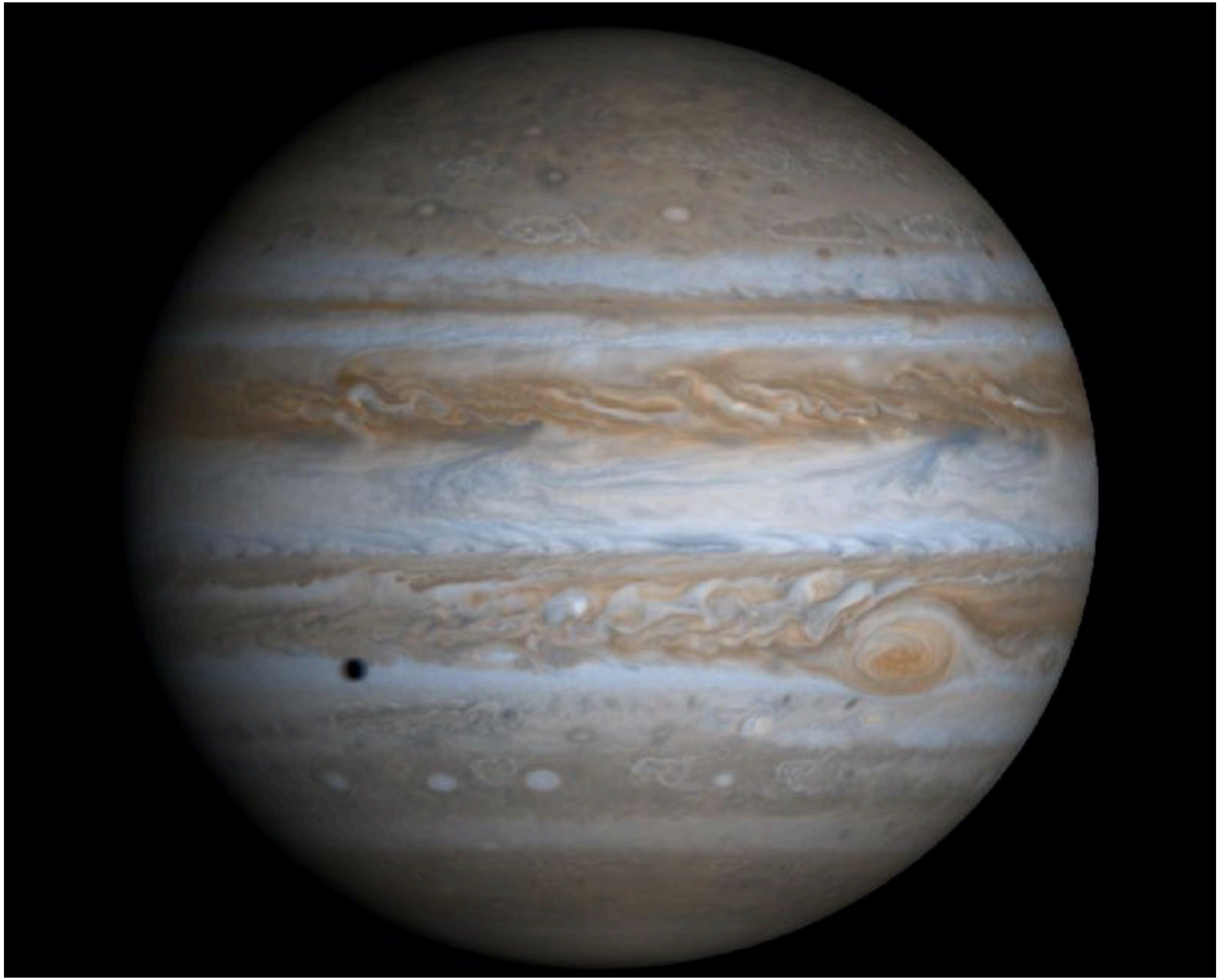
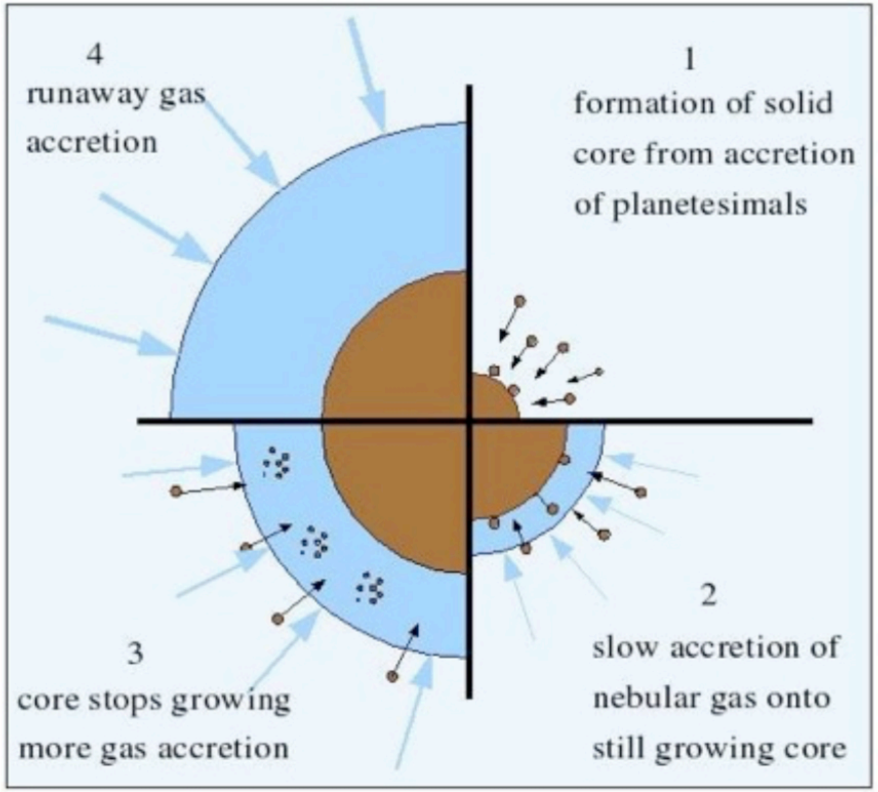
Class 22 – Apr 21st, 2020



