

## Seminar Today

- **Lindy Elkins-Tanton**
- Carnegie Institute of Washington
- Title: Water and carbon delivery to terrestrial planets: Primary and late accretion
- When: Friday, January 13, 2011 at 3:30 PM
- Where: Earth and Marine Sciences (E&MS) Building, Room B210

Earth



Venus



Mars

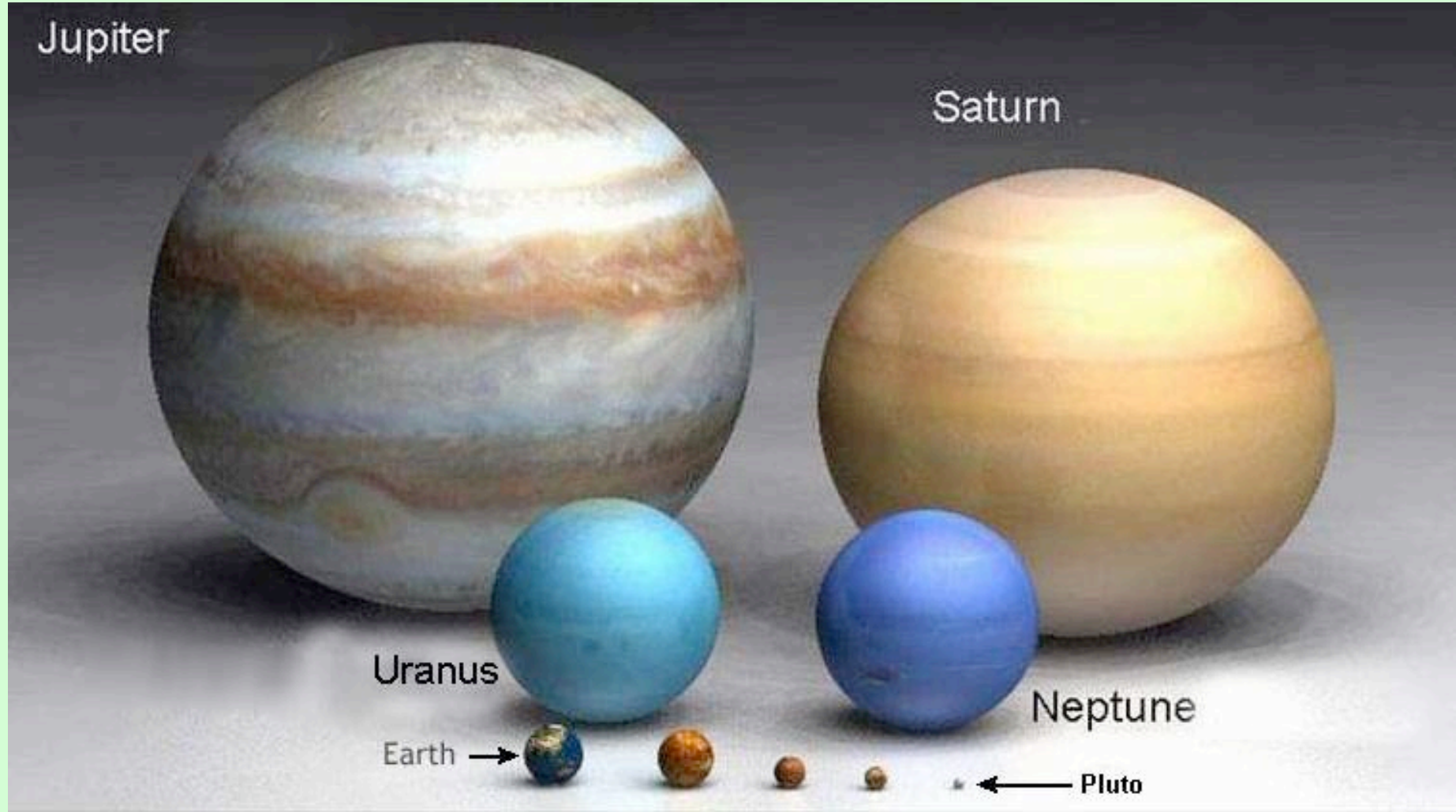


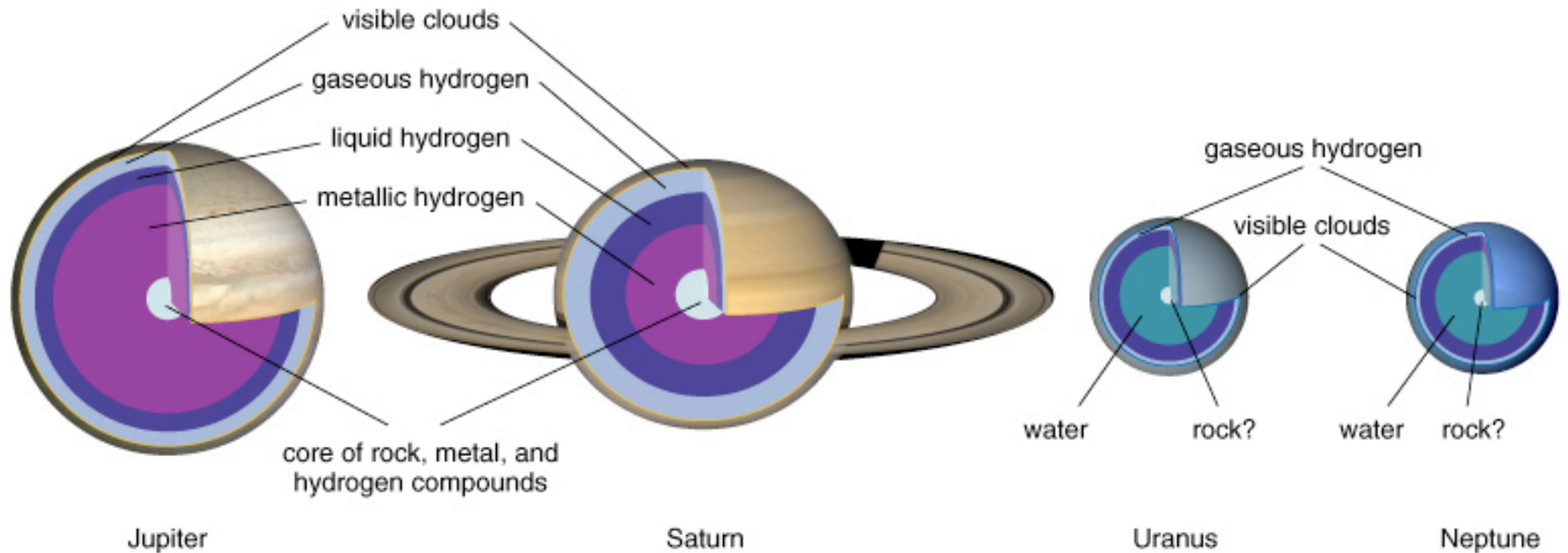
Mercury



Pluto







