Cerberus: Modeling the Atmospheric Composition of Exoplanets for ARIEL/CASE

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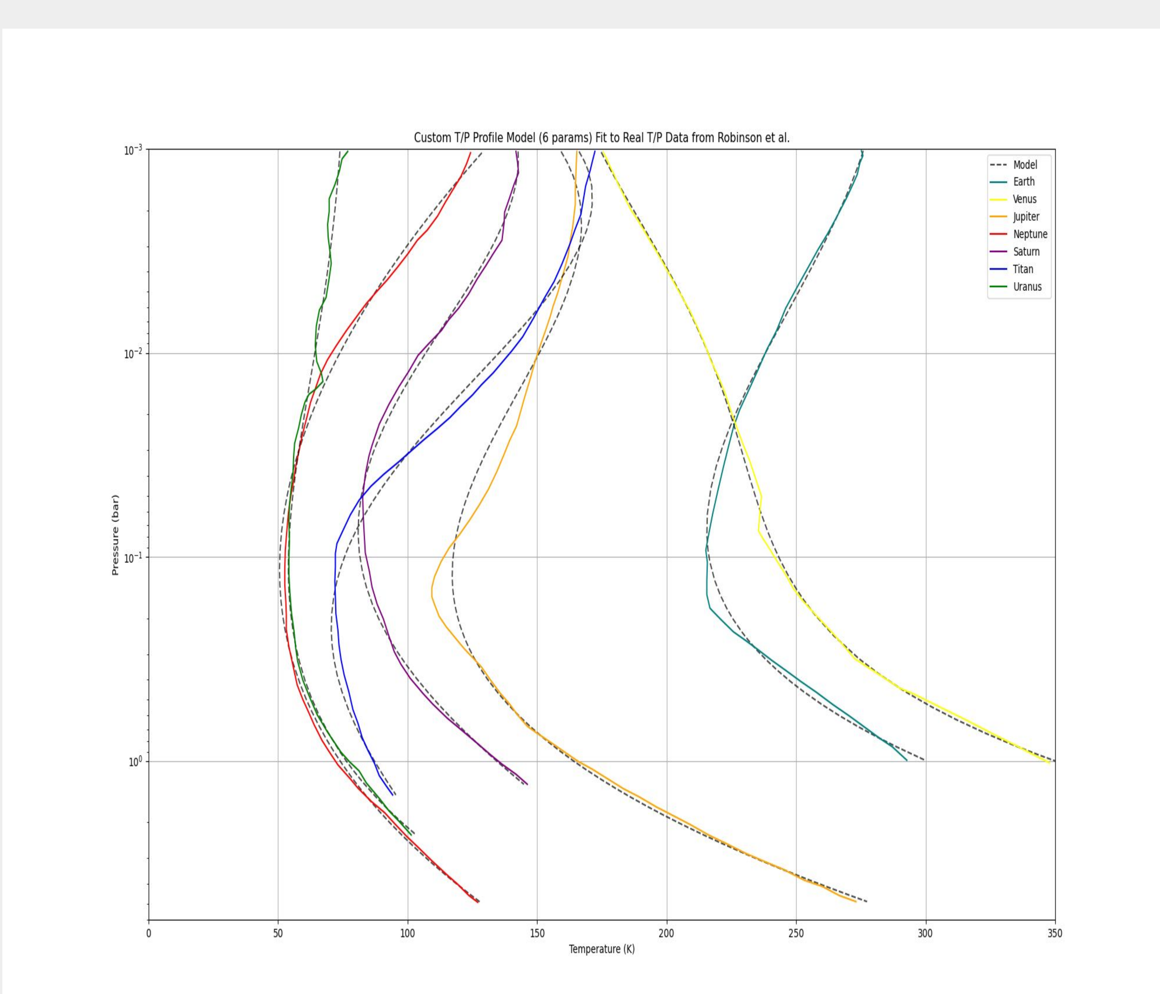
ARIEL/CASE Mission and the Excalibur Pipeline

Excalibur is the Jet Propulsion Laboratory's data reduction pipeline supporting the ESA/NASA ARIEL/CASE mission, which will collect spectra for approximately 1,000 exoplanets to enable a detailed characterization of their atmospheres[1]. Cerberus, a module of the Excalibur pipeline, is in charge of modeling the chemistry within these atmospheres and simulating their absorption spectra. Cerberus will then be used to retrieve chemical abundances or volume mixing ratios from the exoplanet spectrum measured by ARIEL/CASE. In this project, we built a new chemical equilibrium model within Cerberus to generate transmission spectra to be used for atmospheric retrievals.

