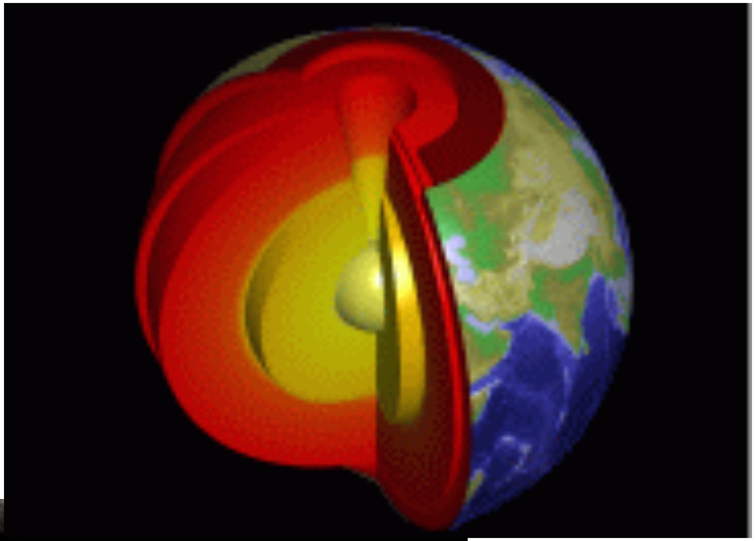
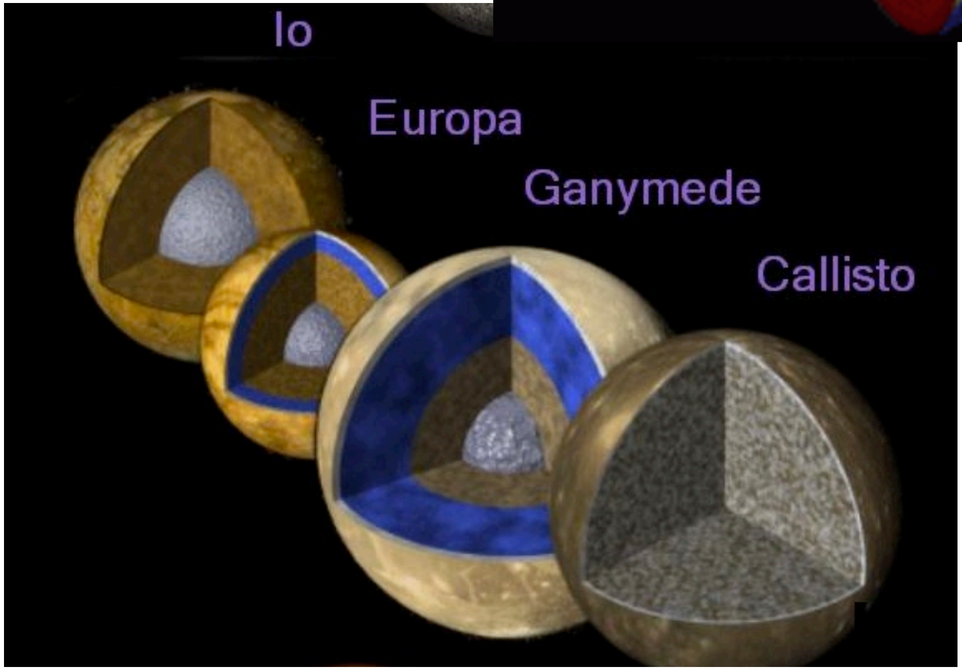
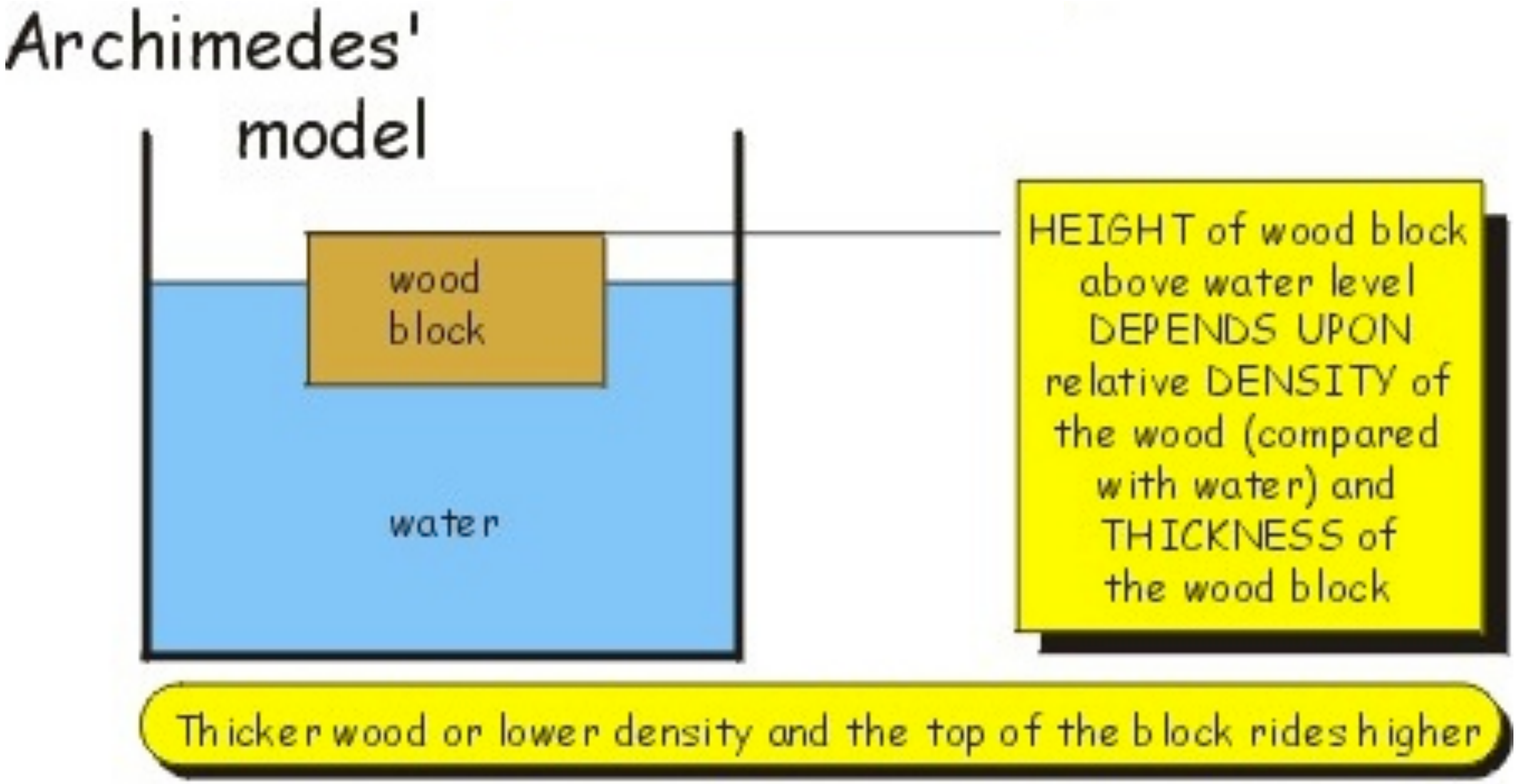
Planetary Interiors

Earth's Interior Structure
Hydrostatic Equilibrium
Heating
Constituent Relations
Gravitational Fields
Isostasy
Magnetism





