Introduction: exoplanets detected
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Aim: Link observables to atmospheric composition and spectral features
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CHEOPS, TESS, K2, PLATO
Aim: Link observables to atmospheric composition and spectral features

Teff
Rp & Mp

CHEOPS, TESS, K2, PLATO

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Aim: Link observables to atmospheric composition and spectral features

Teff

R

CHEOPS, TESS, K2, PLATO

Rp & Mp

a

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Outline

- Hot-rocky planets secondary (outgassed) atmospheres
- Hot-giant planets primary atmosphere
Modeling hot mini-Neptunes & hot Jupiters

- Synthetic emergent & transmission spectra
- Photochemical mixing ratios
- Chemical Calculations (Disequilibrium chemistry, Miguel & Kaltenegger, 2014; Miguel+2015)
  - Thermal profile (Based on Guillot 2010)
- Planetary data (g,a)
- Stellar Flux
- Elemental abundances composition

Link between planet & atmospheric observables

Stellar data (T_eff, R_★)
Modeling hot exoplanets: equilibrium vs. disequilibrium chemistry.

Diagram showing the volume mixing ratios of different compounds (CO$_2$, CH$_4$, CO, H$_2$O) as a function of pressure (in bars) for GJ 436b.
Modeling hot exoplanets
equilibrium vs. disequilibrium chemistry

![Graph showing pressure (bars) vs. volume mixing ratios for various compounds with lines representing different conditions. The graph plots CO₂, CH₄, CO, and H₂O concentrations at different pressures, with GJ 436b labeled.]
Modeling hot exoplanets
equilibrium vs. disequilibrium chemistry

Equilibrium chemistry

Equilibrium chemistry
Modeling hot exoplanets
equilibrium vs. disequilibrium chemistry

Pressure (bars)

Volume mixing ratios

GJ 436b

Vertical Mixing

“Quench level”

Equilibrium chemistry

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Modeling hot exoplanets 
equilibrium vs. disequilibrium chemistry

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Mini-Neptune Models: synthetic transmission & emergent spectra

GJ 436b

Miguel+2014, Miguel+in prep.
also:
Moses+2013, Agundez+2014

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Mini-Neptune Models: synthetic transmission & emergent spectra

GJ 436b

Miguel+2014, Miguel+in prep. also: Moses+2013, Agundez+2014
Mini-Neptune Models: synthetic transmission & emergent spectra

GJ 436b

Emergent spectra

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GJ 436b

Emergent spectra

Transmission spectra

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

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Volume Mixing Ratio


Miguel & Kaltenegger, 2014

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Mini-Neptune Mo photochemistry a

0.01 AU

Pressure (bars)

Volume Mixing Ratio

Other photochemical models:

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


Miguel & Kaltenegger, 2014

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Outline

Hot-rocky planets
secondary (outgassed)
atmospheres
Motivation: Hot rocky Kepler candidates
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Stellar effective temperature (K)

Semi major axis (AU)

$R_p < 2.5R_{\text{Earth}}$
Motivation: Hot rocky Kepler candidates

Stellar effective temperature (K)

- Stellar effective temperature (K): 3000, 3500, 4000, 4500, 5000, 5500, 6000, 6500, 7000
- Semimajor axis (AU): 0.01, 0.1, 1

- $T_p > 1000$ K
- $R_p < 2.5R_{\text{Earth}}$

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Motivation: Hot rocky Kepler candidates

Semi-major axis (AU)

Stellar effective temperature (K)

- Kepler 10b
- Corot-7b
- Mercury

Criteria:
- $T_p > 1000 \, \text{K}$
- $R_p < 2.5 R_{\text{Earth}}$
Developed simple approach to predict initial atmospheric composition of hot-rocky planets based on observables.
Link observables to atmospheric composition

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Hot rocky exoplanet’s have silicates atmospheres!

Miguel+ 2011 - updated 2014
see also Schaefer & Fegley 2009
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Interior from atmospheric data

Observables ($a, R_p, T_{\text{eff}}$)
Interior from atmospheric data

Observables ($a, R_p, T_{\text{eff}}$) → Atmospheric Composition → Crust Composition
Interior from atmospheric data

Observables ($a, R_p, T_{\text{eff}}$)

Atmospheric Composition

Crust Composition
Interior from atmospheric data

Observables ($a, R_p, T_{\text{eff}}$)

Atmospheric Composition

Crust Composition
Interior from atmospheric data

Observables \((a, R_p, T_{\text{eff}})\)

Atmospheric Composition

Crust Composition
Take home message!

**Hot-Giants:** we link observables ($a$, $T_{\text{eff}}$, $R$) with atmospheric TP profile, chemistry and observable spectral features using disequilibrium chemistry.

Our grid can be used to select targets, characterise exoplanets and interpret atmospheric retrieval analysis.

**Hot-rocky:** we calculated the gases outgassed from the surface and built the atmosphere. The most abundant species are Na and SiO, we found less $O_2$. Disequilibrium chemistry -specially vertical mixing- is extremely important.