UNIVERSITY of CALIFORNIA
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CONDENSATION-INHIBITED CONVECTION AND THERMAL EVOLUTION OF URANUS AND NEPTUNE

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

BACHELOR OF SCIENCE

in

ASTROPHYSICS

by

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Abstract

Condensation-inhibited convection and thermal evolution of uranus and neptune

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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

Since the work of Rupert Wildt(Wildt, 1947), astronomers have been modeling hydrogen dominated planets. The influential paper of the mid-twentieth century was written by Wendell DeMarcus(DeMarcus, 1958). In this paper, DeMarcus gave a lengthy description.... Attempts at modeling the interior structure and atmosphere of the solar system giant planets significantly accelerated in the later half of the twentieth century shortly after Frank Low, confirmed by way of observation, that Jupiter was radiating more heat than it received from the Sun (Low, 1966). By the 1970's, modeling efforts by (Harold C. Graboske & Olness, 1975), (Hubbard, 1977), and (James B. Pollack & Harold C. Graboske, 1977) for Jupiter and Saturn began incorporating model atmospheres with models of interiror structure to better investigate the thermal evolution of these giant planets.

In section 1.1, we review prior work done on model Uranus and Neptune. In section 1.2, we review prior work done on the formation of water condensation zones in these hydrogen rich atmospheres. In chapter 2, we describe our model and present our results. In chapter 3, we discuss the ramifications of condensation inhibited convection for the thermal

evolution of Uranus. Finally, in chapter 4, we summarize our findings.(Friedson & Gonzales, 2017) (Leconte et al., 2017) (James B. Pollack & Harold C. Graboske, 1977)(Fortney et al., 2011) (Harold C. Graboske & Olness, 1975) (Guillot, 2019) (Guillot, 1995)

test

1.1 Model Uranus and Neptune with Dry Convection

Will review current understanding of solar system giant planet thermal evolution here, referencing work done by Fortney, et al., and others. Not sure how far back I want to go here, but will probably mention when, and by who, thermal evolution modeling began, and then quickly get into the thermal evolution background from fortney papers.

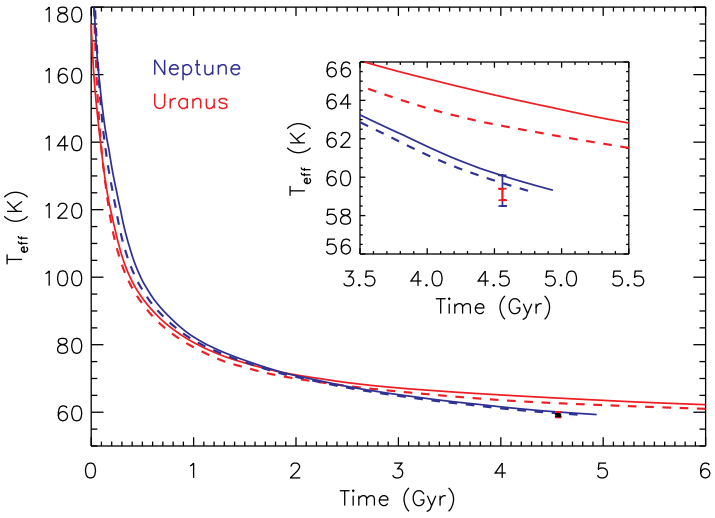

Figure 1.1: Thermal evolution of Uranus and Neptune

1.2 Condensation-inhibited Convection

This section will contain theory and results surrounding condensation in hydrogen rich atmospheres, citing LeConte, Friedson, others.

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Model Uranus and Neptune with Condensation-inhibited Convection