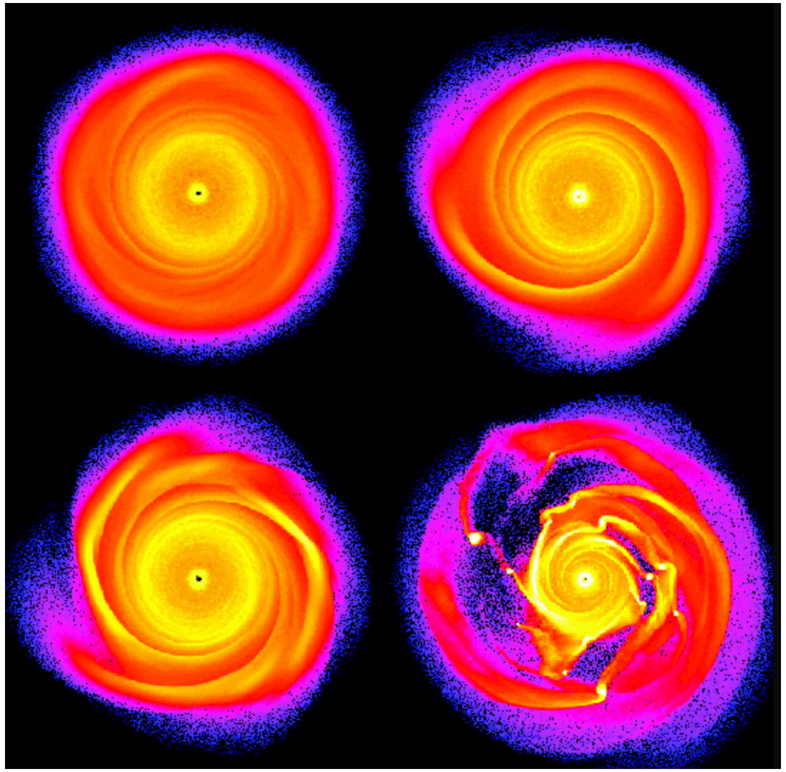
Giant Planet Formation

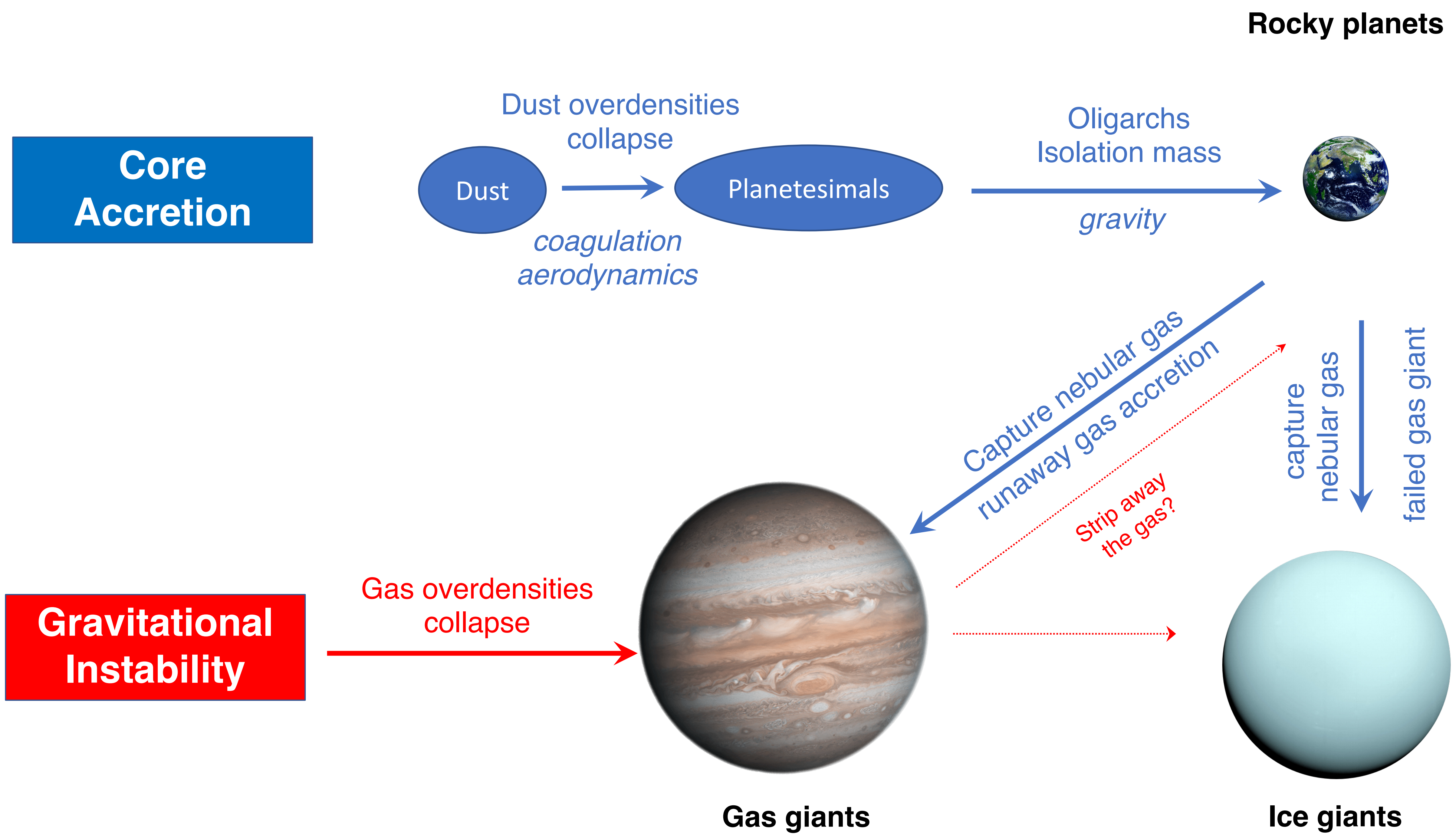
Two Modes