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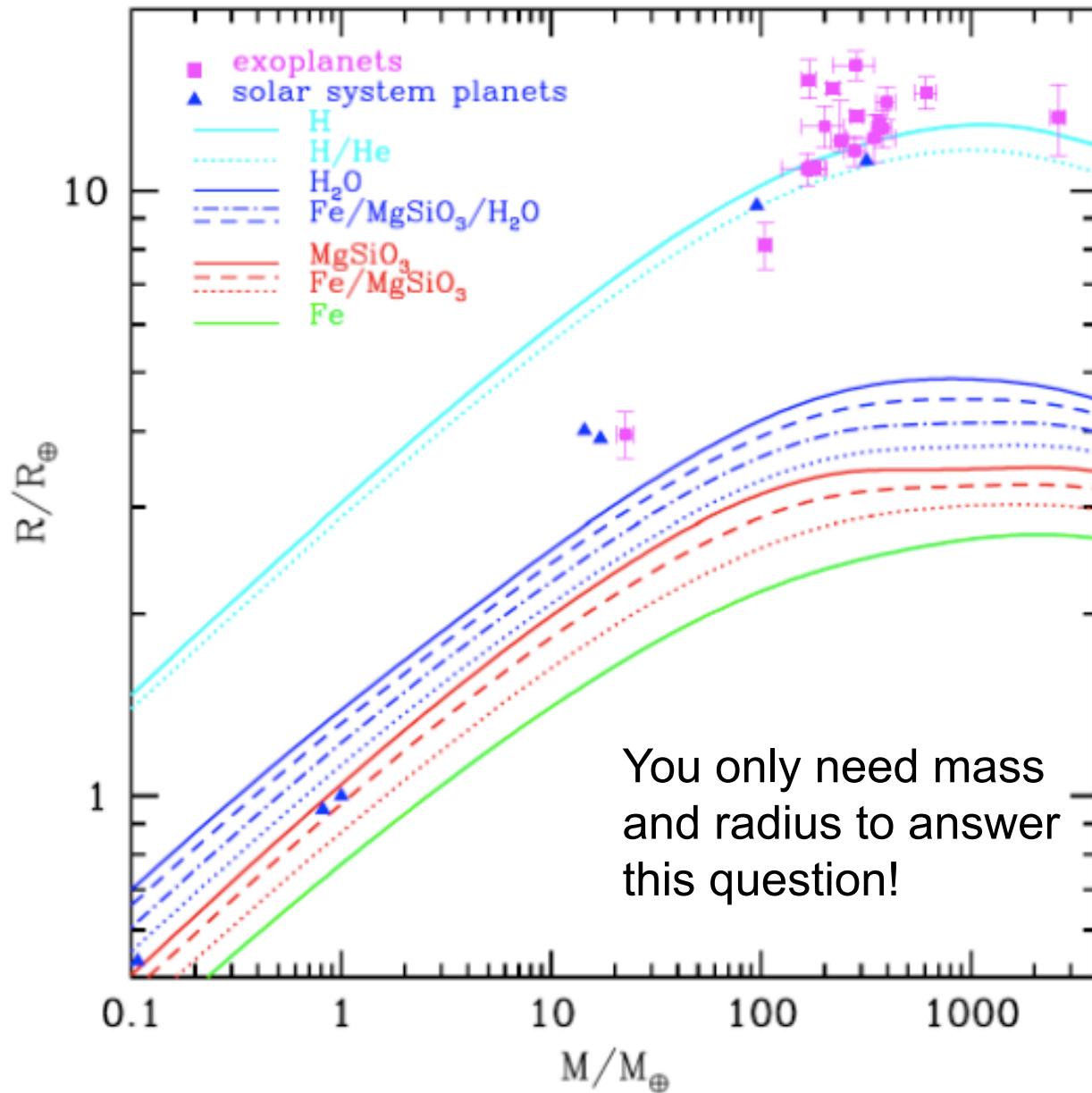
## Jupiter

Diameter = 143,800 km  
 5.2 AU's from Sun  
 Year = 11.9 Earth Yrs  
 318 Earth Masses  
 Density = 1.3 gm/cm<sup>3</sup>