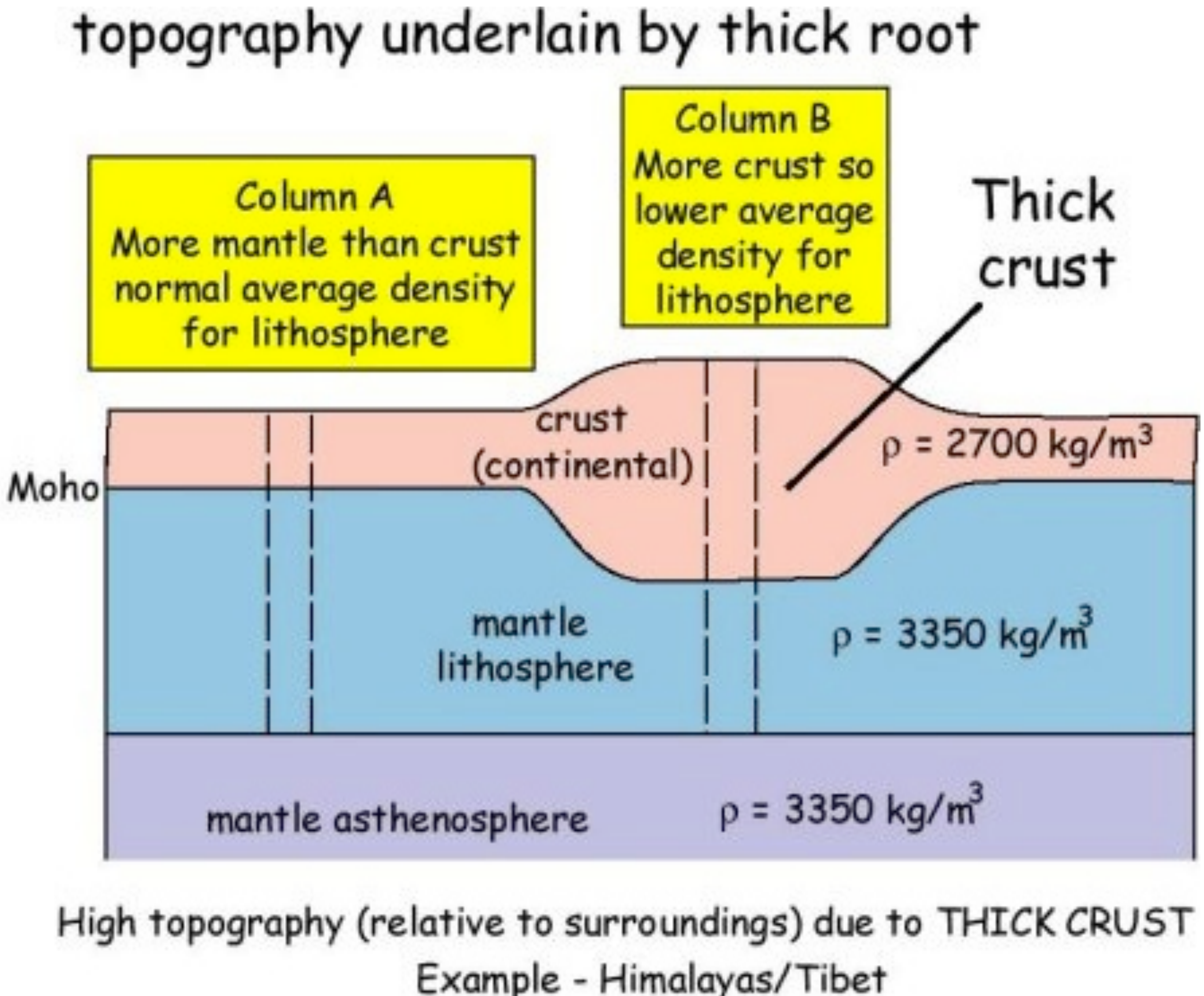
Isostasy



Courtesy of U of Leeds

Now apply this idea to topography and the crust…

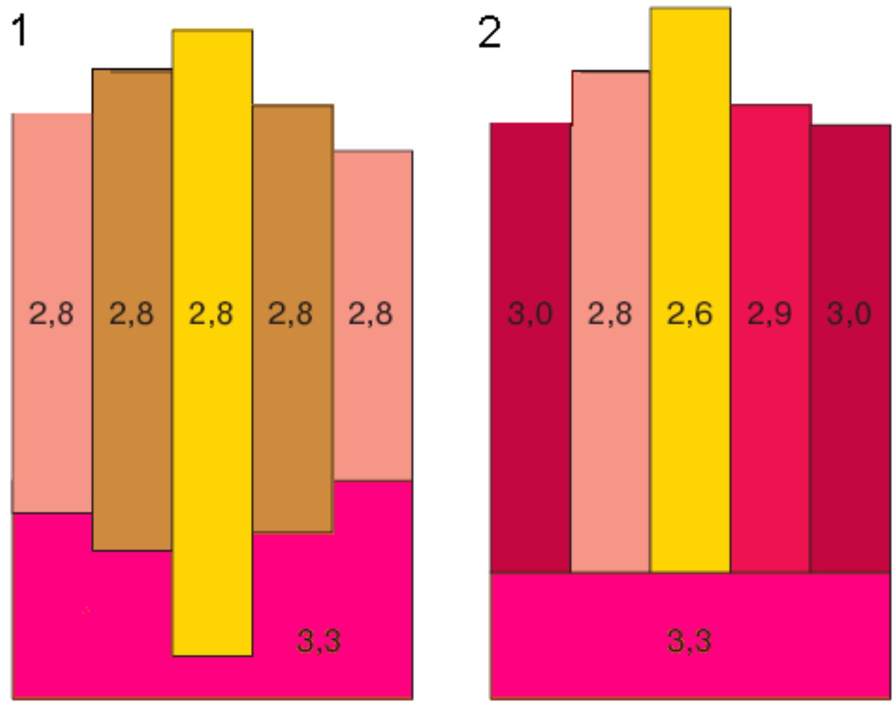
Airy Model



Courtesy of U of Leeds

The Earth's Crust

Credit: Wikipedia



1. **Airy Scheme:** Accommodate topography with crustal 'root' (assumes same ρ for all of the crust)
2. **Pratt Scheme:** Lateral density variation causes topography

The Earth's granitic (lower density) continental crust varies from < 20 km under active margins to ~80 km thick under the Himalayas.

The basaltic (higher density) oceanic crust has an average thickness of 6 km with less near the spreading ridges.

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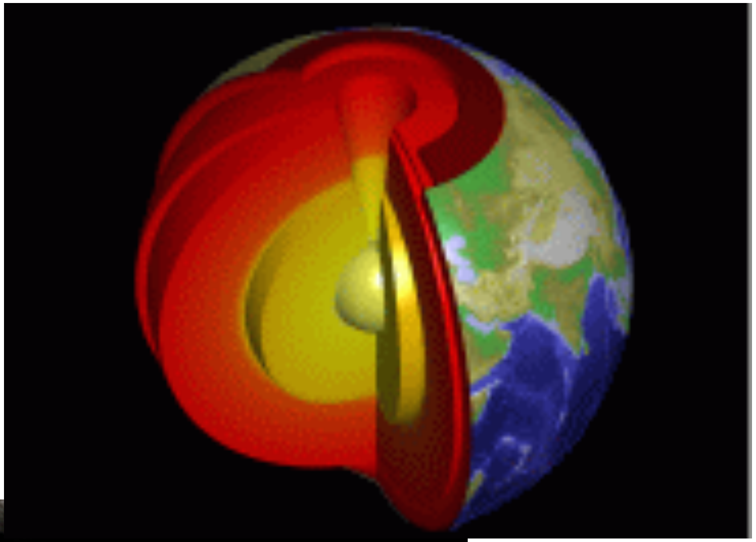
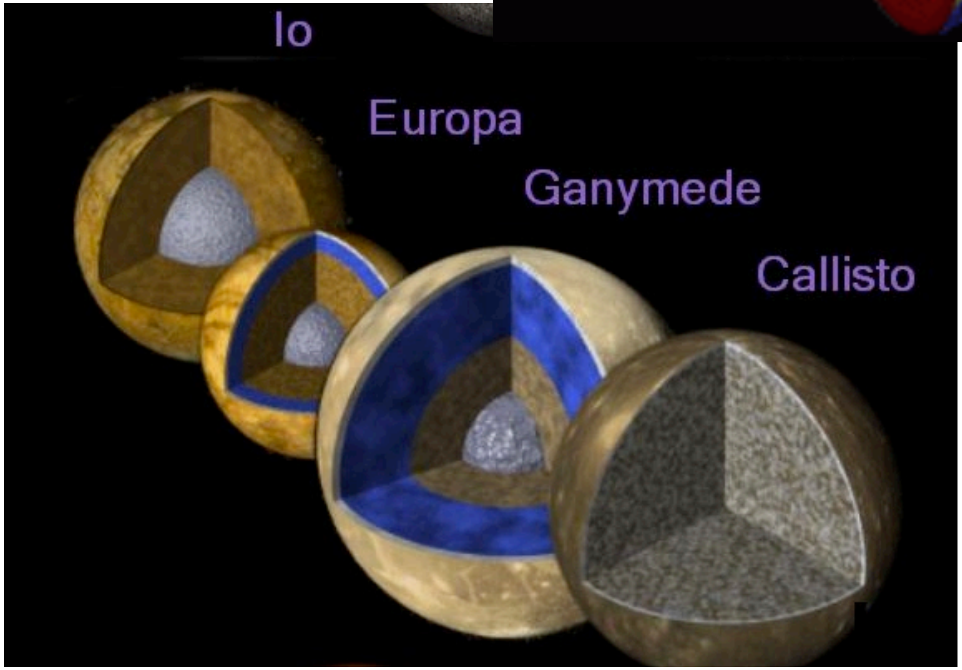
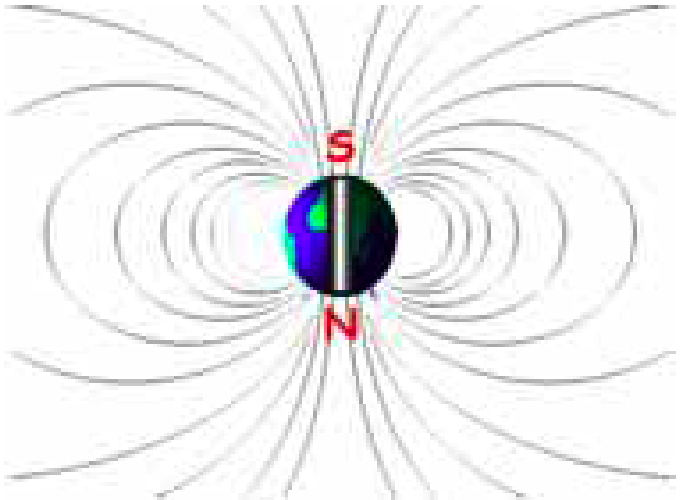




Magnetosphere (Chapter 7)

