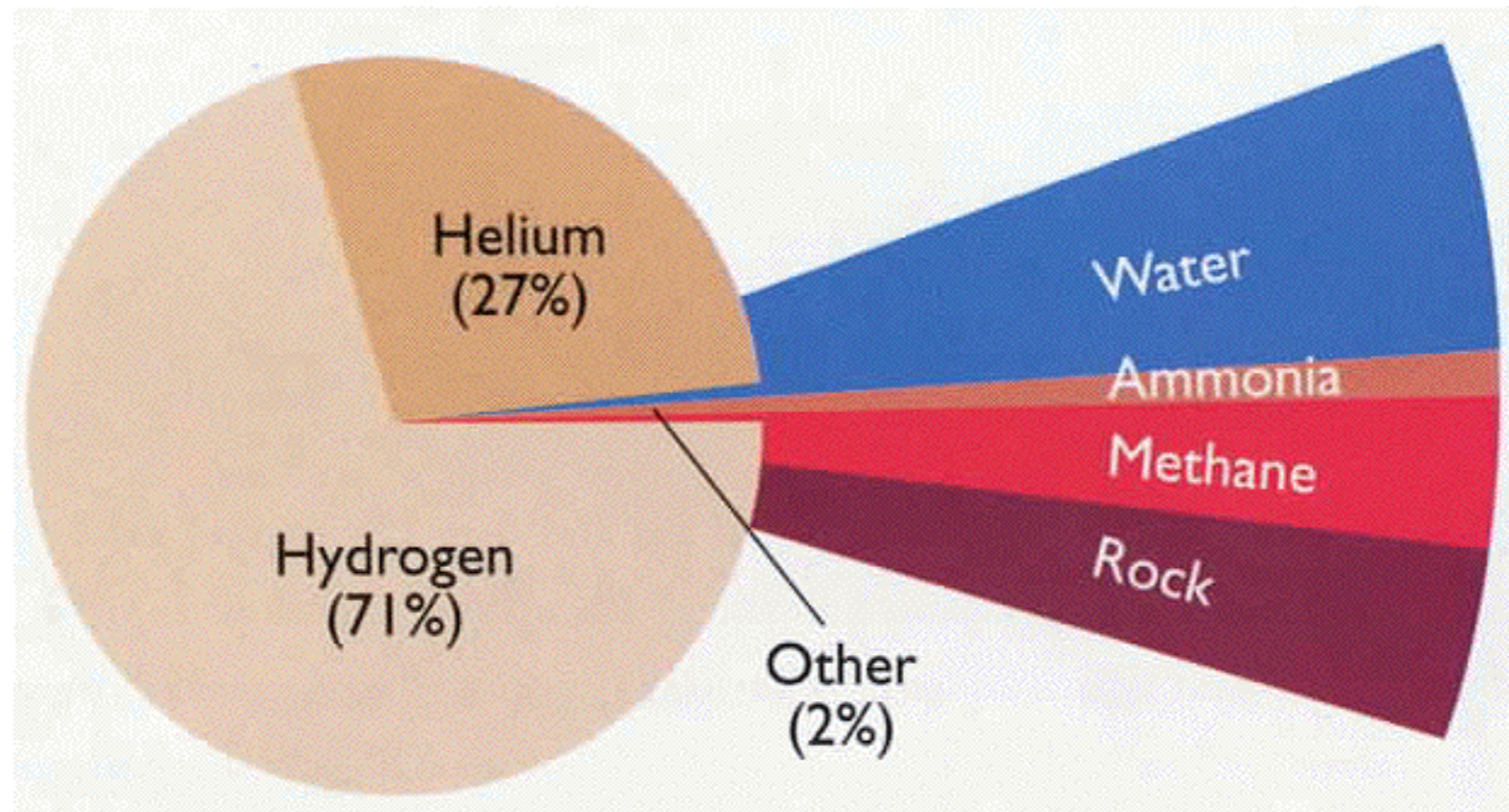


# Formation and Evolution of the Solar System

What's Initially Available:

