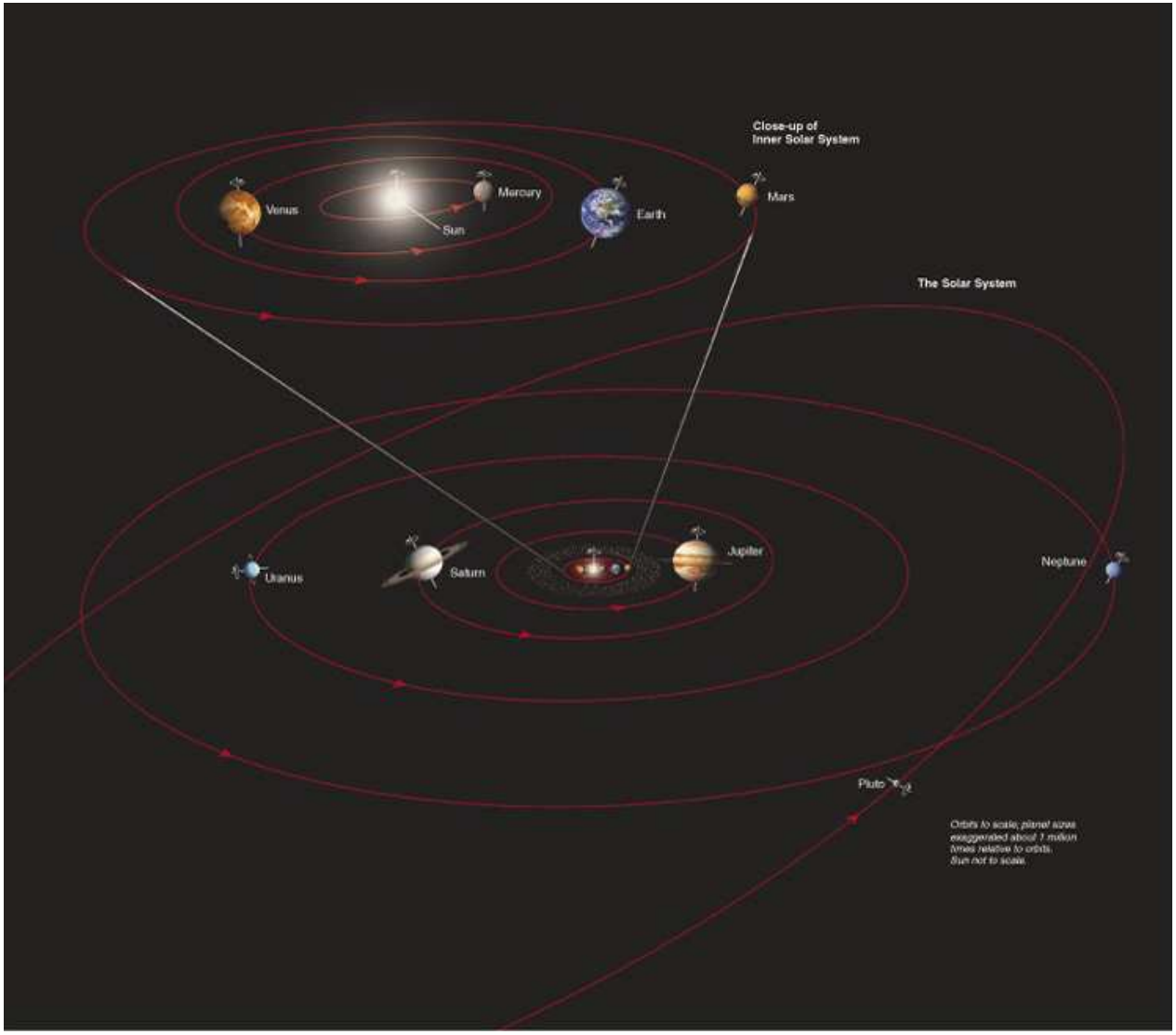


"If the solar system was brought about by an accidental collision, then the appearance of organic life on this planet was also an accident, and the whole evolution of Man was an accident too."