Earth's Magnetic Field



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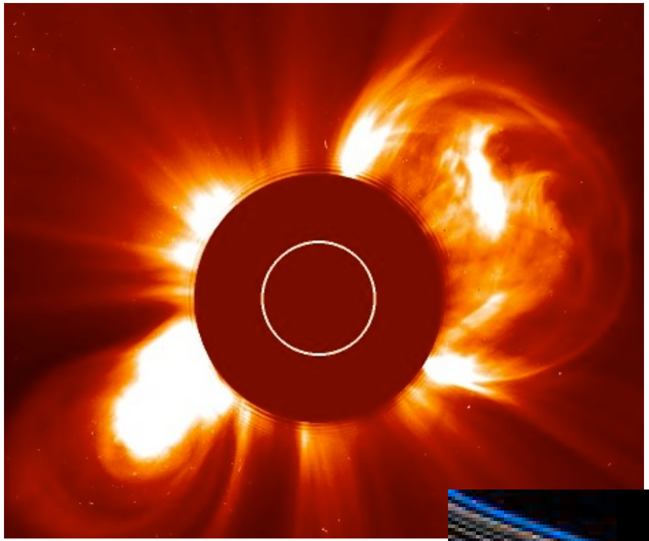
Solar Wind



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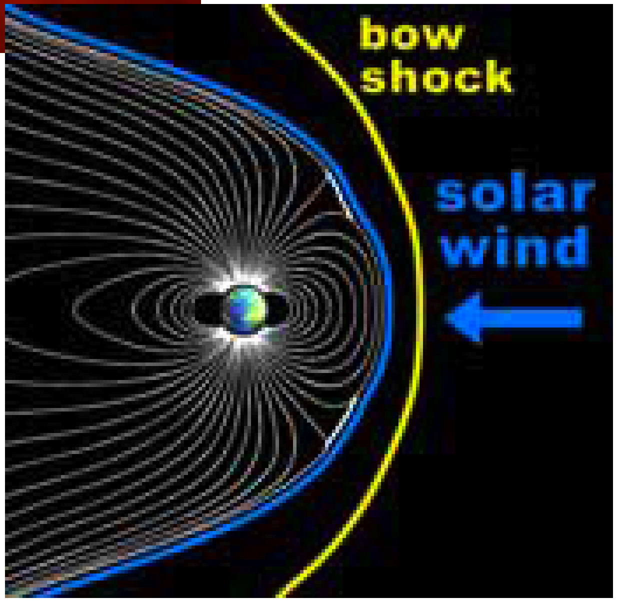


Similar to a "bar magnet", the Earth's intrinsic field is roughly dipolar.

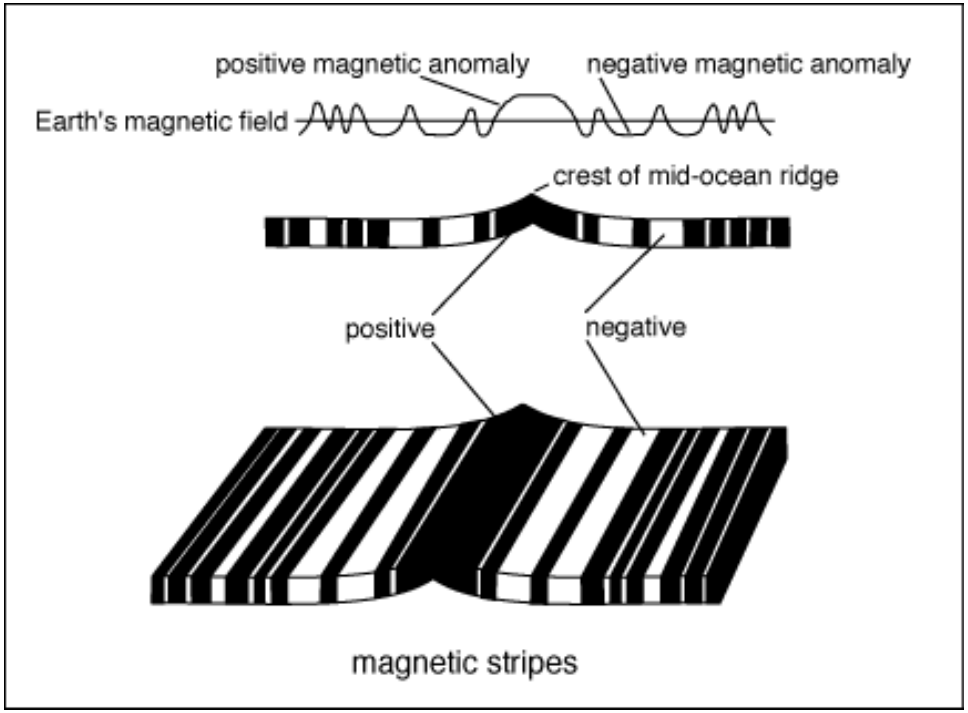
The solar wind deforms the magnetic field, and creates both a magnetopause and bow shock.

The Earth's Magnetic Field

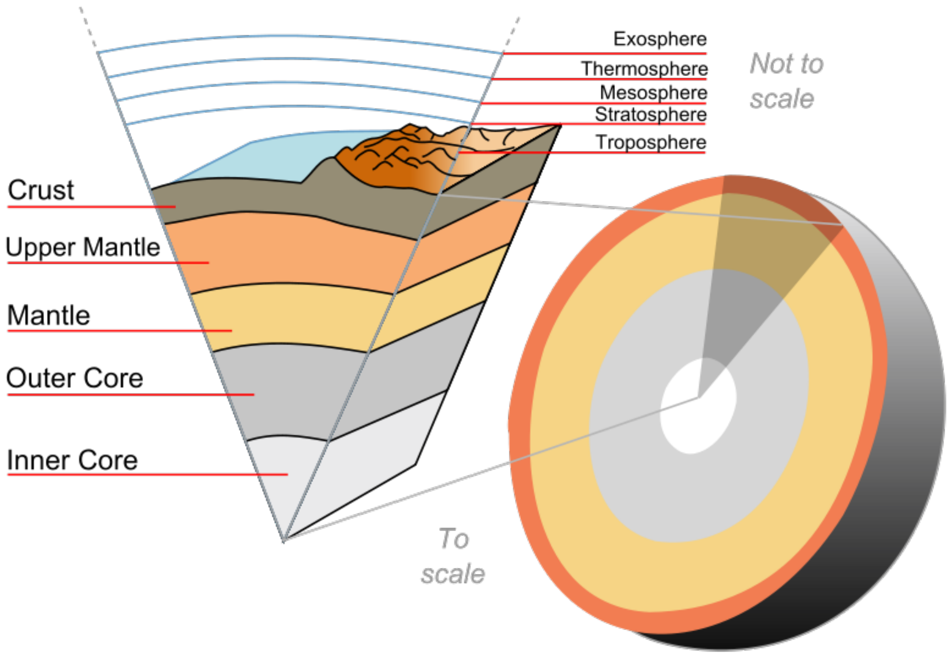
Changes in the Earth's magnetic field

Drift of the magnetic pole

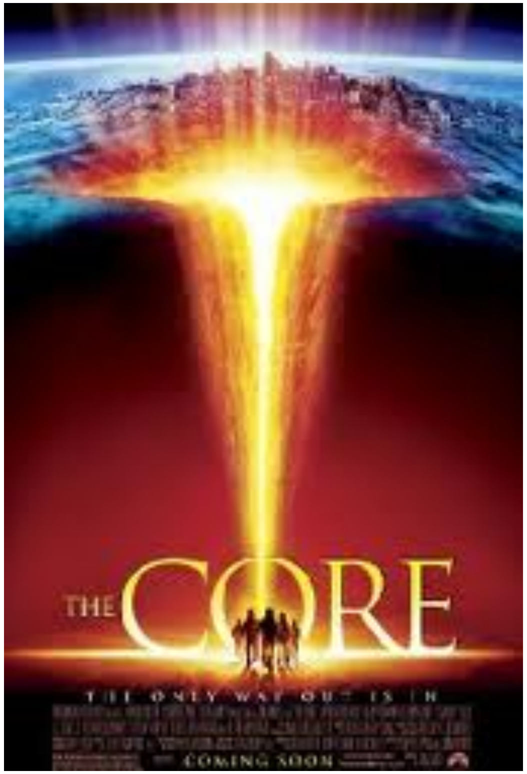
Reversal of the field direction recorded in the sea floor



