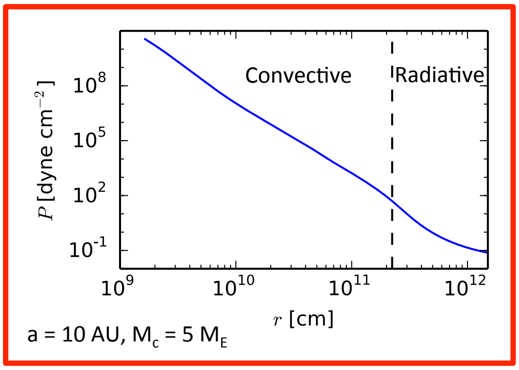
Minimum Core Masses for Giant Planet Formation

Piso, Youdin, & Murray-Clay (ApJ, 2015, 800, 82)
Piso & Youdin (ApJ, 2014, 786, 21)

We determine the **minimum core mass, M_crit, to form a giant planet** before the gas in the protoplanetary disk dissipates, assuming the limiting case in which the **solid cores no longer accrete planetesimals** and the cores' atmospheres are dominated by **Kelvin-Helmholtz contraction**. We explore the effects of a **non-ideal equation of state (EOS)** and **grain growth opacities** on atmospheric evolution.

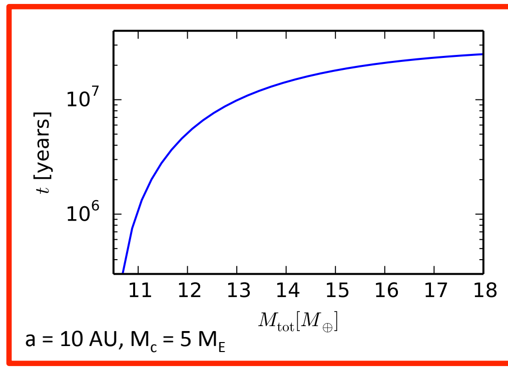
ATMOSPHERIC MODEL SUMMARY

- **Quasi-static** evolution of **spherically symmetric atmospheres** in **hydrostatic balance** and **embedded in a gas disk**
- Negligible planetesimal accretion => solid core of **fixed mass**
- **Inner convective** & **outer radiative** regions
- **Constant luminosity** throughout the radiative region



L ~ -dE/dt →

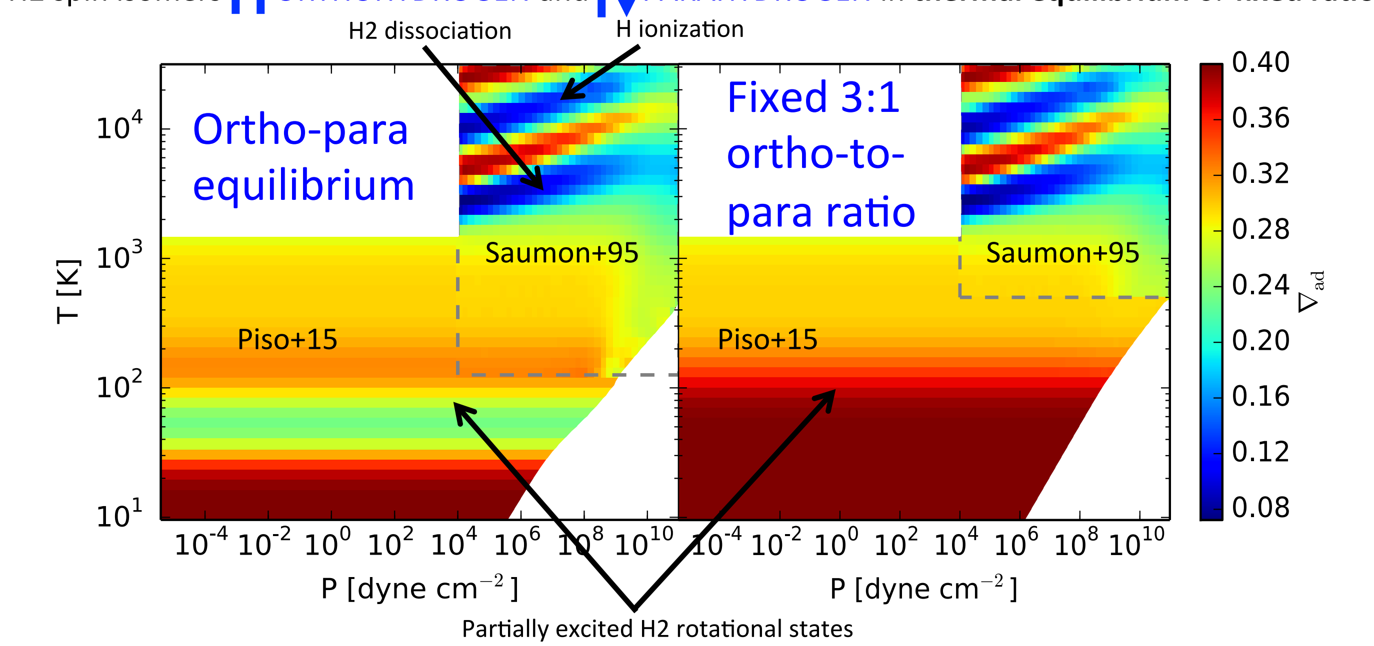
$$\nabla_{ad} = \left(\frac{d\ln T}{d\ln P}\right)_{ad}$$