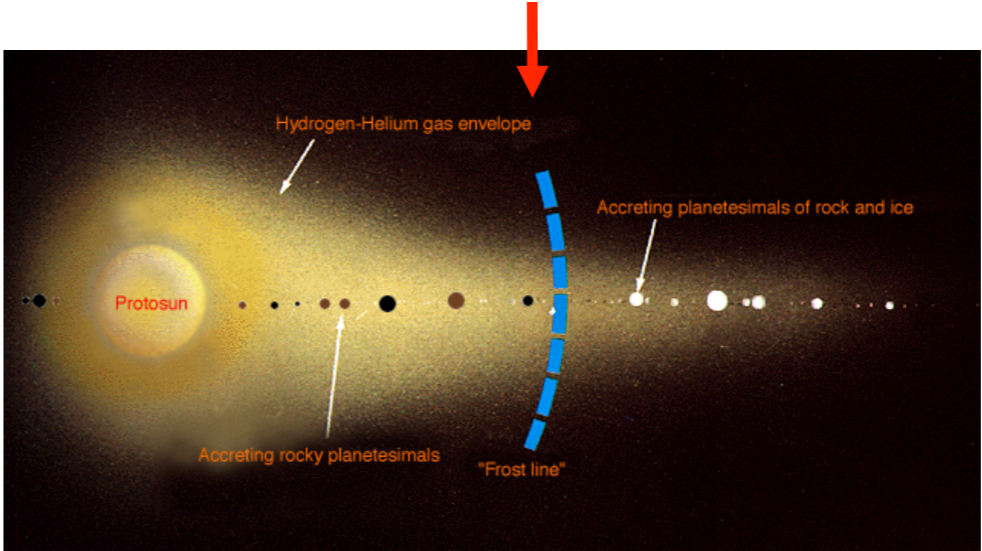
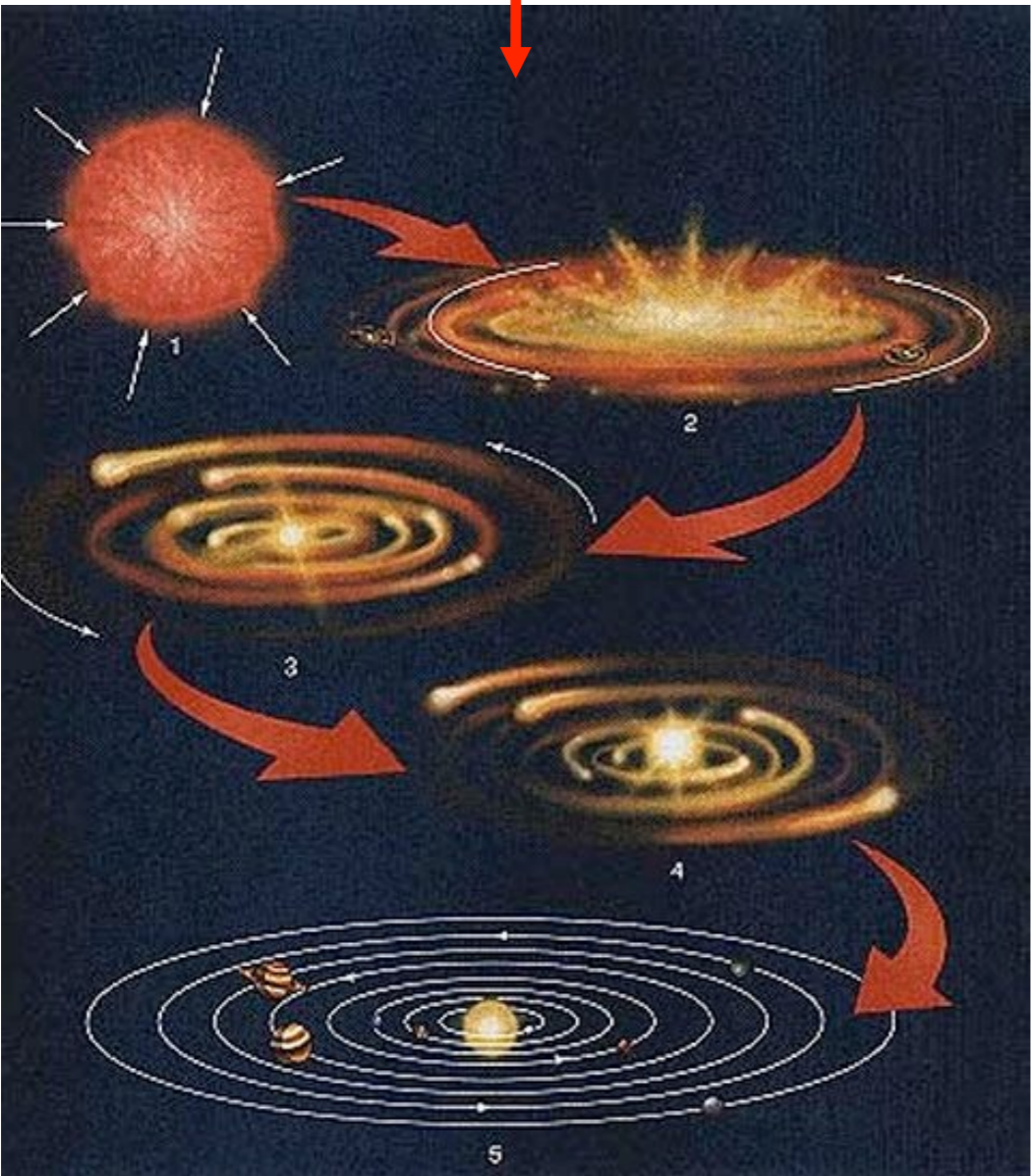


Solar Nebula - Composition

# Nebular Model

Planets gradually form out of the rotating disk of gas & dust

Beyond the “frost line”, ices can condense, allowing more massive planets to form



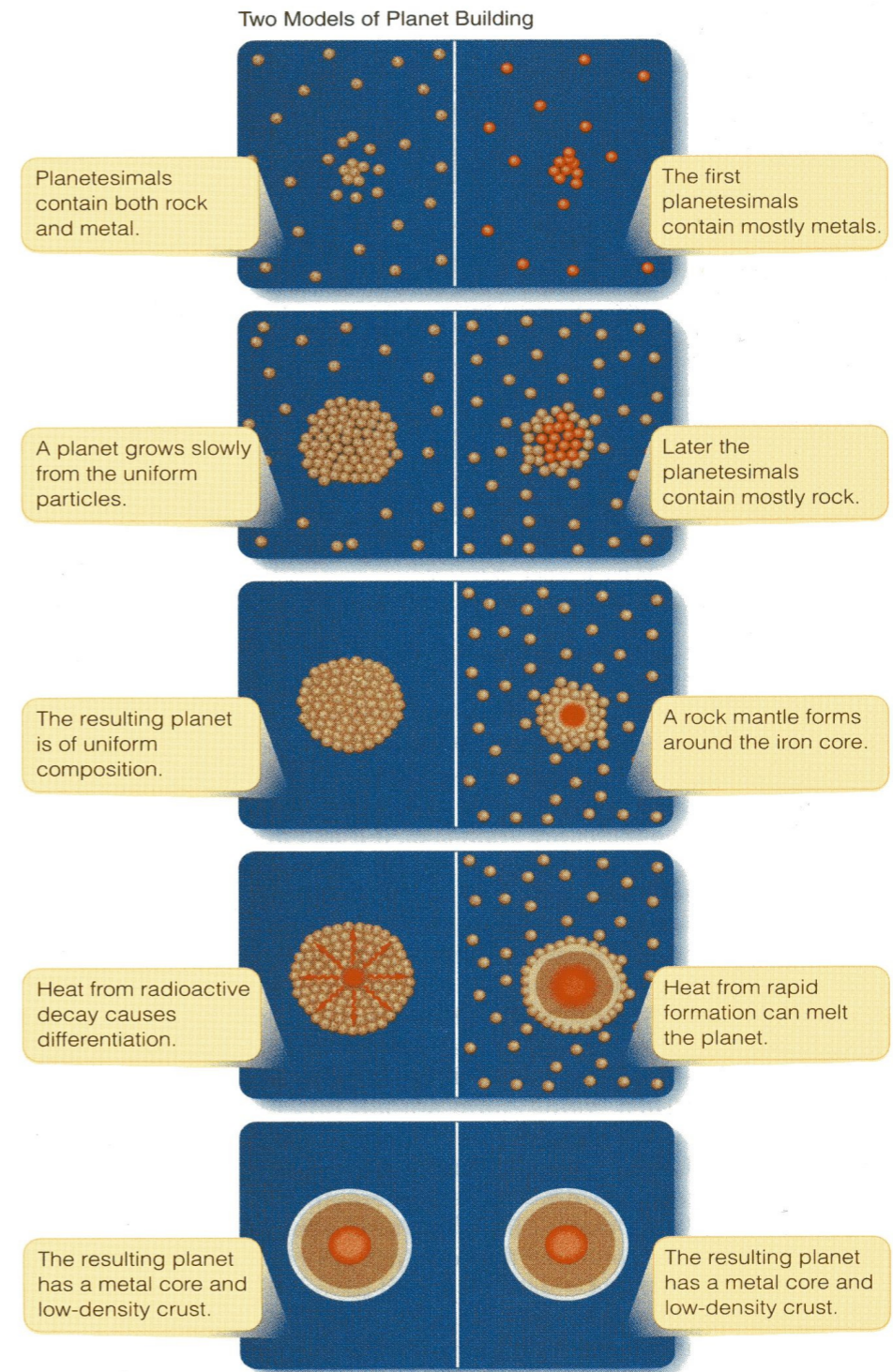
Refractories  
(rock,  
metal)

