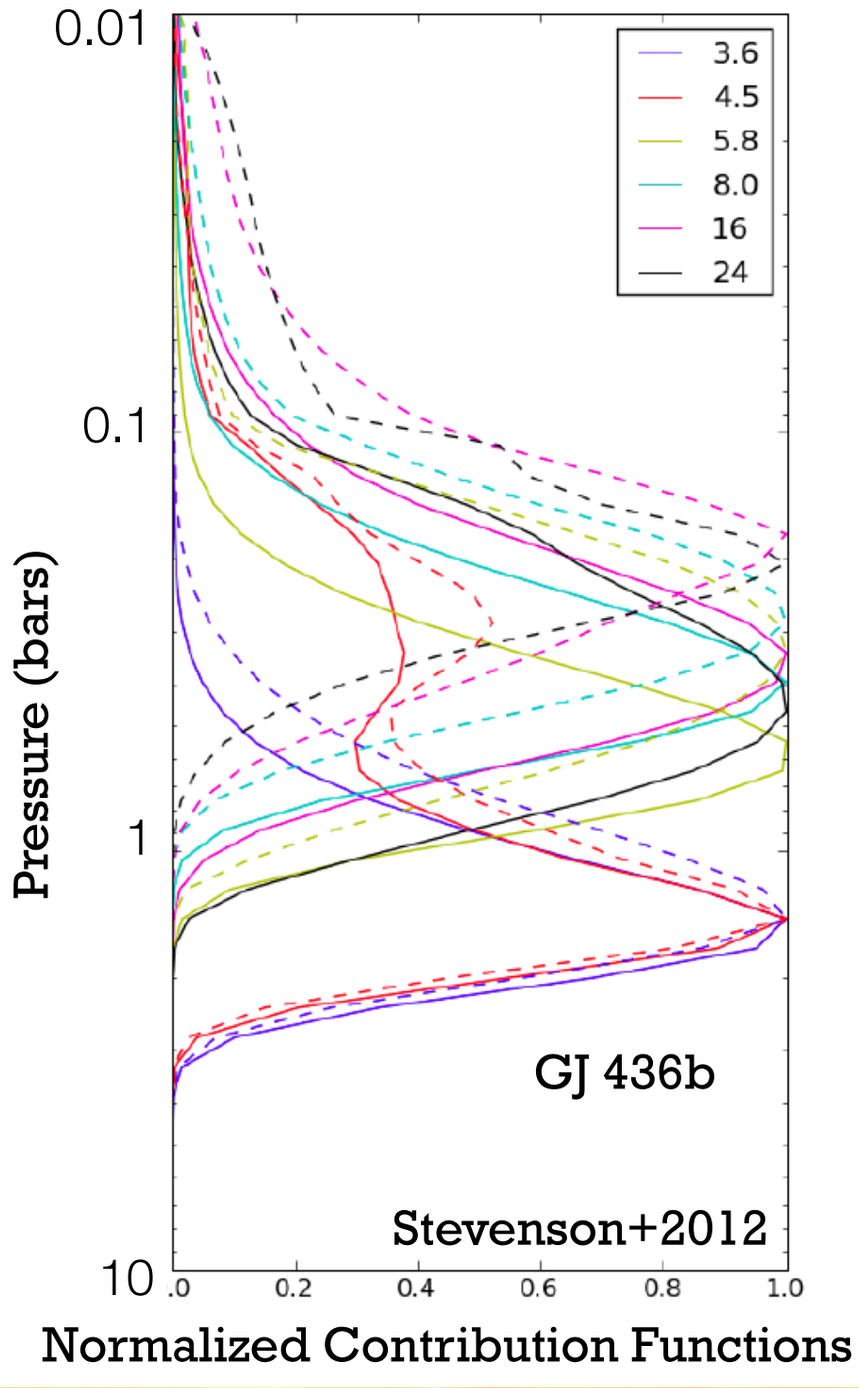




Modeling T-P of hot Mini-Neptunes and EGPs with H/He dominated atmosphere

Thermal profile (Guillot 2010), $T(\tau,\gamma,T_{in},T_{irr})$





Modeling photochemistry of hot Mini-Neptunes and EGPs with H/He dominated atmosphere

Equilibrium chemistry

Yamila Miguel (MPIA)

Quy Nhon, Vietnam - April, 2014

Modeling photochemistry of hot Mini-Neptunes and EGPs with H/He dominated atmosphere

Disequilibrium chemistry

~~Equilibrium chemistry~~

Yamila Miguel (MPIA)

Quy Nhon, Vietnam - April, 2014

Modeling photochemistry of hot Mini-Neptunes and EGPs with H/He dominated atmosphere

Molecular Diffusion

Vertical Mixing
(eddy diffusion coefficient)

Disequilibrium chemistry

~~Equilibrium chemistry~~

Yamila Miguel (MPIA)

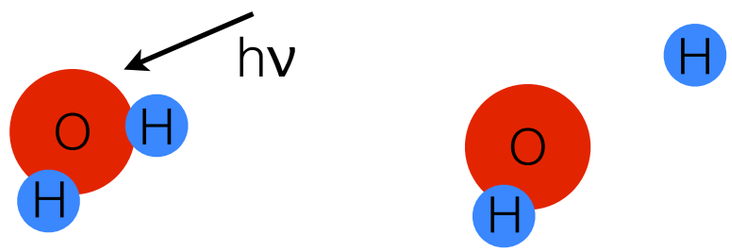
Quy Nhon, Vietnam - April, 2014

Modeling photochemistry of hot Mini-Neptunes and EGPs with H/He dominated atmosphere

Molecular Diffusion

Vertical Mixing
(eddy diffusion coefficient)

