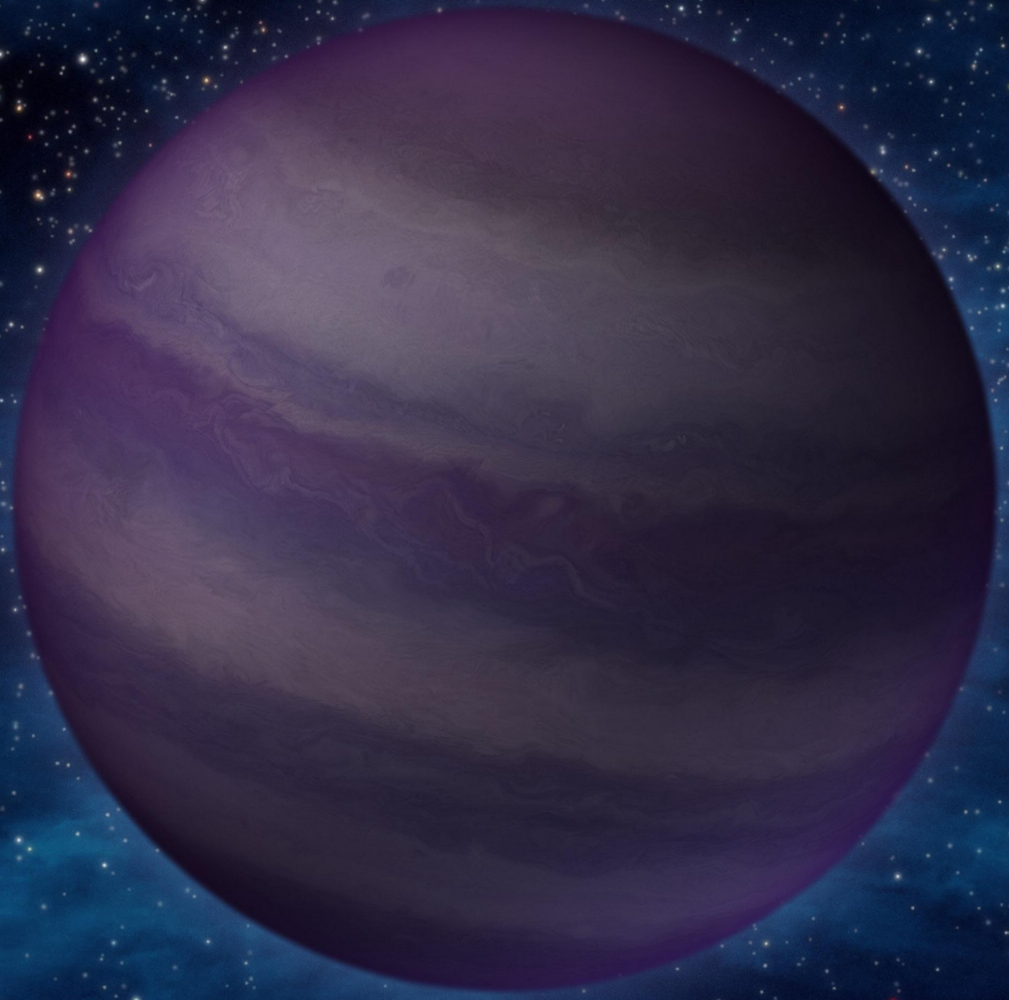
Atmosphere Models for Cool Brown Dwarfs and Giant Exoplanets

Mark Phillips, Isabelle Baraffe, Pascal Tremblin, Gilles Chabrier, Eric Hebrard, Adam Burgasser

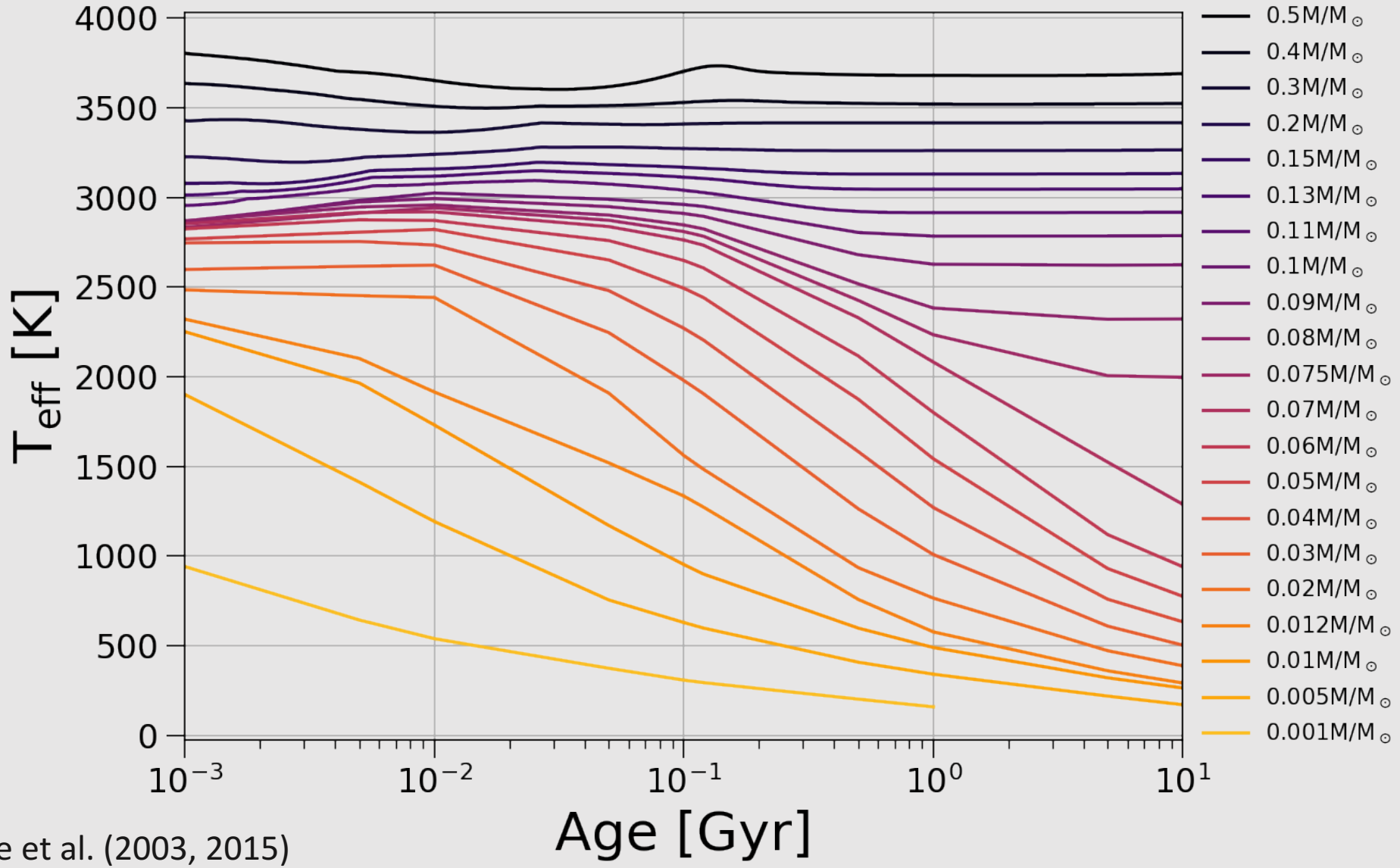


Spectroscopy of Exoplanets
11th July 2018

Contact: mp537@exeter.ac.uk

Science & Technology Facilities Council

Brown Dwarf Evolution



Data from Baraffe et al. (2003, 2015)

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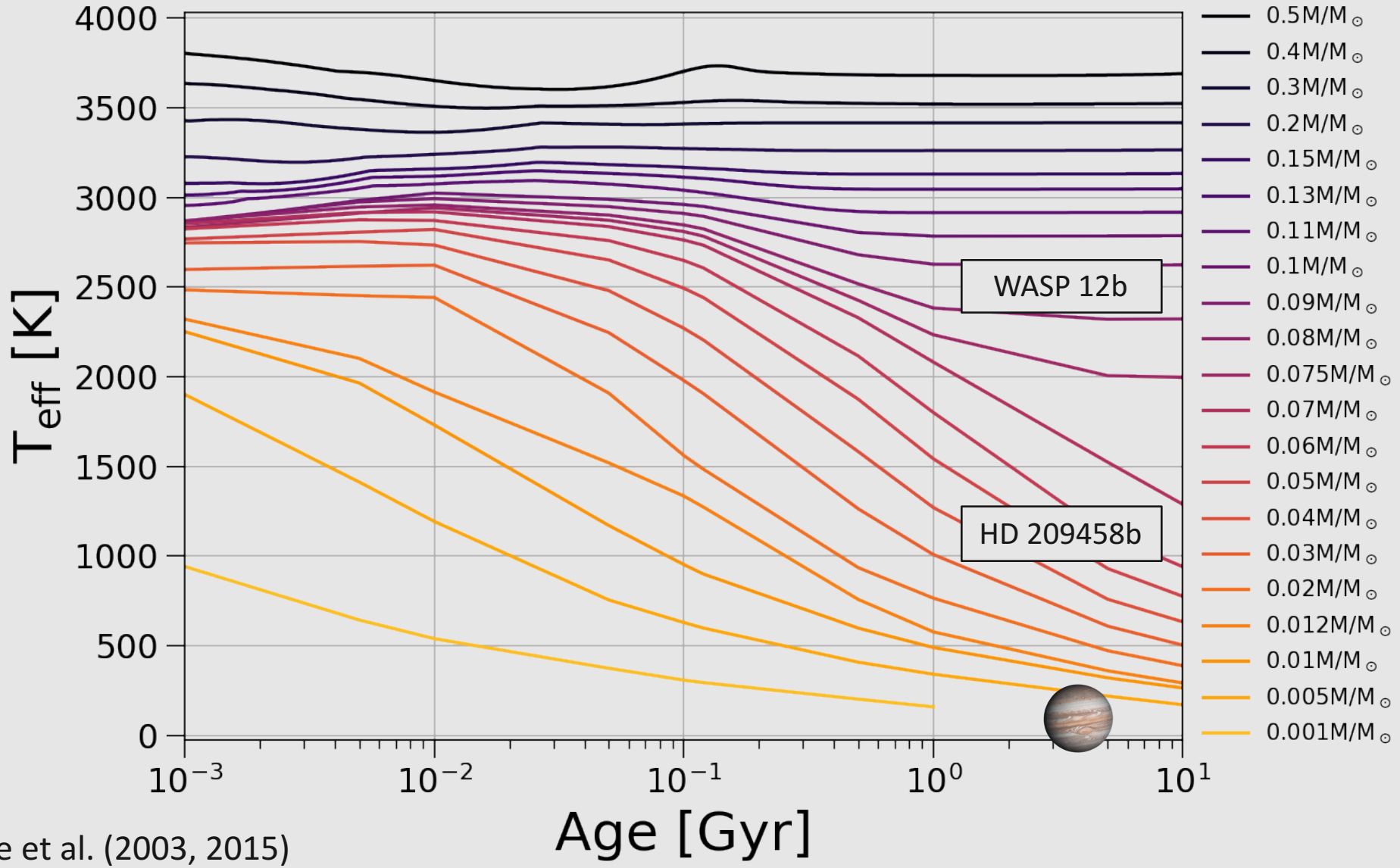

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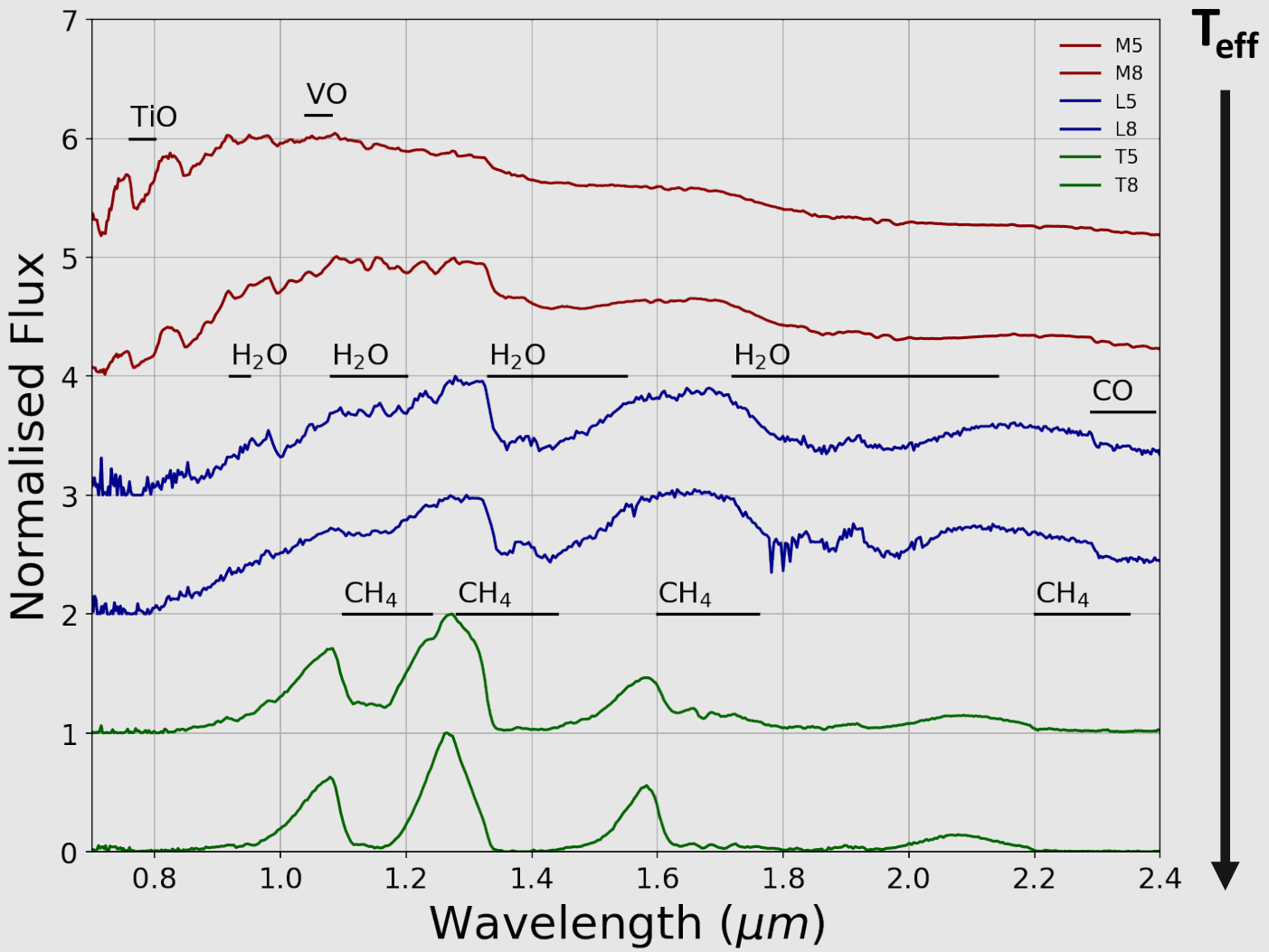
Spectral Types



T_{eff}

M Dwarfs – TiO and VO absorption features in the red optical

L Dwarfs – Absence of TiO and VO features and increasing H_2O bands across the near-infrared

T Dwarfs – Strong CH_4 absorption bands across the near-infrared

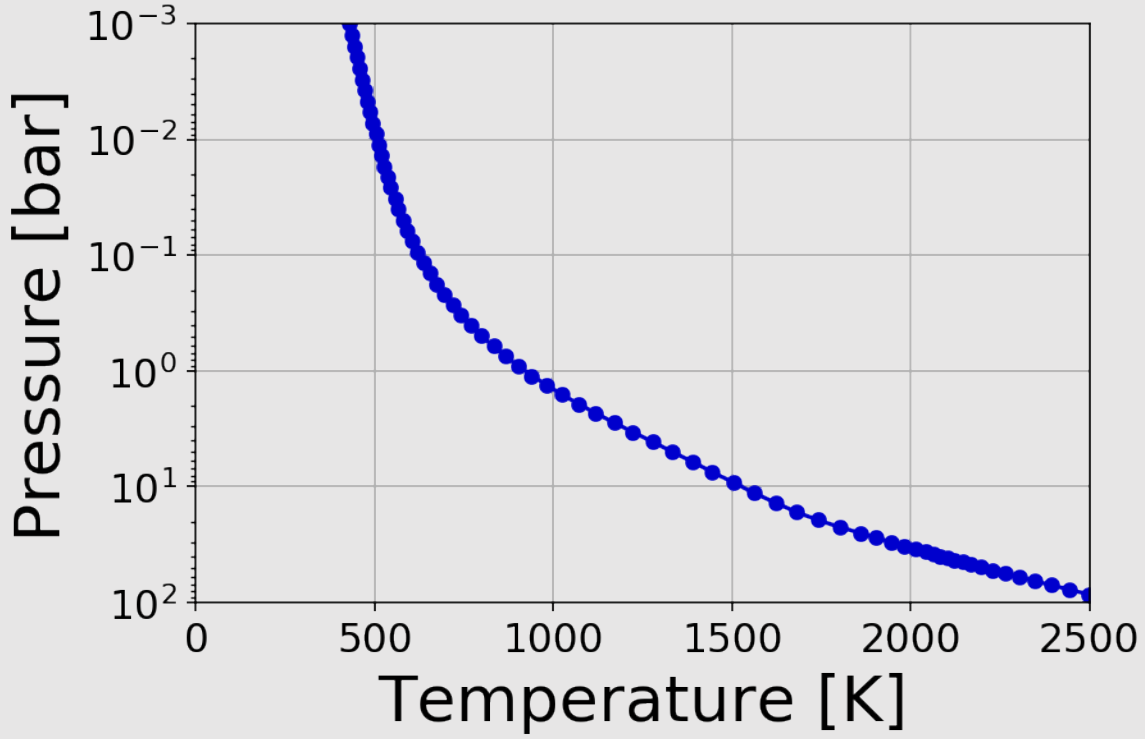
Data from the SpeX Prism Library

ATMO – radiative-convective forward model

ATMO

Solves for the steady state structure of an atmosphere using the Newton-Raphson method

$$F_{rad} + F_{conv} = \sigma T_{eff}^4 \qquad \frac{dP}{dz} = -\rho g$$



Tremblin et al. (2015), Goyal et al. (2017)