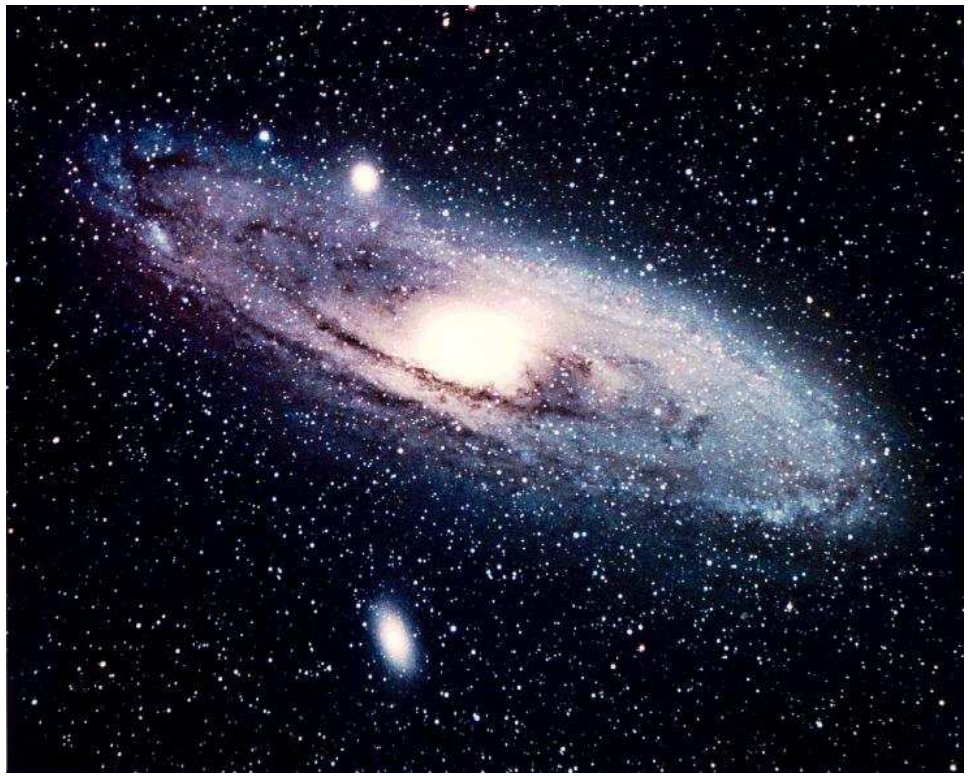
C. S. Lewis

What We Will Learn Today

- How was our solar system born?
- What caused the observed patterns in our solar system?
- Why do we have two types of planets
- How did the planets form?

The Early Universe

- The Big Bang produced H & He
- Matter collapsed in local regions, which became galaxies



Earlier Generation Stars

- Within galaxies, some of the gas collapsed to form the first generation of stars
  - Mostly made of Hydrogen & Helium
- These massive stars ended their short lives in a spectacular supernova
- This process created and seeded interstellar gas with more “metals” (elements like C, N, O, Fe…)
- Next generation stars are born with higher “metallicity”
- About 4.6 billion years ago, the Sun is born from the Solar Nebula

“We are star-stuff”

