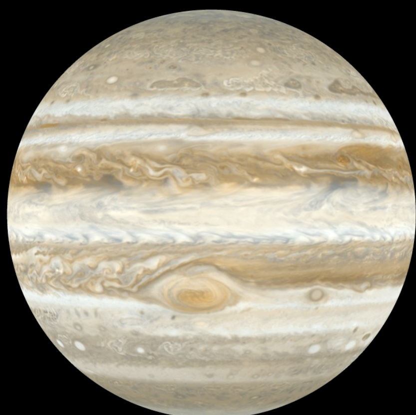
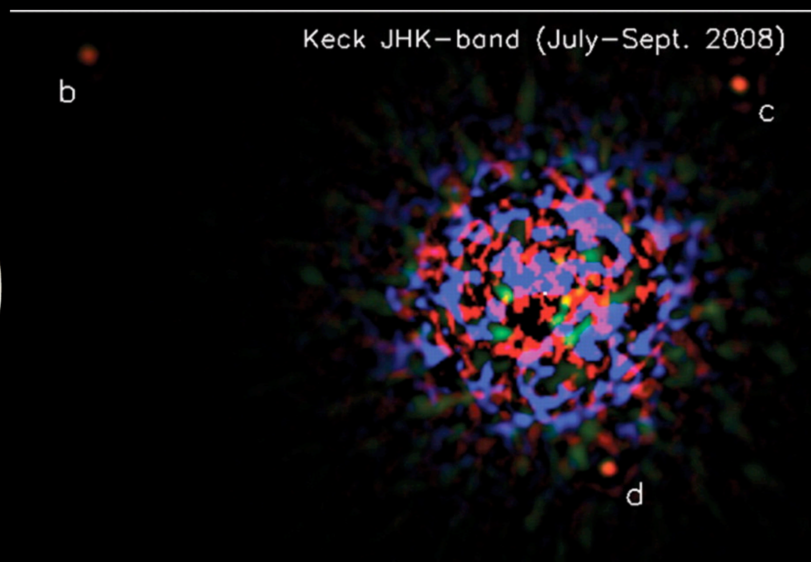
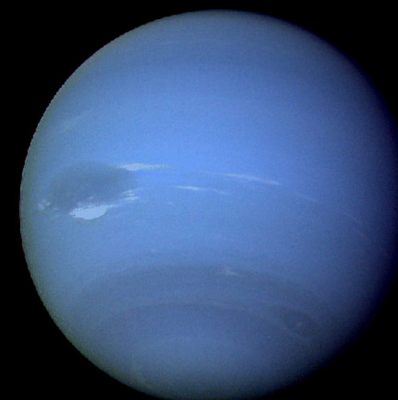
Three Species of Giant Planets

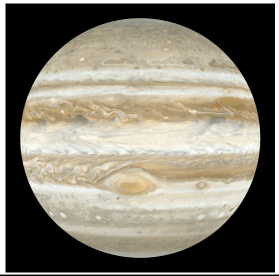
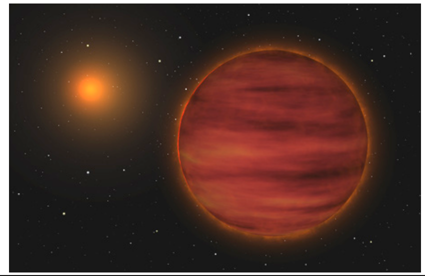
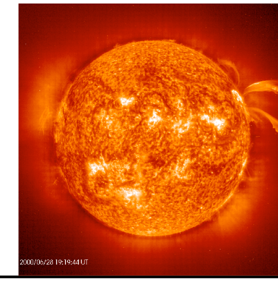