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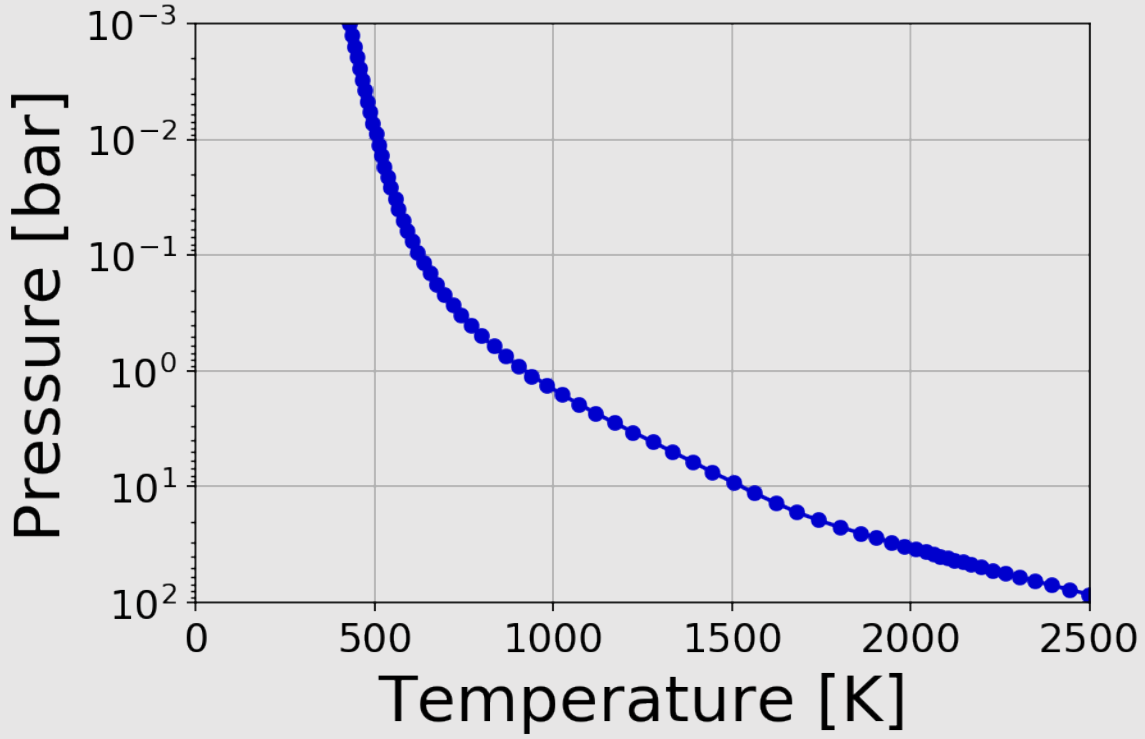

Calculate abundances

Tremblin et al. (2015), Goyal et al. (2017)

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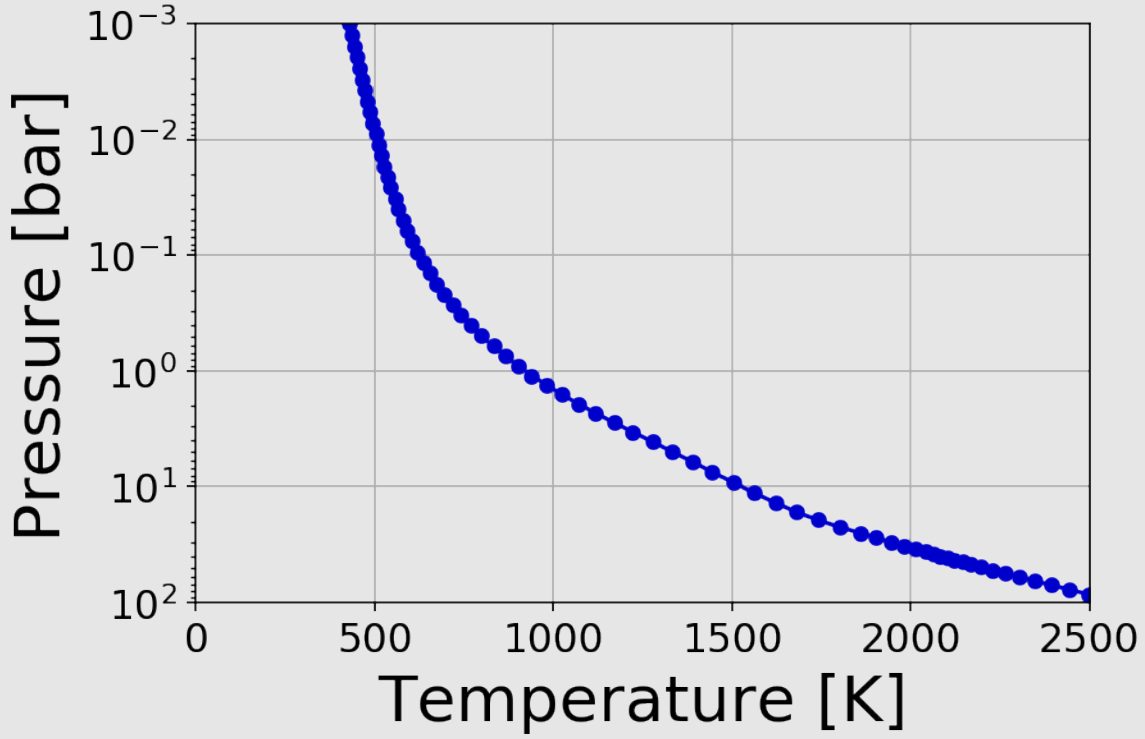

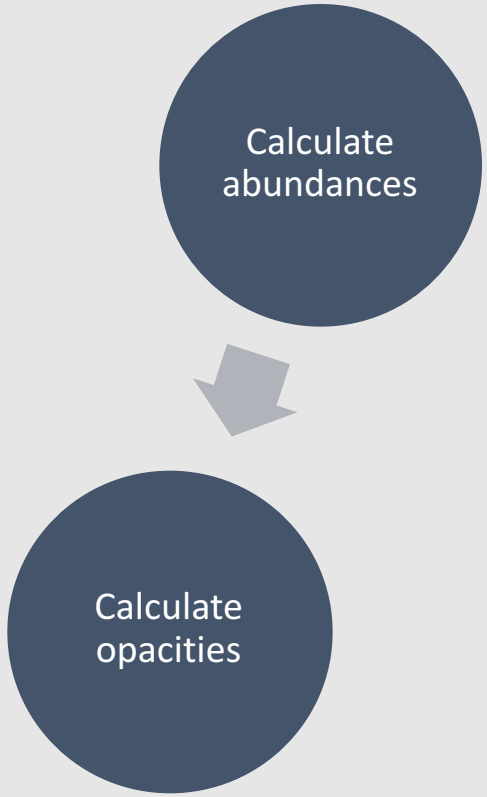

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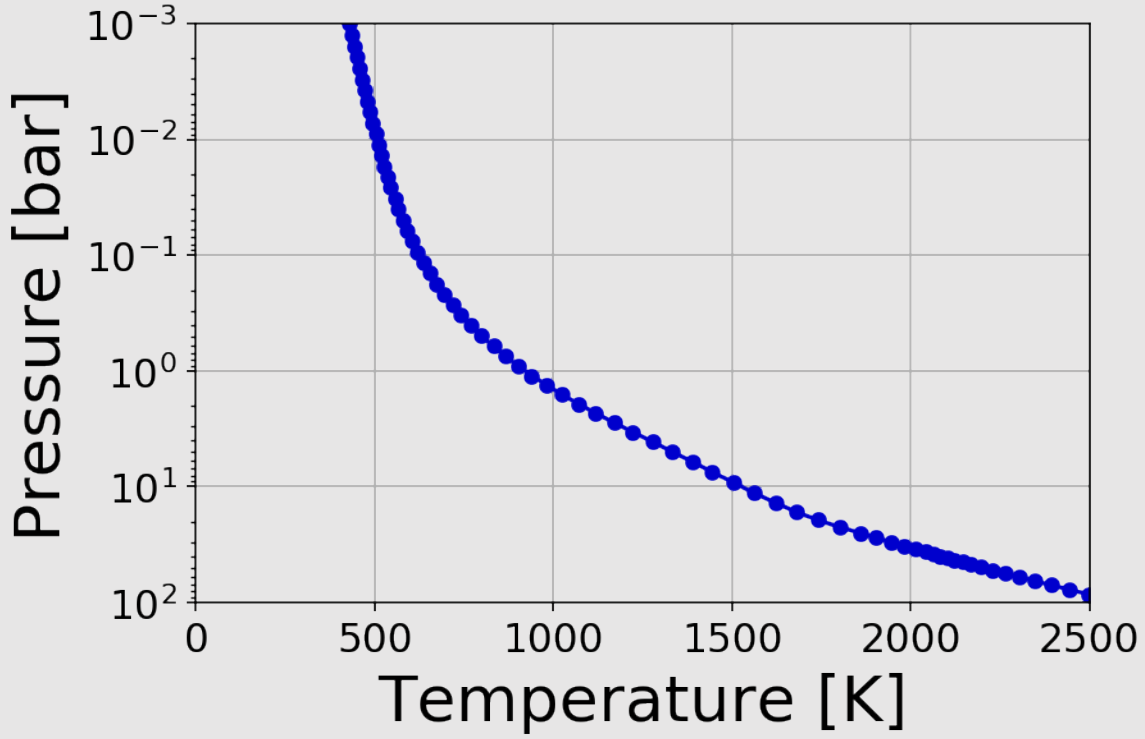

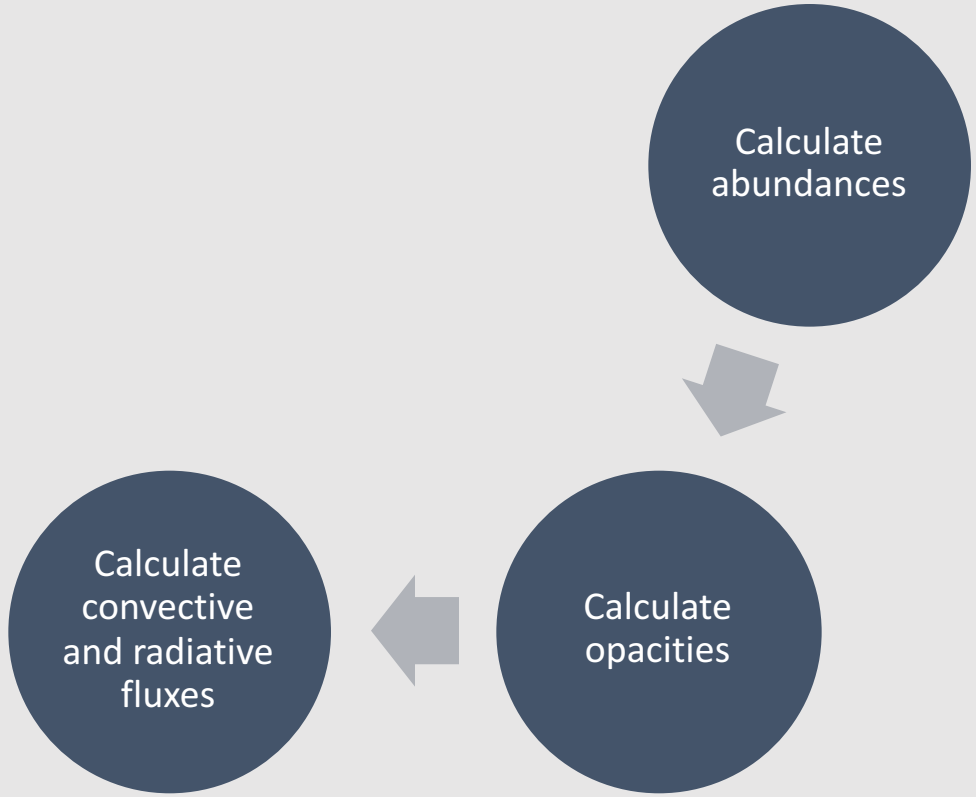

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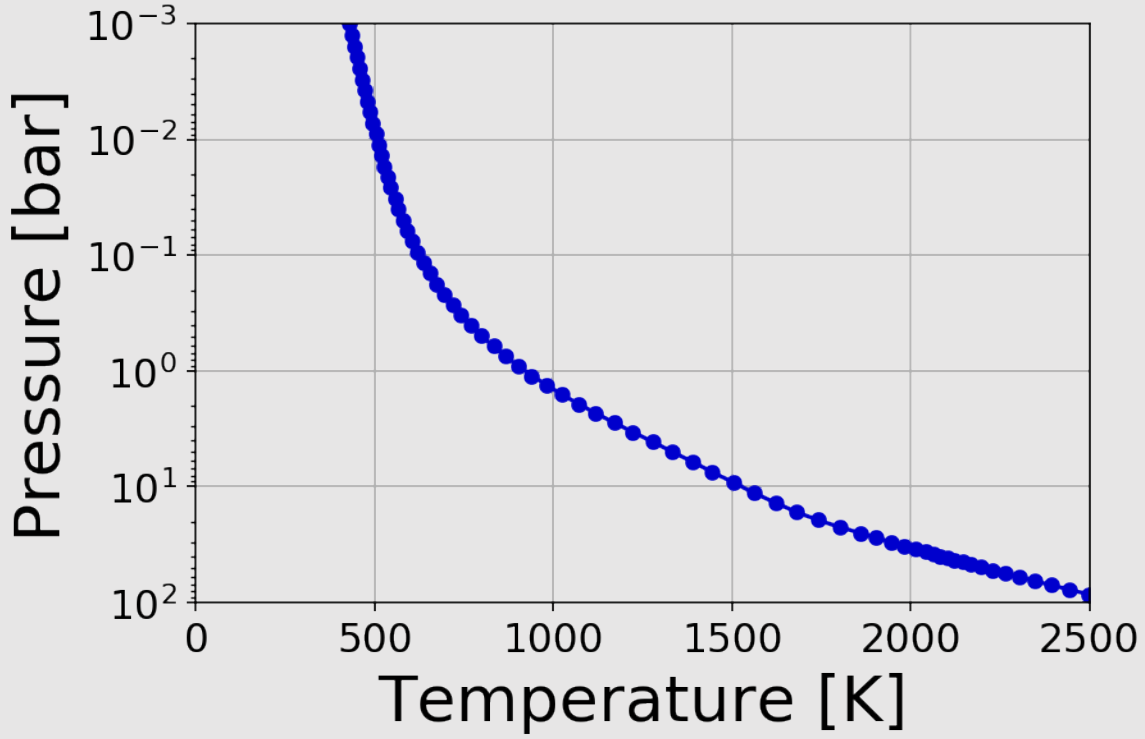

