UNIVERSITY of CALIFORNIA
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THERMAL EVOLUTION OF URANUS WITH CONDENSATION-INHIBITED CONVECTION

A thesis submitted in partial satisfaction of the requirements for the degree of

BACHELOR OF SCIENCE

in

ASTROPHYSICS

by

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Abstract

Thermal Evolution of Uranus with Condensation-inhibited Convection

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This will be the last section written, once we have finished our analysis.

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To Who,

the owl

Acknowledgements

I'd like to thank my attorney, Bob Loblaw

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Introduction

Observations of Uranus show a planet that appears to be in thermal equilibrium with the Sun. Observation has also shown that Uranus is cooler than its more distant neighbor, Neptune. Meanwhile, thermal evolution models for Uranus have not matched observation, instead predicting a warmer effective temperature during the current epoch(Fortney et al., 2011), (M. Podolak, 1991), (W.B. Hubbard, 1995), (L. Scheibe, 2019) [There are other papers by Nettelmann 2013, Linder 2019 that I haven't looked at yet].

There have been various attempts to model the underluminous Uranus. [how much should i go into work done with different EOS's?] The formation of stable layers, trapping internal energy in the the interior of Uranus and Neptune was proposed by (M. Podolak, 1991). Work on the formation of stable condensation zones, inhibiting convection, have been investigated by (Friedson & Gonzales, 2017), (Leconte et al., 2017), and (Guillot, 1995).

2

Methodology

[List out the equations of state that we are using, and what model atmosphere]