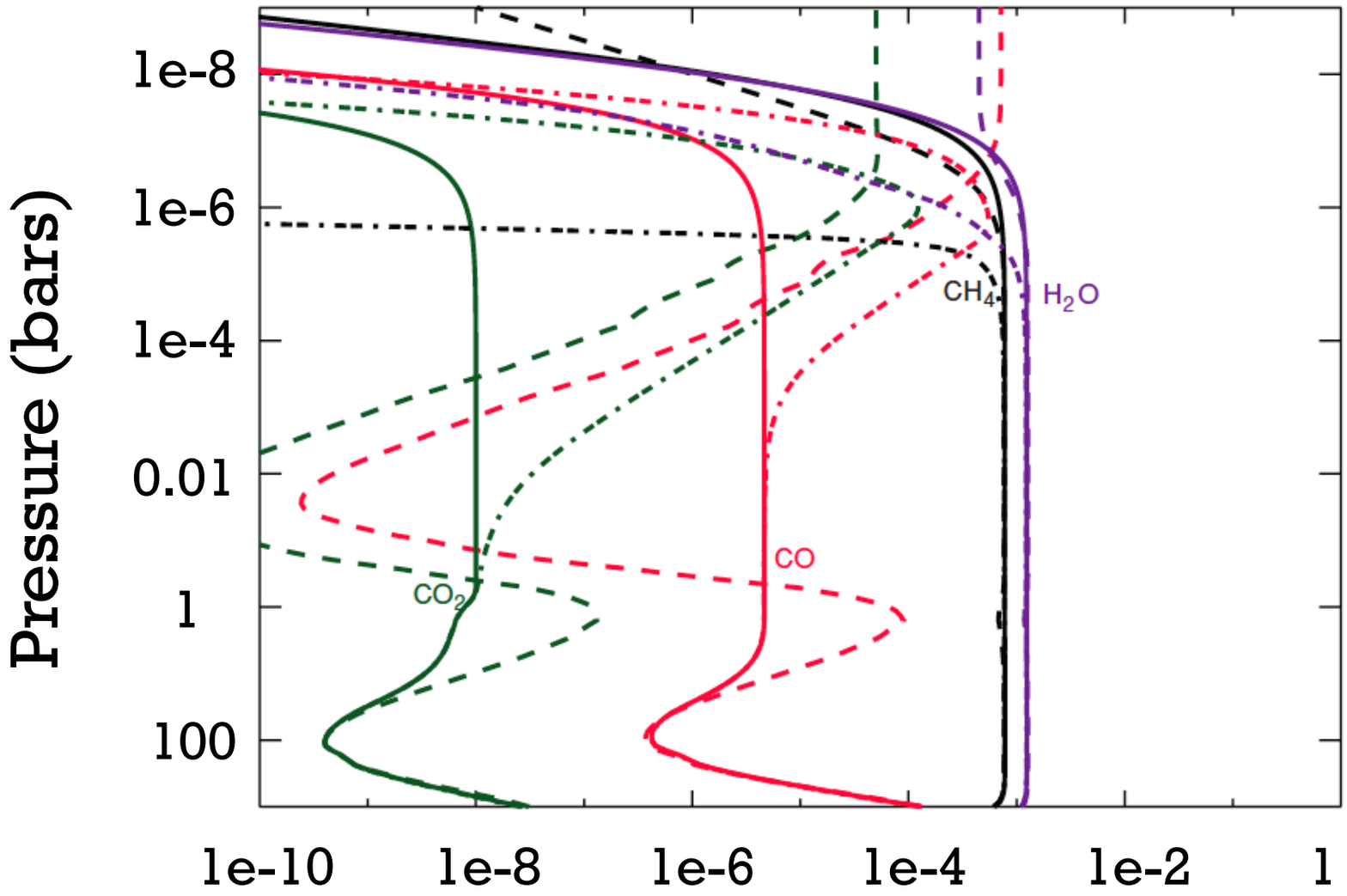
Photochemistry



Disequilibrium chemistry

~~Equilibrium chemistry~~

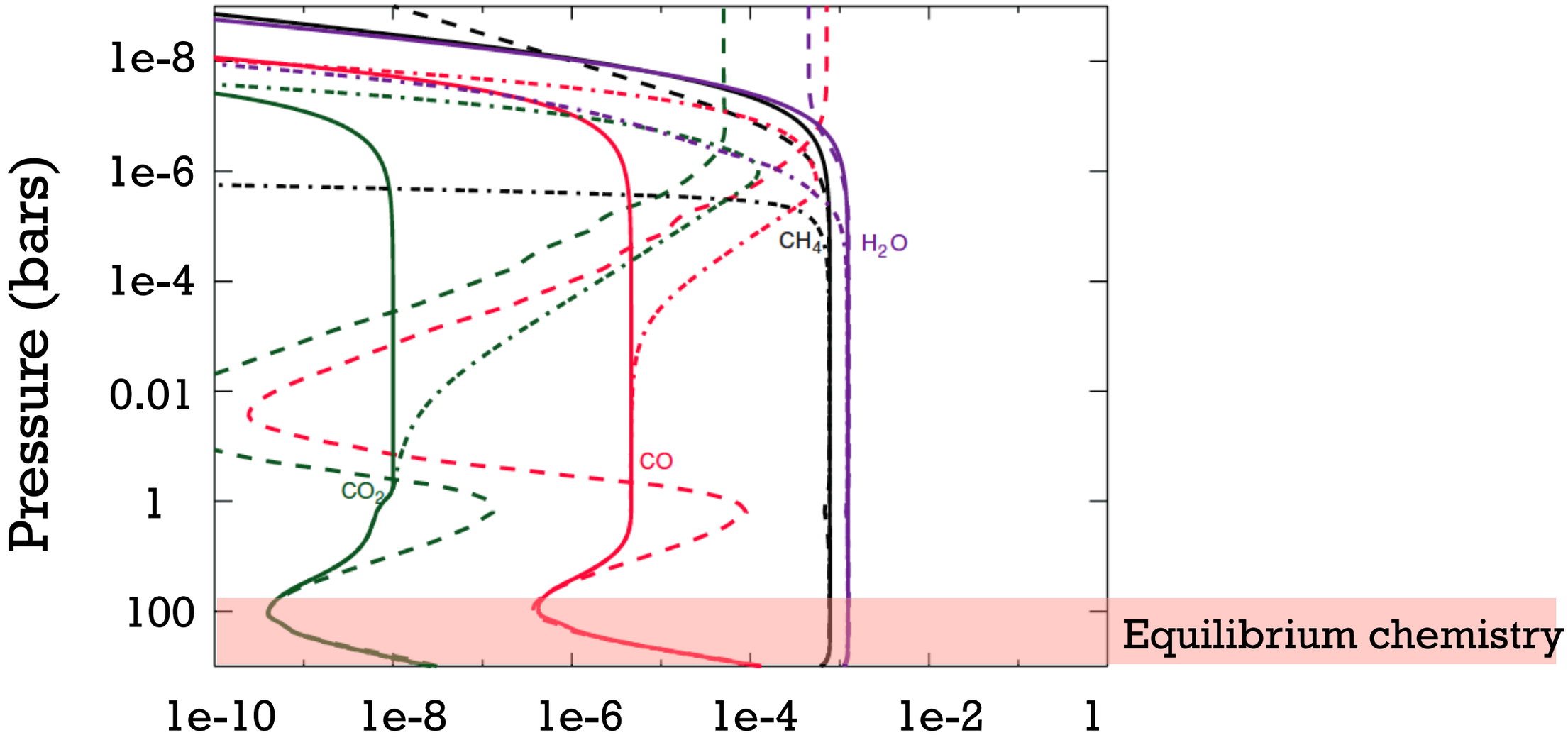
Modeling photochemistry of hot Mini-Neptunes and EGPs with H/He dominated atmosphere



Line+2011

Other photochamical models on EPGs: Zahnle+2009a,b, Line+2010, Moses+2011, 2013, Venot+2012,2014, Kopparapu+2012