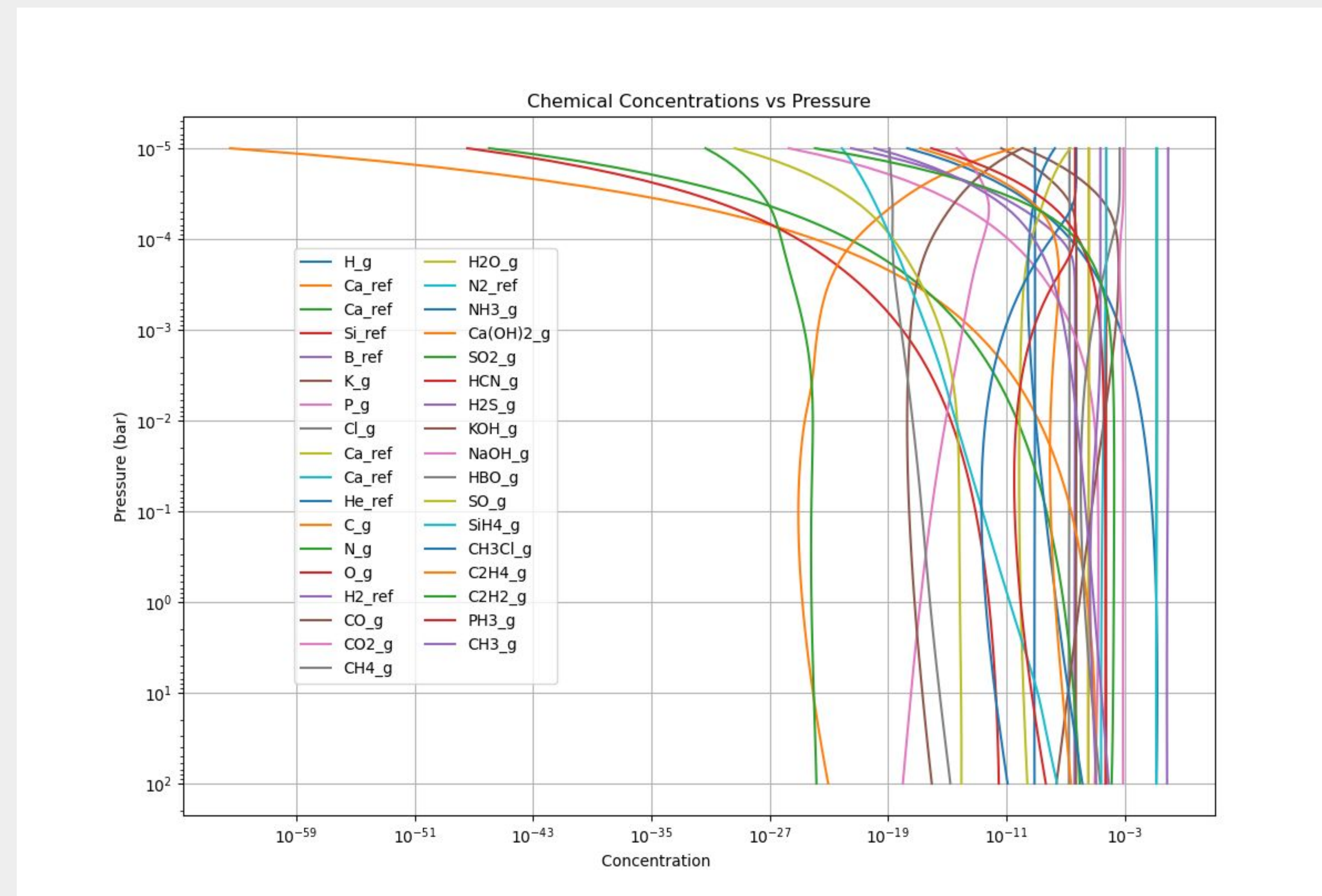
Variable Temperature Pressure Profiles

We developed a function to generate dynamic temperature pressure profiles that better reflect realistic atmospheric conditions, moving beyond the previous isothermal assumptions.