Core Accretion + Gas Capture

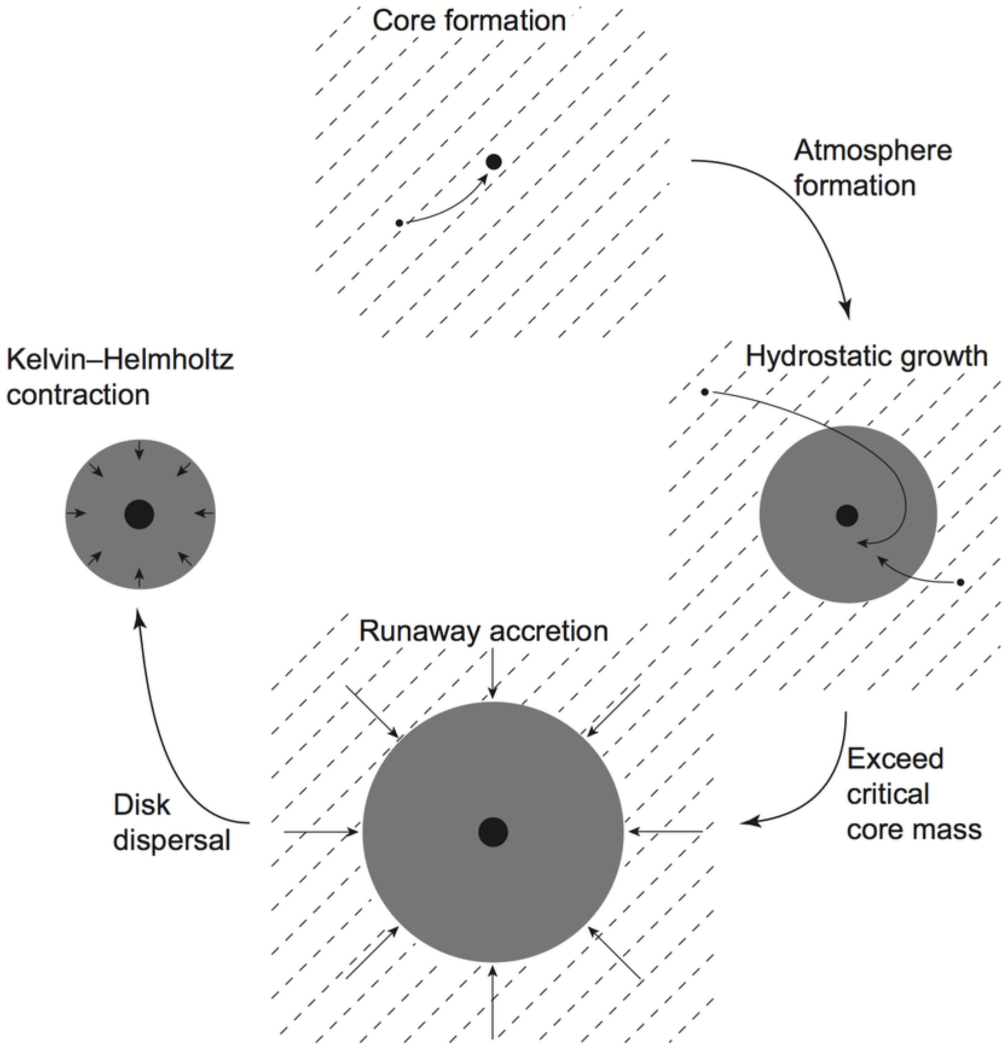


Gravitational Instability
(Disk Fragmentation)