2.1 Numerical Model

2.2 Results

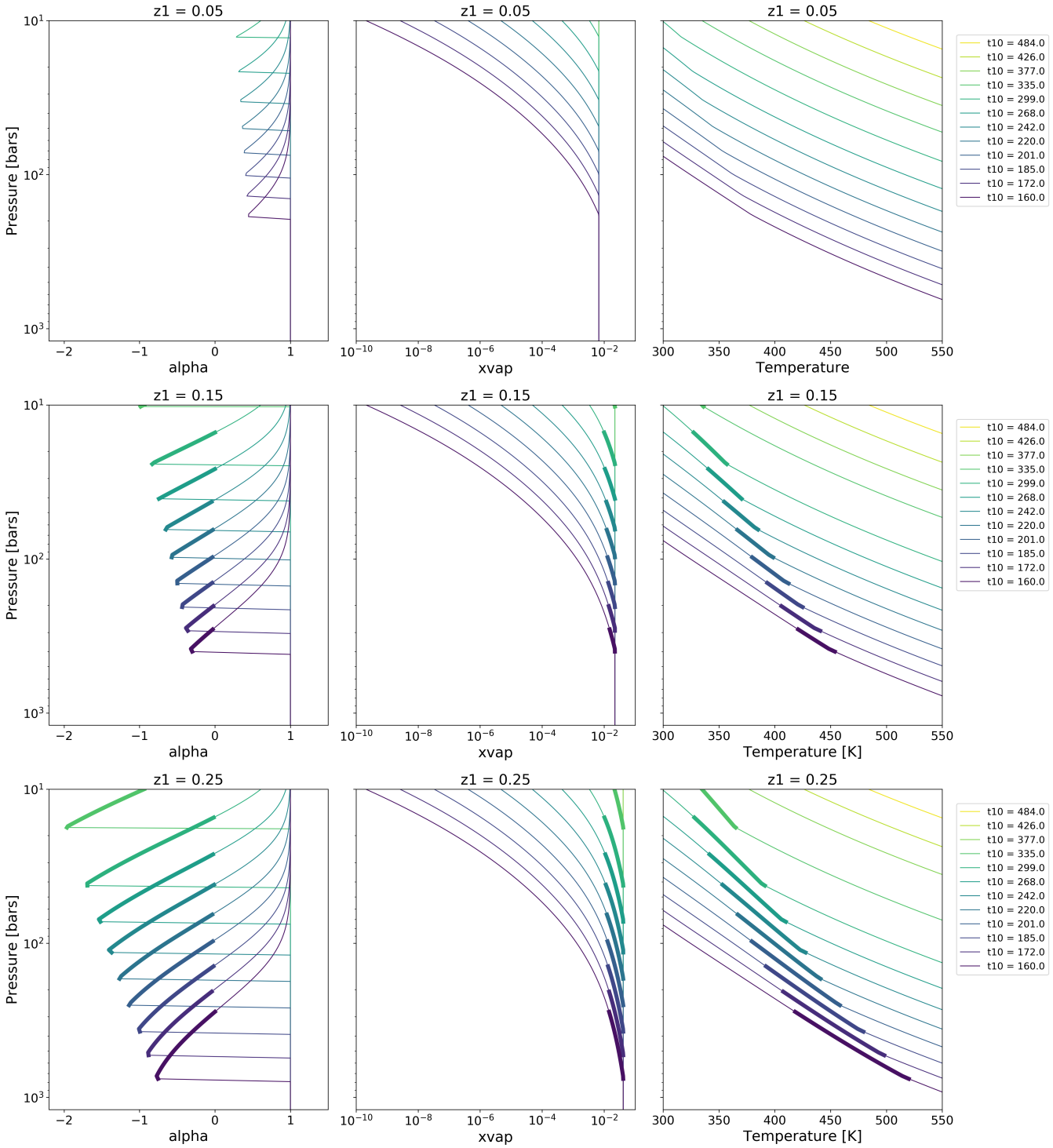

Figure 2.1: Need to add description here

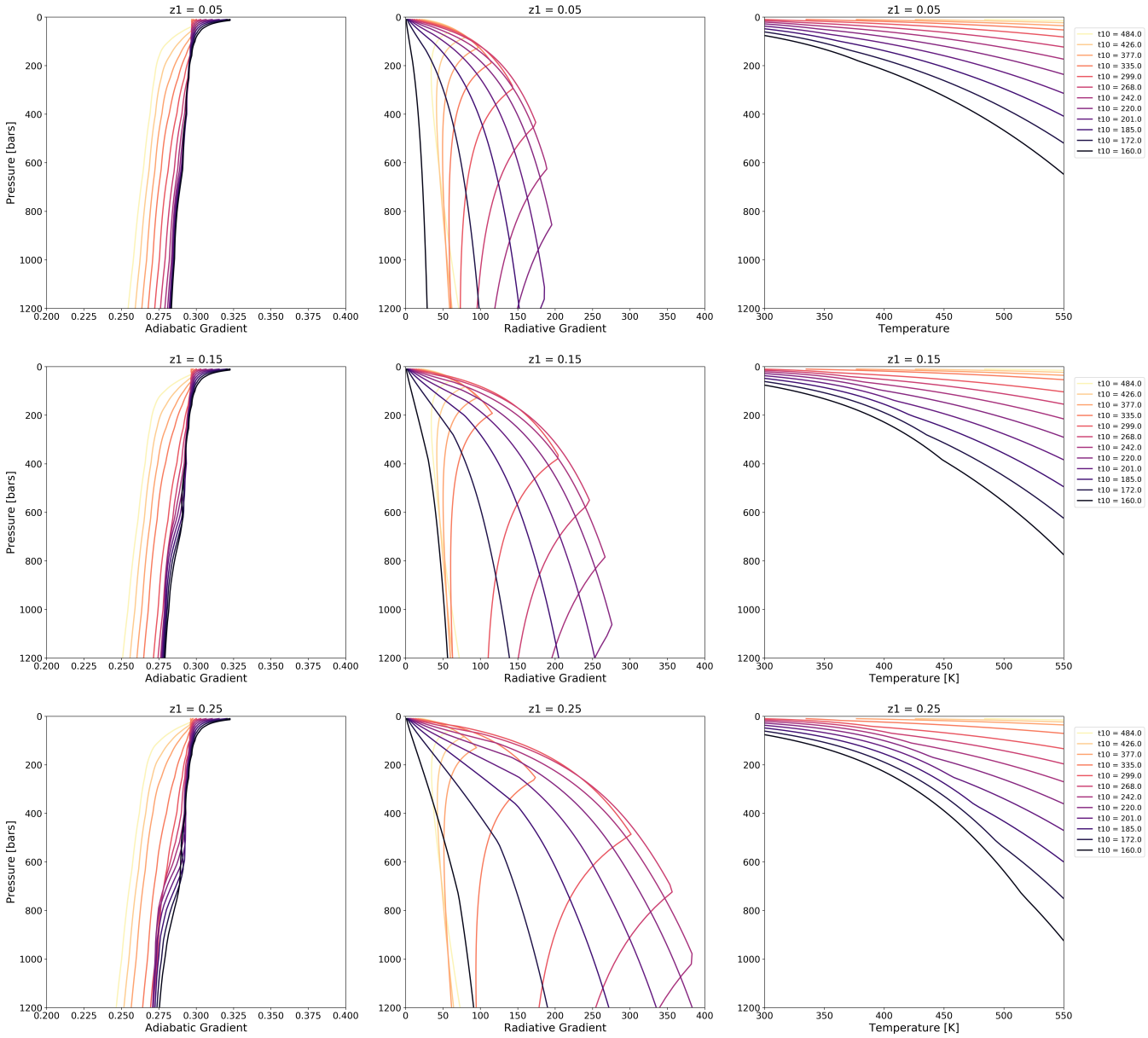

Figure 2.2: Need to add description here

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Discussion and Conclusions

Appendix A

Some Ancillary Stuff

Ancillary material should be put in appendices. The guidelines are not clear whether bibliography comes before or after the appendices, but they *suggest* appendices come first. Ancillary material should be put in appendices. The guidelines are not clear whether bibliography comes before or after the appendices, but they *suggest* appendices come first. Ancillary material should be put in appendices. The guidelines are not clear whether bibliography comes before or after the appendices, but they *suggest* appendices come first. Ancillary material should be put in appendices. The guidelines are not clear whether bibliography comes before or after the appendices, but they *suggest* appendices come first.

Bibliography

DeMarcus, W. (1958). The constitution of jupiter amd saturn. *Astronomical Journal*, 63, 2–27.

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).

Guillot, T. (2019). Uranus and neptune are key to understand planets with hydrogen atmospheres. *arXiv.org*.

Harold C. Graboske, Jr., J. B. P. A. S. G. & Olness, R. J. (1975). The structure and evolution of jupiter: The fluid contraction. *The Astrophysical Journal*, 199, 265–281.

Hubbard, W. (1977). The jovian surface condition and cooling rate. *Icarus*, , 30, 305–310.

James B. Pollack, Allan S. Grossman, R. M. & Harold C. Graboske, J. (1977). A calculation of saturn's gravitational contraction history. *Icarus*, , 30, 111–128.

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.

Low, F. (1966). Observations of venus, jupiter, and saturn at 20 . *Astronomical Journal*, 71, 391.

Wildt, R. (1947). The constitution of the planets (council report on the progress of astronomy). *Monthly Notices of the Royal Astronomical Society*, , 107, 84.