The Earth's Magnetic Field

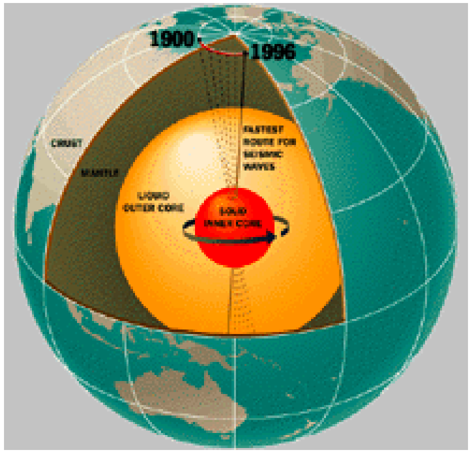


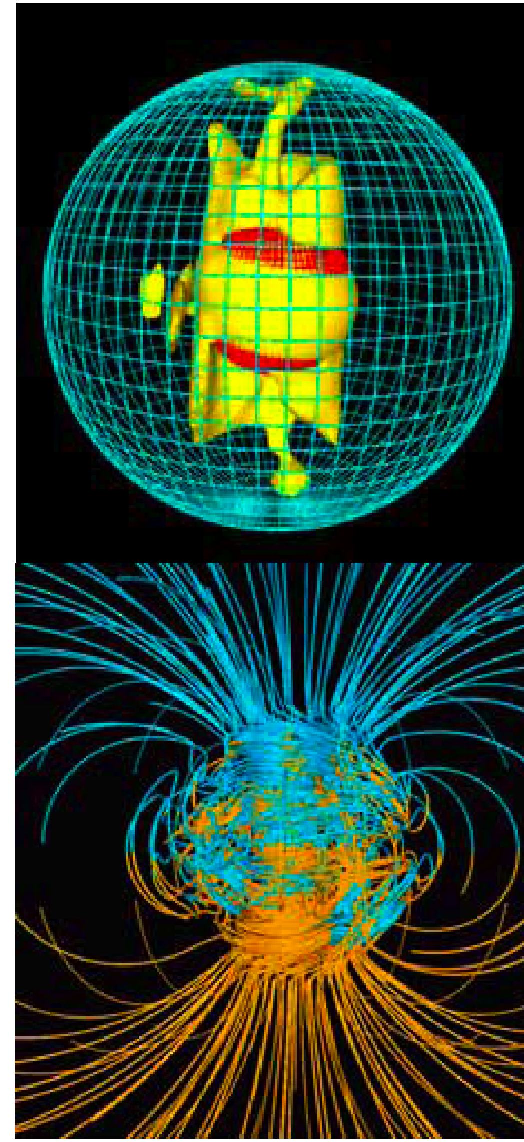
Changes observed in the paleomagnetic record of the Earth's magnetic field indicate it can not be a 'permanent magnet'



The highly conductive liquid outer core has the capacity to carry the electric currents needed to support a geodynamo

Earth's Magnetic Field





From Glatzmeier and Roberts

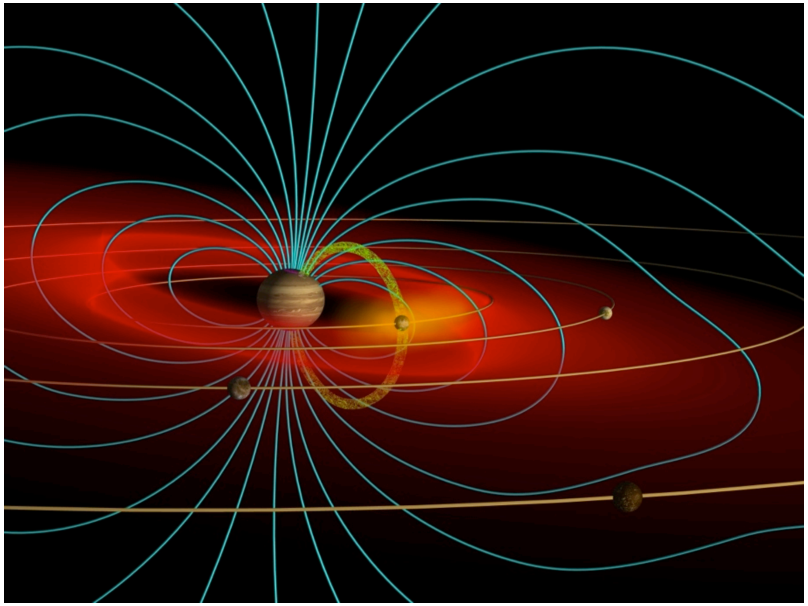
The Geodynamo and Magnetic Reversals

Freezing of liquid iron onto the solid inner core combined with buoyancy of lighter alloys provides free energy to set up convection.
The Coriolis force causes helical fluid flows. This prevents fields from canceling each other out.
Non-uniform heat transfer through Earth's mantle results in possibility of field reversals. The reversal rate seems to be controlled by the solid inner core.

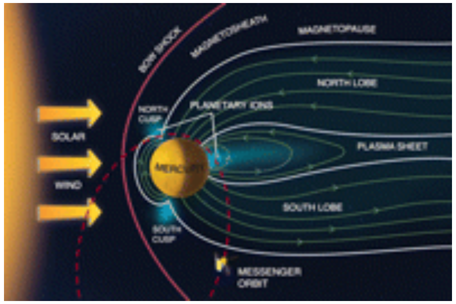
Other Planetary Magnetic Fields

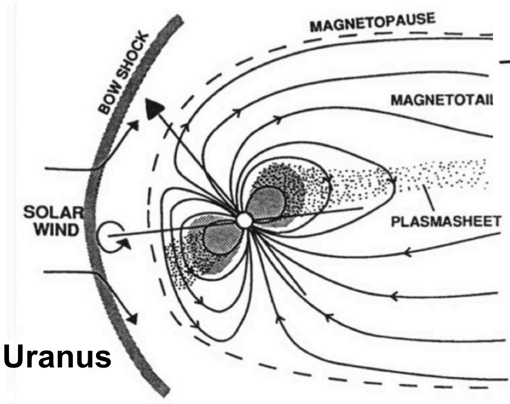
Mercury, Earth, Jupiter, Saturn, Uranus and Neptune all have confirmed global magnetic fields sourced internally. To date, Ganymede is the only moon with a dynamo driven magnetic field.