volatiles  
(ices & gas)  
and  
refractories

- Two possible sequences of formation of terrestrial (rocky) planets:
- Merge homogeneous collection of planetesimals, then differentiate
- Form planets while condensation is still happening

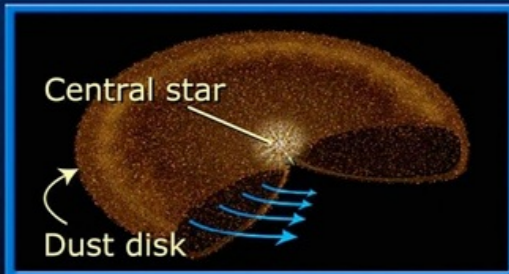
**Table 5-3 The Condensation Sequence**

Temperature (K)	Condensate	Planet (Estimated Temperature of Formation; K)
1500	Metal oxides	Mercury (1400)
1300	Metallic iron and nickel	
1200	Silicates	
1000	Feldspars	Venus (900)
680	Troilite (FeS)	Earth (600) Mars (450)
175	H <sub>2</sub> O ice	Jovian (175)
150	Ammonia-water ice	
120	Methane-water ice	
65	Argon-neon ice	Pluto (65)



# TWO PLANET FORMATION SCENARIOS

## Accretion model



Orbiting dust grains accrete into "planetesimals" through nongravitational forces.



Planetesimals grow, moving in near-coplanar orbits, to form "planetary embryos."

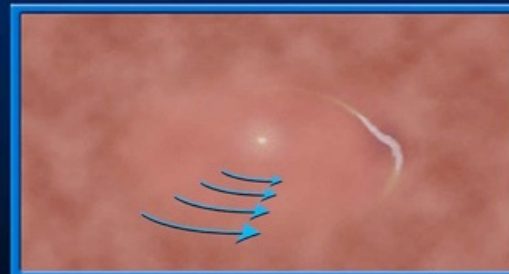


Gas-giant planets accrete gas envelopes before disk gas disappears.



Gas-giant planets scatter or accrete remaining planetesimals and embryos.

## Gas-collapse model



A protoplanetary disk of gas and dust forms around a young star.



Gravitational disk instabilities form a clump of gas that becomes a self-gravitating planet.



Dust grains coagulate and sediment to the center of the protoplanet, forming a core.

