Library of Self-consistent Simulated Exoplanet Atmospheres

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Nathan Mayne, Ben Drummond, David Sing, Eric Hebrard, Nikole Lewis, Pascal Tremblin, Mark Phillips, Tom Evans, Hannah Wakeford
Pressure-Temperature using Radiosonde
planetary orbit

secondary eclipse

primary eclipse

= transit
Planet Specific Atmospheric Library

Which Model?

✴ 1D Radiative Convective Equilibrium model ATMO
(Tremblin 2015, Amundsen 2014, Drummond 2016, Goyal 2017)

What does grid contain?
✴ 89 Observationally Significant hot Jupiter and warm Neptune exoplanets
✴ Radiative Convective Equilibrium P-T profiles
✴ Equilibrium Chemical Abundances with ionic species
✴ Transmission and Emission spectra, Contribution Functions
(Goyal et al. in prep)

What are main grid variables for each planet?
✴ 4 Recirculation factors
✴ 6 Metallicity
✴ 6 C/O ratios

If you need models for any planet let us know!!
Solving Radiative Transfer Consistently with Equilibrium Chemistry

\[ \frac{\partial I}{\partial \tau} = I - S \]

Solve radiative transfer

\[ \text{min}(\Delta G) \]

Compute Equilibrium Chemistry

K

Compute Opacities

Under the Constraints of

Conservation of Energy

Hydrostatic Equilibrium

\[ F_{\text{rad}} + F_{\text{conv}} - \sigma T_{\text{eff}}^4 = 0 \]

\[ \frac{d}{dz} (P_{\text{gas}} + P_{\text{turb}}) - \rho g = 0 \]
Brown-Dwarf P-T Profile

Tremblin et al. 2015

- Teff=875K, logg=5.0, [M/H]=0.3, logkzz=0
- Teff=875K, logg=5.0, [M/H]=0.3, logkzz=8, $\gamma=1.2$
- Teff=580K, logg=4.5, logkzz=0
- Teff=580K, logg=4.5, logkzz=8, $\gamma=1.27$
Hot Jupiter P-T profile

Goyal et al. in prep.

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Rainout vs. Local Condensation

![Graph showing the comparison between Rainout Condensation and Local Condensation with respect to temperature (K) and pressure (bar).](image1)

![Graph showing the comparison between Rainout Condensation and Local Condensation with respect to wavelength (μm) and opacity (W m⁻² μm⁻¹).](image2)
Alkali Line Profiles

Pressure (bar)

Temperature (K)

Wavelength (μm)

$F^\lambda_p$ (Wm$^{-2}$μm$^{-1}$)

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Effect of Metallicity (WASP-17b)
Effect of Metallicity (WASP-17b)
Inversions (WASP-121b)

Temperature (K)

Pressure (bar)

\[ F^\lambda_p (W m^{-2} \mu m^{-1}) \times 10^6 \]

Wavelength (\(\mu m\))

0.002 cm\(^2\)/g
0.004 cm\(^2\)/g
0.006 cm\(^2\)/g
0.02 cm\(^2\)/g

H\(2O\)

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First Detection of Stratosphere (Temperature Inversion) in Exoplanet Atmosphere

Application of Grid

An ultrahot gas-giant exoplanet with a stratosphere

Thomas M. Evans, David K. Sing, Tiffany Kataria, Jayesh Goyal, Nikolay Nikolov, Hannah R. Wakeford, Drake Deming, Mark S. Marley, David S. Amundsen, Gilda E. Ballester, Joanna K. Barstow, Lotfi Ben-Jaffel, Vincent Bourrier, Lars A. Buchhave, Ofer Cohen, David Ehrenreich, Antonio García Muñoz, Gregory W. Henry, Heather Knutson, Panayotis Lavaux, Alain Lecavelier des Etangs, Nikole K. Lewis, Mercedes López-Morales, Avi M. Mandell, Jorge Sanz-Forcada, Pascal Tremblin, & Roxana Lupu

Nature 548, 58-61 (03 August 2017)
Conclusions

★ This Library can be used to choose best targets for characterization using JWST.

★ Constrain P-T profiles of various hot Jupiter and warm Neptune exoplanet atmospheres.

★ Detect key molecular species.

★ Constrain various physical and chemical processes like type of condensation, inversions, recirculation factor, metallicity, C/O ratio etc.
Thank You

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If you need any more information on the library/grid please talk to me.