Carl Sagan

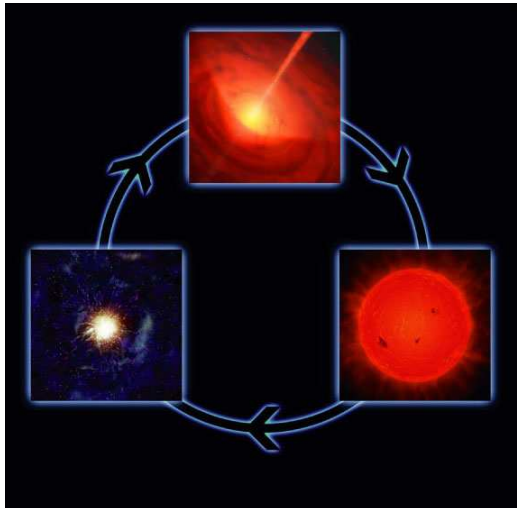


Fig 8.1

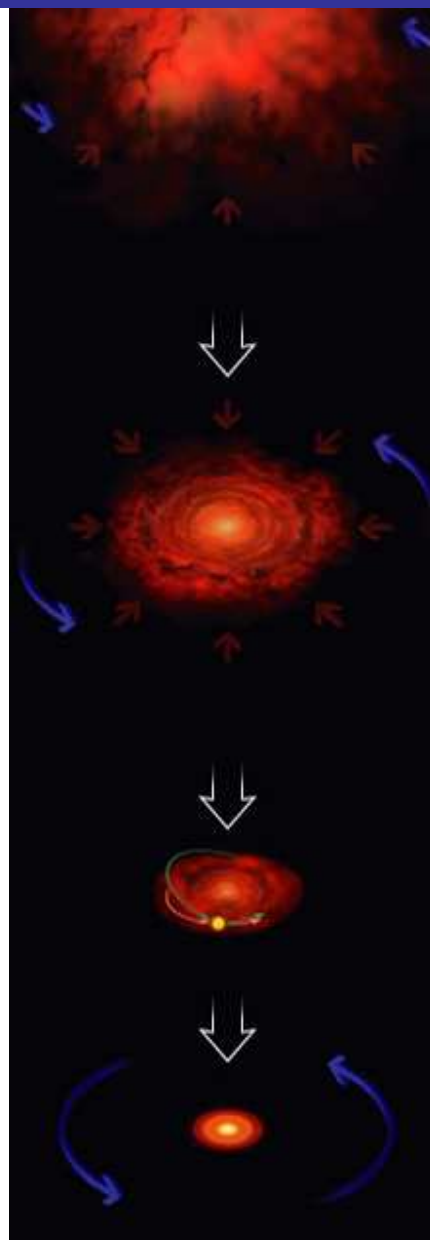


Fig 8.3

Can We See Other Nebulae?

Can We See Other Nebulae?

- Stars being born today are in interstellar clouds
- A close look at Orion nebula reveals several proto-planetary disks (proplyds)
- Observations of baby solar systems gives credence to the theory of how ours formed

Fig 8.2

Solar System Formation

- Large chunk of gas & dust: Solar Nebula lived peacefully
- Some disturbance triggered a collapse
  - Nearby Supernova
  - Another cloud passed close by
- Once collapse stars, it feeds on itself
  - Remember inverse square law?
  - Proceeds faster and faster

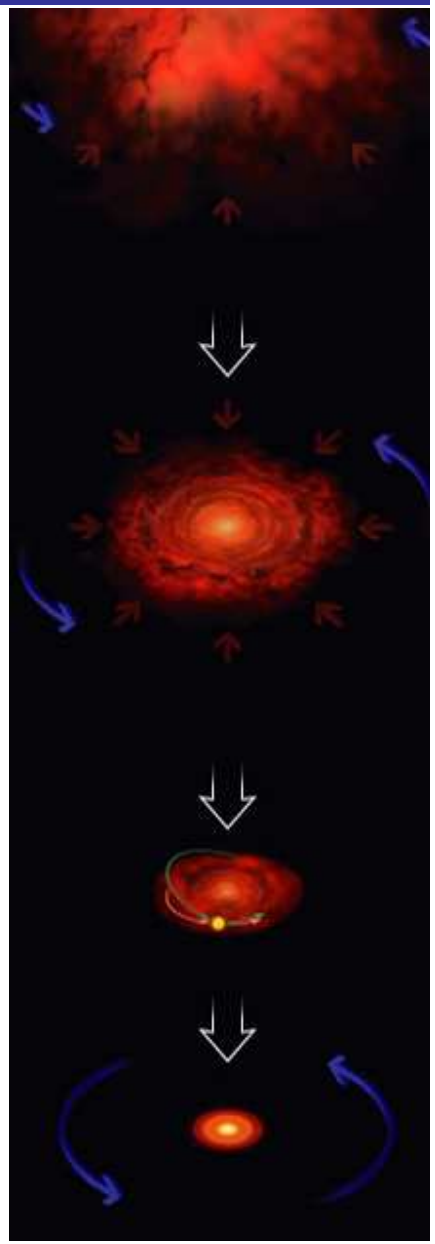


Fig 8.3

The Collapse Continues

- The core gets hotter and hotter
  - Conservation of energy: Potential to Kinetic (remember temperature?)
- Spinning becomes faster
  - Conservation of angular momentum
- Direction of motions becomes organized
  - Random movements get organized due to many collisions, aligning with velocity kick of original disturbance
  - As it spins, cloud flattens at poles and bulges at equator
  - Once central disk forms, it grows due to collisions
  - High eccentricity orbits collide more, favoring low eccentricity orbits