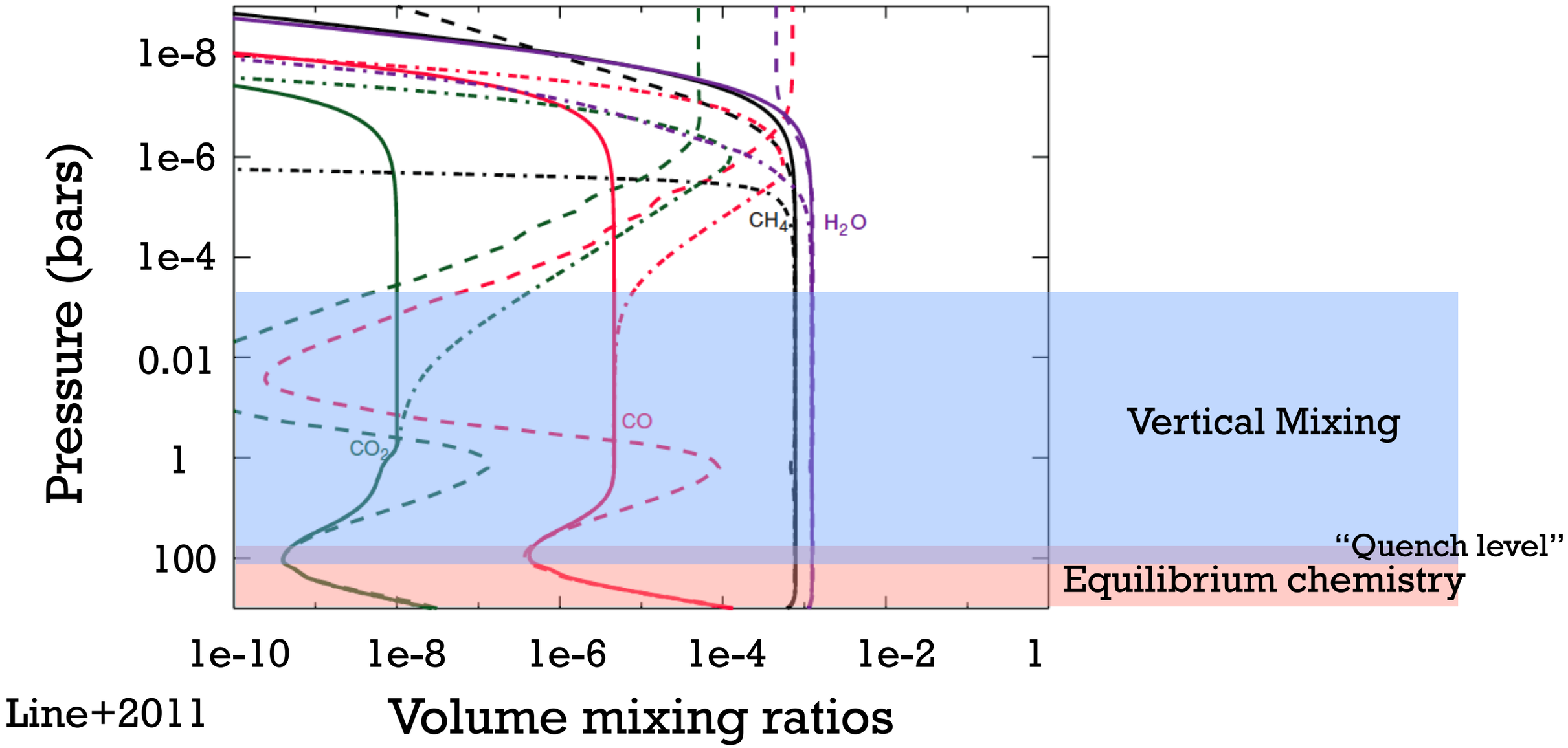
Modeling photochemistry of hot Mini-Neptunes and EGPs with H/He dominated atmosphere



Line+2011

Other photochamical models on EPGs: Zahnle+2009a,b, Line+2010, Moses+2011, 2013, Venot+2012,2014, Kopparapu+2012

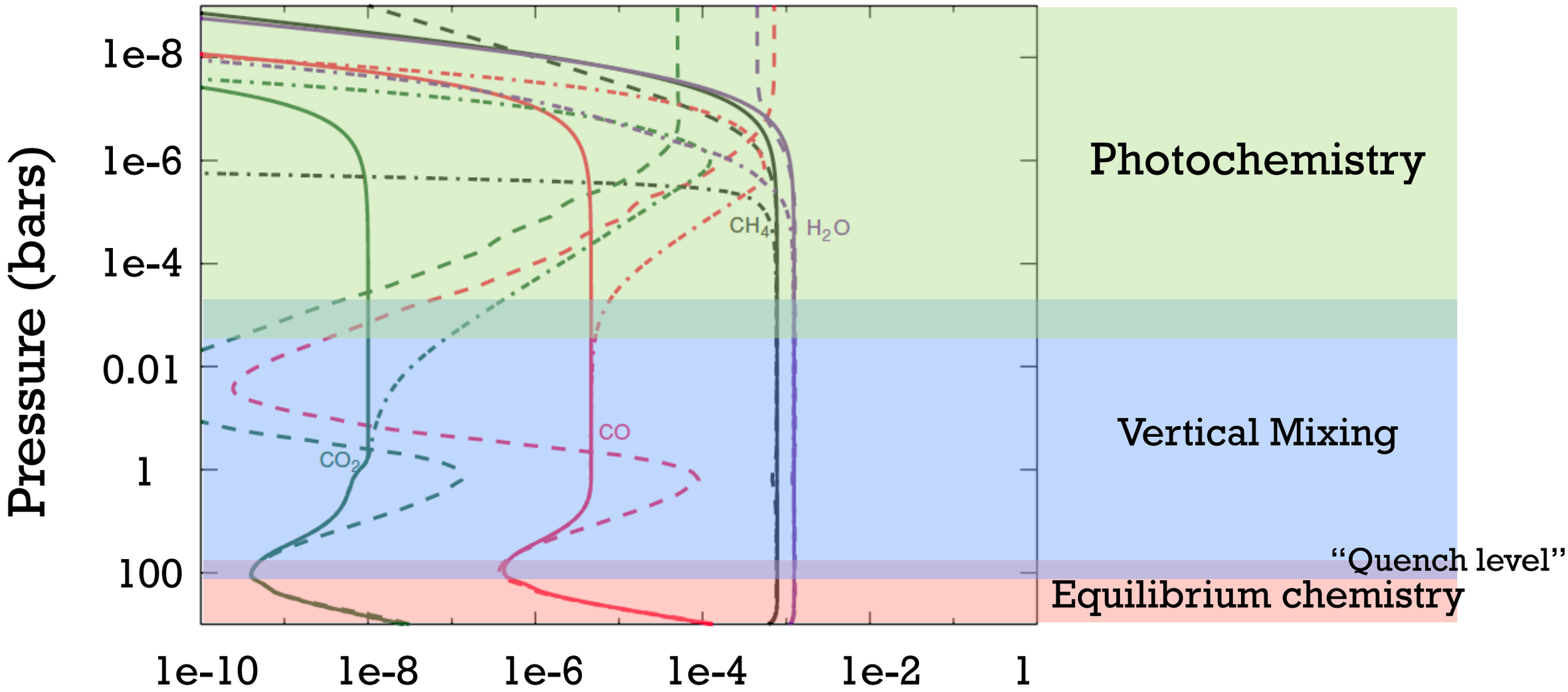
Modeling photochemistry of hot Mini-Neptunes and EGPs with H/He dominated atmosphere