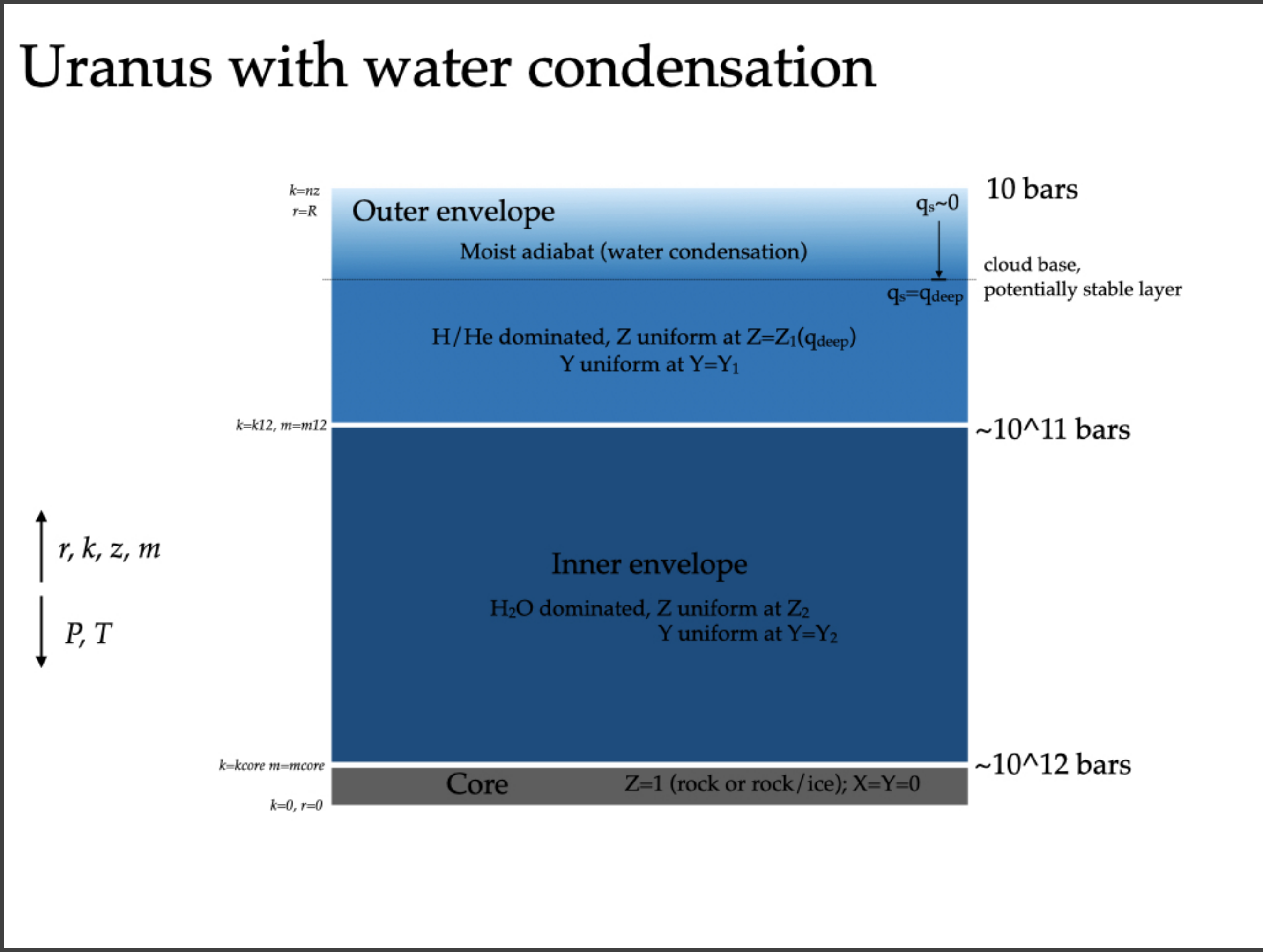

Figure 2.1: Interior structure of Uranus with moist adiabatic layer

3

Results

3.1 Condensation-inhibited Convection

3.2 Formation of Radiative Layer

3.3 Thermal Evolution

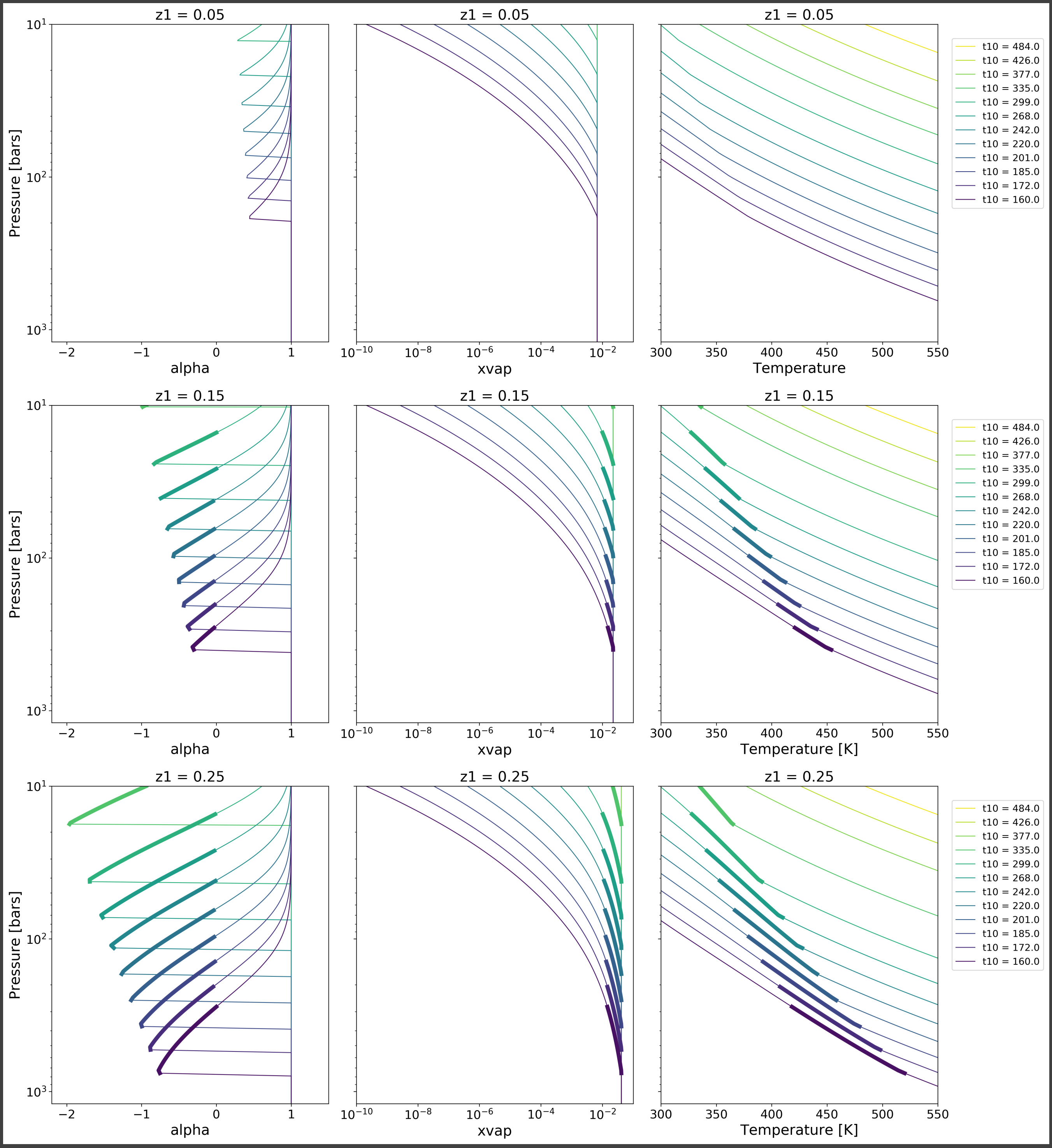

Figure 3.1: Need to add text here

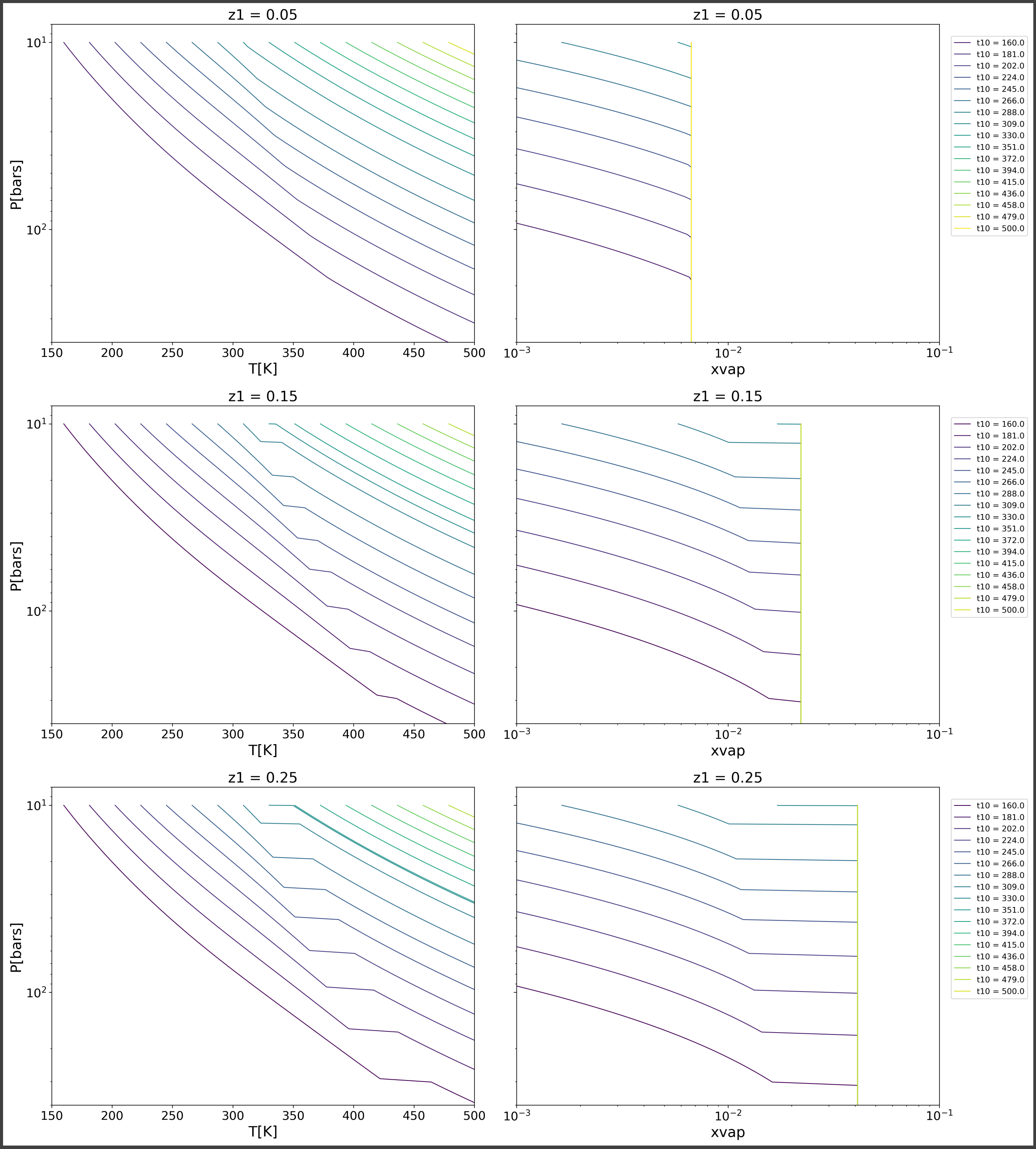

Figure 3.2: Need to add description here

4

Discussion and Conclusions

Appendix A

Some Ancillary Stuff

Bibliography

Fortney, J. J., Ikoma, M., Nettelmann, N., Guillot, T., & Marley, M. S. (2011). Self-consistent model atmospheres and the cooling of the solar system's giant planets. *The Astrophysical Journal*, 729, 32.

Friedson, A. J. & Gonzales, E. J. (2017). Inhibition of ordinary and diffusive convection in the water condensation zone of the ice giants and implications for their thermal evolution. *Icarus*, 297, 160–178.

Guillot, T. (1995). Condensation of methane, ammonia, and water and the inhibition of convection in giant planets. *Science*, (pp. 1697–1699).

L. Scheibe, N Nettelmann, R. R. (2019). Thermal evolution of uranus and neptune: Adiabatic models. *Astronomy and Astrophysics*, A70, 632.

Leconte, J., Selsis, F., Hersant, F., & Guillot, T. (2017). Condensation-inhibited convection in hydrogen-rich atmospheres: Stability against double-diffusive processes and thermal profiles for jupiter, saturn, uranus, and neptune. *Astronomy and Astrophysics*, A98, 598.

M. Podolak, W.B. Hubbard, D. S. (1991). Models of uranus' interior and magnetic field. *Uranus, Editors: J.T. Bergstralh, E.D. Miner, M. Shapely Matthews*, (pp.$\tilde{2}$9).

W.B. Hubbard, D. S. (1995). The interior of neptune. *Neptune and Triton, Editor: D.P. Kruikshank*, (pp. 109).