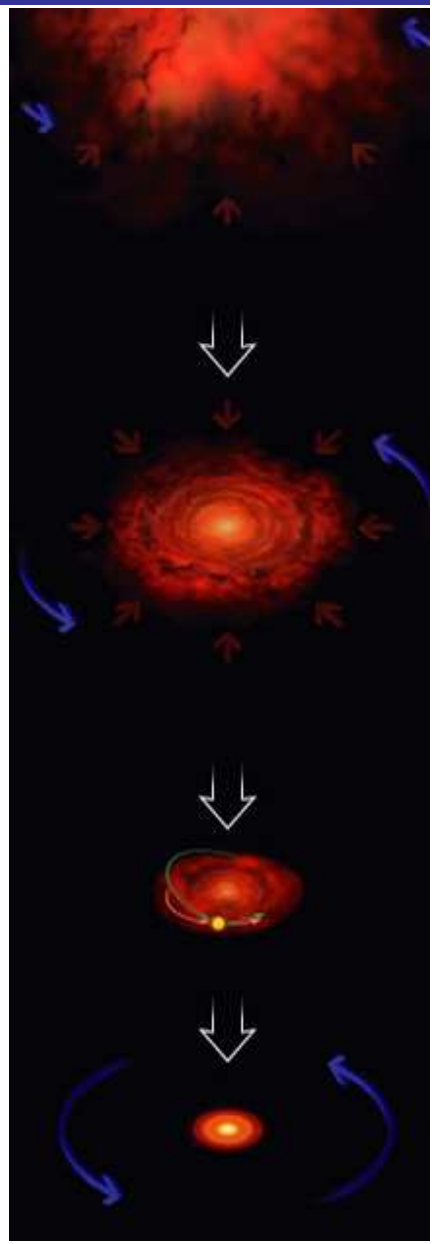


Fig 8.3

Observational Evidence

- We have seen flattened debris disks around other newborn stars
- Computer simulations lead to a flat disk
- Other examples seen such as spiral galaxies and accretion disks around black holes & dense stars