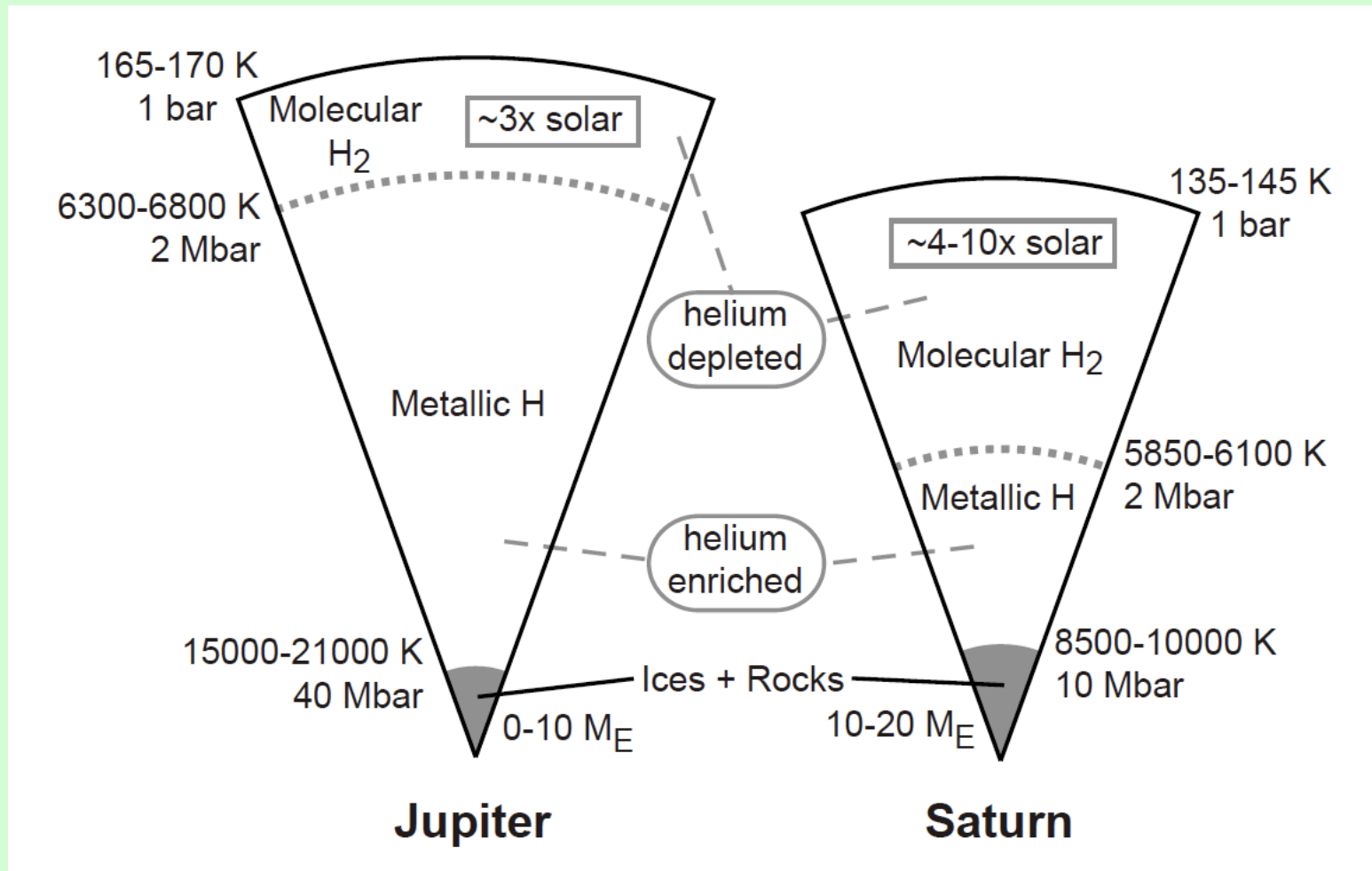
## Saturn

Diameter = 120,540 km  
 9.5 AU from Sun  
 Year = 29.5 Earth Yrs  
 95 Earth Masses  
 Density = 0.7 gm/cm<sup>3</sup>

# What are these planets made of?



# A View Into Jupiter and Saturn



- Compared to the Sun, both Jupiter and Saturn are enhanced in non H/He elements
  - “metals” (to an astronomer) or “heavy elements”

# Heavy elements: How much and where are they?

- Knowledge of the H EOS from 1-10 Mbar limits our knowledge of Jupiter

***The core masses and total abundances of heavy elements are our main data in understanding the formation of giant planets.***