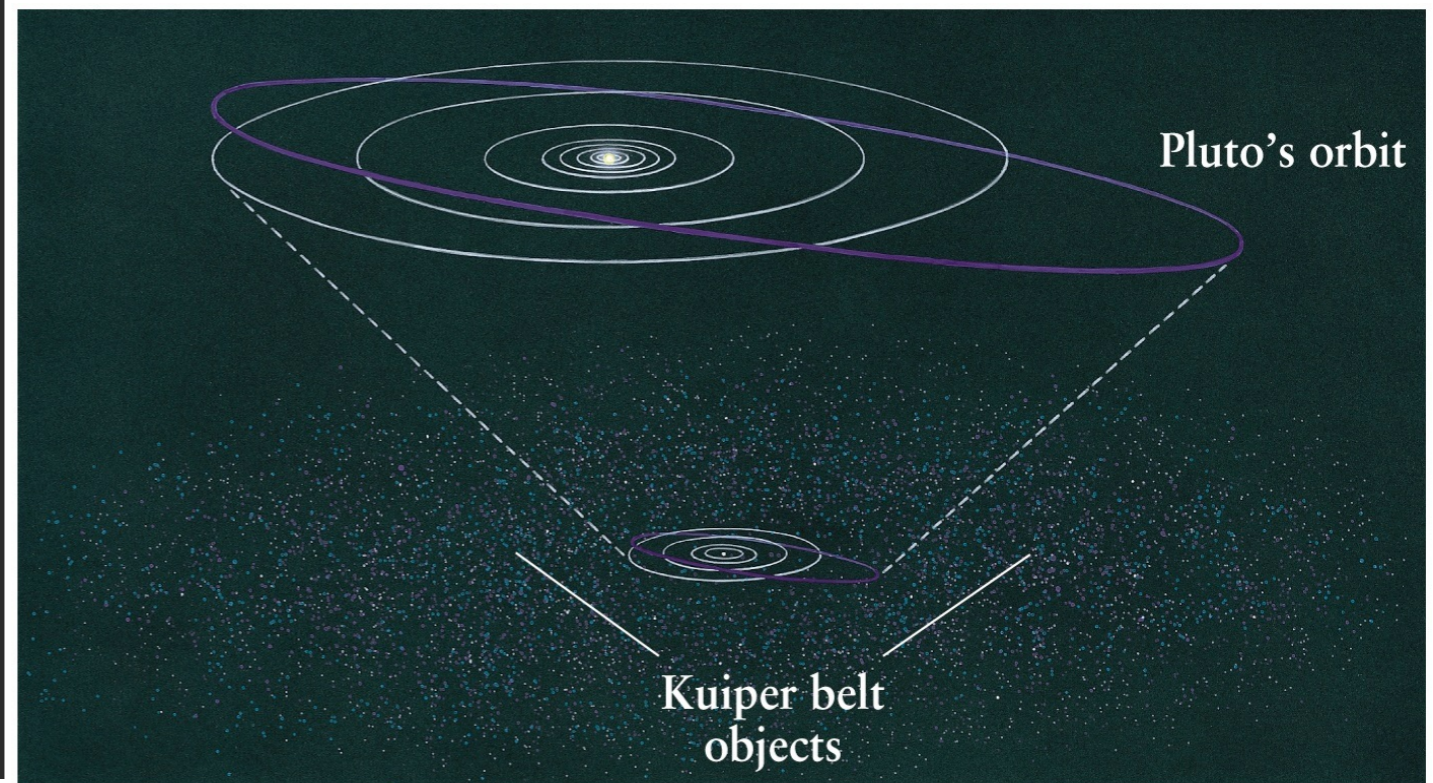
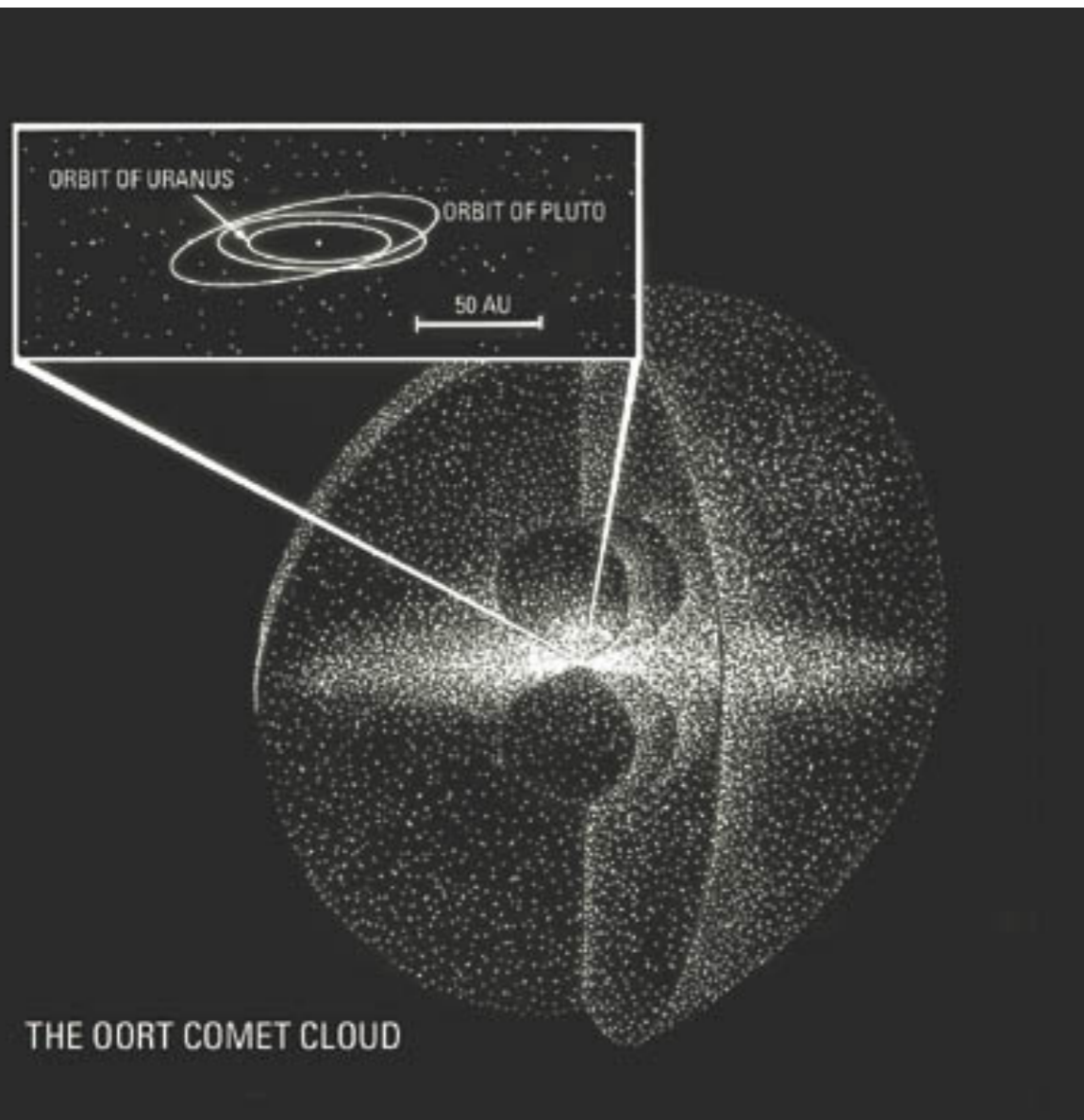
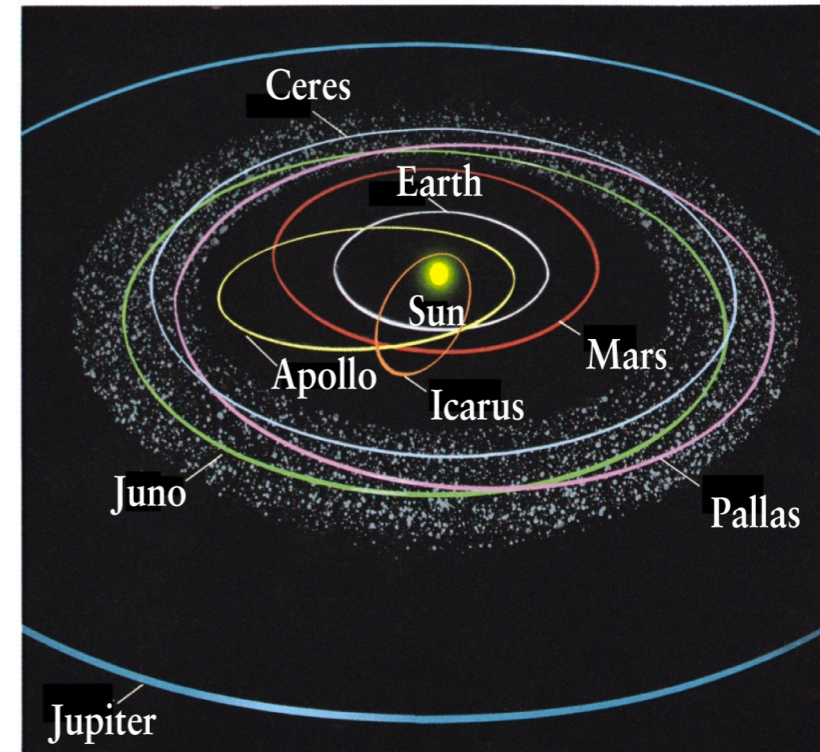