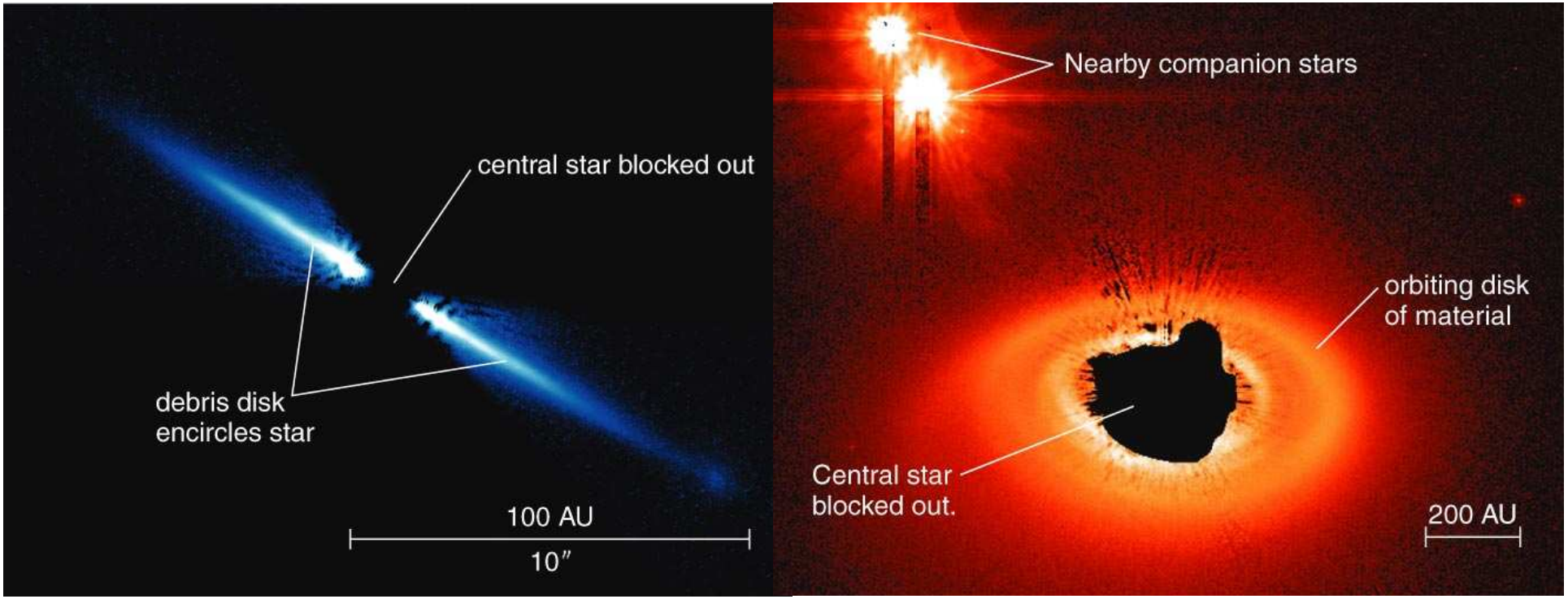


Fig 8.4

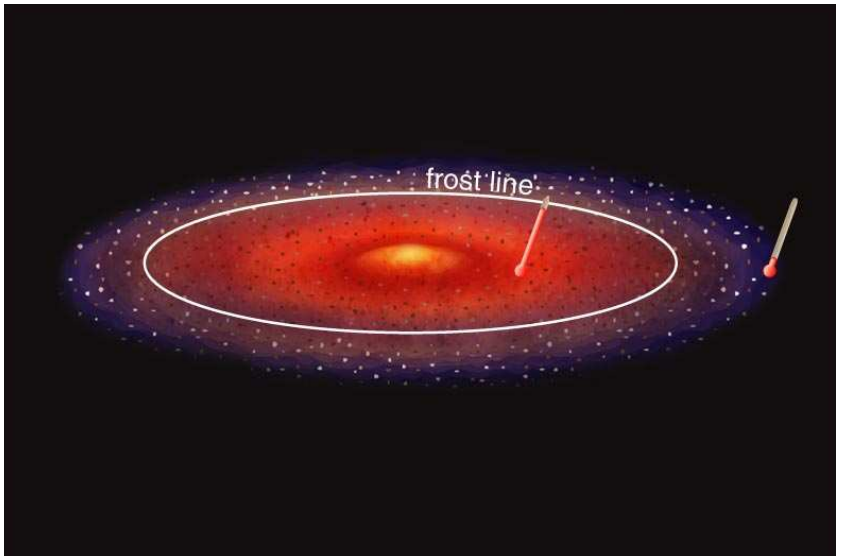
A Star is Born!

- The core gets hotter and hotter
- Eventually, reaches 10 million K
- At this temperature
  - H has been broken up into proton & electron
    - Remember disassociation?
  - Protons collide due to speed, despite mutual repulsion
  - When they get very close, they suddenly like each other, a lot!
  - 4 H nuclei (i.e. protons) combine to form a He nucleus and give off energy
    - $E = mc^2$
  - The Sun shines with its own light and is born as a star!
  - Solar wind blows away a lot of the nebular gas into outer space

The Two Types of Planets

- Solar nebula composition
  - 98% H & He
  - 1.4% H-compounds (H_20, CH_4, NH_3)
  - 0.4% minerals
  - 0.2% metals (Iron, nickel, aluminum)
- Different materials condense at different temperature
  - Within Mercury's orbit, nothing condenses
  - Within frost line, metals and minerals condense
  - Beyond frost line, H-compounds condense