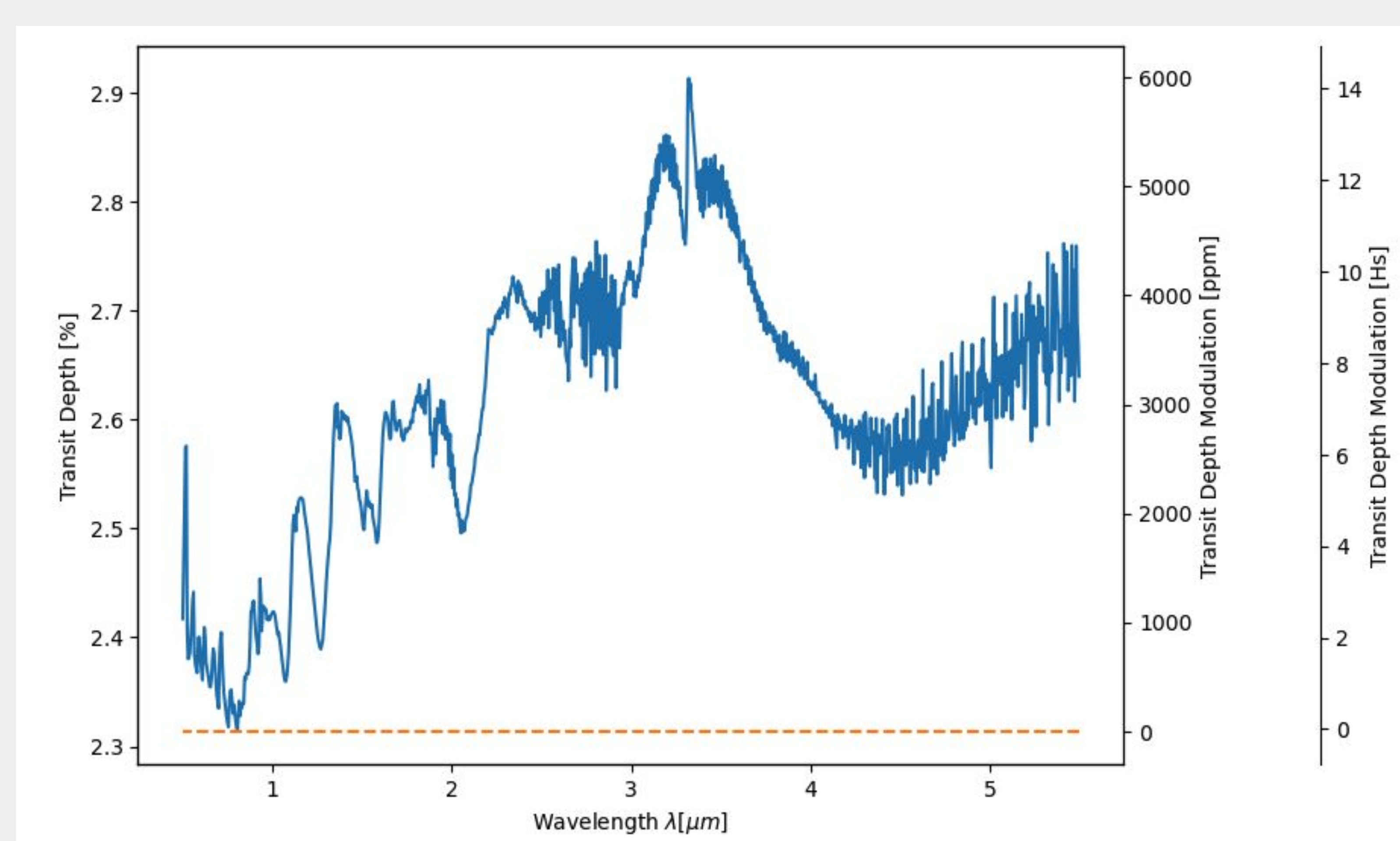
Thermodynamic Equilibrium

Using these temperature pressure profiles, we integrated the TEA (Thermochemical Equilibrium Abundances) code to compute self-consistent molecular mixing ratios[2].