The planet sweeps out a wide gap as it continues to feed on gas in the disk.

For Jovians:

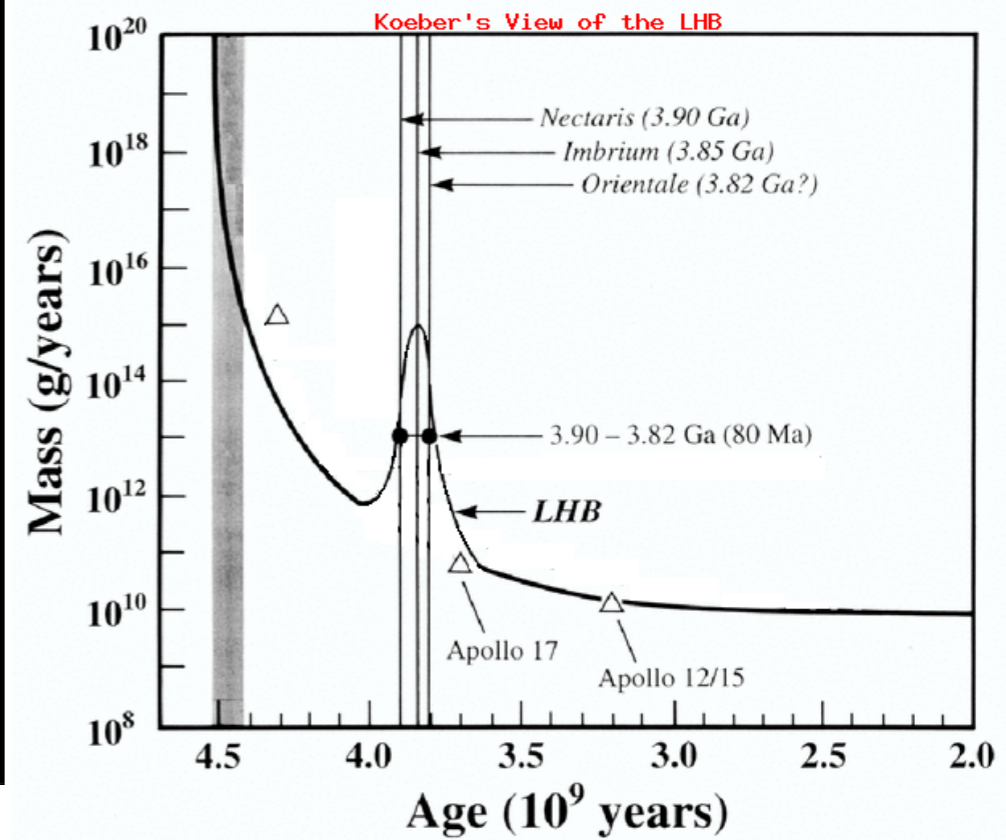
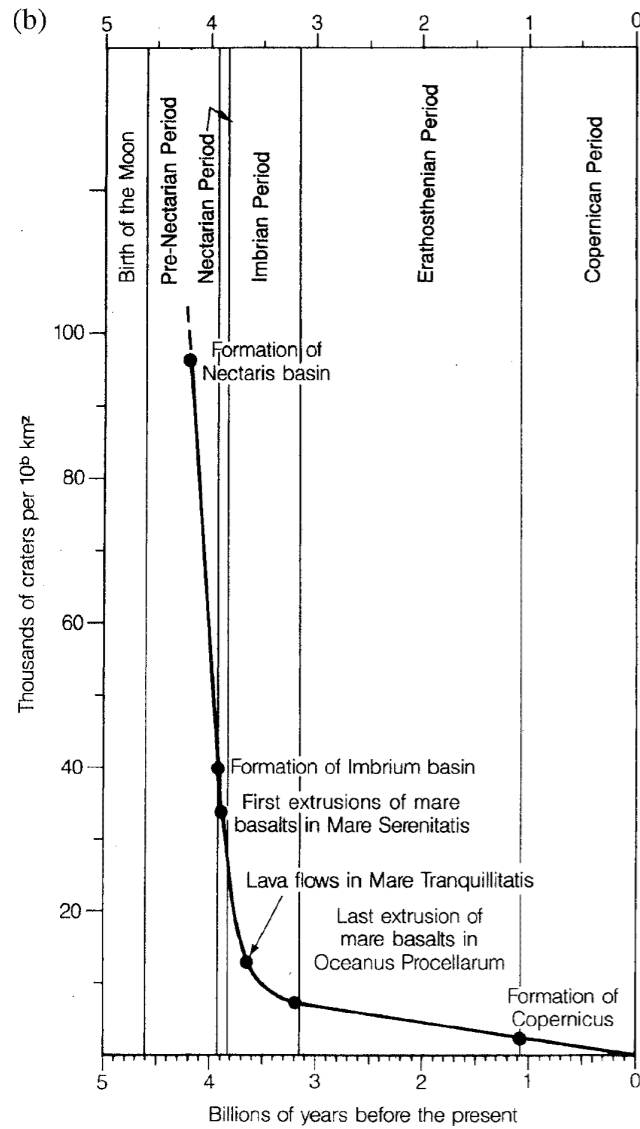
- Accrete cores first, then lighter material
- Rapid catastrophic disk collapse