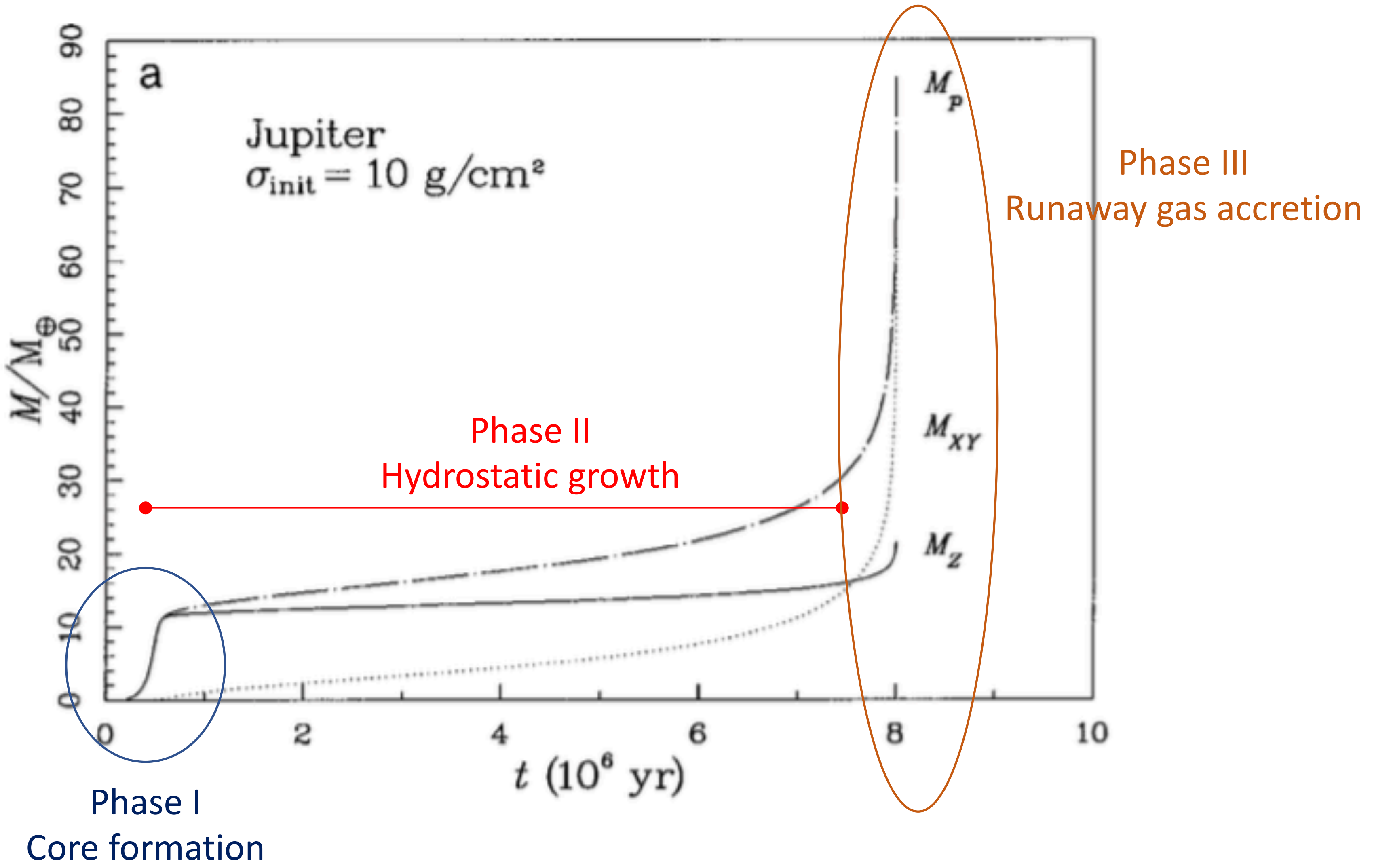



Rocky planets
Core Accretion
Dust overdensities collapse
Dust
Planetesimals
coagulation aerodynamics
Oligarchs Isolation mass
gravity
Capture nebular gas
runaway gas accretion
Strip away the gas?
capture nebular gas
failed gas giant
Gravitational Instability
Gas overdensities collapse
Gas giants
Ice giants