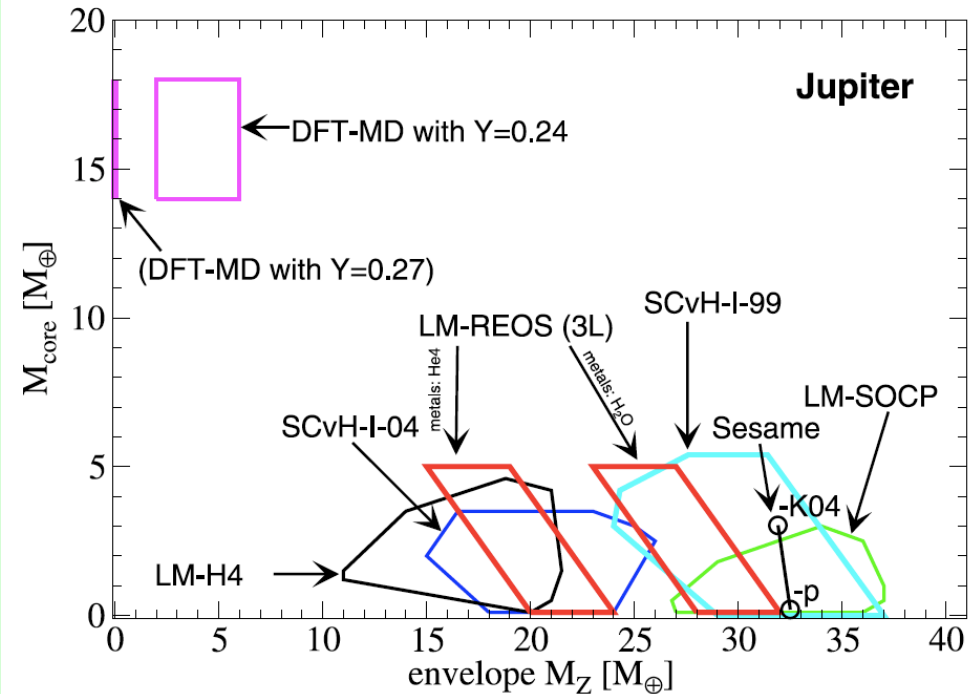
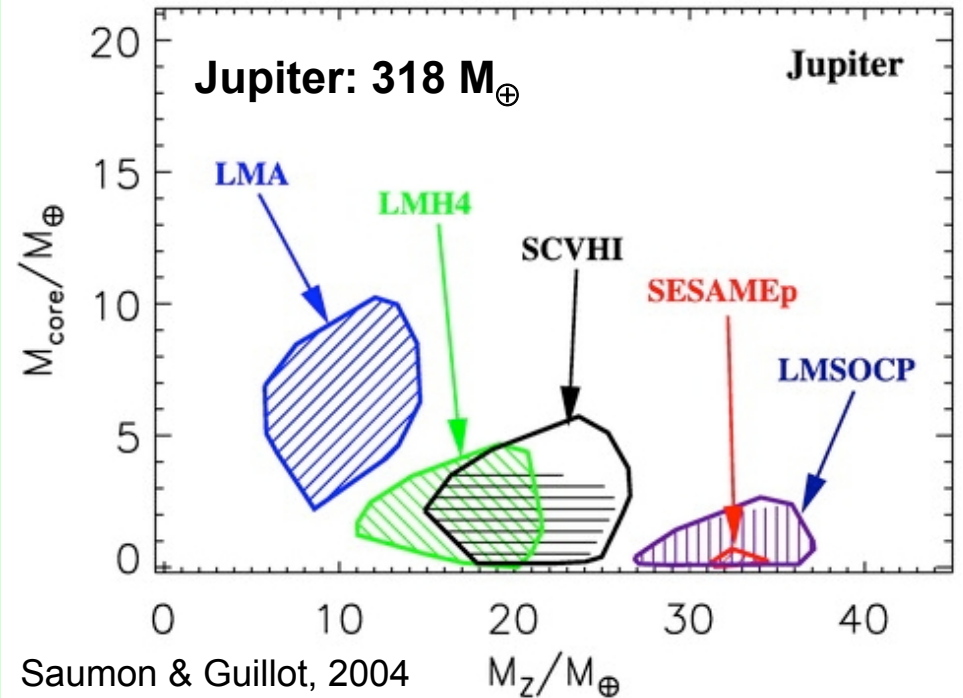
***In total...***