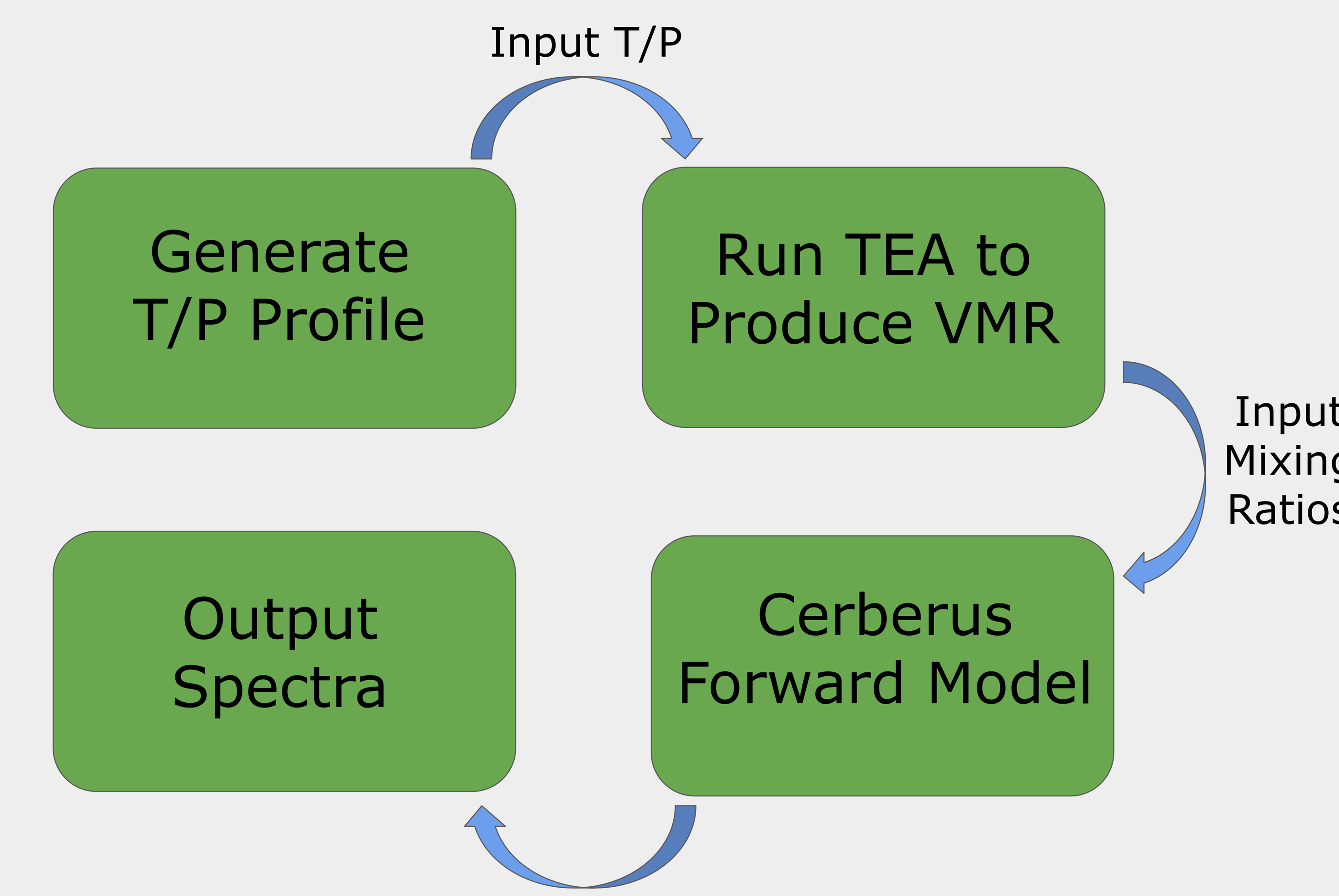


Simulated Spectra

Shown below is the output spectrum of a hot Earth-like atmosphere generated by the updated Cerberus forward model.



New Model Architecture



Next Steps and Challenges

Future work will focus on incorporating disequilibrium chemistry into the pipeline to more accurately reflect the conditions of exoplanetary atmospheres[3]. We would also like to do a retrieval on JWST data and compare the results of the updated model with previous Cerberus performances as well as other existing forward models. We note that through the expansion of species lists and the integration of layer by layer analysis, the computation cost is very large and running retrieval using MCMC becomes a concern.

References and Acknowledgements

1. Al-Refaie, A. F., et al. "Taurex 3: A fast, dynamic, and extendable framework for retrievals." *The Astrophysical Journal*, vol. 917, no. 1, 1 Aug. 2021, p. 37, https://doi.org/10.3847/1538-4357/ac0252.
2. Blecic, Jasmina, et al. "Tea: A code calculating thermochemical equilibrium abundances." *The Astrophysical Journal Supplement Series*, vol. 225, no. 1, 1 July 2016, p. 4, https://doi.org/10.3847/0067-0049/225/1/4.
3. Roudier, Gael M., et al. "Disequilibrium chemistry in exoplanet atmospheres observed with the Hubble Space Telescope." *The Astronomical Journal*, vol. 162, no. 2, 1 July 2021, p. 37, https://doi.org/10.3847/1538-3881/abfdad.

We would like to thank the Stone family for providing the funding to conduct this work