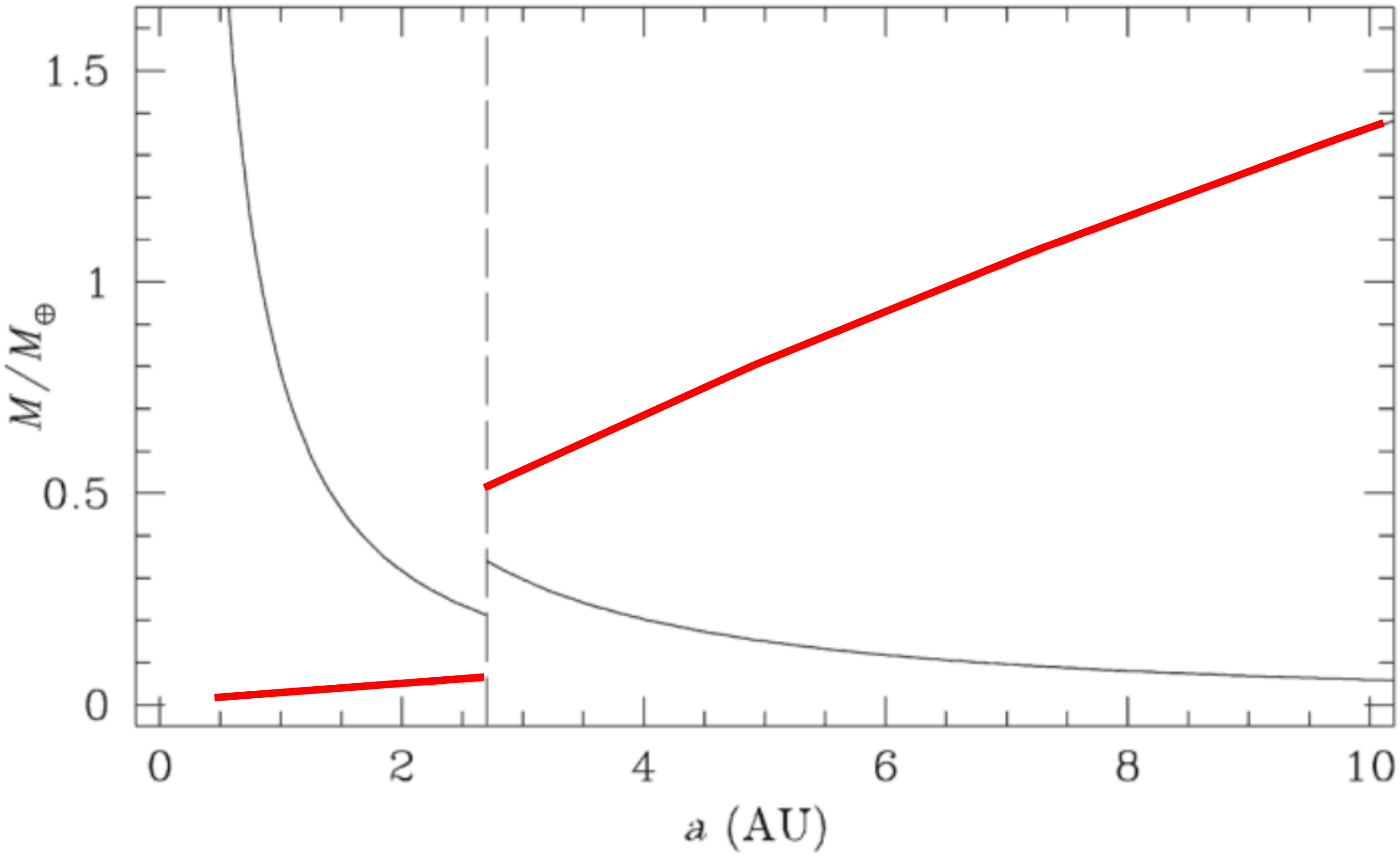
Core Accretion + Gas Capture



Core Accretion + Gas Capture



Mass to maintain non-negligible envelope
vs
Isolation Mass



Critical core mass

ELSEVIER
Planetary and Space Science
Volume 30, Issue 8, August 1982, Pages 755-764