Planets, asteroids (minor planets), Kuiper Belt Objects (another form of minor planet)

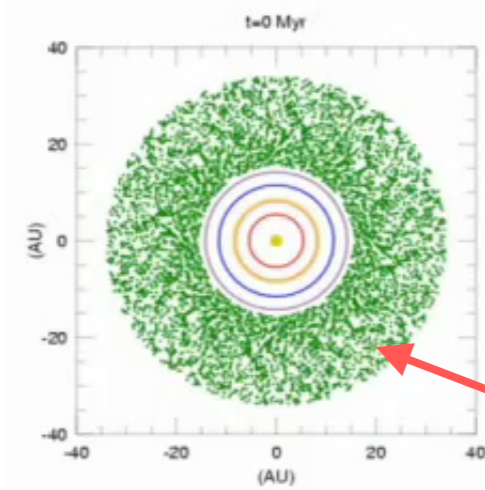
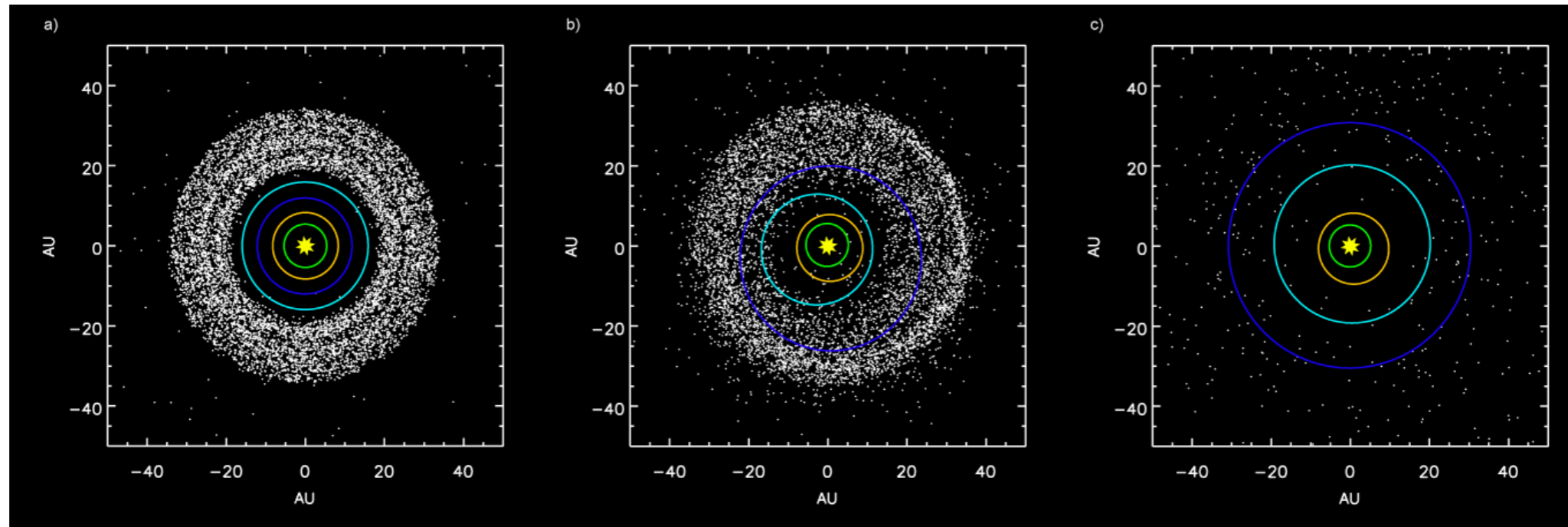