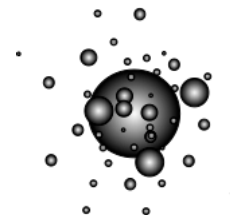
Sally Dodson-Robinson

Spherical, Self-Gravitating Objects

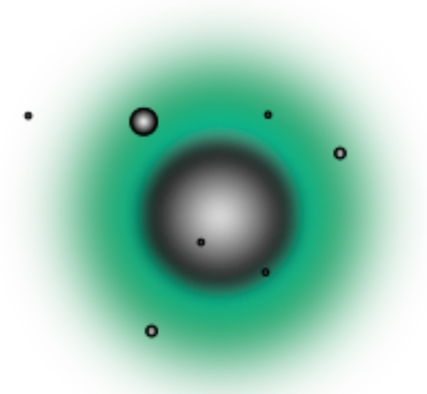
Picture			
Mass Scale	Jupiter	10 Jupiters	100 Jupiters
Formation Efficiency	~10%	Unknown (being measured)	10-30% in local clouds
Formation Mechanism	Bottom-up	Intermediate (possibly triggered)	Top-down
Multiplicity	N planets orbit 1 star	Unknown	Singles or binaries with M_1/M_2~1

Bottom-Up Planet Growth

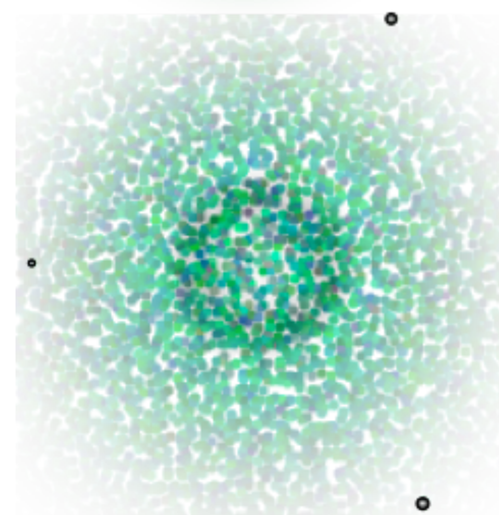
1. Rock and/or ice planetesimals collide, stick together by gravity
   Terrestrial planets stop here



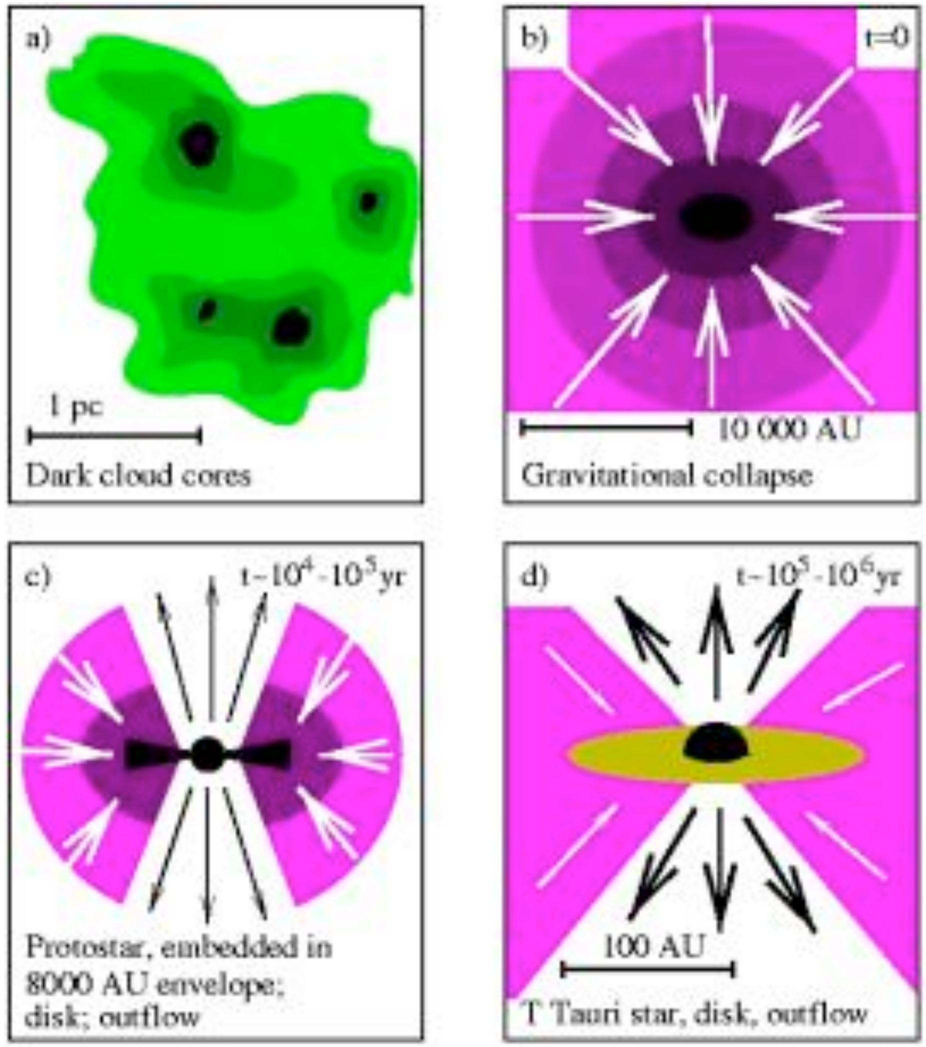
2. Gas begins to gather slowly on large (>10 $M_{\oplus}$) solid core
   Ice giants (Uranus and Neptune) stop here