Formation of the giant planets ☆

D.J. Stevenson

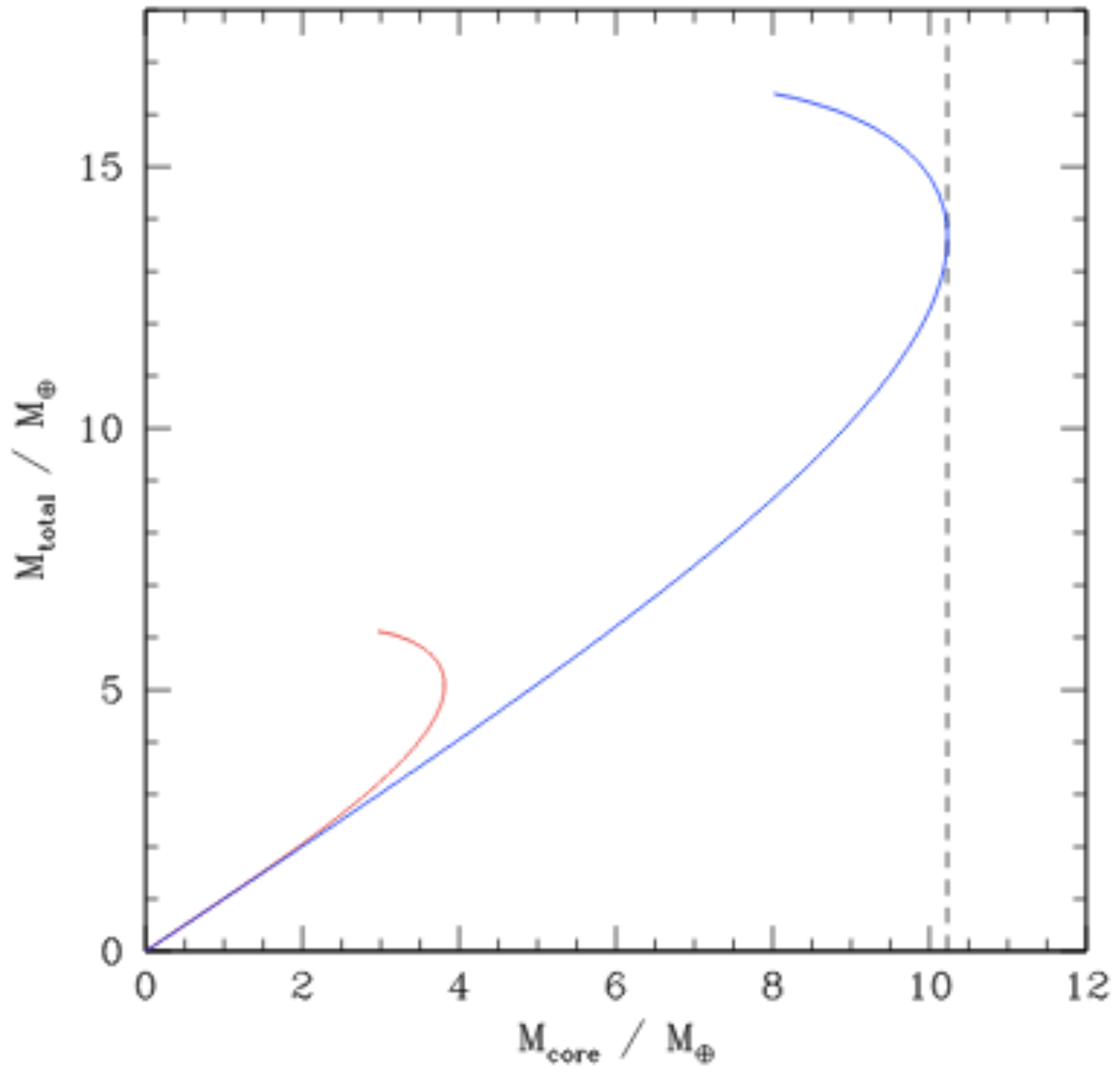
⊞ Show more

https://doi.org/10.1016/0032-0633(82)90108-8

Abstract

Observational constraints on interior models of the giant planets indicate that these planets were all much hotter when they formed and they all have rock and/or ice cores of ten to thirty earth masses. These cores are probably soluble in the envelopes above, especially in Jupiter and Saturn, and are therefore likely to be primordial. They persist despite the continual upward mixing by thermally driven convection throughout the age of the solar system, because of the inefficiency of double-diffusive convection. Thus, these planets most probably formed by the hydrodynamic collapse of a gaseous envelope onto a core rather than by direct instability of the gaseous solar nebula. Recent calculations by Mizuno (1980, *Prog. Theor. Phys.* **64**, 544) show that this formation mechanism may explain the similarity of giant planet core masses. Problems remain however, and no current model is entirely satisfactory in explaining the properties of the giant planets and

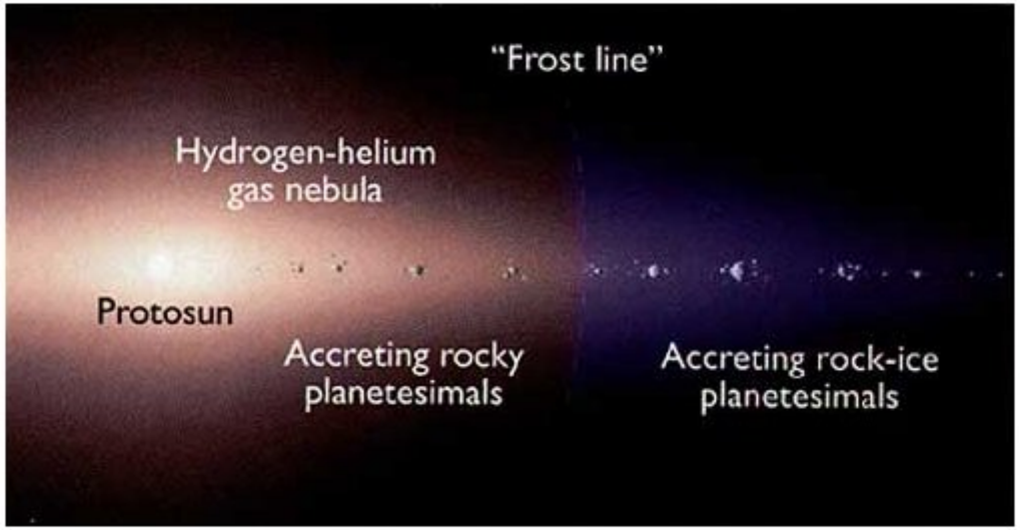
Stevenson, 1982



Formation by Core Accretion

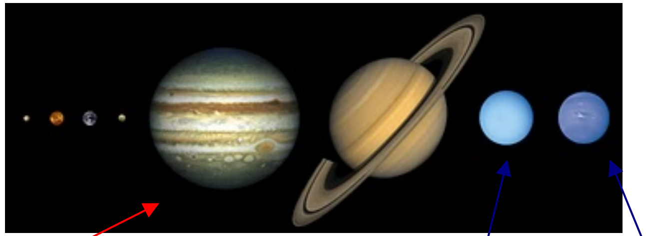
Inward of snowline

Accreting
rocky cores
(small)



Outward of snowline

Ice comes to aid!
Growing big
icy/rocky cores.