Nature

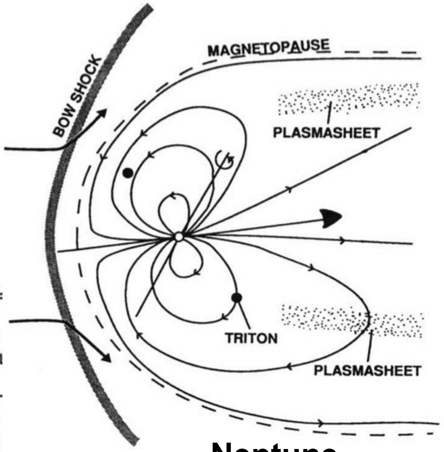


Nature



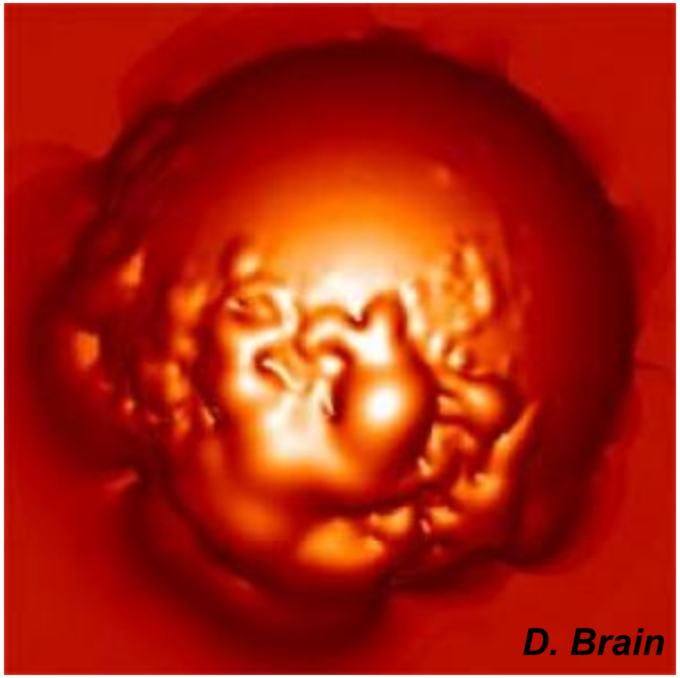


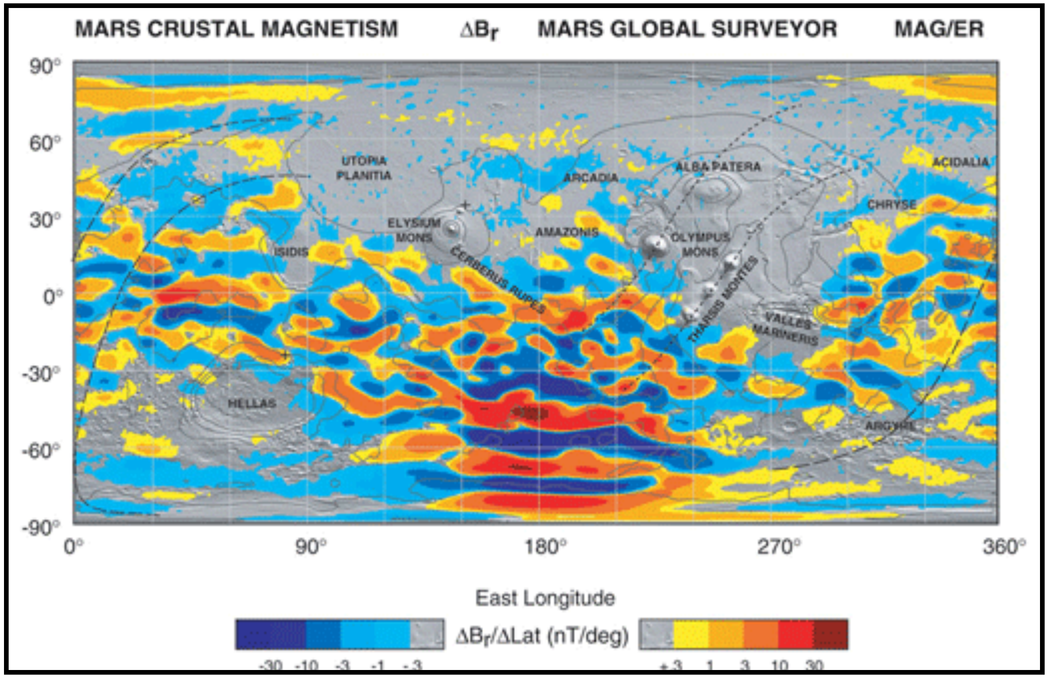
Uranus



Neptune

Mars Remnant Magnetism



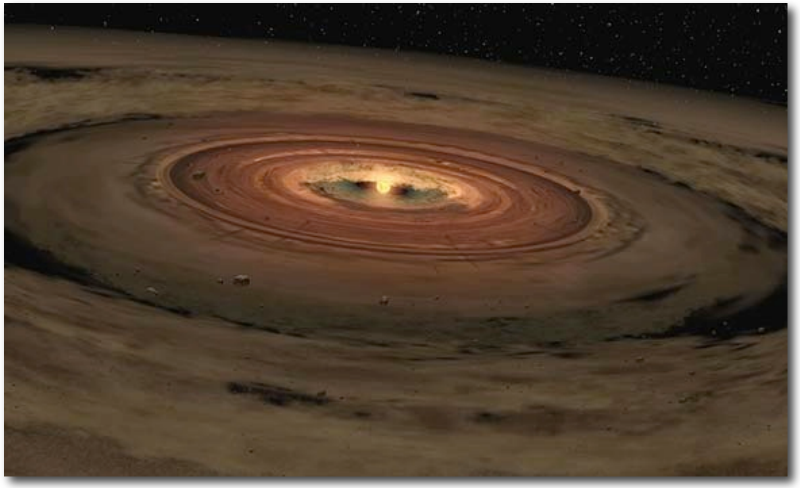


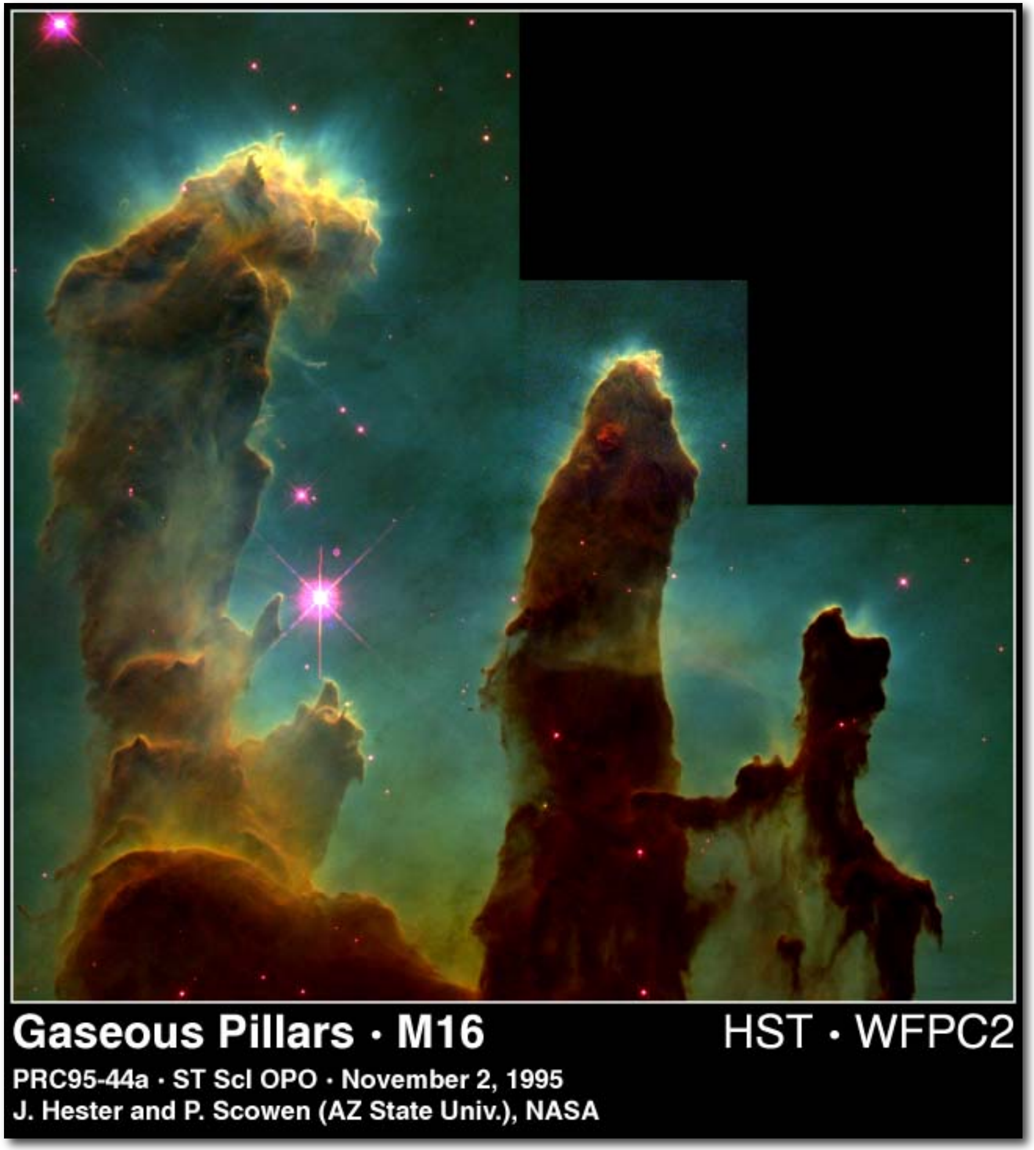
Mars currently has no global magnetic field, but clues to a past dynamo are locked in the remnant magnetization of the crust.

- **Is this lack of global field responsible for the atmospheric loss?**
- **Can we date the dynamo ‘turn-off’ point?**

Solar System/Planet Formation

For more details, read chapter 13…





Solar System Formation: Constraints

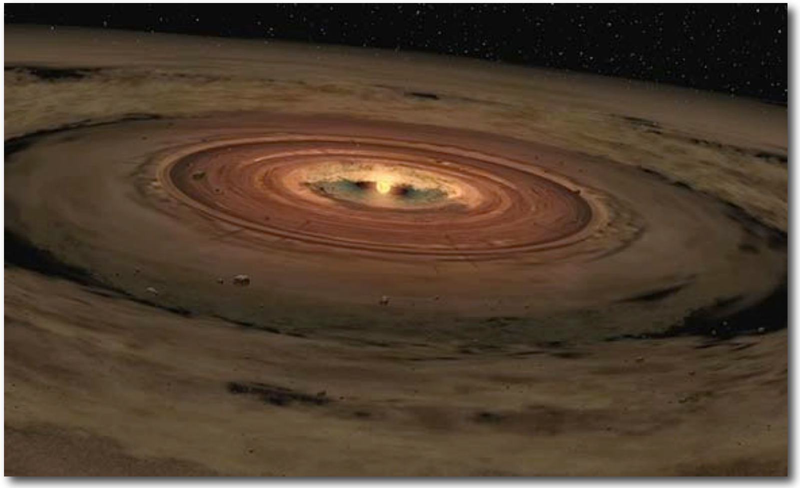
- Sun has 99.8% of mass, <2% of angular momentum
- Low inclination & eccentricity of planet orbits
- Most planets have low obliquity
- Large outer planets have ~solar composition
- Small inner planets enriched in heavy elements
- Impact craters on virtually every planetary body
- “Debris” in asteroid belt, Kuiper belt
- Meteorites have common age: ~4.6 Ga
- Oldest Moon rocks ~4.36 – 4.5 Ga