∇_{ad} relates **P, T, rho** => determines atmospheric profile and parametrizes **EOS**

Atmospheric evolution and M_crit are highly dependent on EOS and DUST OPACITY

H2 spin isomers ↑↑ ORTHOHYDROGEN and ↑↓ PARAHYDROGEN in **thermal equilibrium** or **fixed ratio**



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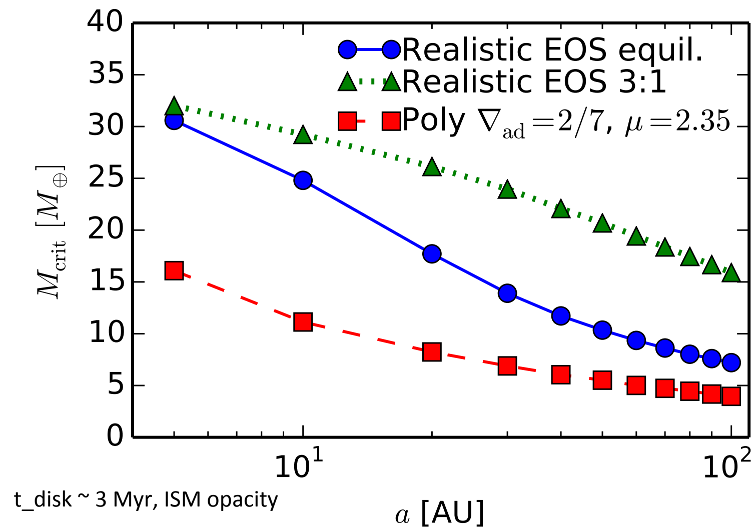
Variations in the adiabatic gradient due to **H2 dissociation** and **variable occupation of H2 rotational states** INCREASE the atmospheric evolutionary time when compared to an ideal gas polytrope => **M_crit** INCREASES



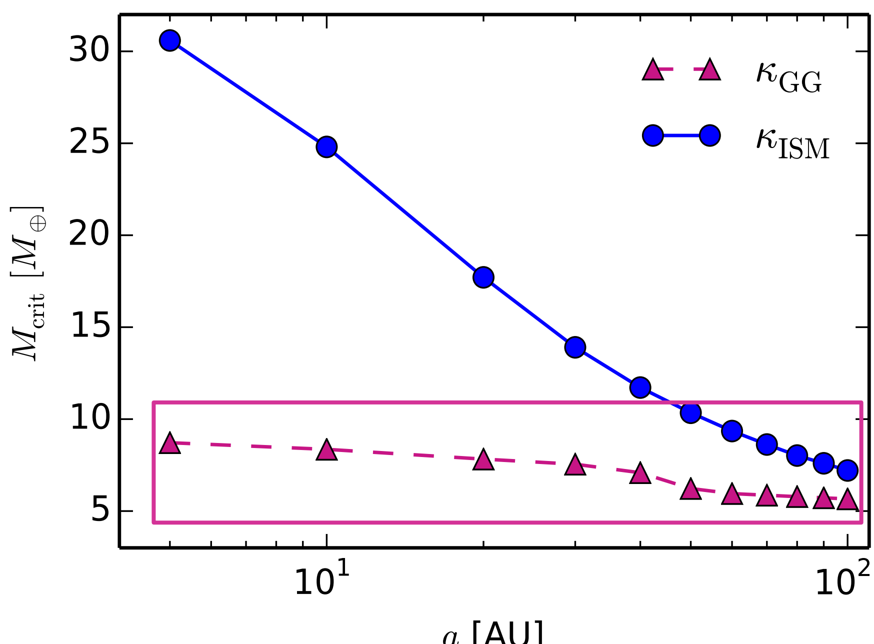
Grain growth opacity DECREASES **M_crit**

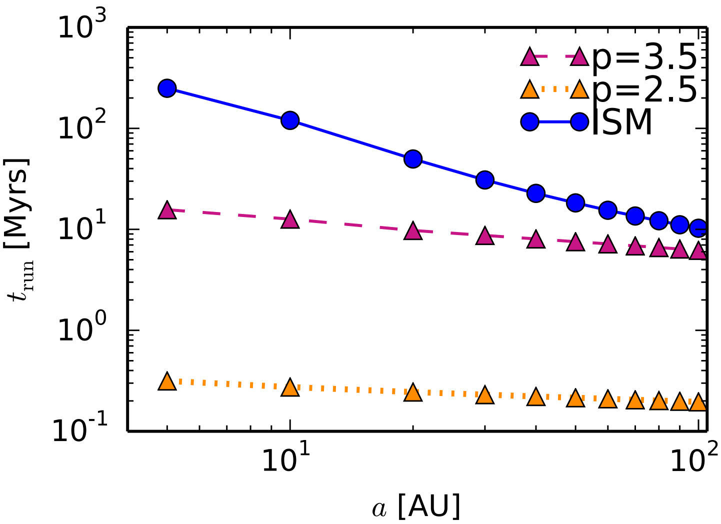
For size distribution dN/ds ~ s^(-p), p = 3.5 max. particle size = 1 cm:

M_crit is

~8 M_E @ 5 AU

~5 M_E @100 AU





If coagulation is taken into account, p = 2.5, the time to runaway accretion **decreases by more than one order of magnitude** -> **Critical Core Mass could be up to one order of magnitude lower!**