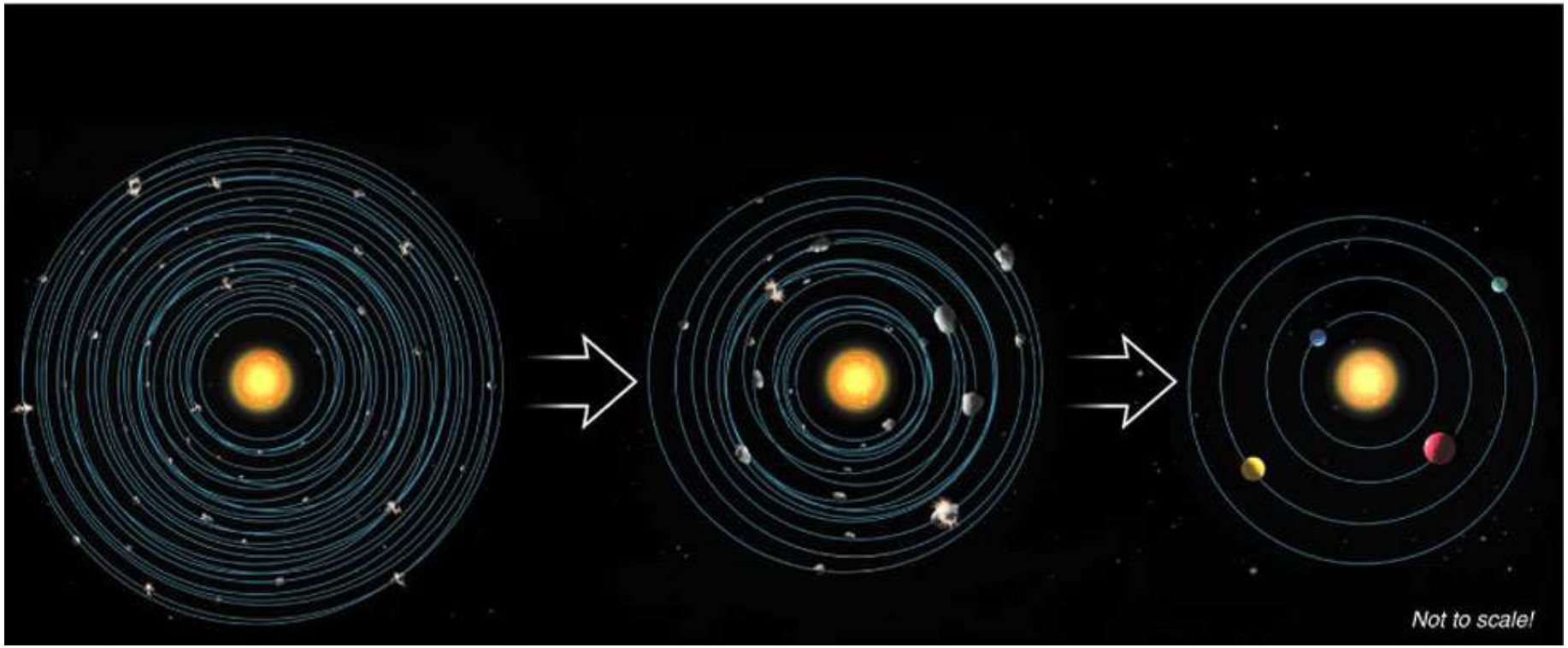
Fig 8.5



Formation of Terrestrial Planets

- Process of **accretion**
  - Initial “collisions” of tiny particles were gentle touches, allowing them to stick
  - As they grew larger, they grew faster
  - Collisions of larger planetesimals were often destructive
  - Largest of these planetesimals became terrestrial planets

Fig 8.6



Formation of Jovian Planets

- Jury is still out
- Accretion model favored
  - Ices clump and accrete like terrestrial planets
  - Due to higher abundance, they grow larger faster
  - Increased gravity captures and holds H & He "atmosphere"
  - Eventually, the "atmosphere" grows to become most of the planet's mass
  - Collapse process similar to Sun's
    - Responsible for Moon and ring formation

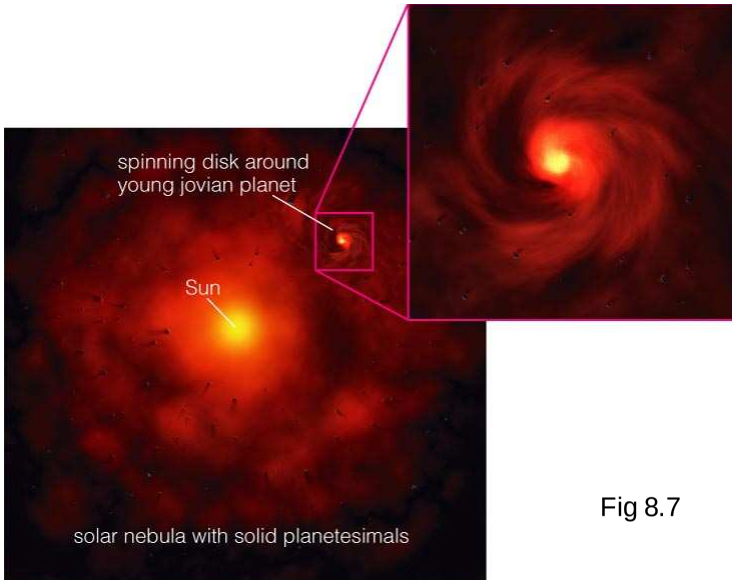


Fig 8.7