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ON THE MINIMUM CORE MASS FOR GIANT PLANET FORMATION

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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 too big, core accretion maybe to slow).

Describe goals and approach of this paper.

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

2. ATMOSPHERE MODELS

2.1. *Basic 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.

The idea is to start gentle with generalities and then get specific with the 2-layer quasistatic model after the basic eqns. have been given.

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

2.3. *Standard Methods of Solution*

shooting vs. Henyey methods to satisfy above BC. Static models powered by accretion and full evolutionary calculations. Note that there's nothing really to explain about the "shooting method" . Fine to state the BC's and that we use the shooting method. That's a difference between a paper and research notes. We probably want the radius version of structure ODEs.

2.4. *Virial Equilibrium and Global Cooling*

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). Defer some derivation to Appendix A. In principle this is still general stuff, i.e. the global cooling eqn applies to all hydrostatic models, not just our quasistatic one.

Before describing our quasistatic method we first describe the general ways that planetary Kelvin-Helmholz contraction differs from the stellar case.

2.5. *Quasi-static Two-layer Model*

Two layer model and simplified treatment of radiative zone. How to obtain an evolutionary series from cooling model between subsequent static atmospheres.

3. ANALYTIC COOLING MODEL

derive model (perhaps deferring some results to an appendix), give and explain expected scalings. Could go after numerical results, but if first can use to explain some numerical results.

4. QUASISTATIC KELVIN-HELMHOLZ CONTRACTION

Show instantaneous profiles. Also L-t, L-M evolution.

4.1. *The End of Quasistatic Evolution*

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. NEGLECTED EFFECTS

EOS, time evolution, planetesimal accretion, inefficient convection (mixing length models). More detailed opacity laws (non-powerlaw, ice sublimation, extension to short period planets).

6.1. *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.

7. CONCLUSIONS

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APPENDIX

DERIVATION OF COOLING MODEL

ANALYTIC COOLING MODEL DETAILS