Line+2011

Other photochamical models on EPGs: Zahnle+2009a,b, Line+2010, Moses+2011, 2013, Venot+2012,2014, Kopparapu+2012

Modeling photochemistry of hot Mini-Neptunes and EGPs with H/He dominated atmosphere

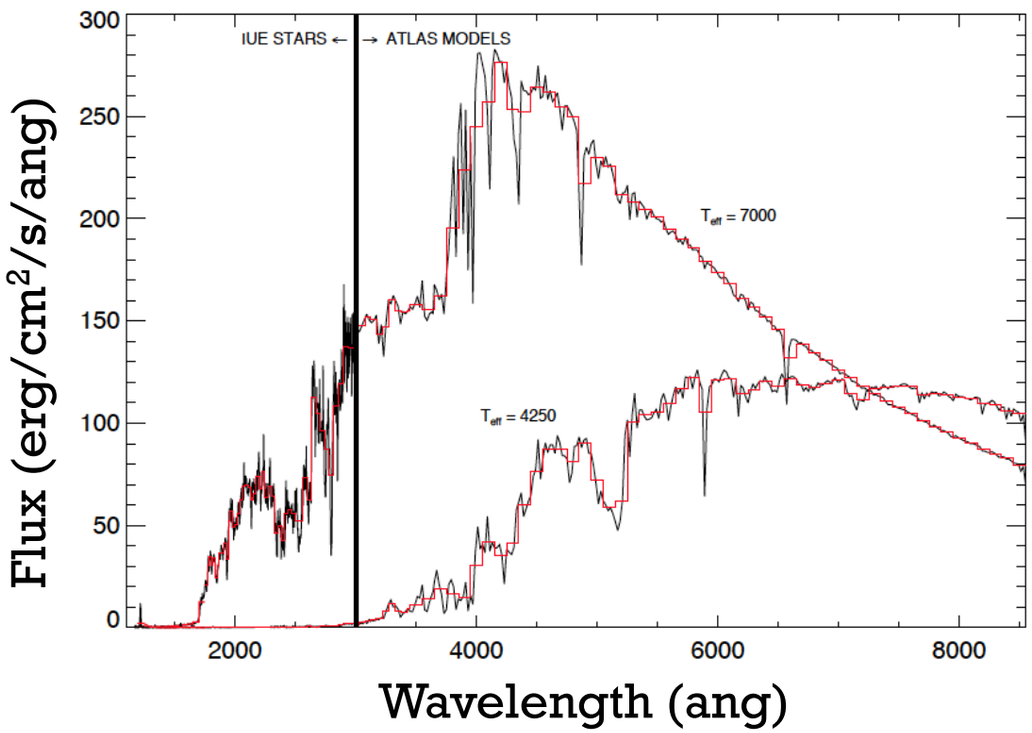


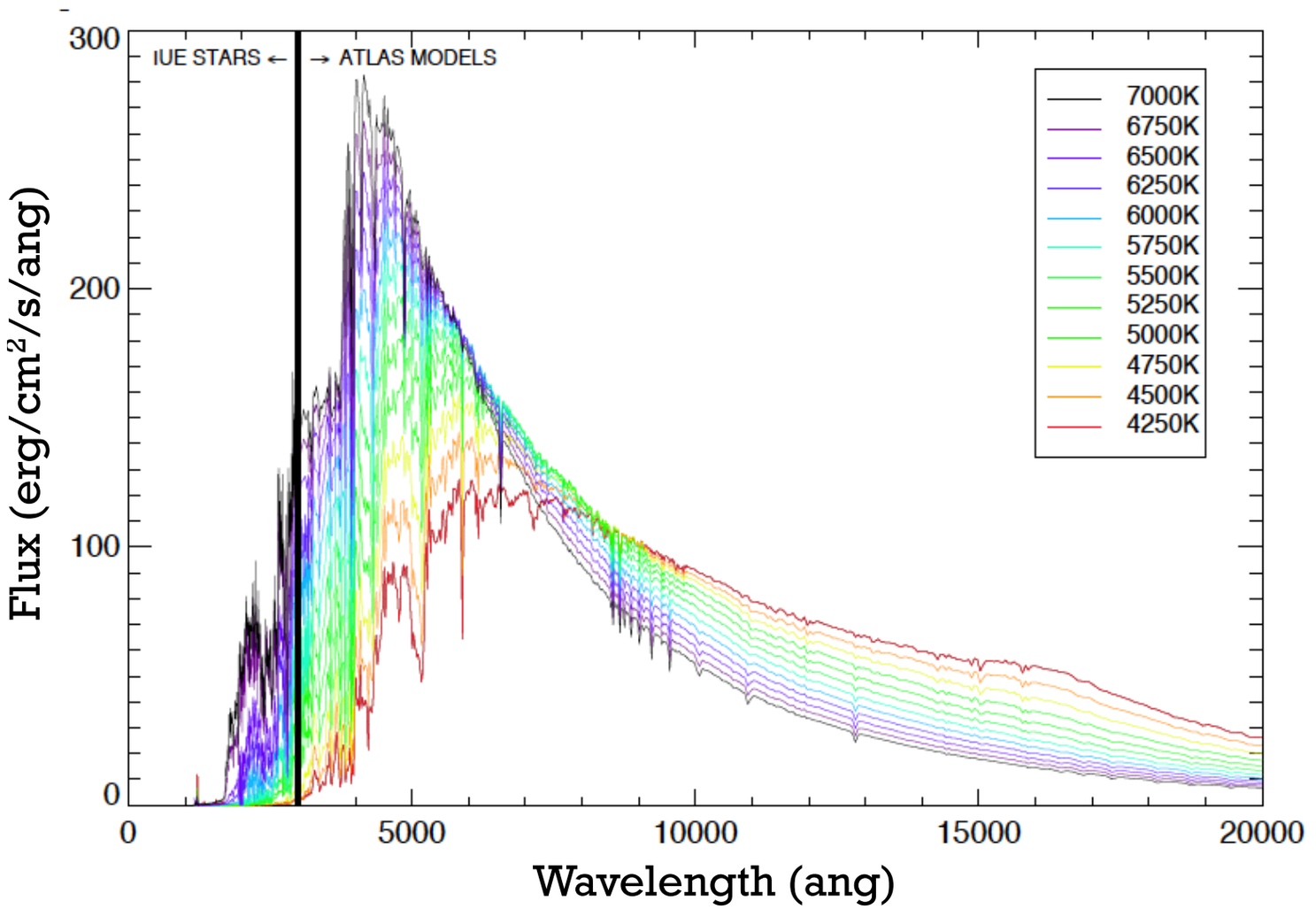
Line+2011

Other photochamical models on EPGs: Zahnle+2009a,b, Line+2010, Moses+2011, 2013, Venot+2012,2014, Kopparapu+2012