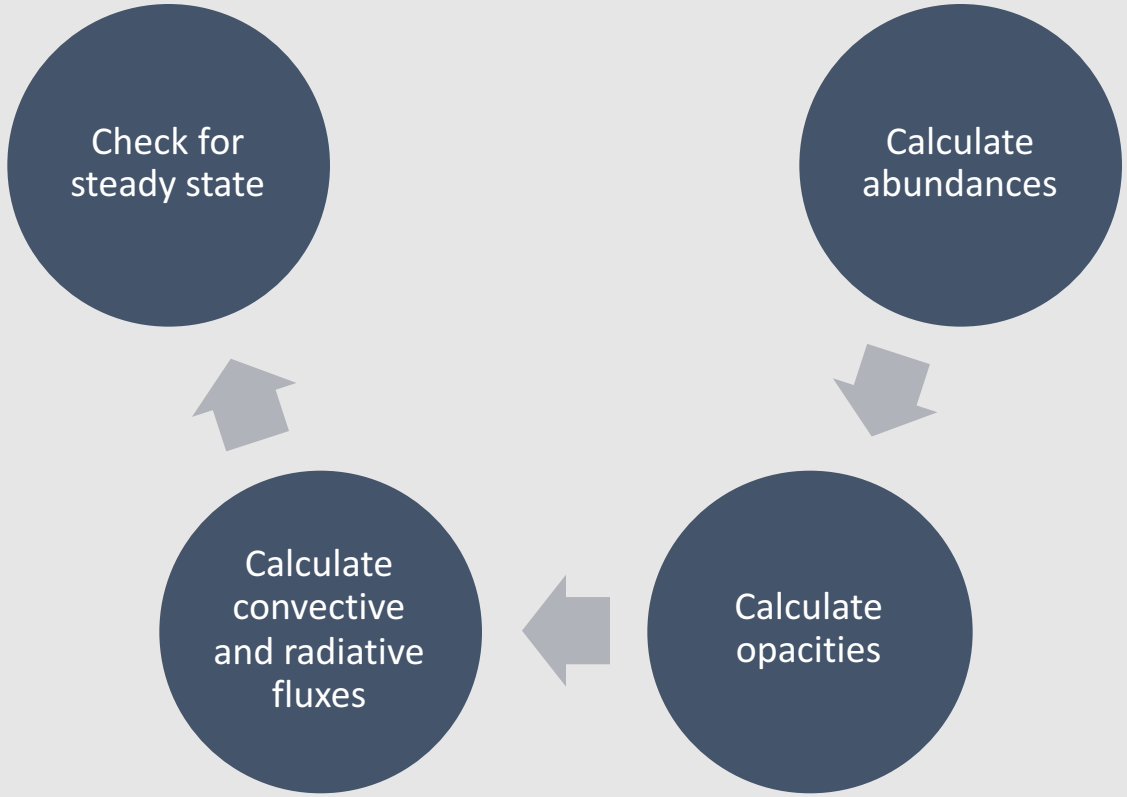

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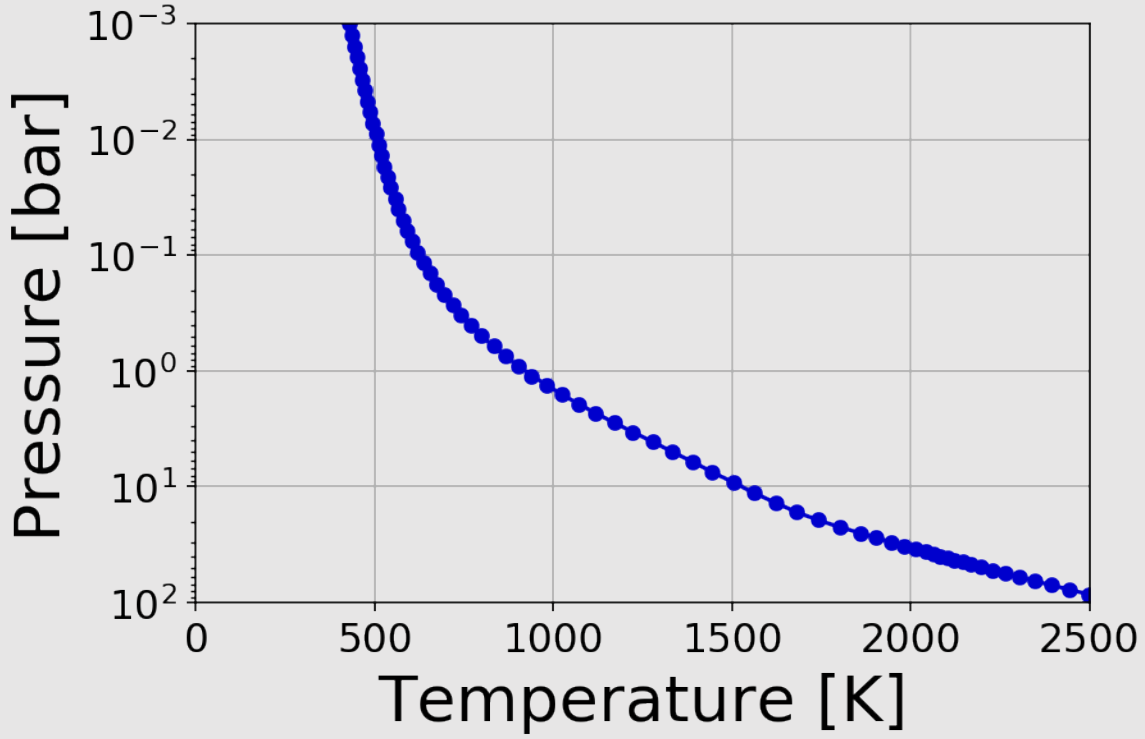

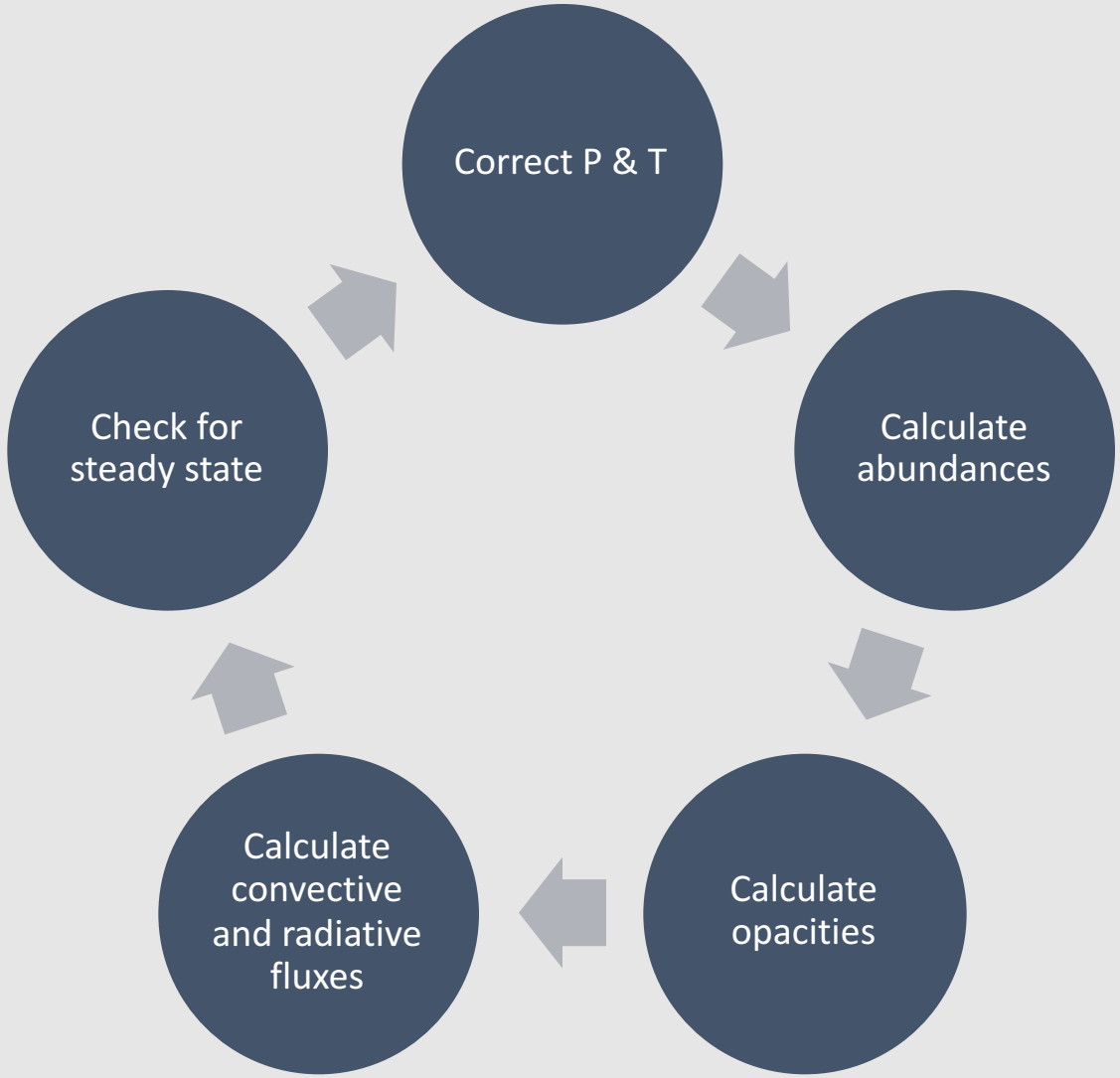

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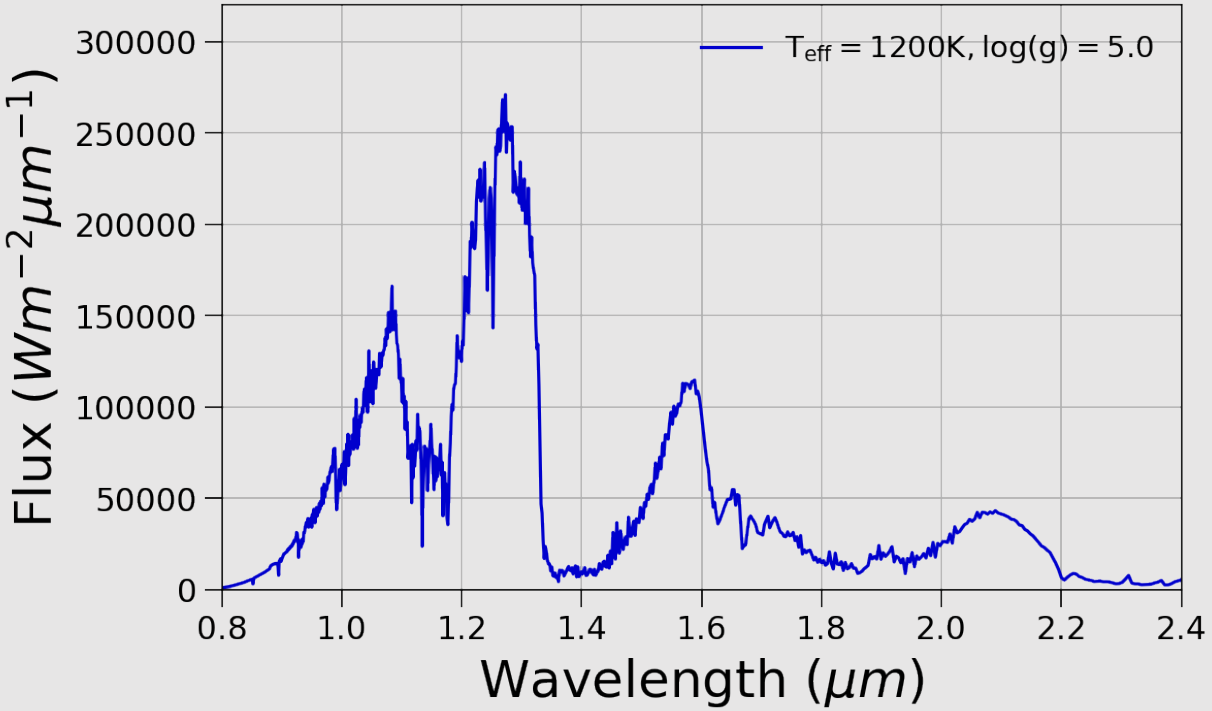

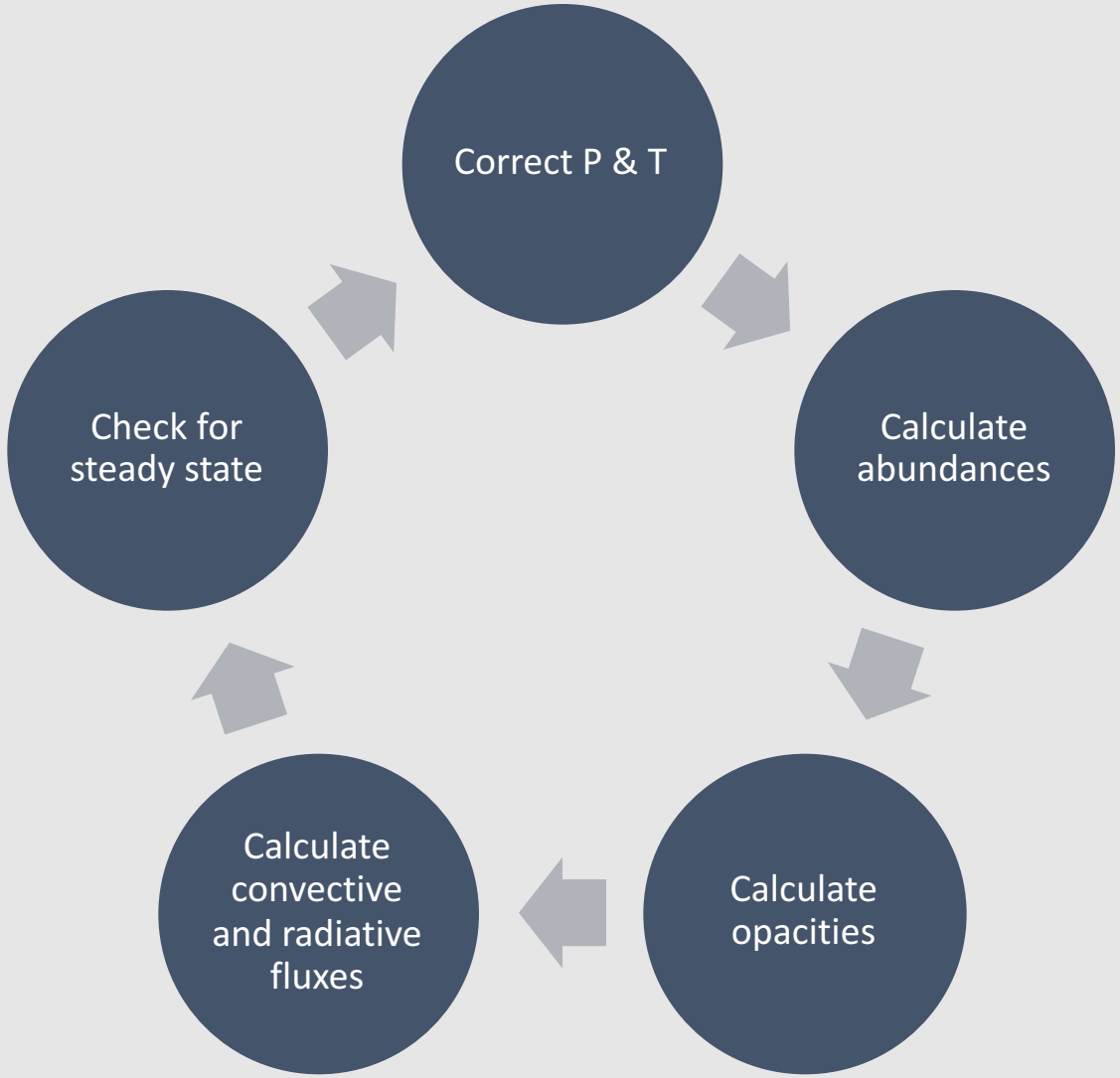

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Opacities

Molecule	AMES-COND – Baraffe et al. (2003)	BT-COND – Allard et al. (2009)	ATMO – Tremblin et al. (2015)
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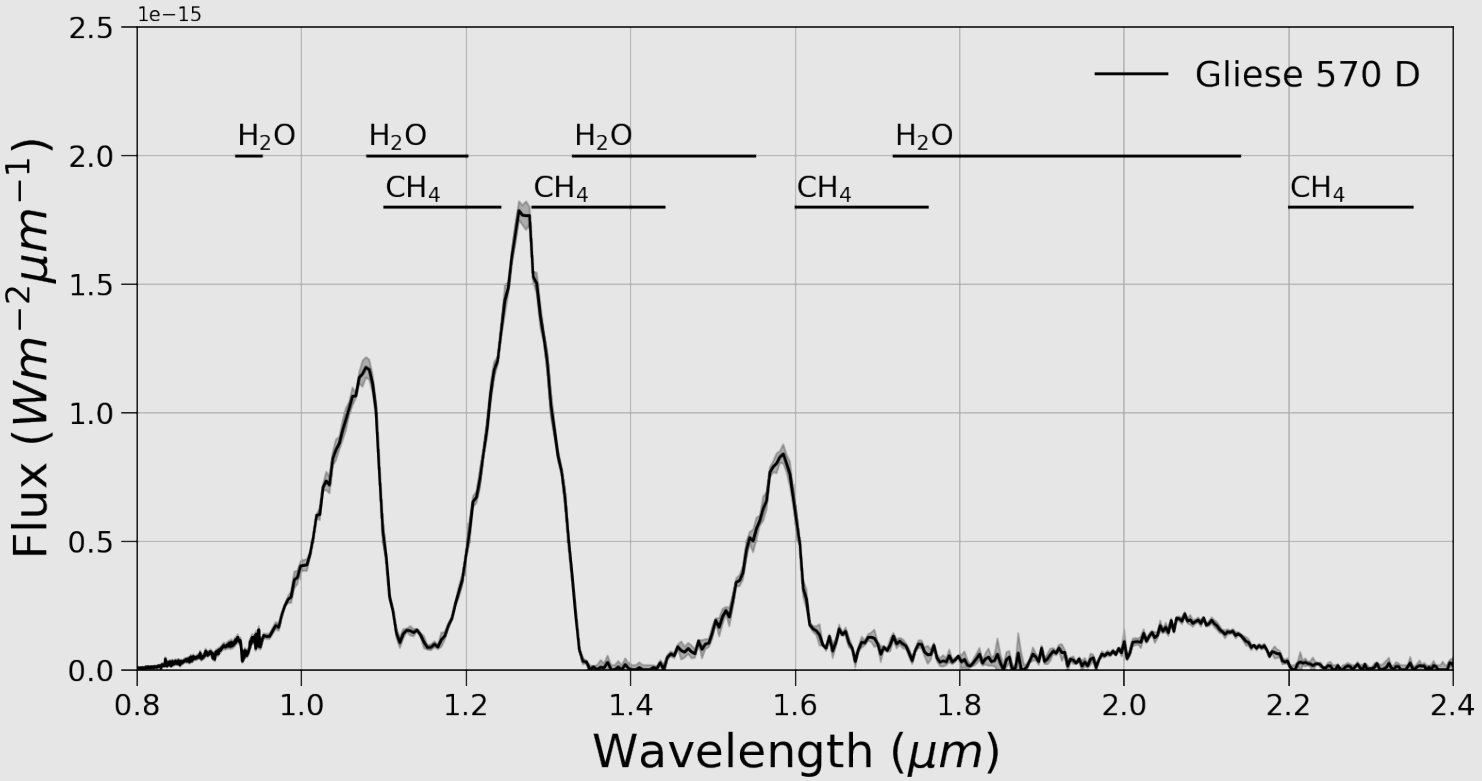