**Saturn:**

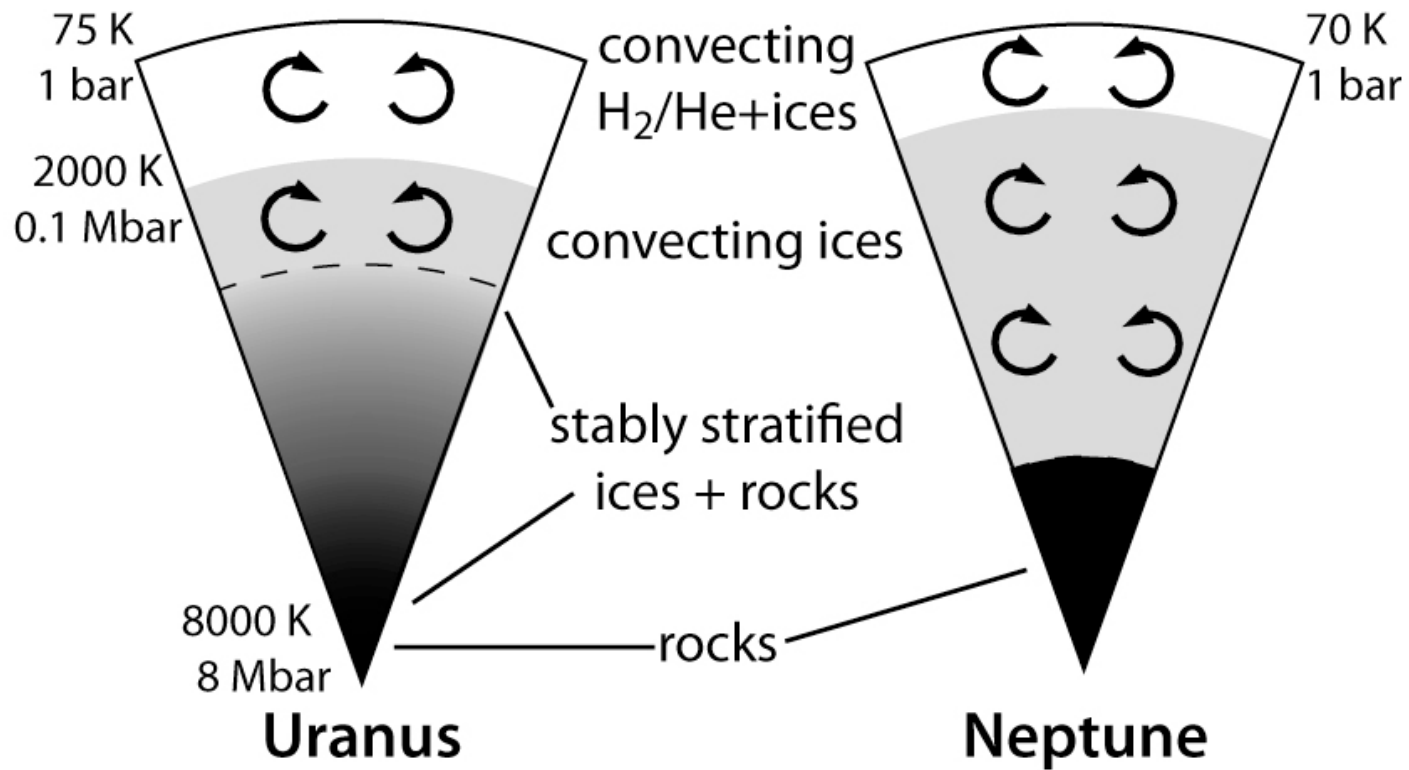
$13 < M_Z < 28 M_{\oplus}$

**Jupiter:**

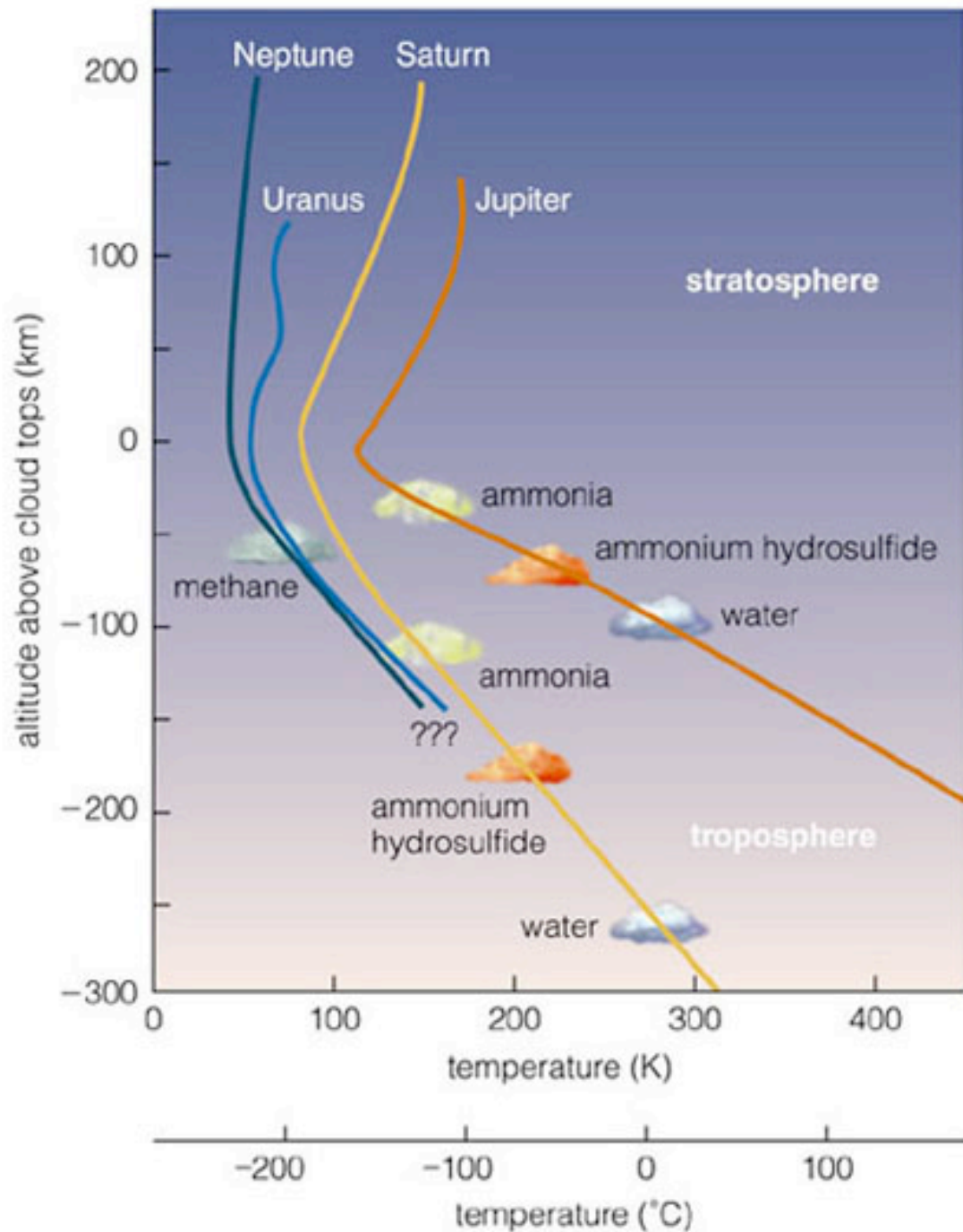
$8 < M_Z < 38 M_{\oplus}$