Modeling hot Mini-Neptunes and EPGs with H/He dominated atmosphere - Stellar flux

Stellar Models from the ATLAS synthetic spectrum (Kurucz, 1979)+UV observations from the IUE (http://archive.stci.edu/iue/). M star from Allard (2001).





Rugheimer+2013

Modeling mini-Neptunes and EGP

Planetary data (g,a)

Stellar data (T_{eff},$R_\star$)

Stellar Flux

Elemental abundances composition

Thermal profile

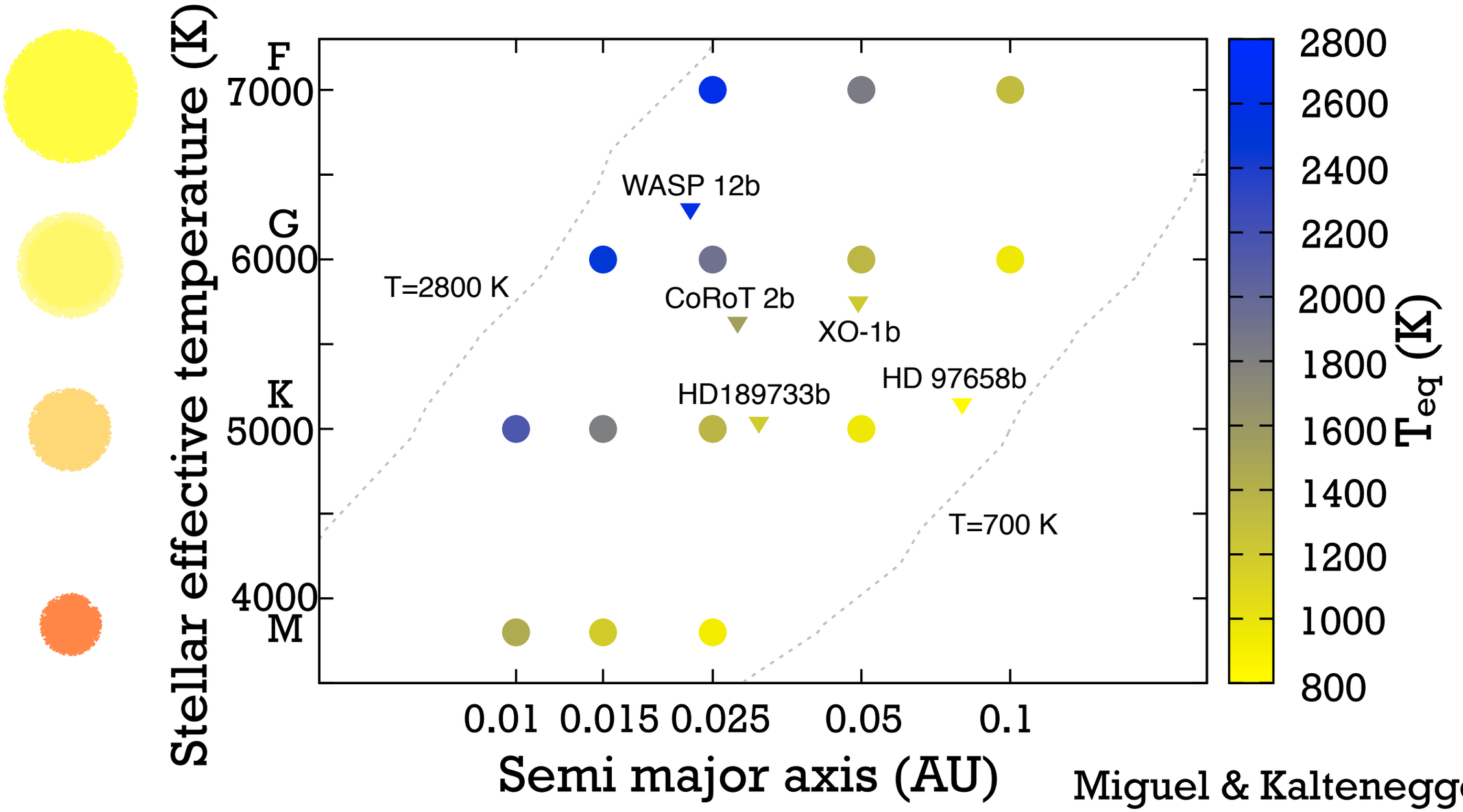
(Based on Guillot 2010)

Chemical Calculations (1D)

(Disequilibrium chemistry, see Kopparapu+2012)