3. Gas falls onto protoplanet at runaway pace; massive gas atmosphere grows in ~1000 years
   Gas giants (Jupiter and Saturn) stop here

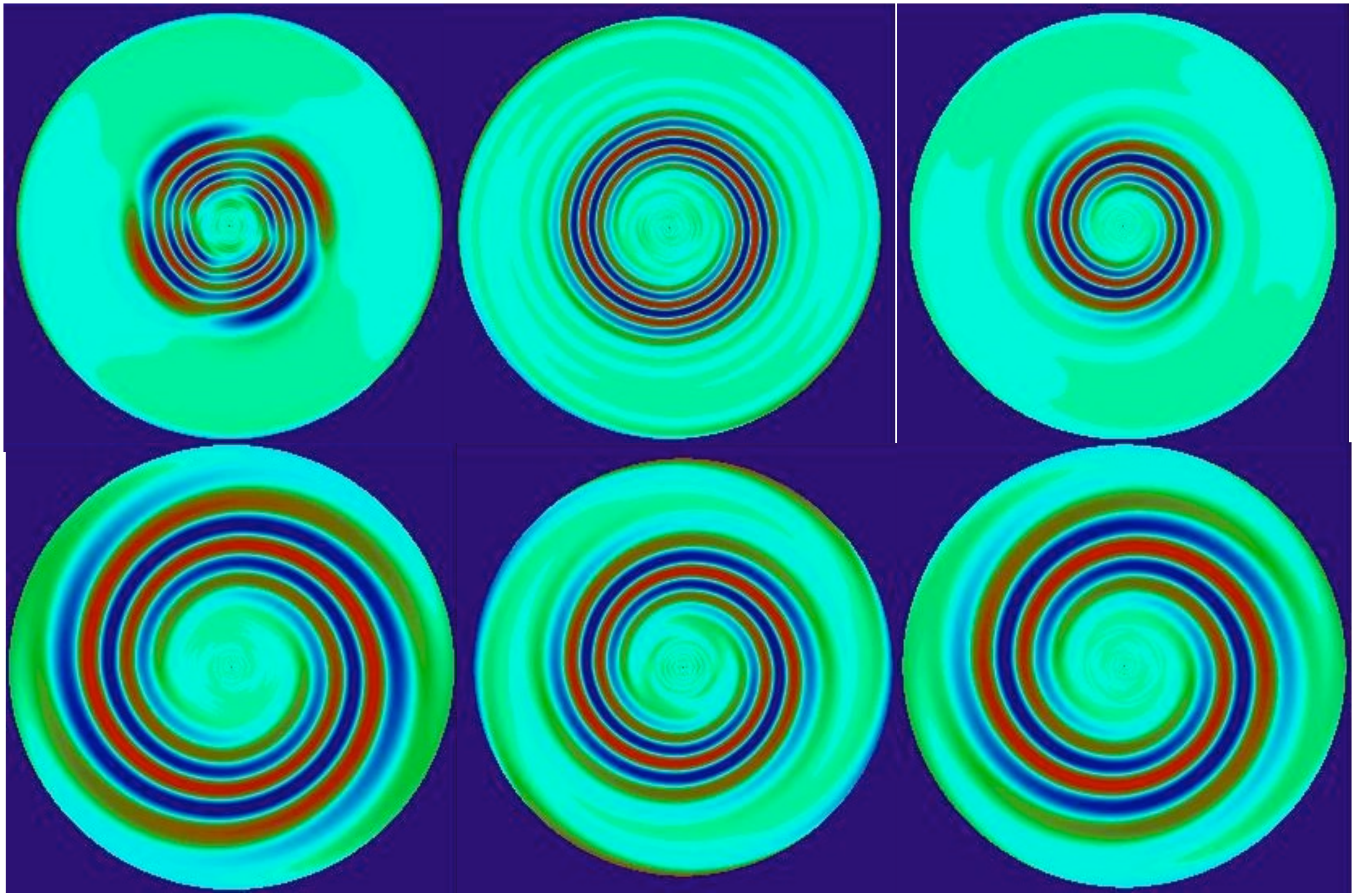


Top-Down Star Formation



Cartoon by Michiel Hogerheijde

Intermediate Mechanism



Dodson-Robinson et al. 2009, arXiv:0909.2662