# The History of the Solar System is Written on the Face of the Moon

## What Does the Moon Tell Us? Two views

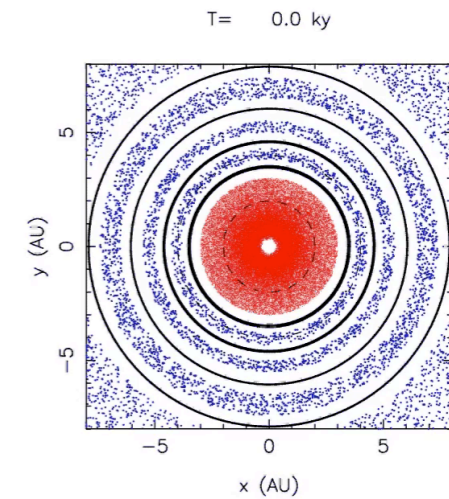


# Mixing via Planetary Migration



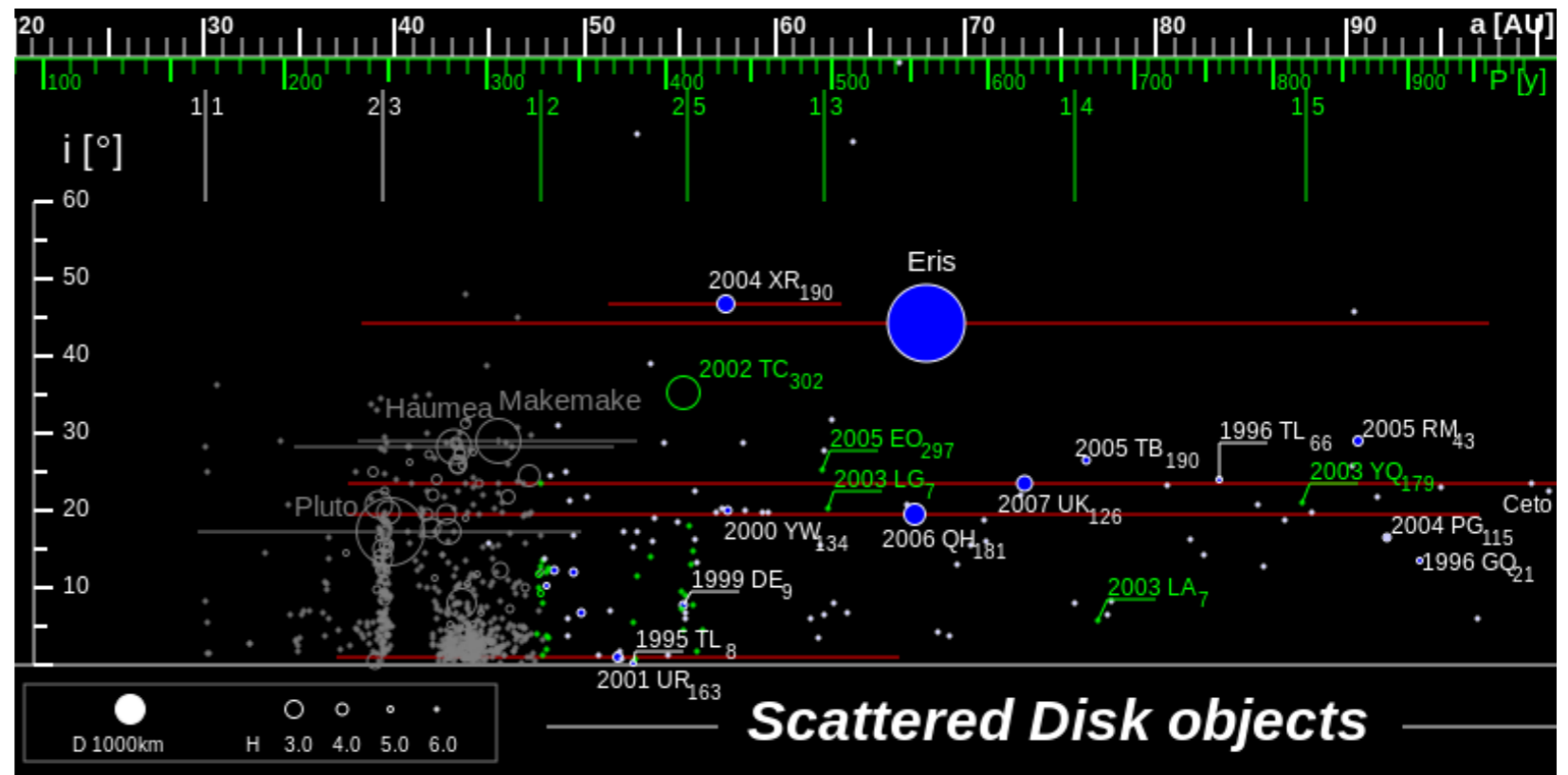
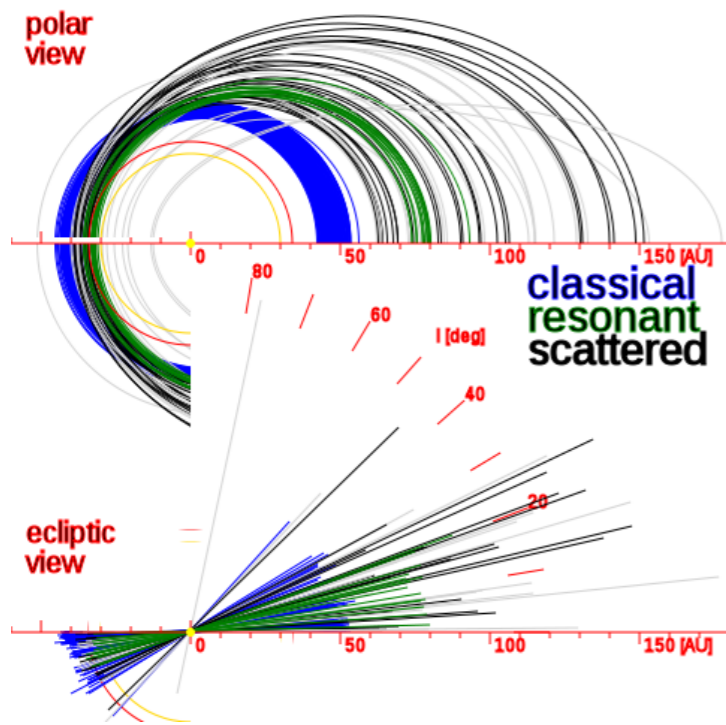
“Nice Model”

“Grand Tack”



Kuiper Belt Objects  
(Pluto, Eris, etc.)