Achieved critical core mass.
Accreted envelope.

Did not reach critical mass.
They are just the icy/rocky cores.

Potential of oblate bodies

Newton's second theorem

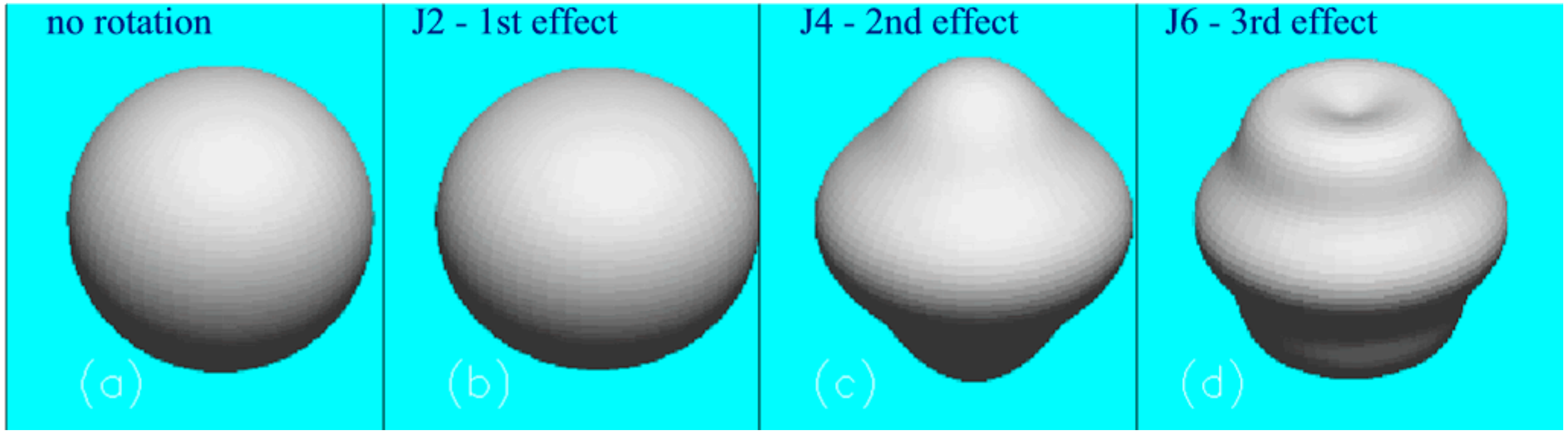
"A spherically symmetric body affects external objects as if all its mass was concentrated in its center"