SpeX spectrum from Burgasser et al. (2004)

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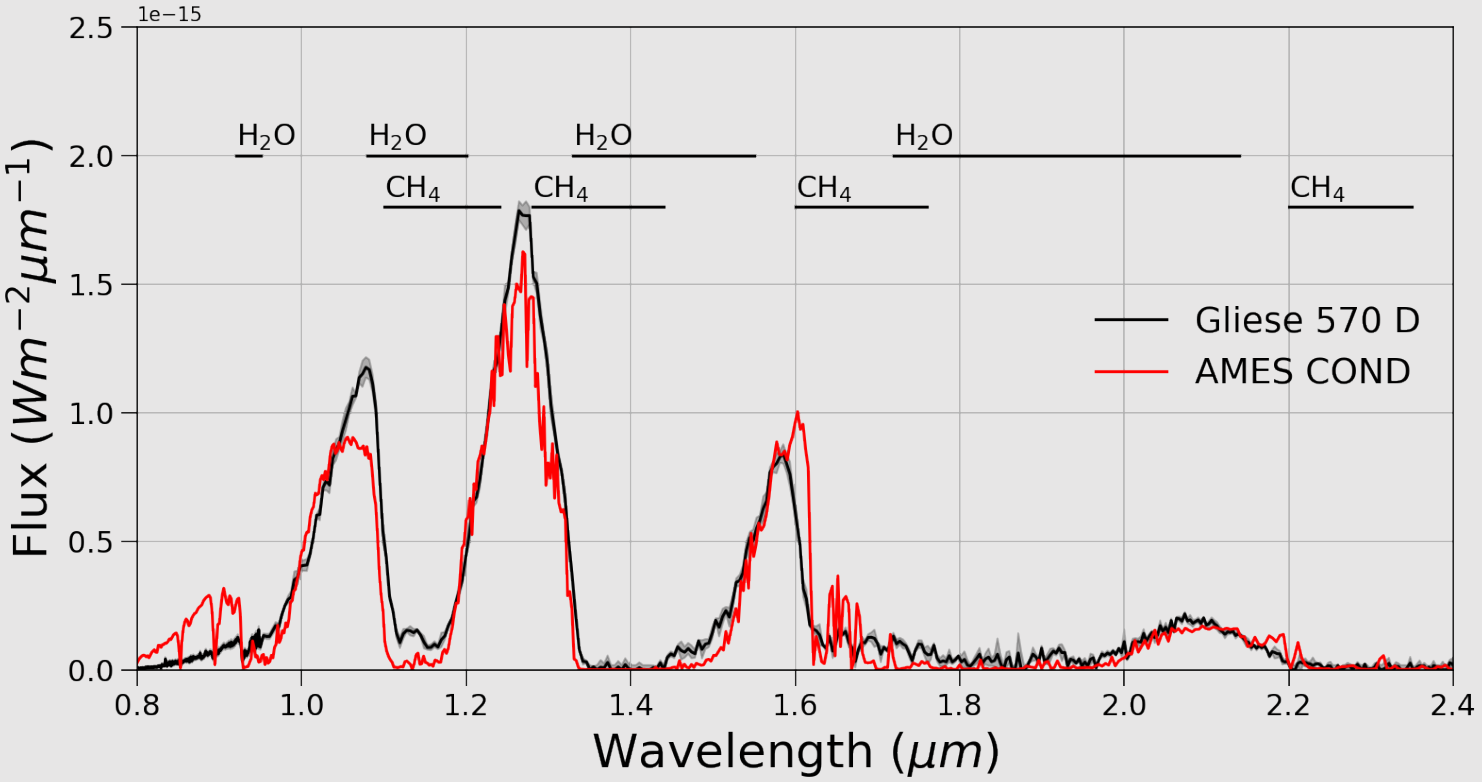

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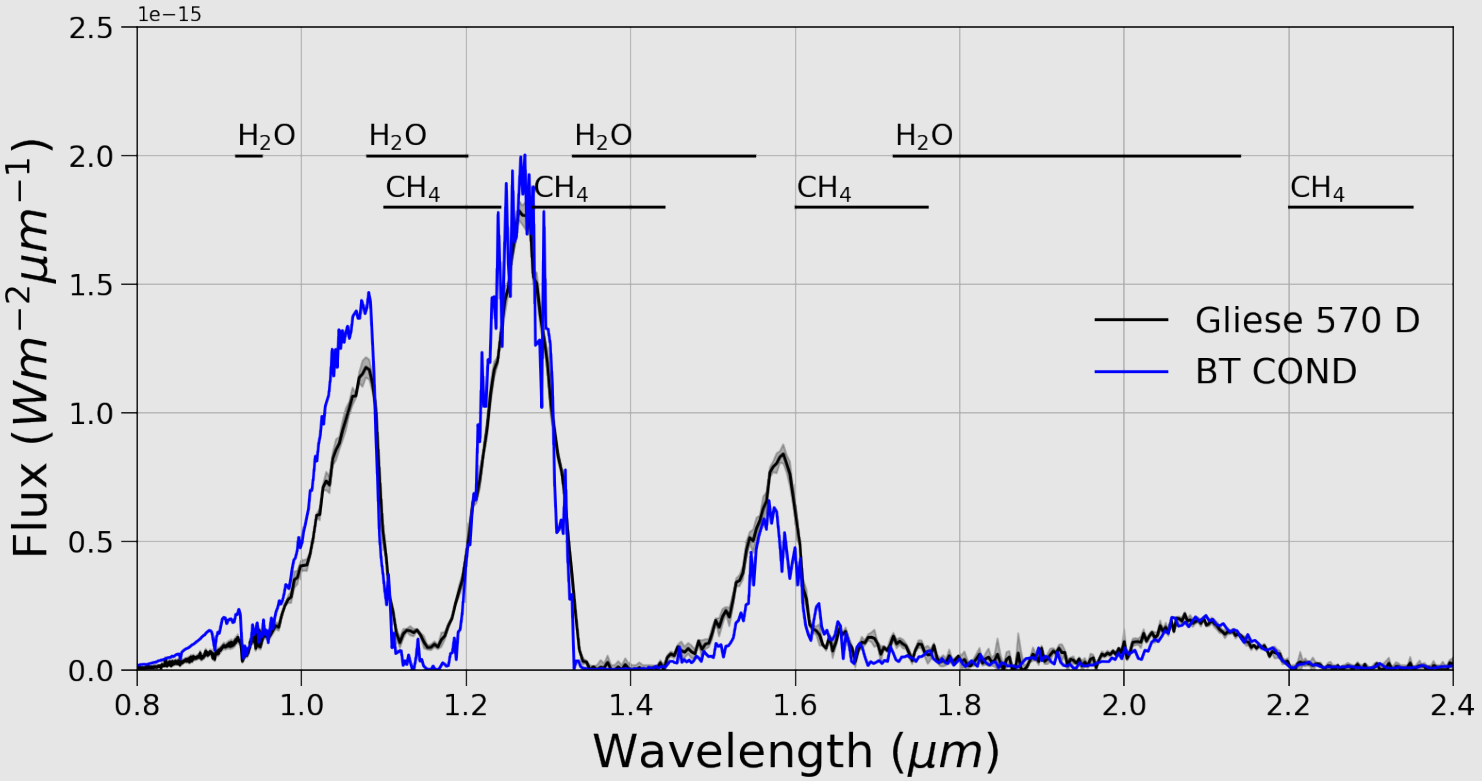

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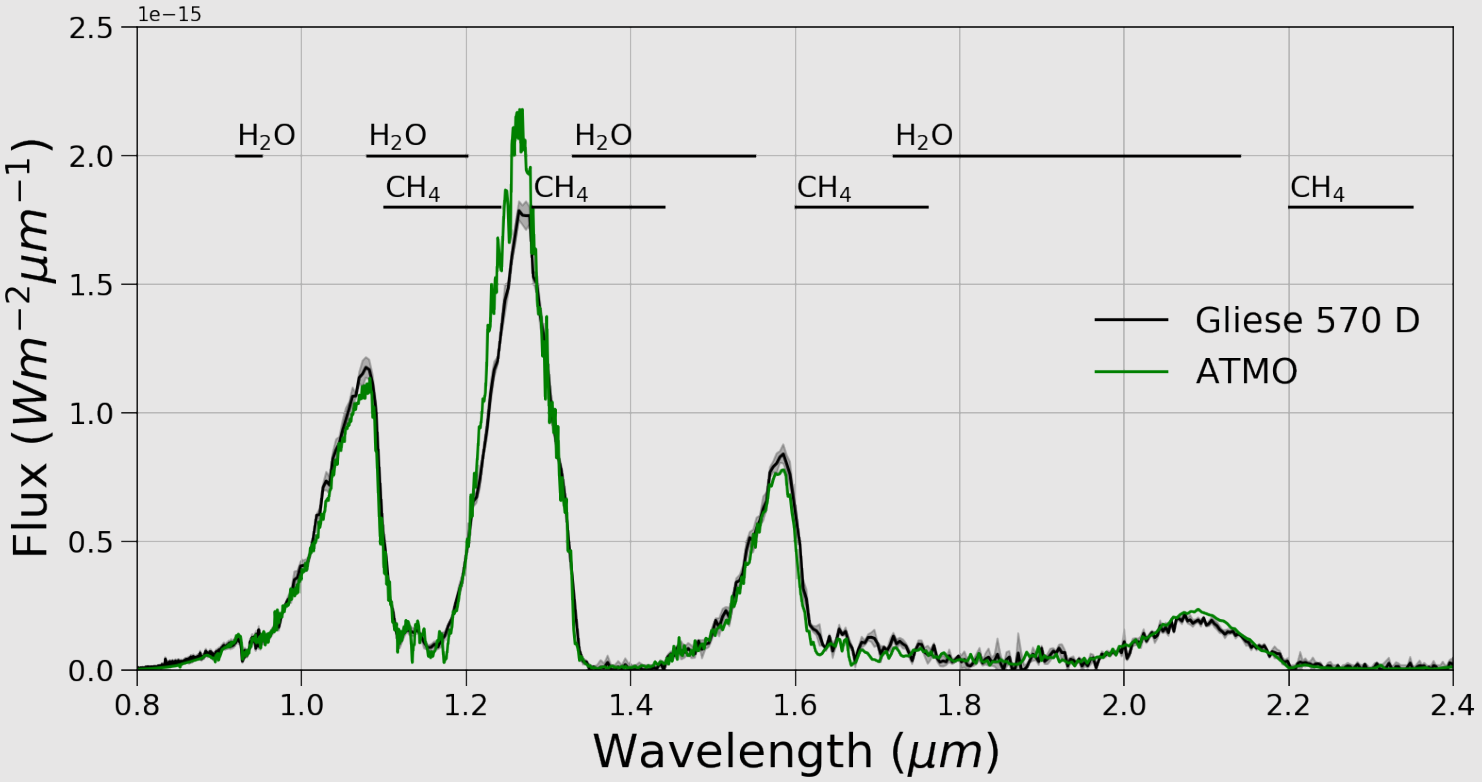
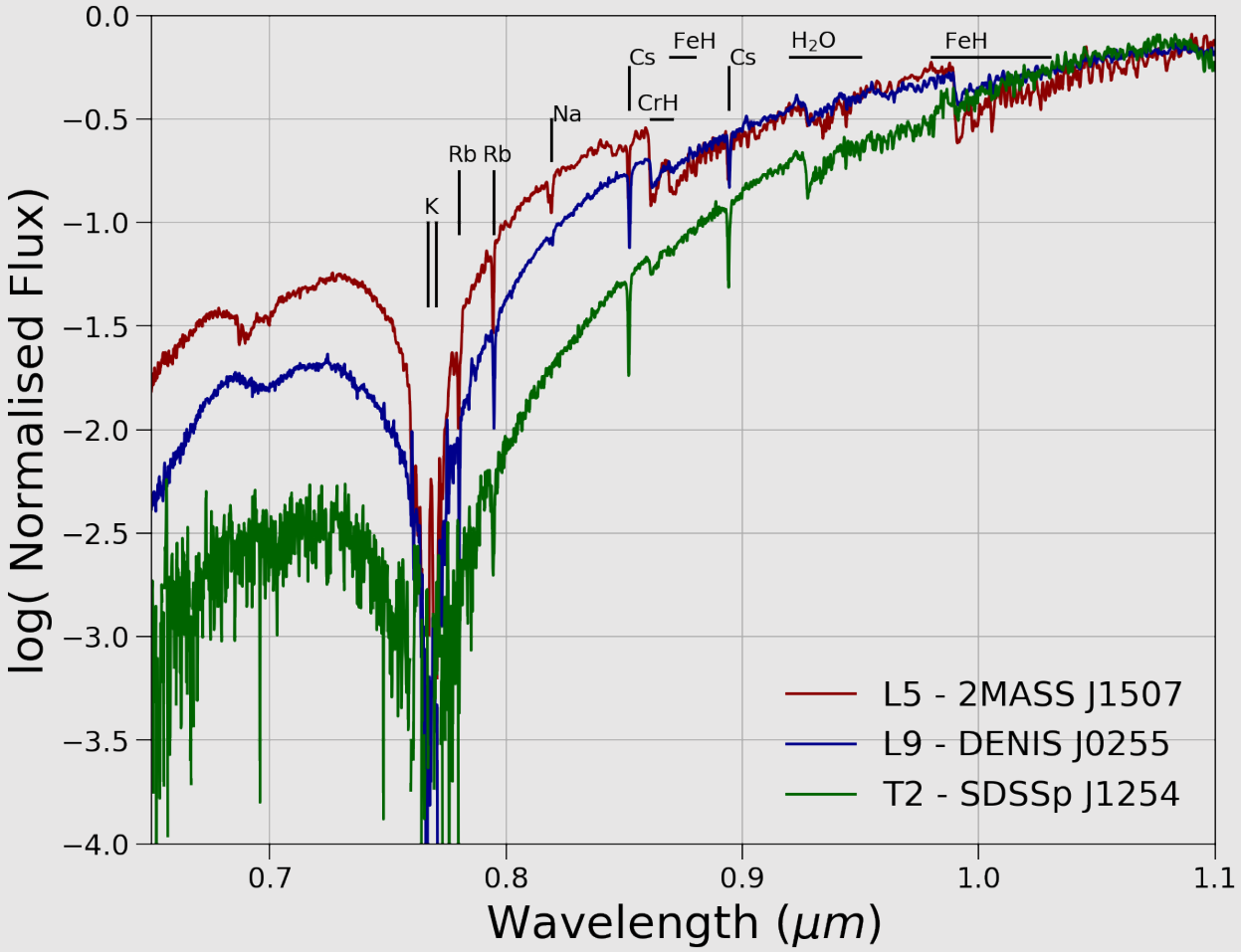
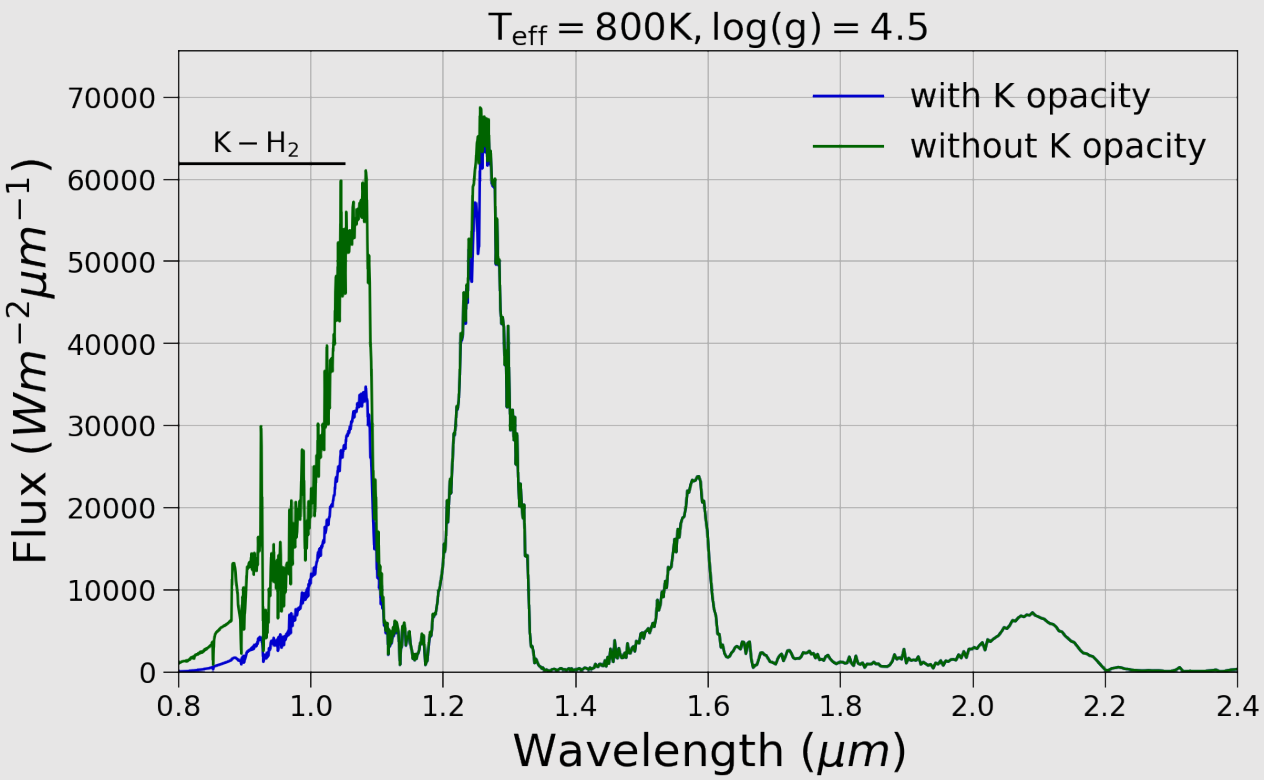


