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LOWER LIMITS ON THE CORE MASS FOR GIANT PLANETS

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1. INTRODUCTION

Background topics to mention include: core accretion history, giant planets at wide separations and theoretical challenges posed (GI probably to big, core accretion maybe to slow).

Describe goals and approach of this paper.

This paper is organized as follows: *(section summaries)*.

2. QUASISTATIC TWO LAYER MODEL

2.1. *Model Assumptions*

Define and describe basic length scales; Describe disk conditions: MMSN etc. Describe basic assumptions: 1D atmosphere, smooth matching onto the disk, atmosphere composition etc., perhaps in list format; Describe assumptions specific to our model: quasistatic, $L_{KH} \gg L_{acc}$, two-layer, constant L. Explain how our model is intermediary between purely static models with $L = L_{acc}$ and full time-dependent evolutionary models. Could be split into sub-subsections.

2.2. *Structure Equations*

Give in radius coordinates. EOS (polytrope, various assumption for $\nabla_{\rm ad}$ and μ) and opacity laws (noting that we only consider cool radiative zones with dust opacities). Give boundary conditions (probably not worth a whole subsection by itself)

3. COOLING HISTORY

Start with basic idea of quasistatic contraction and $L = -\dot{E}$, then write out cooling equation and explain terms. Explain where it comes from (local cooling + virial equilibrium)

3.1. *Role of Finite Pressure*

Give more more general result, but defer derivation to Appendix A. Perhaps not worth a subsection by itself.

4. NUMERICAL METHOD

Explain the shooting technique, then how to obtain an evolutionary series from cooling model between subsequent static atmospheres. Show P-T, M-T, M-R etc. plots. Also L-t, L-M plots.

4.1. *The Gravothermal Catastrophe* or *Entropy Minimum* or *Negative Luminosity* or *Something else?*

Describe that time / luminosity becomes negative when $M_{atm} \sim M_c$.

5. CRITICAL CORE MASS

These are the take home results! Define critical core mass (= minimum between mass doubling and entropy minimum). Explain the assumptions, show that growth is slowest then (M-t plot?)

5.1. *Role of Disk Temperature and Pressure*

Show how critical core mass changes as you vary one parameter while keeping the other constant.

5.2. *Core Mass vs. Cooling Time at Fixed Radius*

5.3. *Core Mass vs. Disk Radius*

5.4. *Opacity Dependence*

Not sure what would go in this section, since we only use one opacity model.

6. DISCUSSION

6.1. *Kelvin-Helmholtz Contraction vs. Planetesimal Accretion*

Compare and contrast our results with Rafikov's, show accretion rates plot; discuss why our fixed core mass assumptions are valid in the regime we are considering.

6.2. *Analytic Cooling Model*

Explain assumptions of analytic model but defer equations and derivations to Appendix B. Show numerical vs. analytic comparison plots and explain role of self gravity.

6.3. *EOS Tables*

Mention and briefly describe Saumon et al. EOS tables as future work.

7. CONCLUSIONS

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APPENDIX

VIRIAL EQUILIBRIUM AND COOLING

ANALYTIC COOLING MODEL