But planets are not spherically symmetric

Oblateness caused by rotation

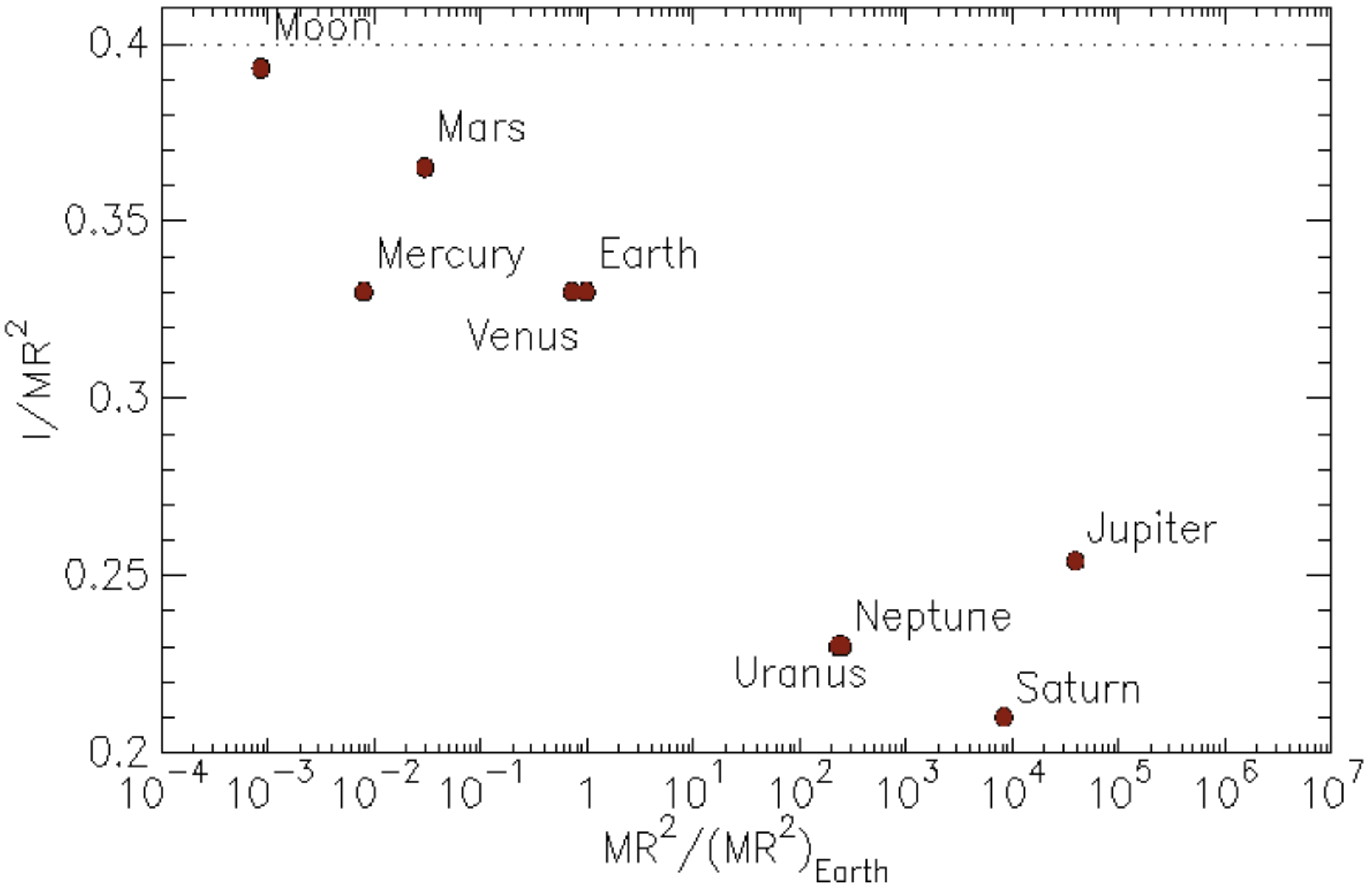
Gravitational Potential

$$\Phi_g(r,\phi,\theta) = -\frac{GM}{r}\left[1 - \sum J_n P_n(\cos\theta)\left(\frac{R}{r}\right)^n\right]$$

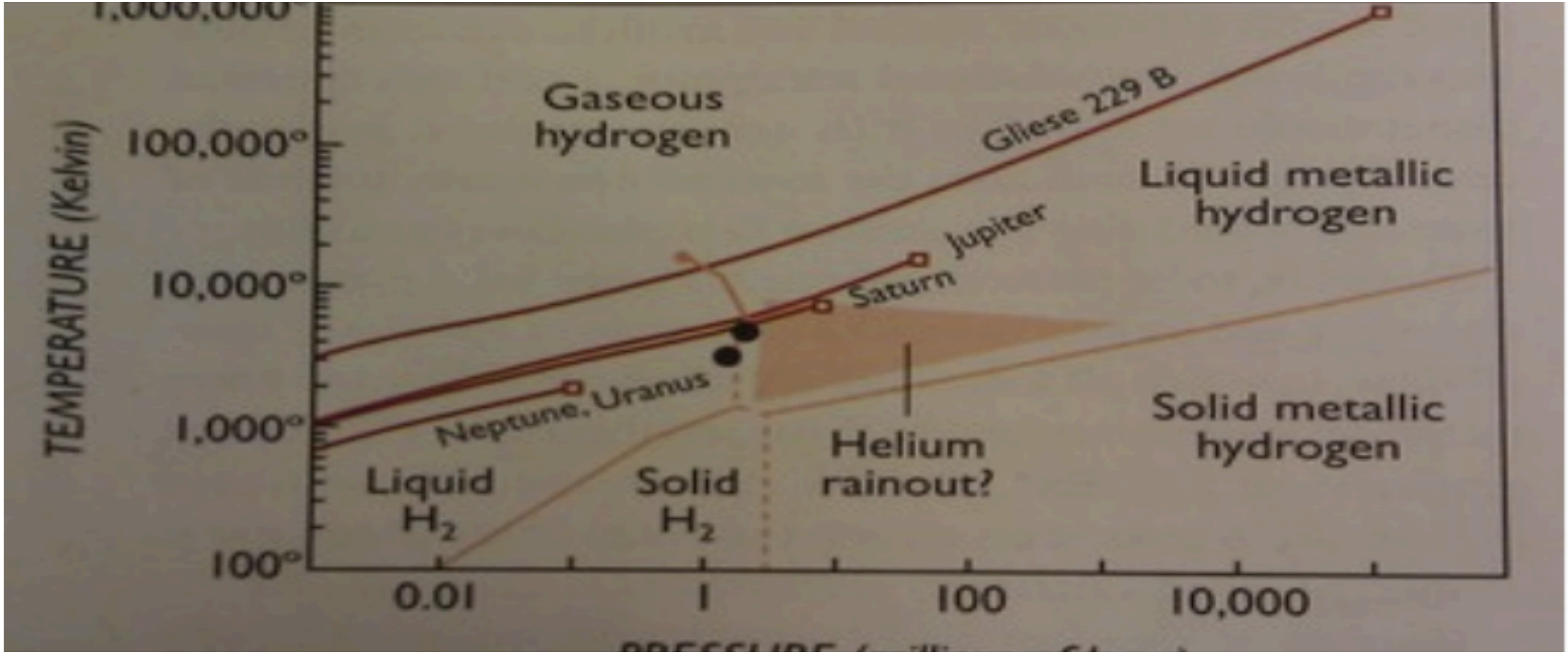


	J_2 (x10^{-6})	J_4 (x10^{-6})	J_6 (x10^{-6})
Jupiter	14696.4+/-0.2	587+/-2	34+/-5
Saturn	16290.7+/-0.3	936+/-3	86+/-9

Deviation from Homogeneity



Core erosion



Gravitational Instability