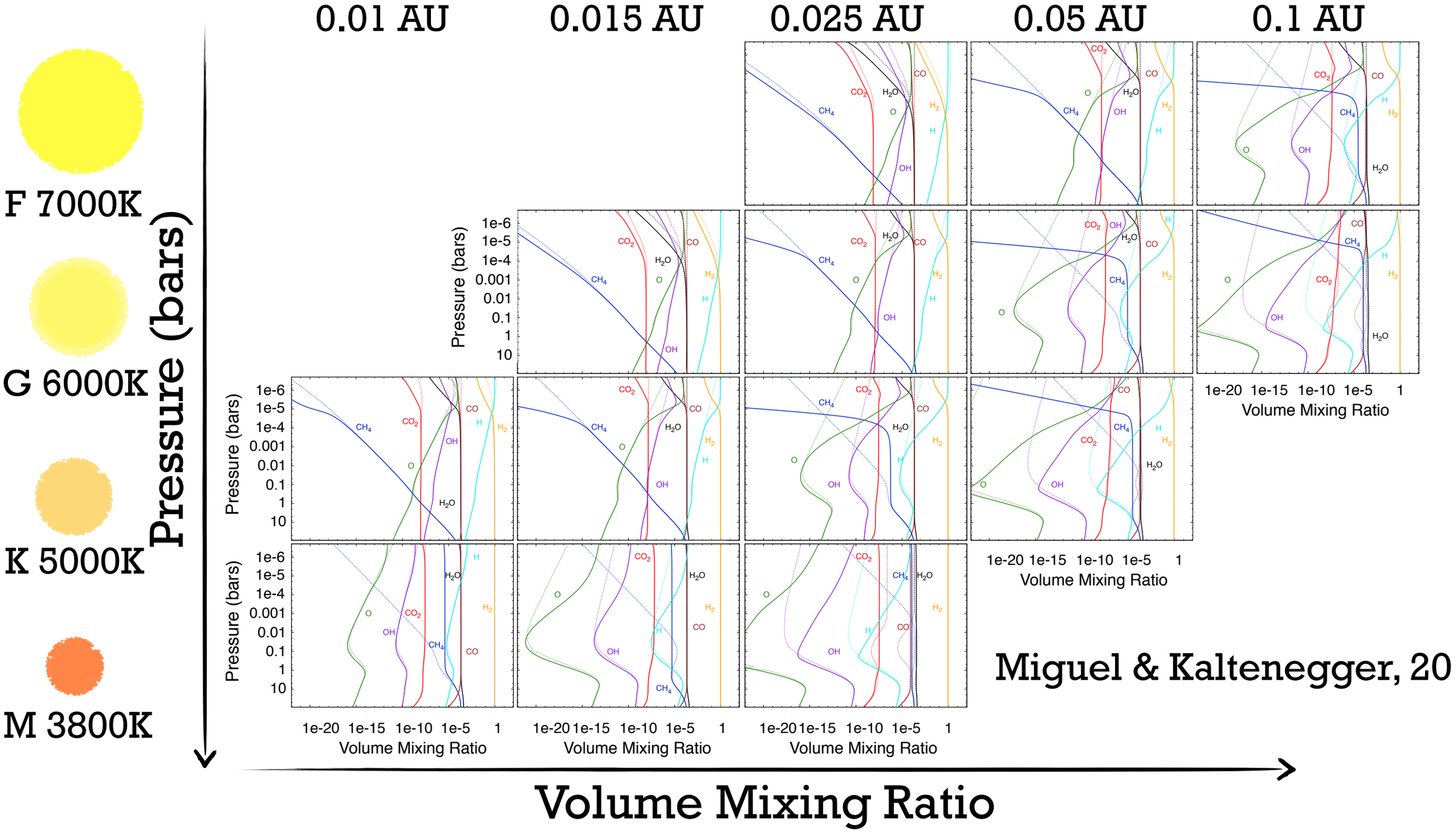
Photochemical mixing ratios

Grid of hot exoplanets



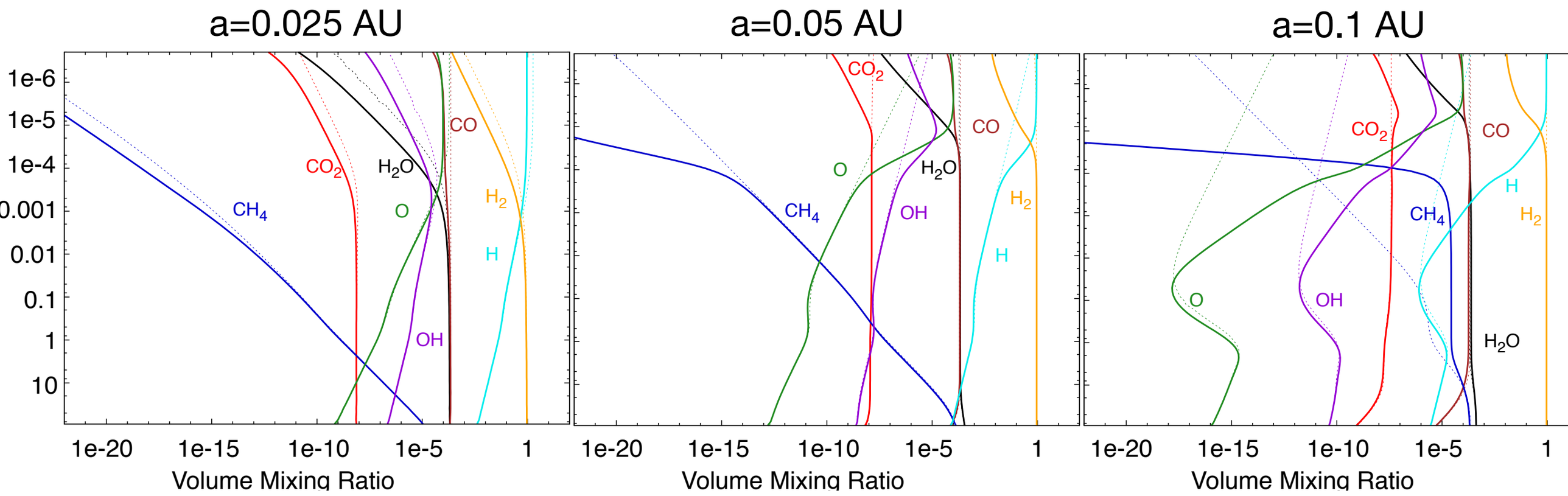
Miguel & Kaltenegger, 2014

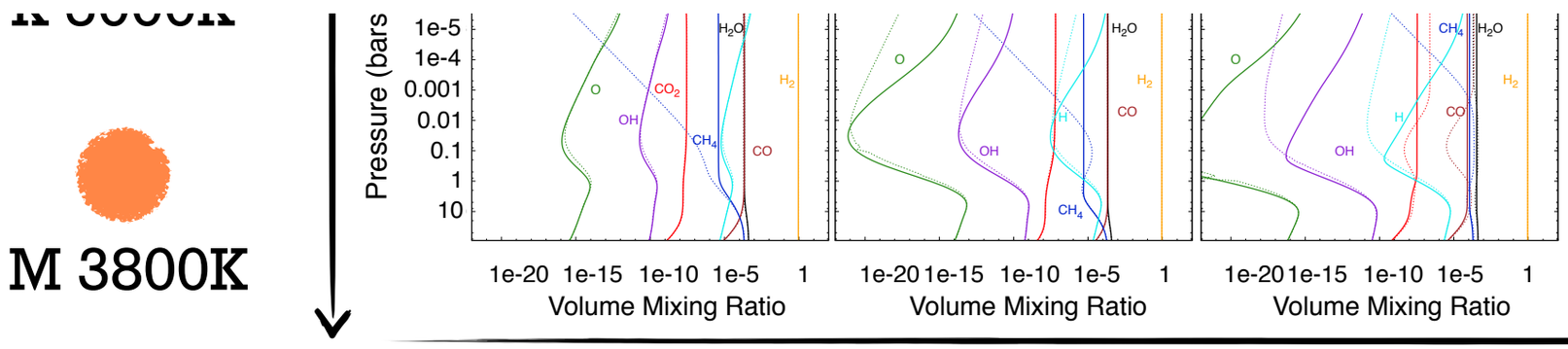
Mini-Neptune Models: photochemistry at ≠ *a* & stellar types