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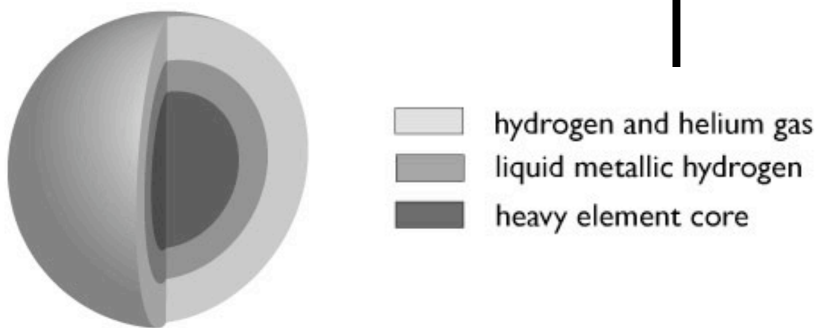
Wide orbit | Close-in orbit

Core accretion



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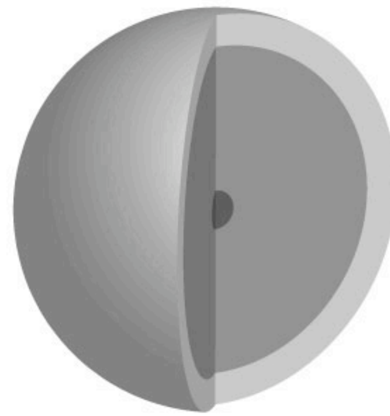
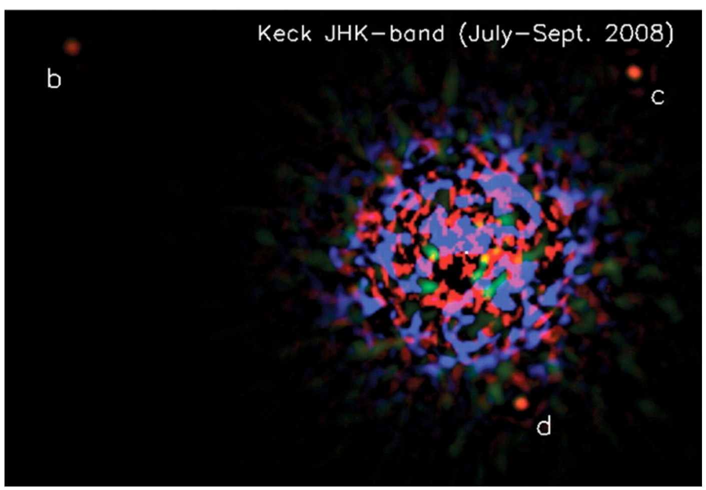