# Uranus and Neptune

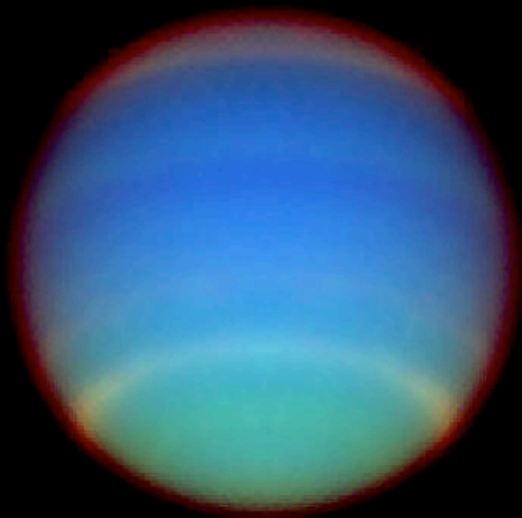


# Atmospheric temperature structure and cloud layers

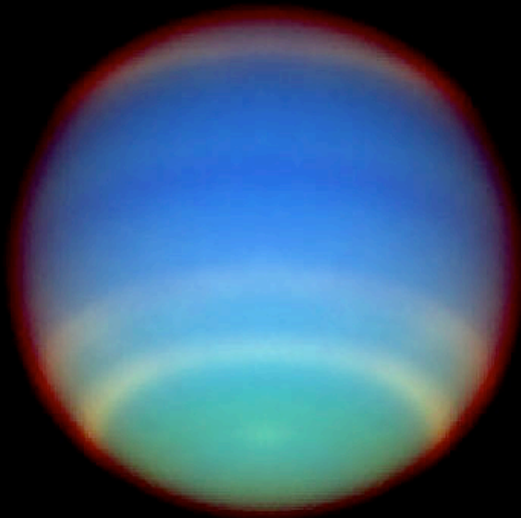