# Scattered Kuiper Belt Population

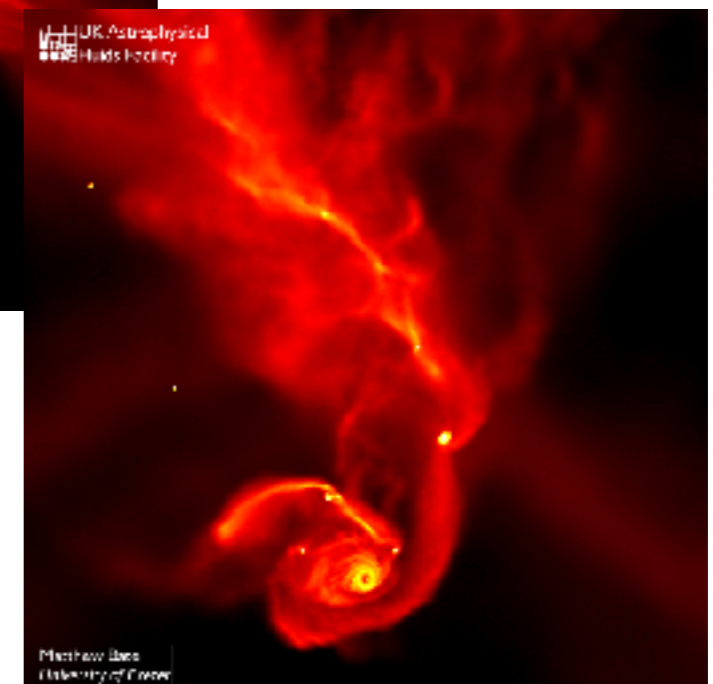
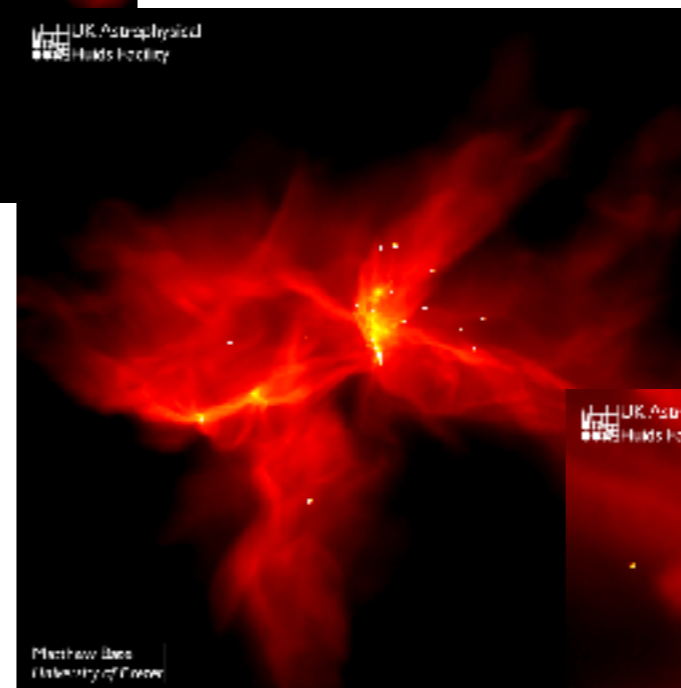
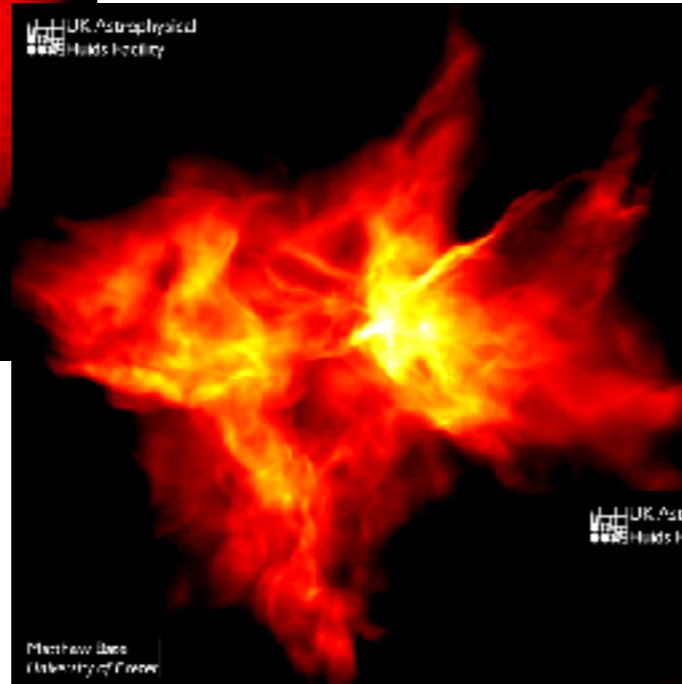
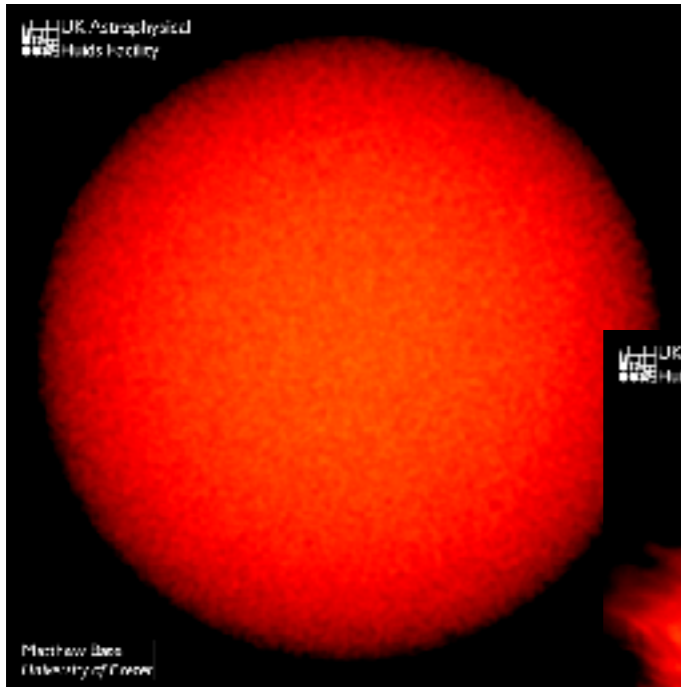


**We will come back to some of these topics when looking more deeply into asteroids, comets, "exodisks", and the like.**

# The Zodiacal Light



# Real Star & Planet Formation will be Messy!



Simulation & visualization by Matthew Bate, University of Exeter.

<http://www.astro.ex.ac.uk/people/mbate/Animations/>