Miguel & Kaltenegger, 2014

Mini-Neptune Models: photochemistry at ≠ *a* & stellar types

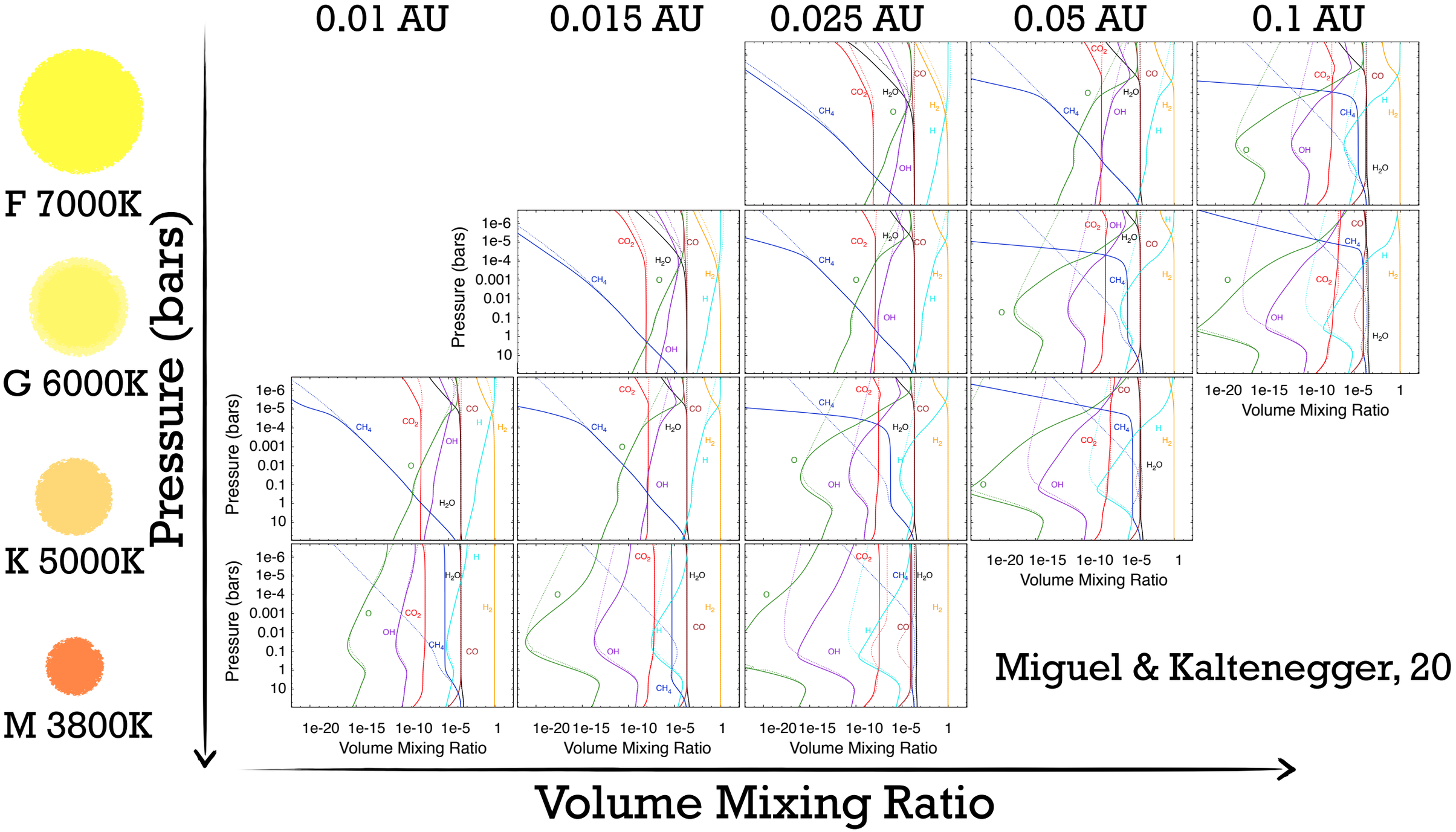




Miguel & Kaltenegger, 2014

Volume Mixing Ratio

Mini-Neptune Models: photochemistry at ≠ *a* & stellar types



Miguel & Kaltenegger, 2014

Mini-Neptune Mod
photochemistry at

0.01 AU 0.

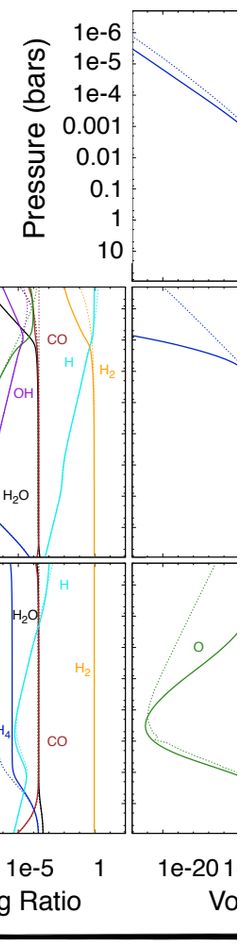
F 7000K

G 6000K

K 5000K

M 3800K

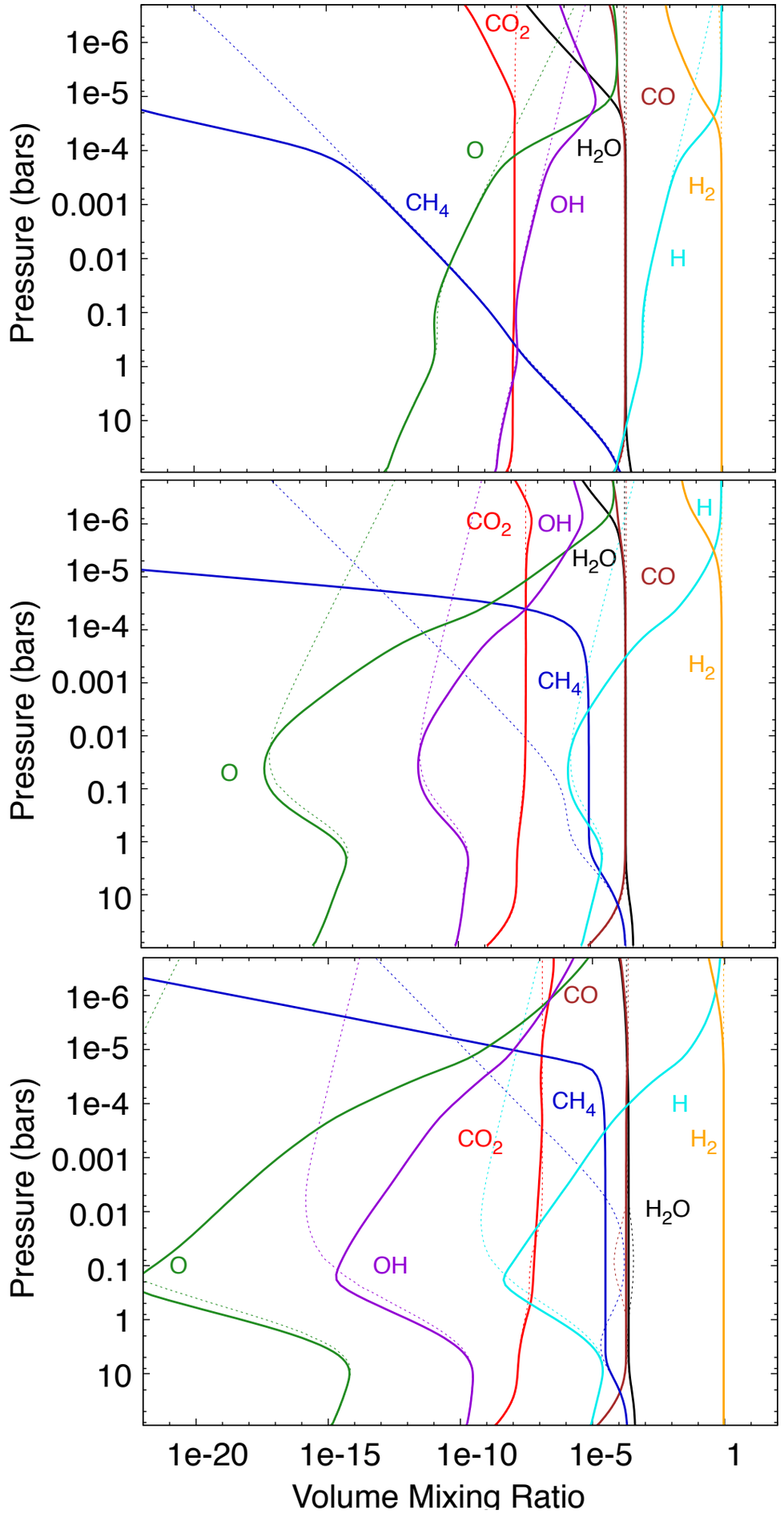
Pressure (bars)



F 7000K

G 6000K

K 5000K

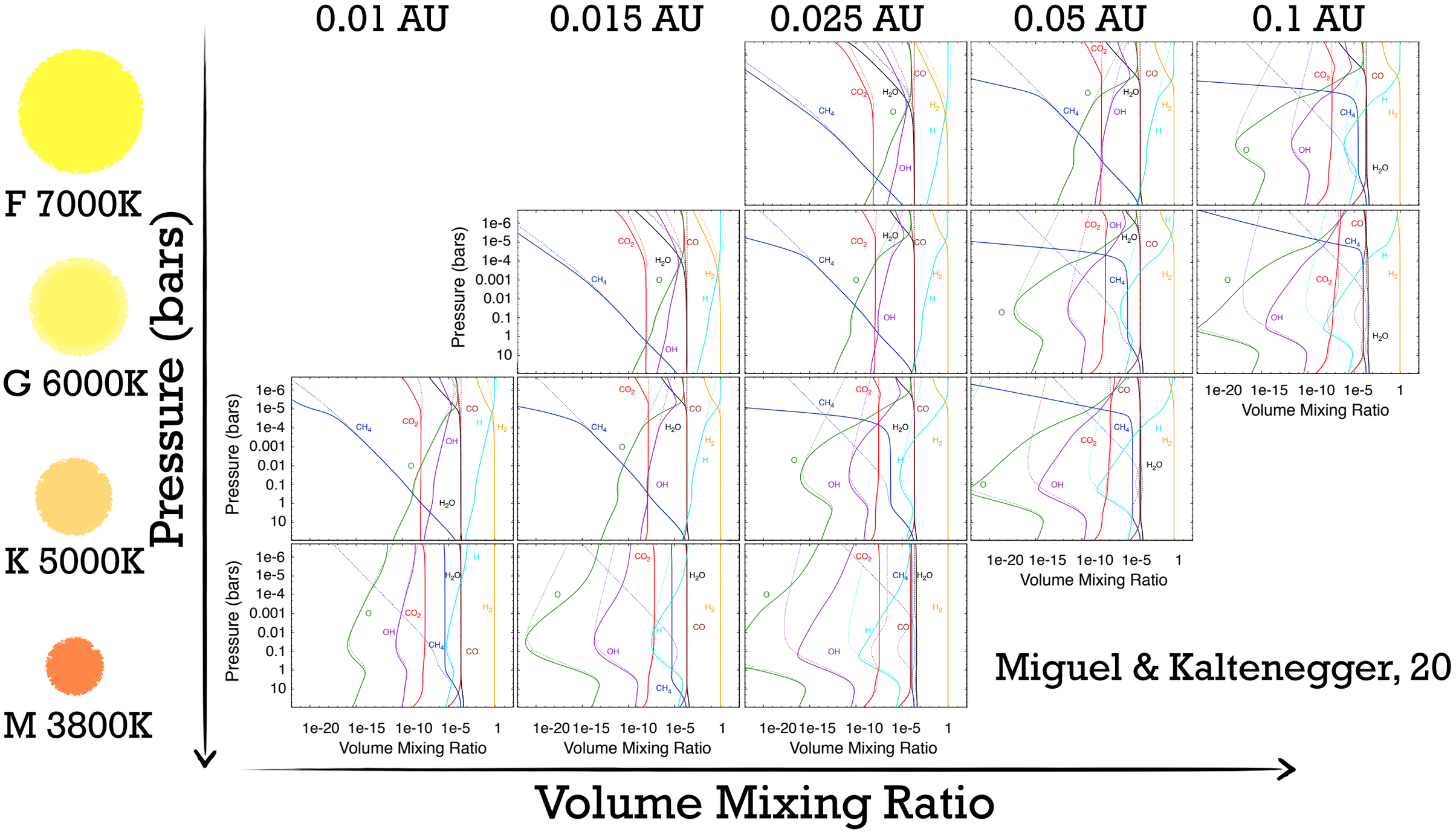


er, 2014

, 2014

Yamila Miguel (MPIA)

Mini-Neptune Models: photochemistry at ≠ *a* & stellar types



Miguel & Kaltenegger, 2014

What's next?

Make similar grids for different elemental abundances composition

Model spectra for these planets

Include clouds and hazes (talk from Christiane Helling)

What can the atmospheres tell us about the formation processes? (Hori Yasunori's talk)

Take home message!

We link observables (a, $T_{eff}\star$, $R\star$) with atmospheric TP profile and chemistry.

Our results can be applied to hot (700<T<2800 K) planets with H/He atmosphere for different Kzz and stellar types, to characterize exoplanets and are a reference to interpret observations and the results of atmospheric retrieval analysis.

Thanks!

Yamila Miguel (MPIA)

Quy Nhon, Vietnam - April, 2014