SpeX spectrum from Burgasser et al. (2004)

Potassium in brown dwarfs



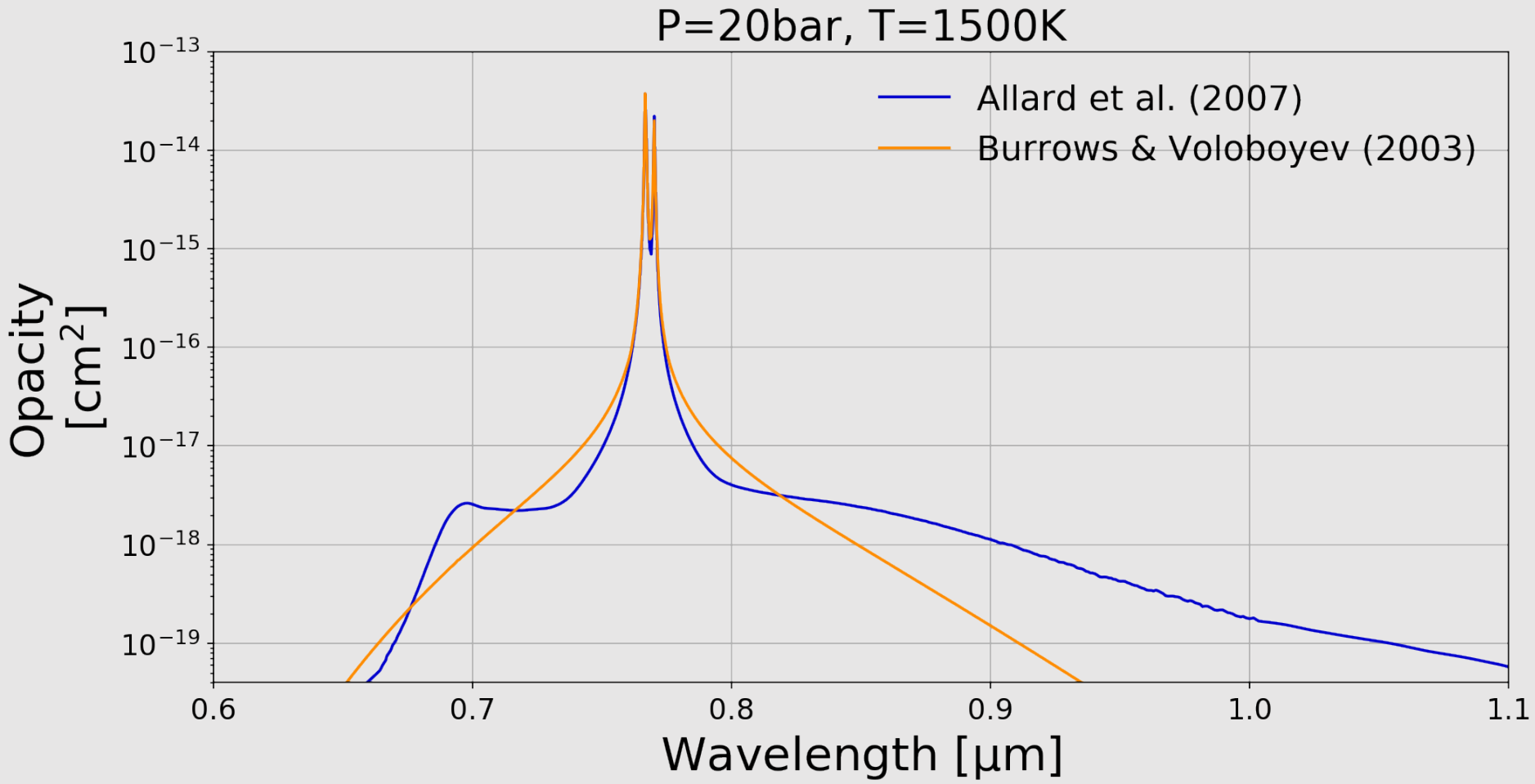


Optical spectra - Kirkpatrick et al. (1999, 2000),
Burgasser et al. (2003)

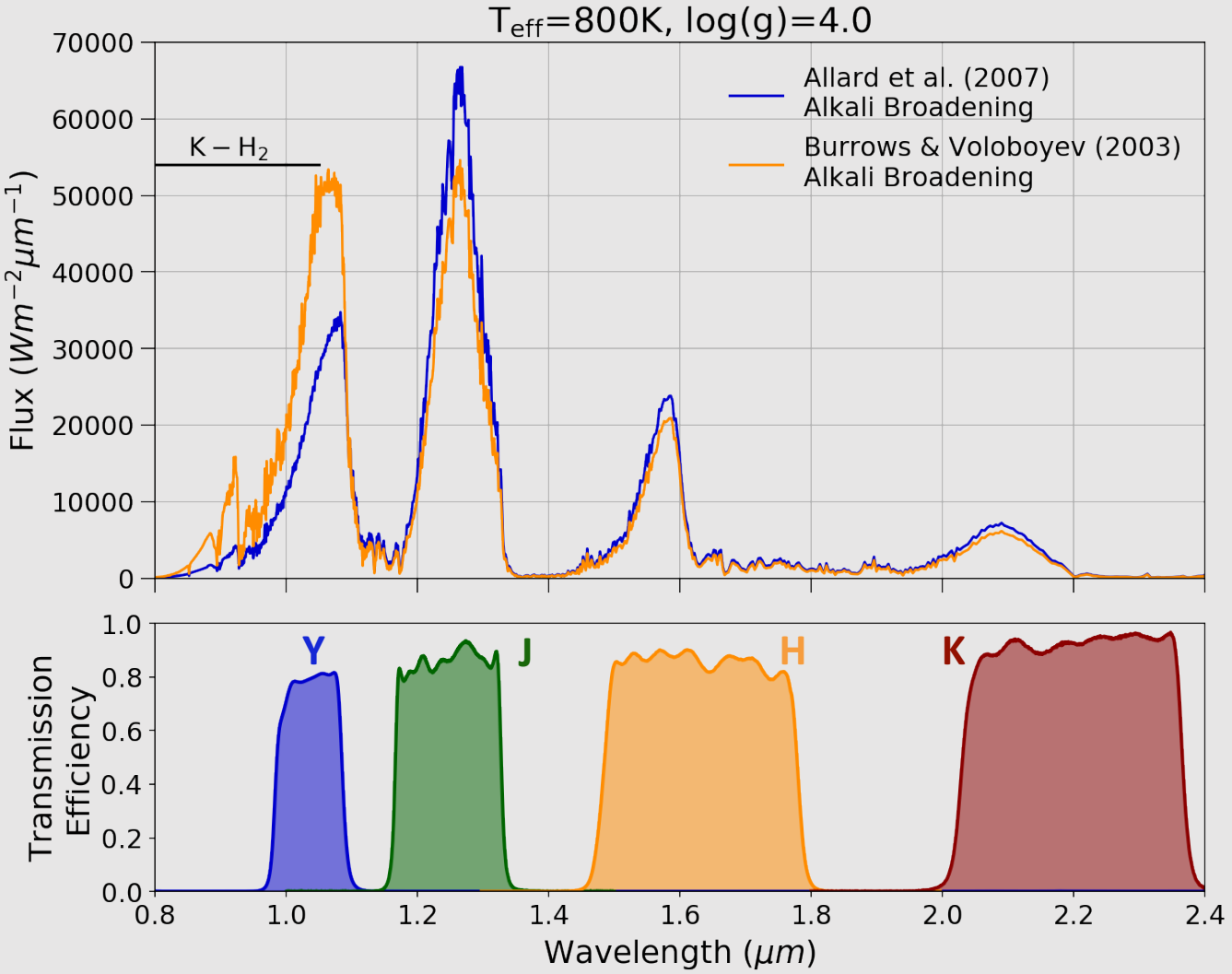
Potassium Opacity

Allard et al. (2007) – Unified line shape theory using molecular potentials calculated using a valence pseudo potential

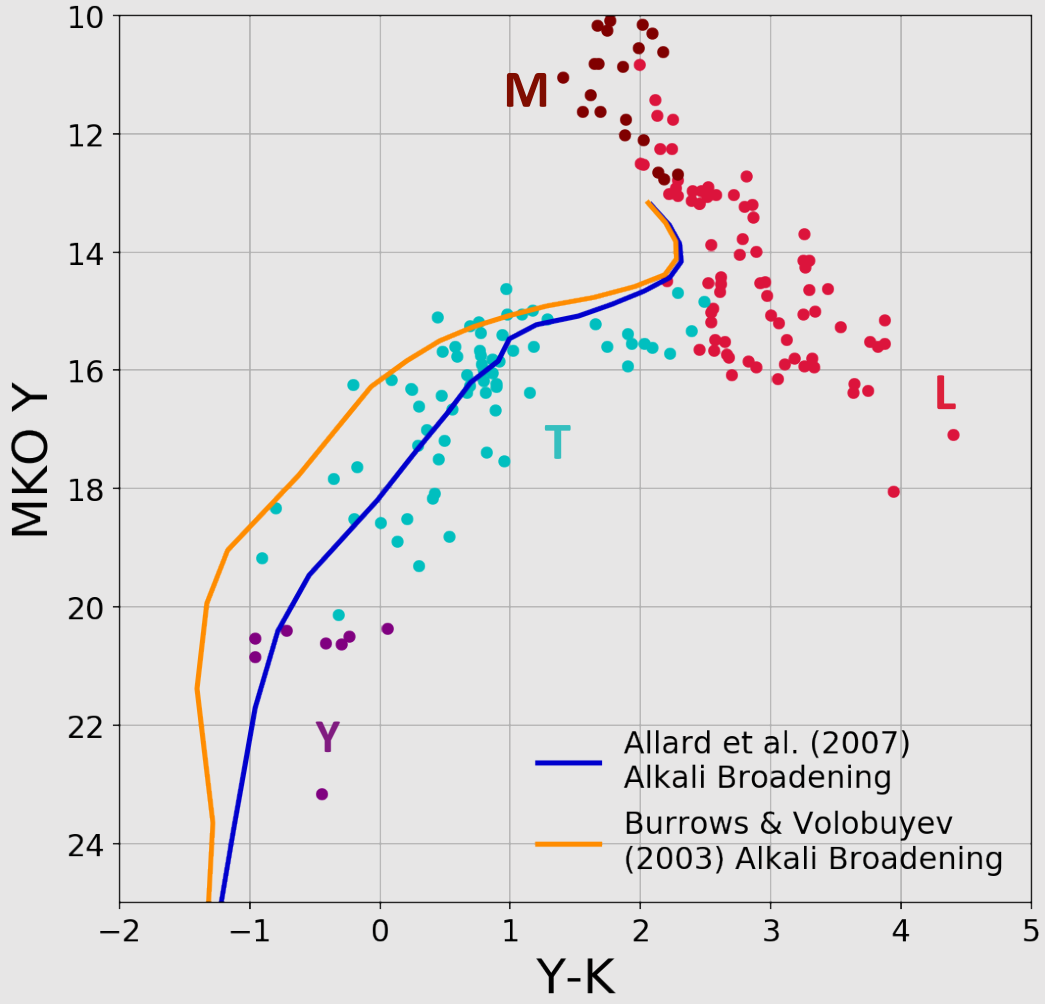
Burrows & Volobuyev (2003) – Unified Franck-Condon model in the quasi-static limit to calculate interaction potentials



Model Comparisons

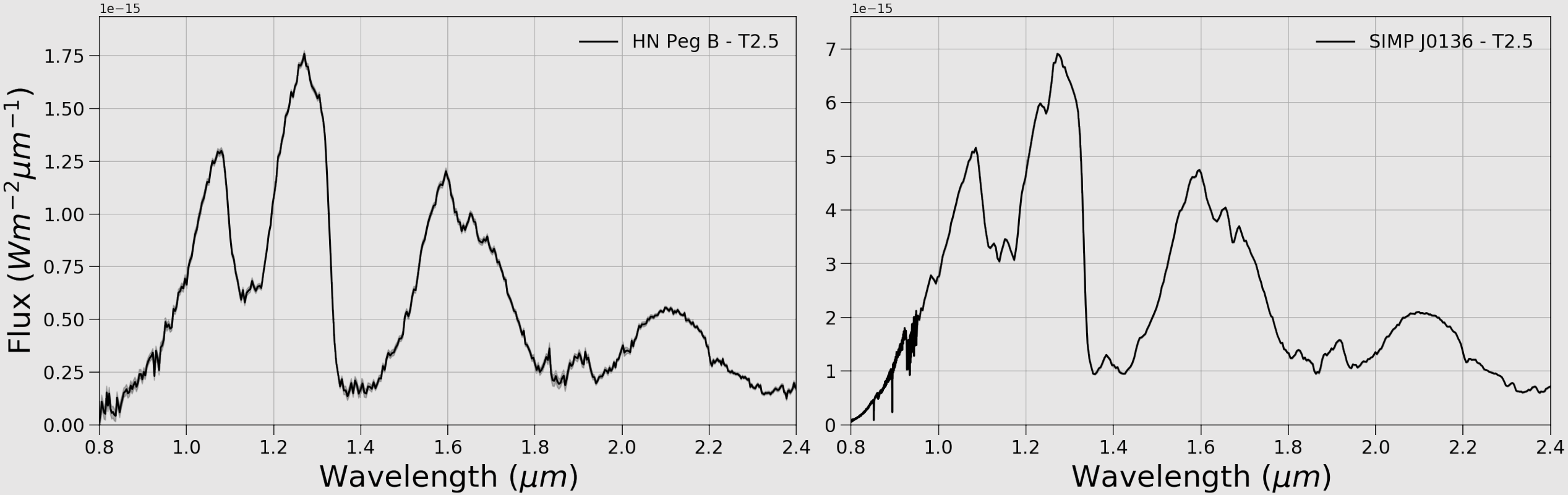


Phillips et al. in prep



Photometry from the Database of Ultracool Parallaxes maintained by Trent Dupuy

Early T dwarfs



NIR spectra from Luhman et al. (2007), Burgasser et al. (2008)

Models with modified thermal structures following Tremblin et al. (2015, 2016, 2017)