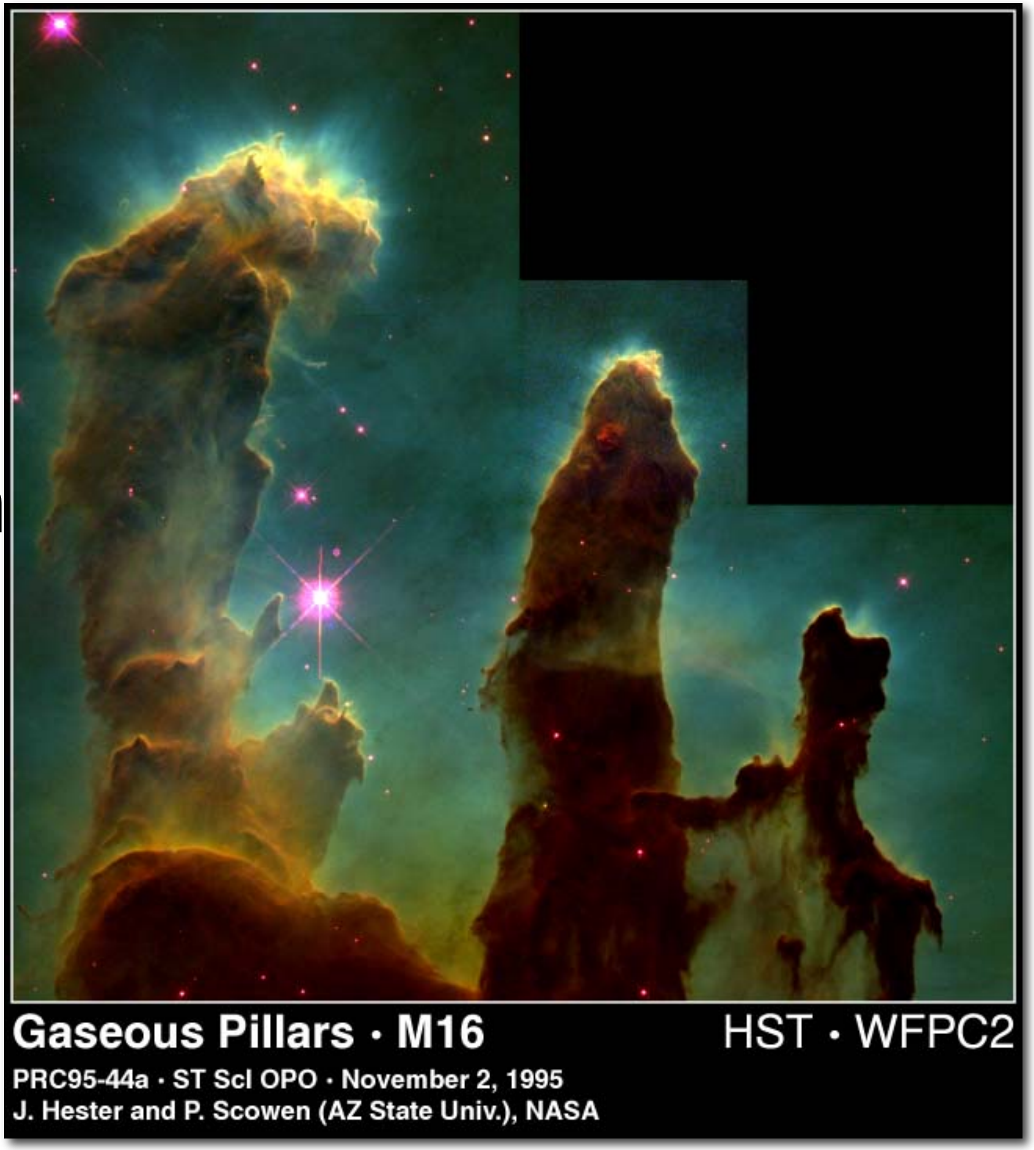
Solar System/Planet Formation

Gas Clouds to Stars/Planets

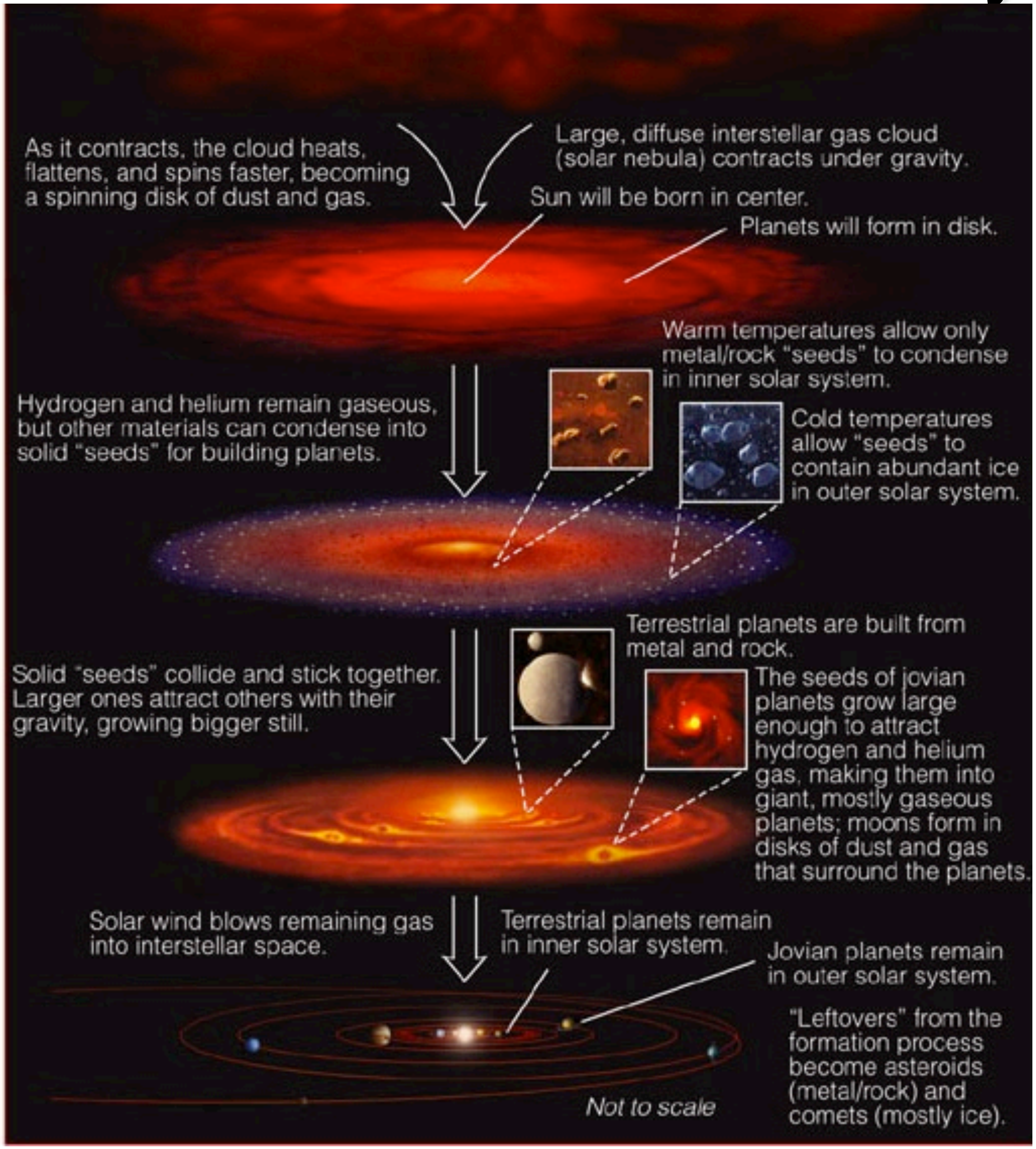
Planet Migration

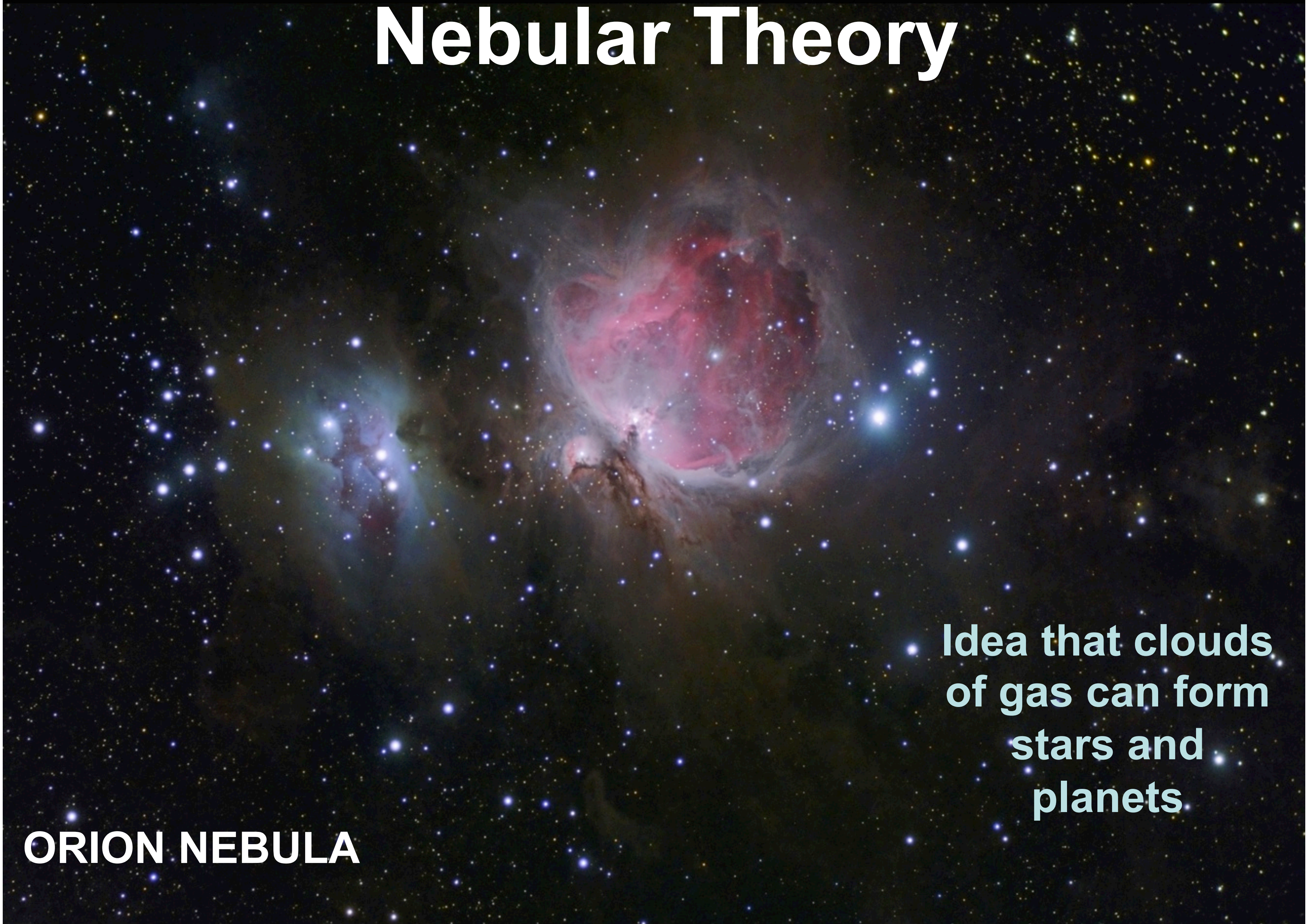
Satellite Formation





The Formation of the Solar System




Nebular Theory
Idea that clouds of gas can form stars and planets
ORION NEBULA

Starting Conditions

<u>Giant Molecular Clouds</u>:

- COLD (10-30 K)
- LARGE (10^2s of light-years across, 10^6 M_{Sun})
- CHEMISTRY:

98% H and He

1.4% "ices"

0.4% "rock"

0.2% metal

*Cloud probably needs to be "nudged" to start forming stars

ORION NEBULA

Formation of the Solar System

STEPS: / **EVIDENCE:**

CLOUD COLLAPSE
- young stars seen in collapsing gas clouds