Jupiter

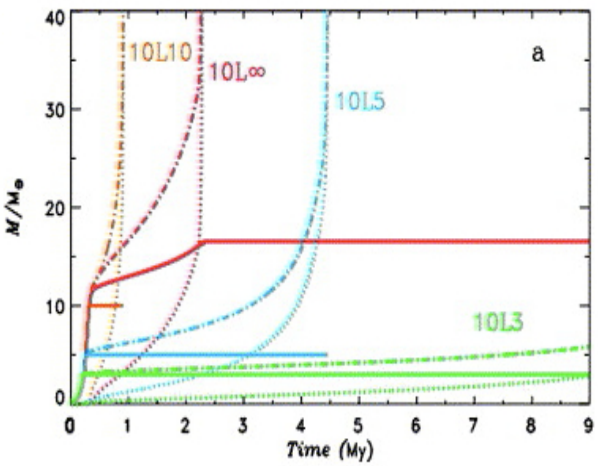
Disk instability



Not viable*

Growth Curves

Jupiter



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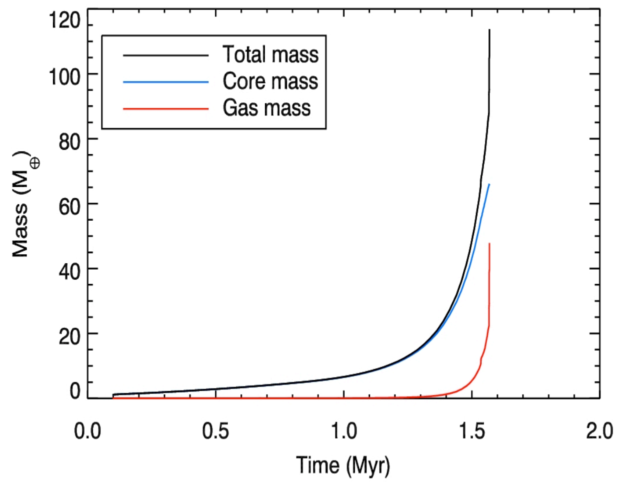
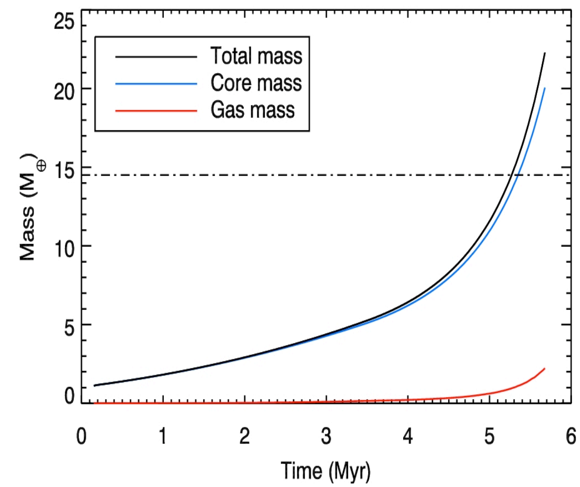


Uranus



GI ⟷ Earth*

5.2 AU
Low solid/gas
Quick formation
Most massive

10 AU
Medium solid/gas
Slower formation
Saturn-like
Intermediate mass

15 AU
High solid/gas
Slow formation
Ice giant
Low mass

Questions

- How common are planets formed by gravitational instability?
- Over what mass ranges do bottom-up, top-down and instability formation overlap?
- Can gravitational instability and core accretion occur in the same disk?
- How can we ensure protoplanetary clumps formed by GI survive and evolve into planets?
- At what distance from the star does core accretion no longer form giant planets?