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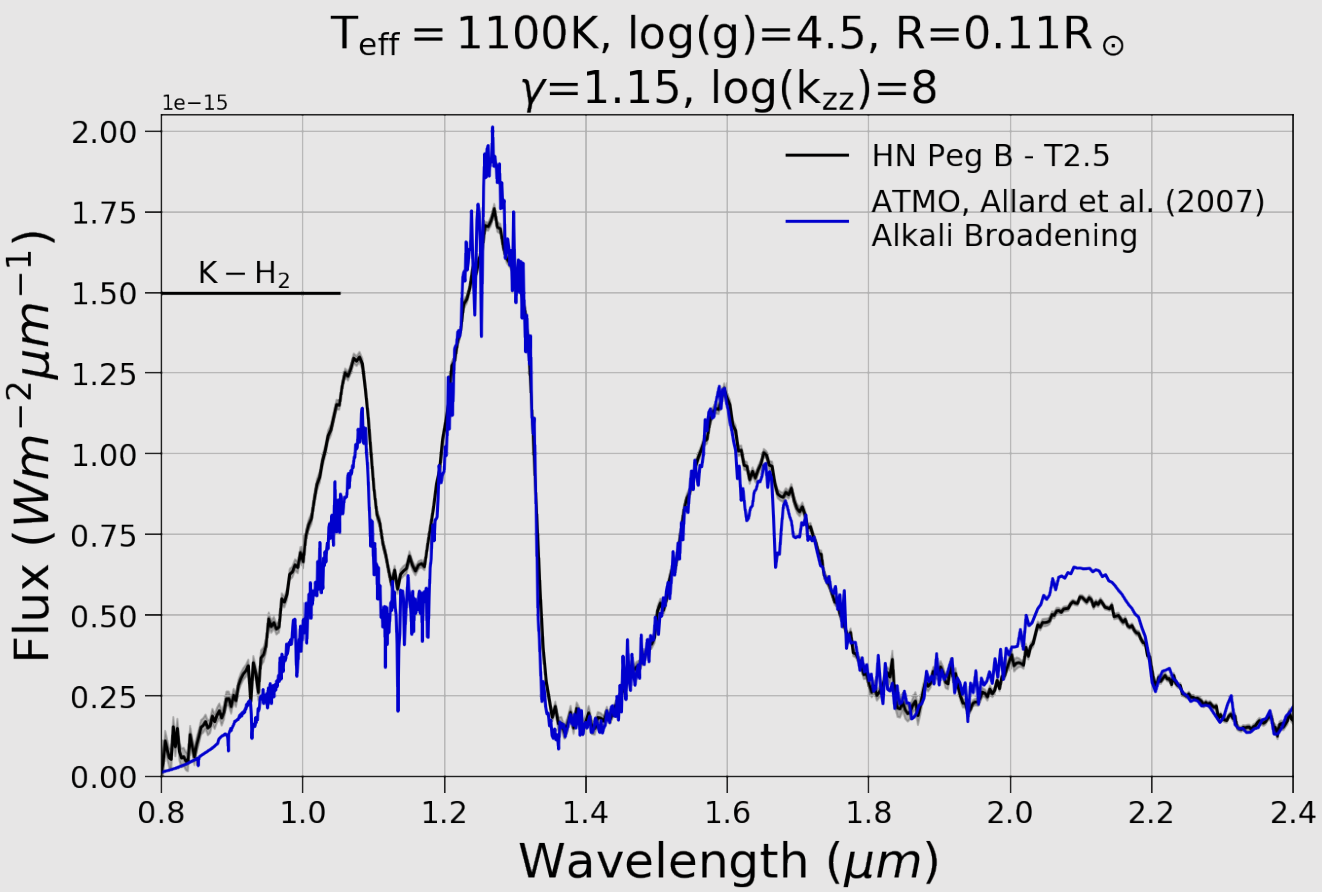

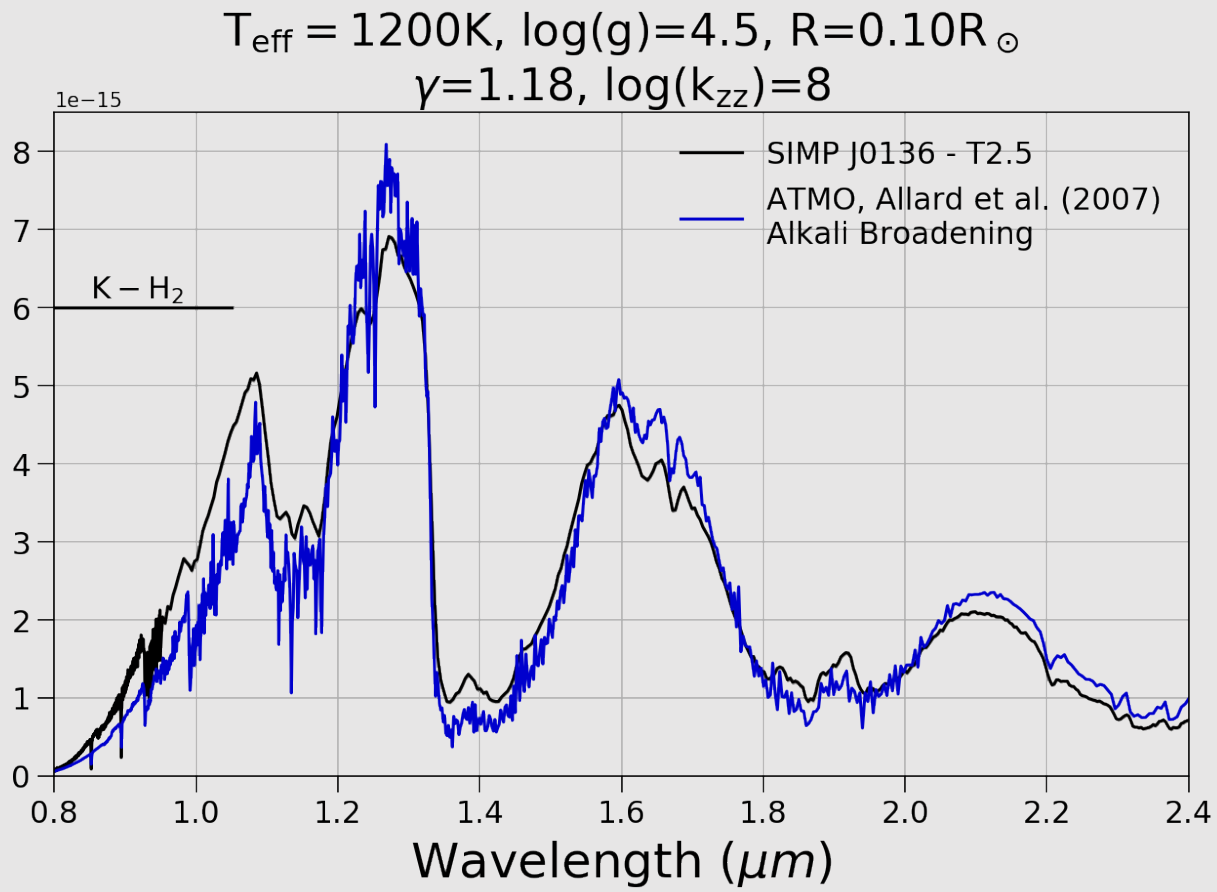

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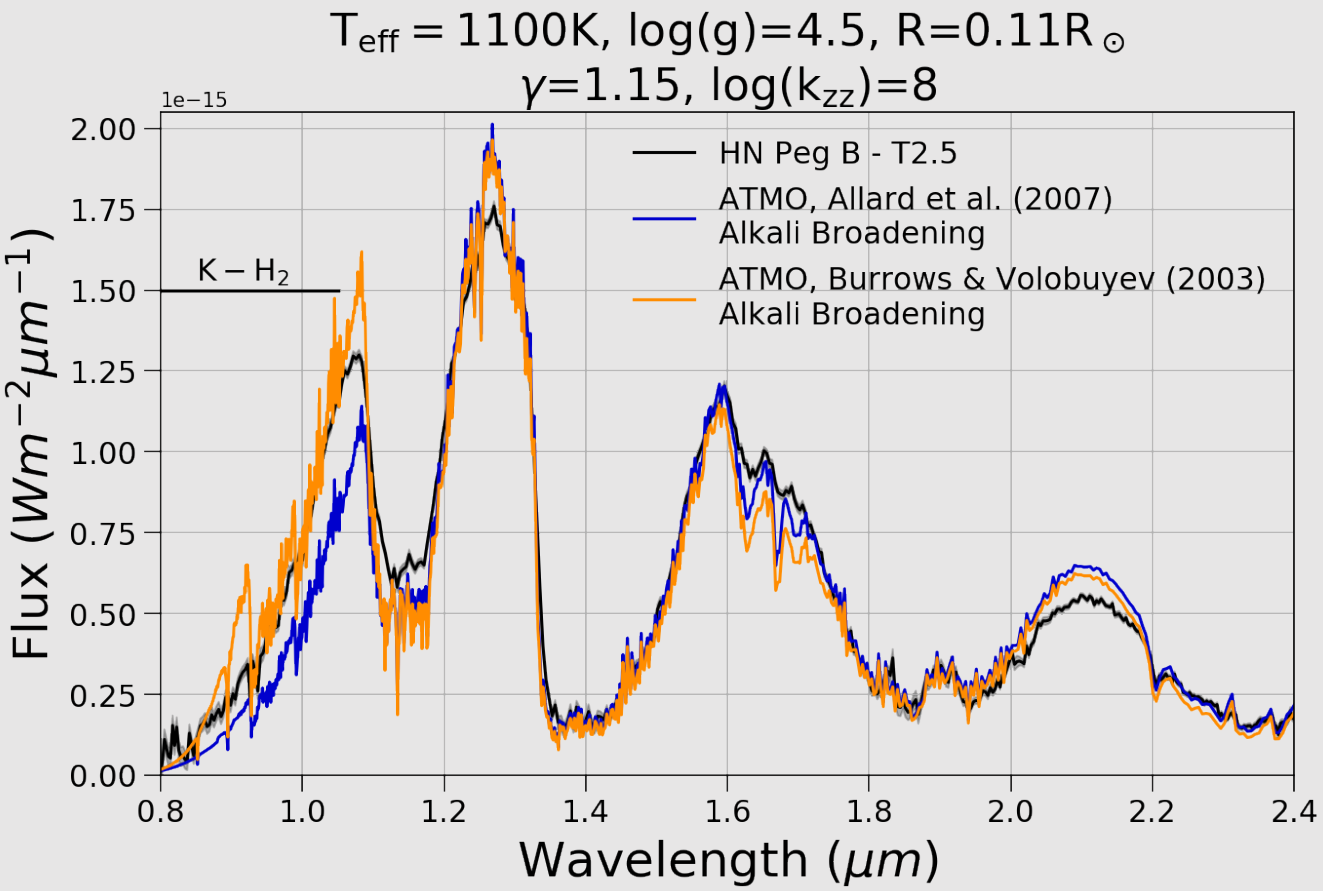

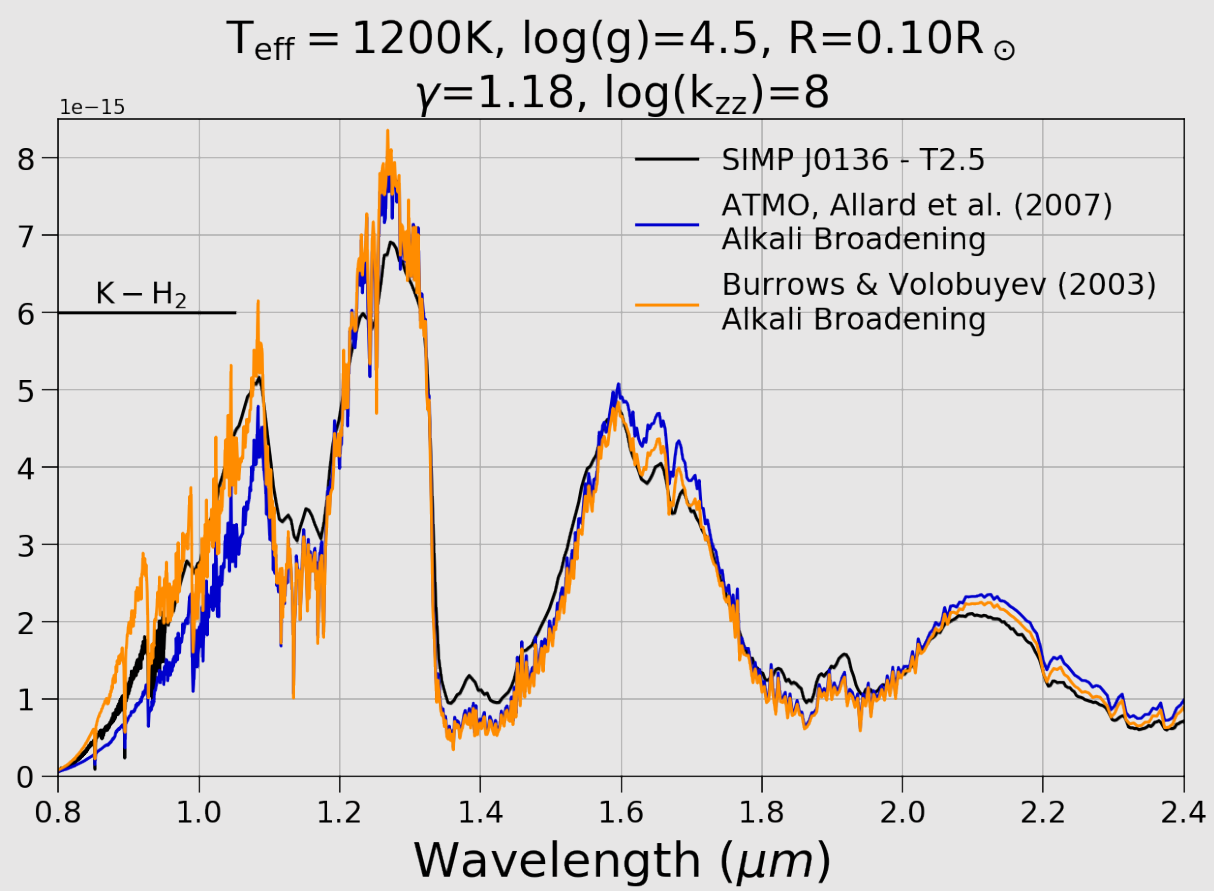

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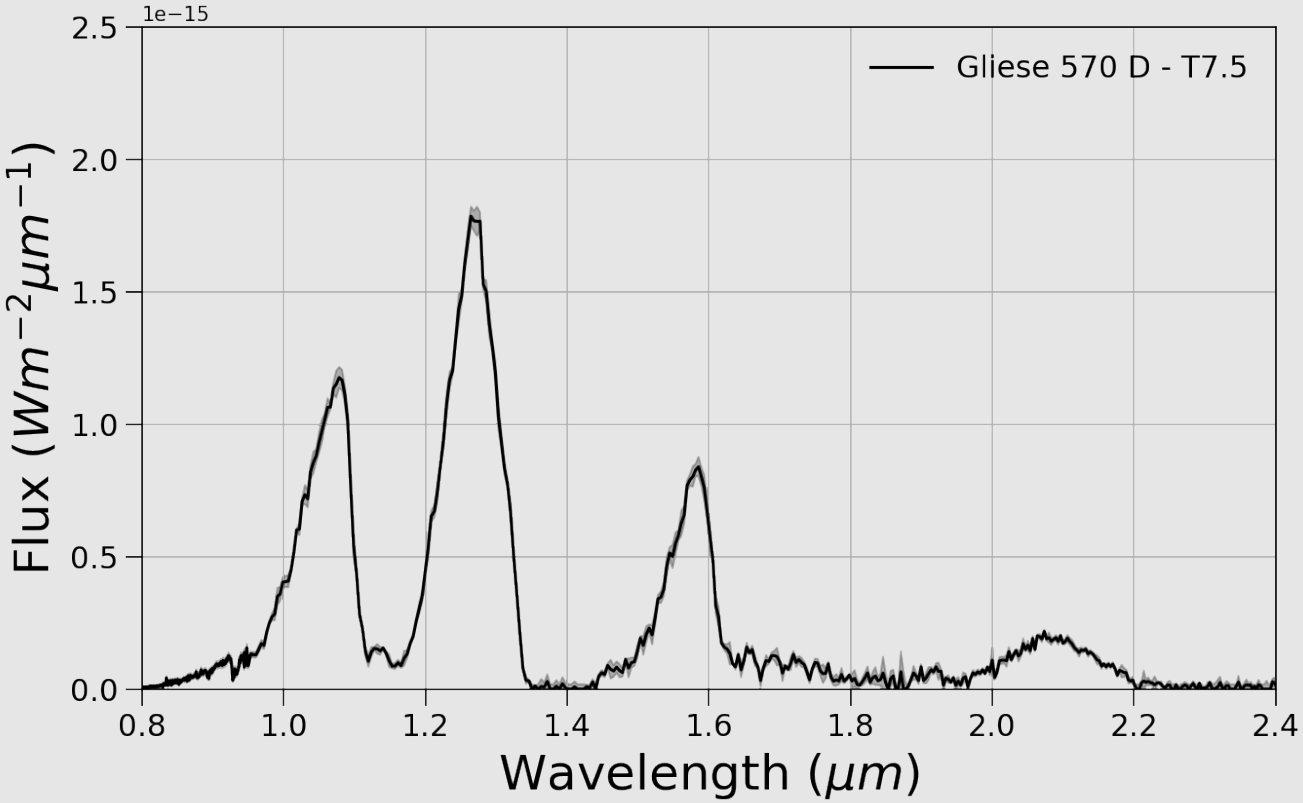