↓

ROTATING DISK
- planets orbit in same direction and same plane
- Sun and planets rotate in same direction
- disks seen around other stars

↓

CONDENSATION
- terrestrial planets and asteroids found near Sun
- jovian planets, icy moons, comets found farther away

↓

ACCRETION
- many meteorites are made of smaller bits
- heavy cratering on oldest planet surfaces
- asteroids, comets are "leftovers"

↓

GAS CAPTURE?
- Jupiter, Saturn are mostly hydrogen and helium

Formation of the Solar System

STEPS:

CLOUD COLLAPSE

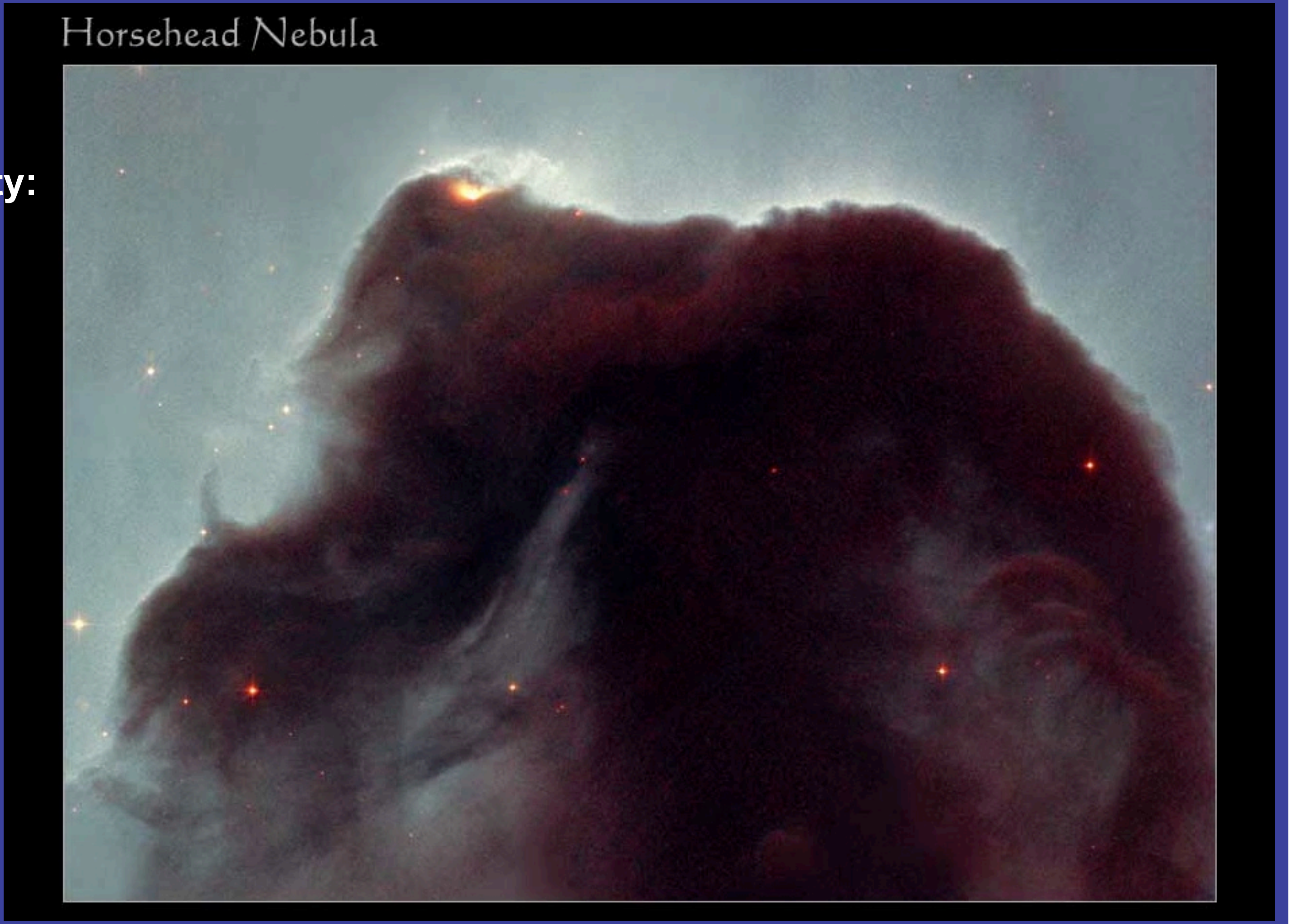
↓

Considering only gravity:

$$t_{\mathrm{ff}}^{1} = \sqrt{\frac{3\pi}{32 G \rho_{\mathrm{cl}}}}$$

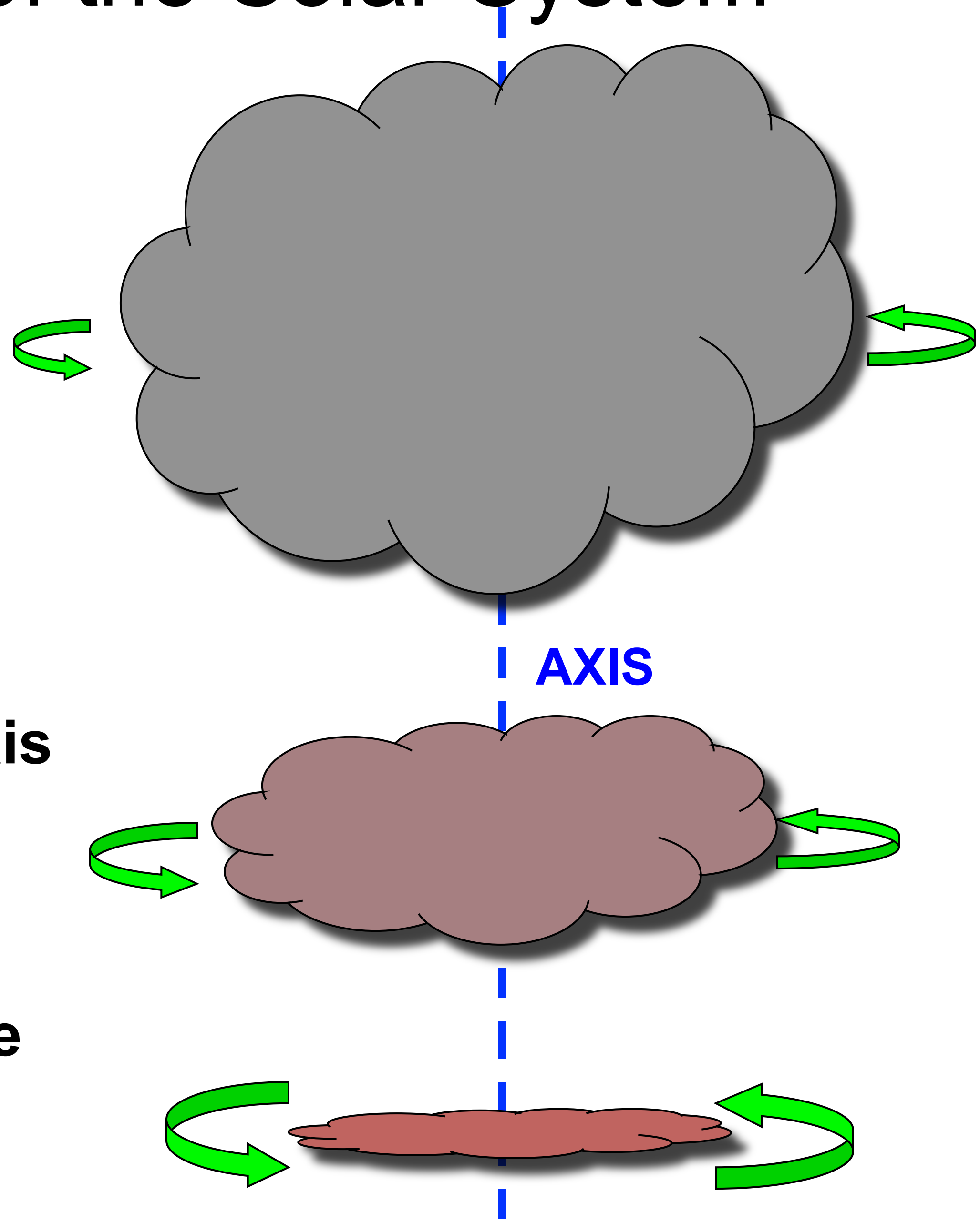
EVIDENCE:

•**young stars seen in collapsing gas clouds**



Formation of the Solar System

Cloud starts out with a tiny rotation…



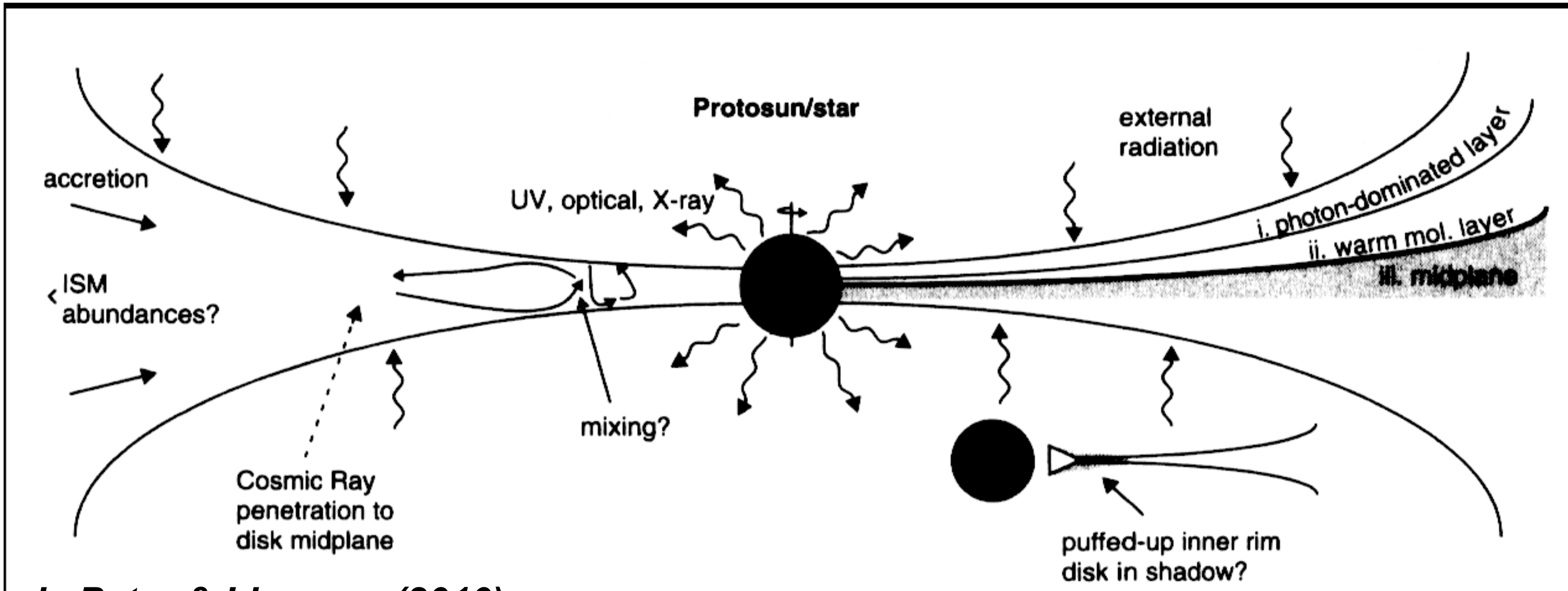
<u>CONSERVATION OF ANGULAR MOMENTUM:</u>

Gas falling <u>toward</u> axis starts rotating faster

Gas falling <u>parallel</u> to axis doesn't rotate faster

Fast rotation helps some gas orbit around center

Formation of the Solar System: Flared Disk



de Pater & Lissauer (2010)

$$\rho_{g_z} = \rho_{g_{z_0}} e^{-z^2/H_z^2}, \tag{13.10a}$$

$$P_z = P_{z_0} e^{-z^2/H_z^2}, \tag{13.10b}$$

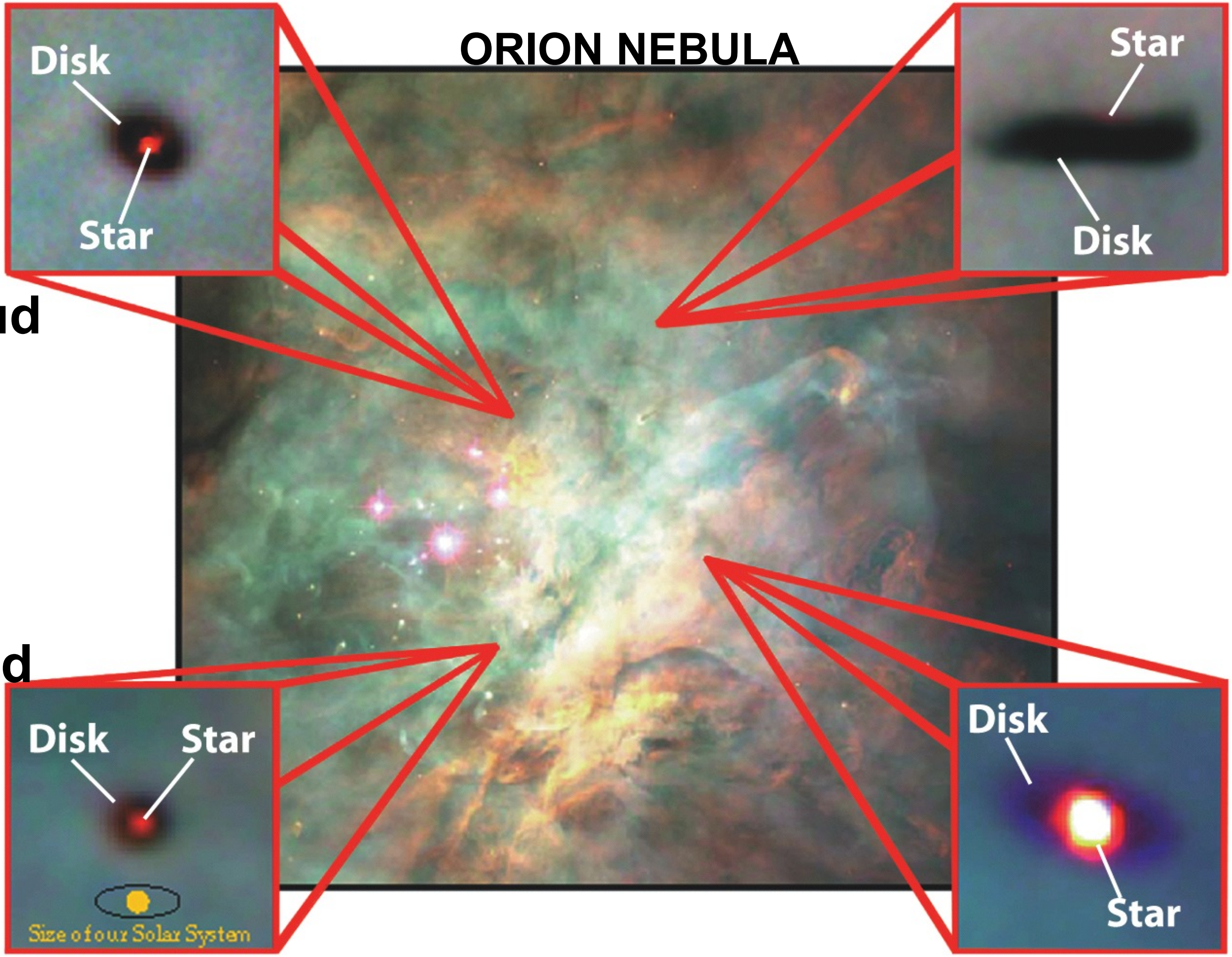
where the Gaussian scale height, H_z, is given by:

$$H_z = \sqrt{\frac{2kTr_\odot^3}{\mu_a m_{amu} G M_\odot}}. \tag{13.11}$$

The Rotating Disk

Part of cloud becomes flattened disk

Examples seen around other stars



Bipolar Outflows: An HST Film

http://n.pr/oimi5j

Formation of the Solar System

STEPS:

CLOUD COLLAPSE

↓

ROTATING DISK

EVIDENCE:

- **young stars seen in collapsing gas clouds**
- **planets orbit in same direction and same plane**
- **Sun and planets rotate in same direction**
- **disks seen around other stars**