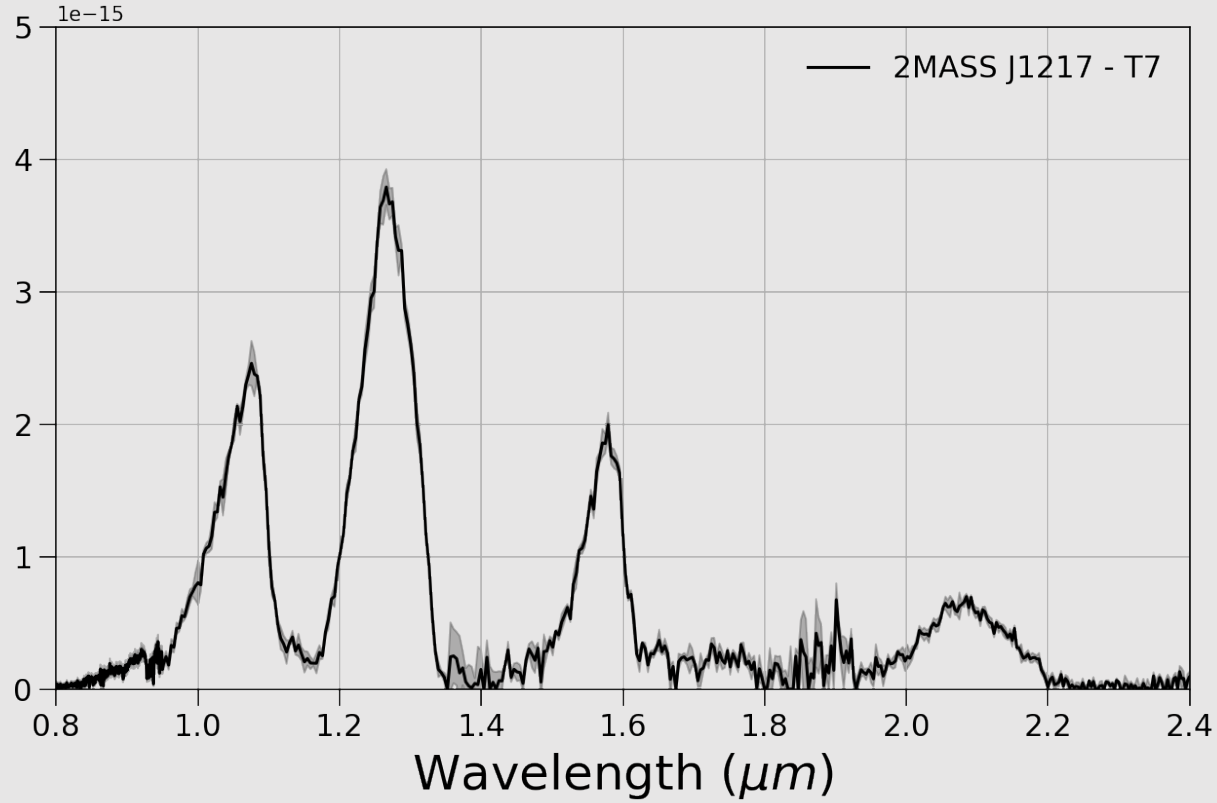

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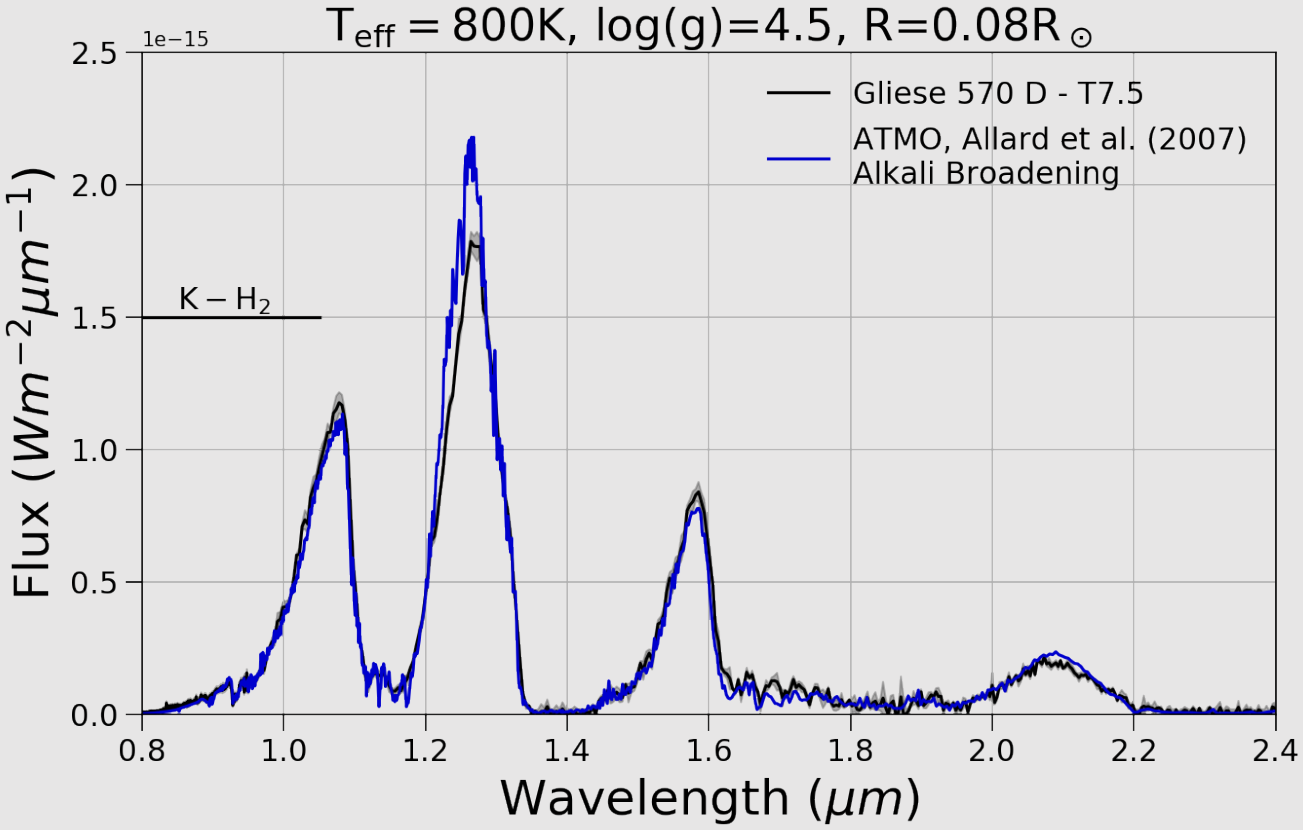

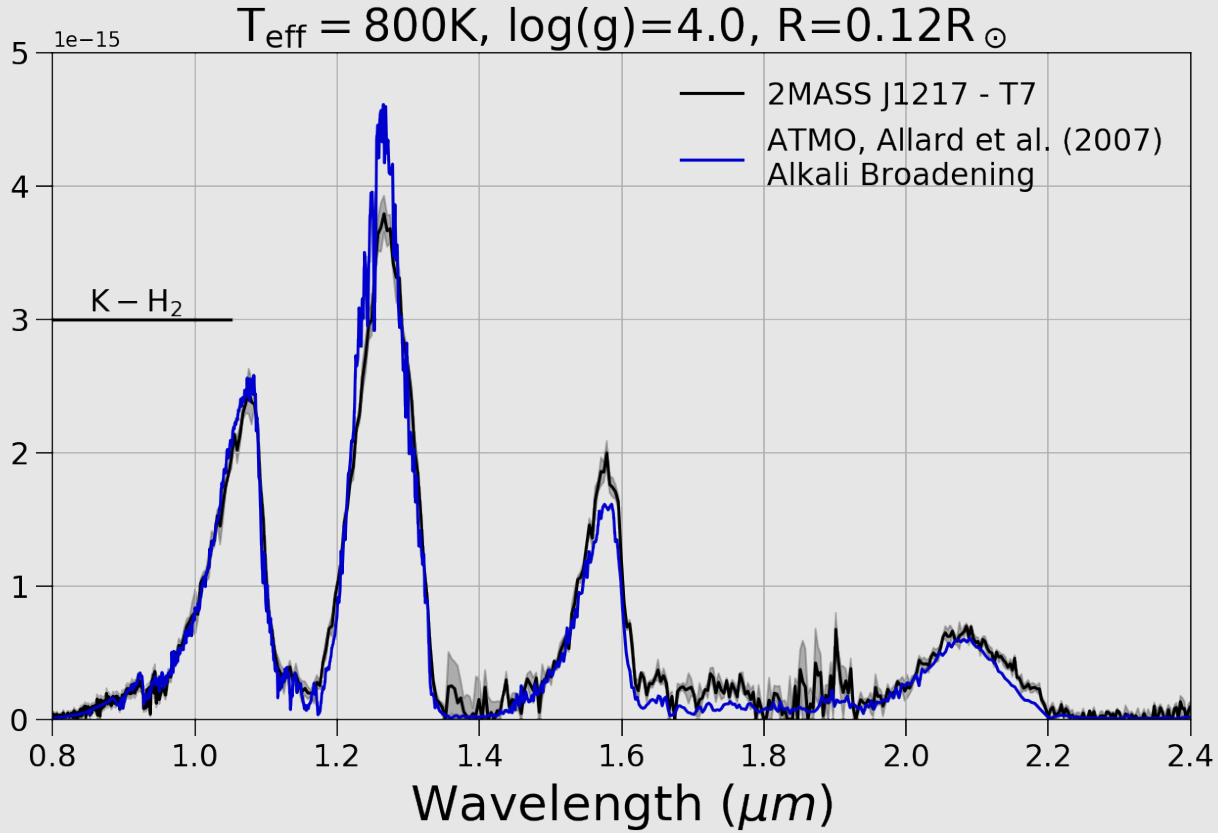

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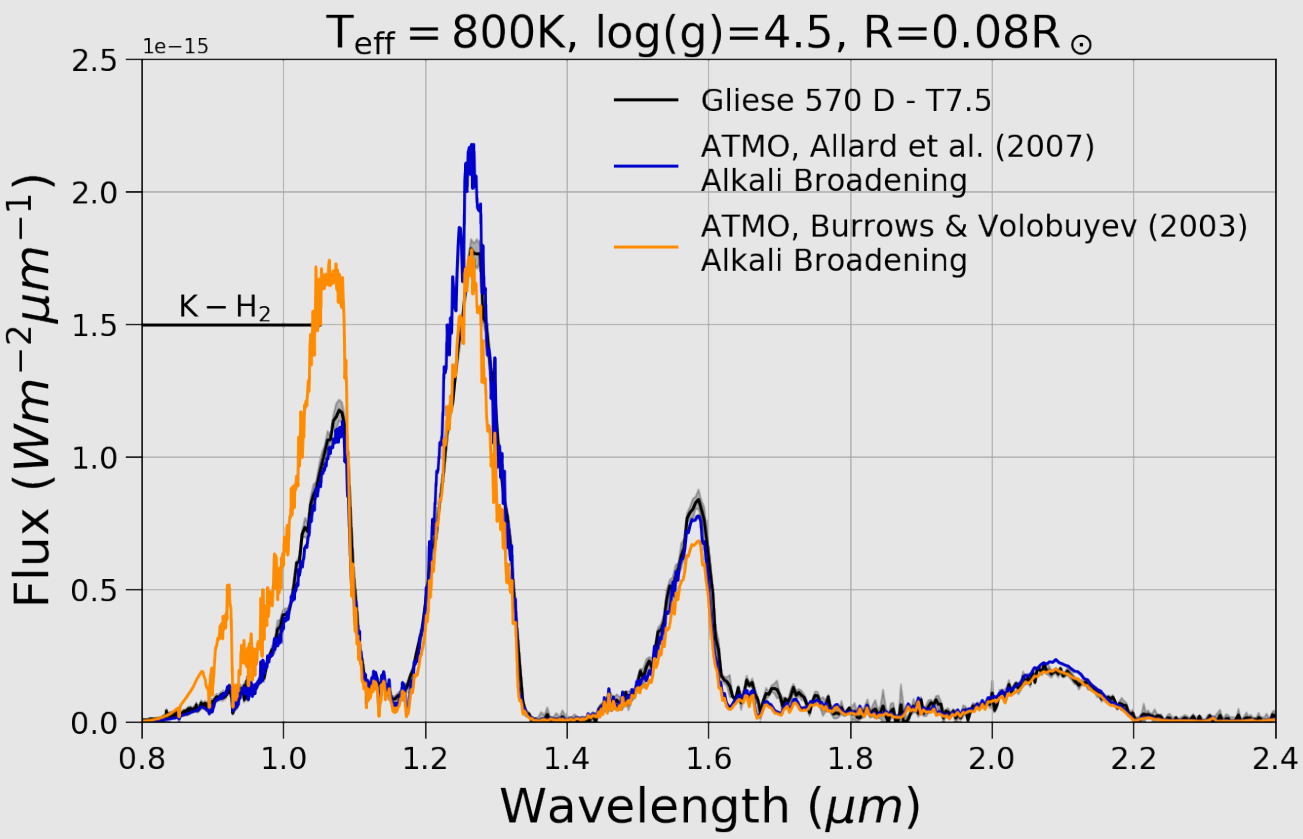

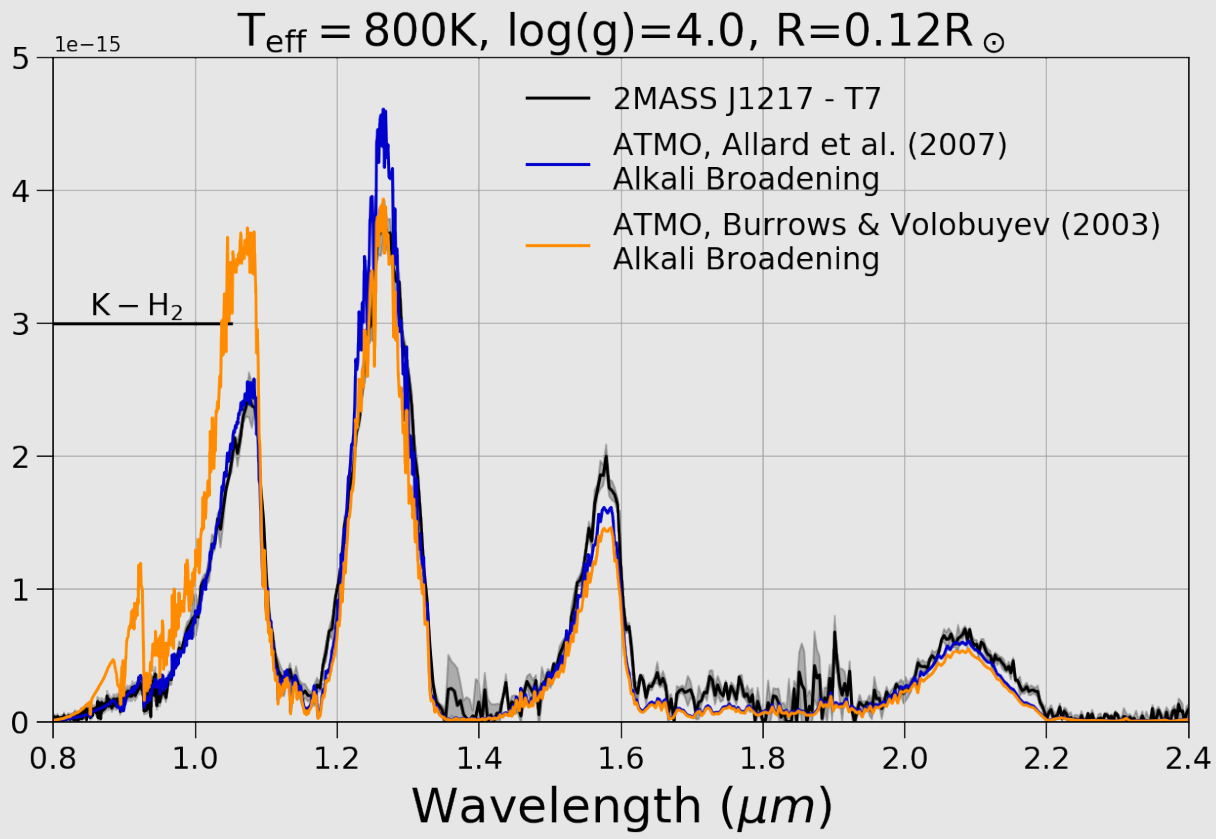

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Perspective

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- Allard et al. (2007) – Too much Y band absorption
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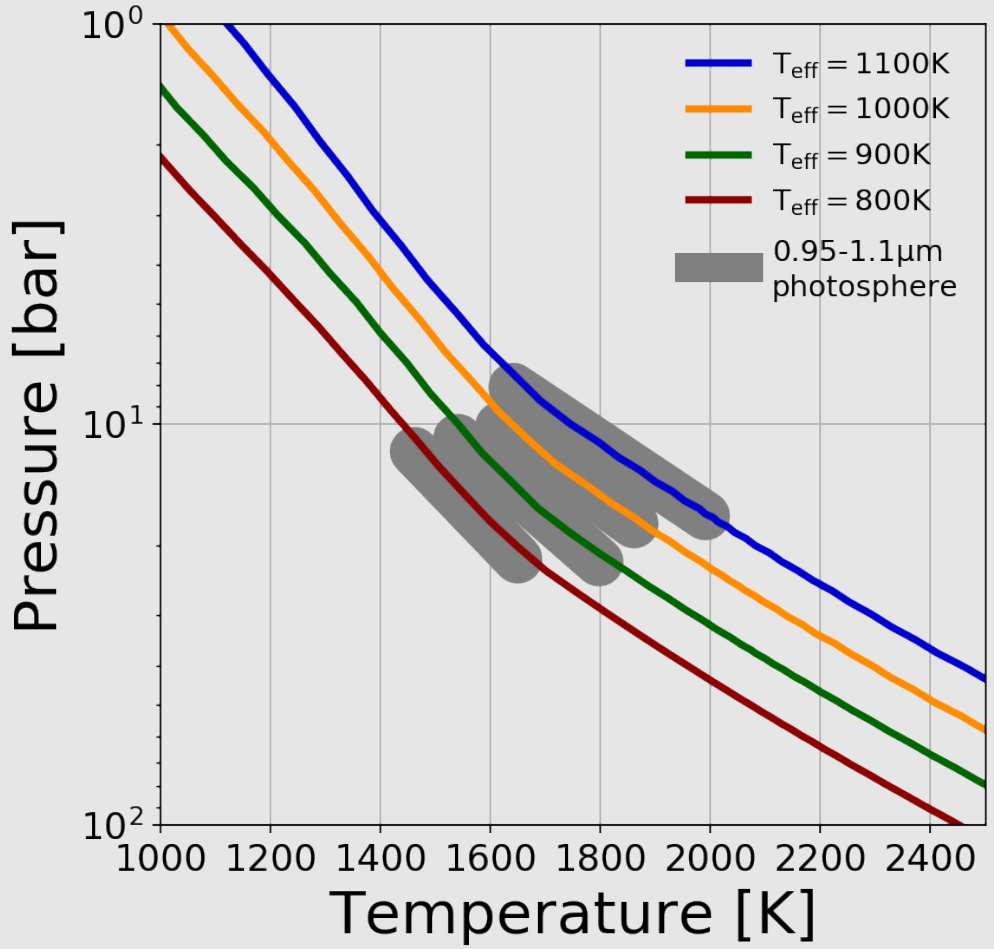

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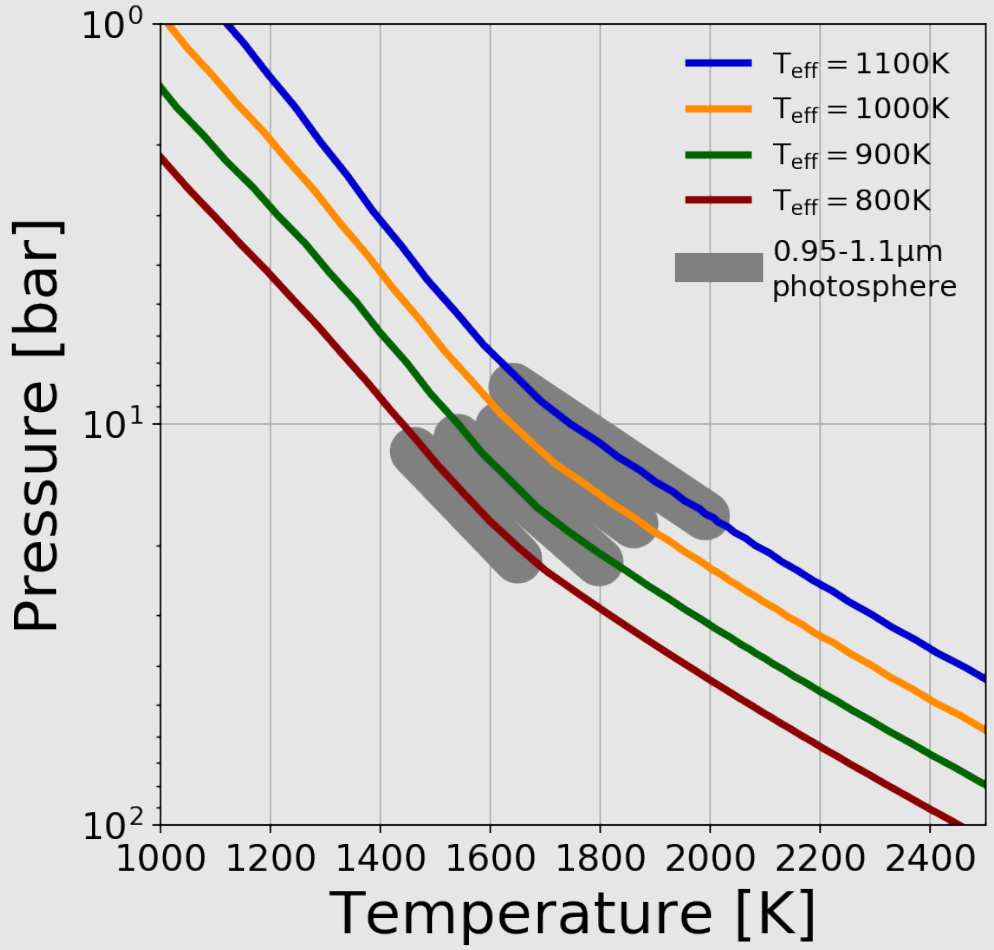
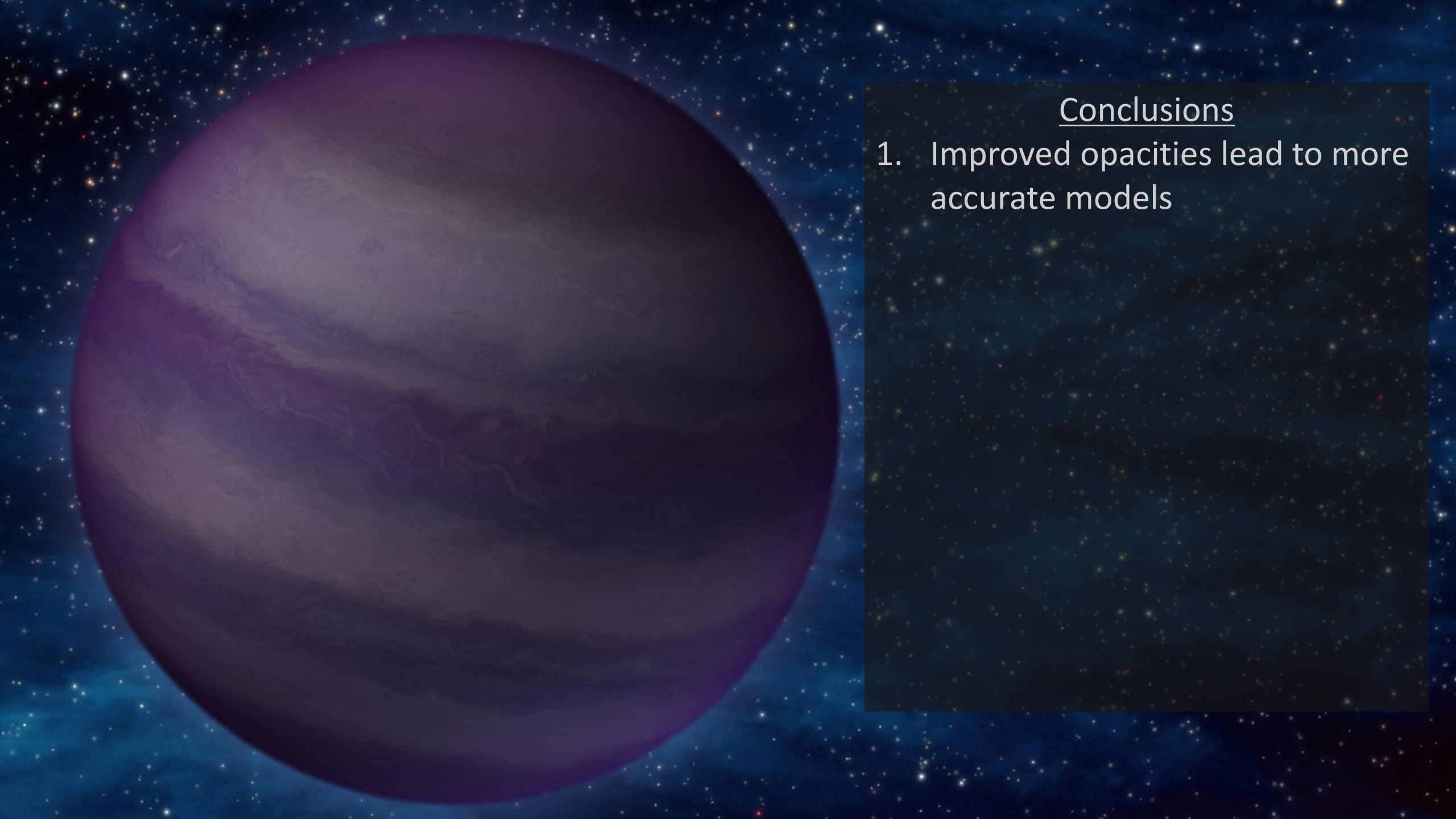
Future work

- Implement new and improved line shape calculations from Nicole Allard
- Validate new alkali broadening with comparisons to observations





Conclusions

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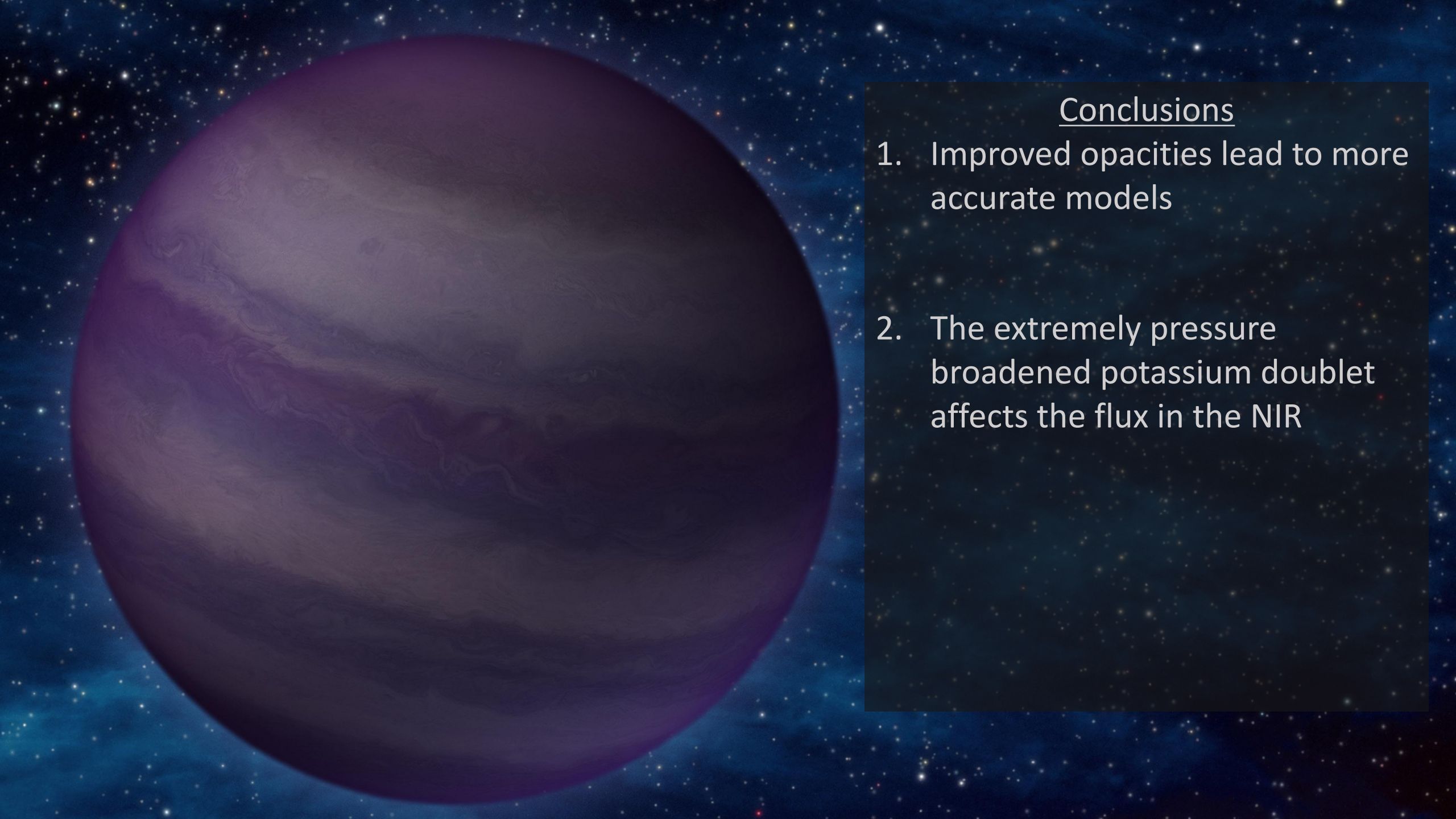

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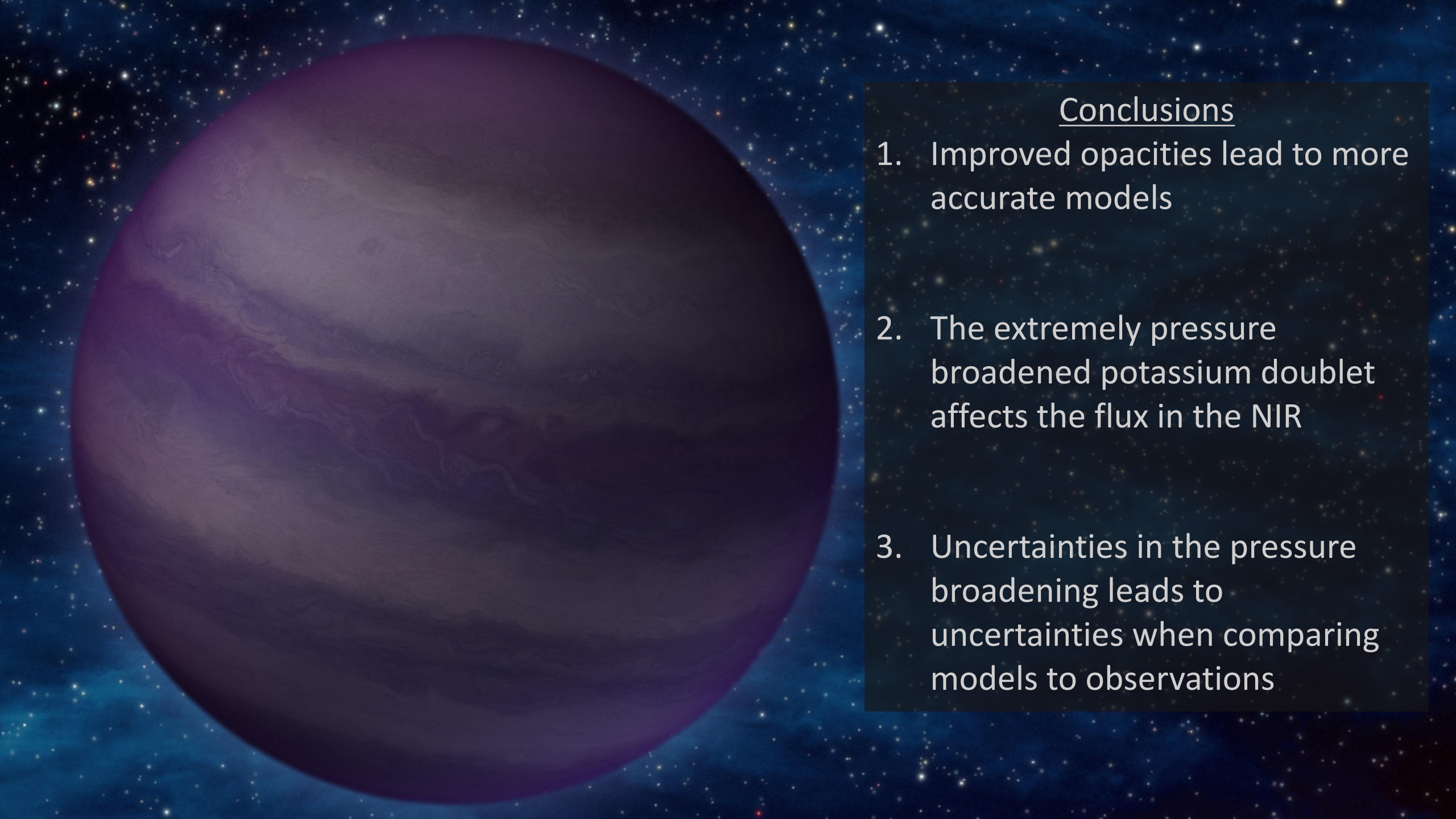

Conclusions

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2. The extremely pressure broadened potassium doublet affects the flux in the NIR

3. Uncertainties in the pressure broadening leads to uncertainties when comparing models to observations