# Giant Planets are Not Static

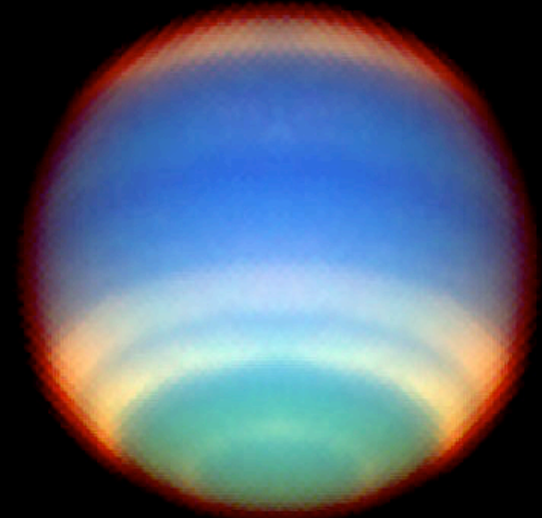
Neptune



1996

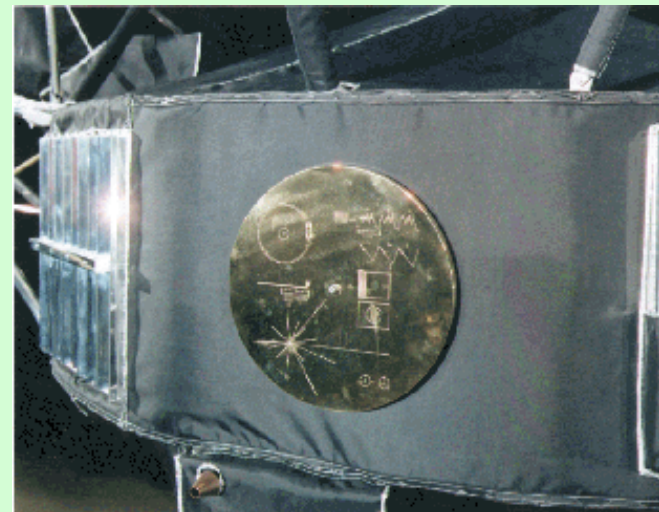
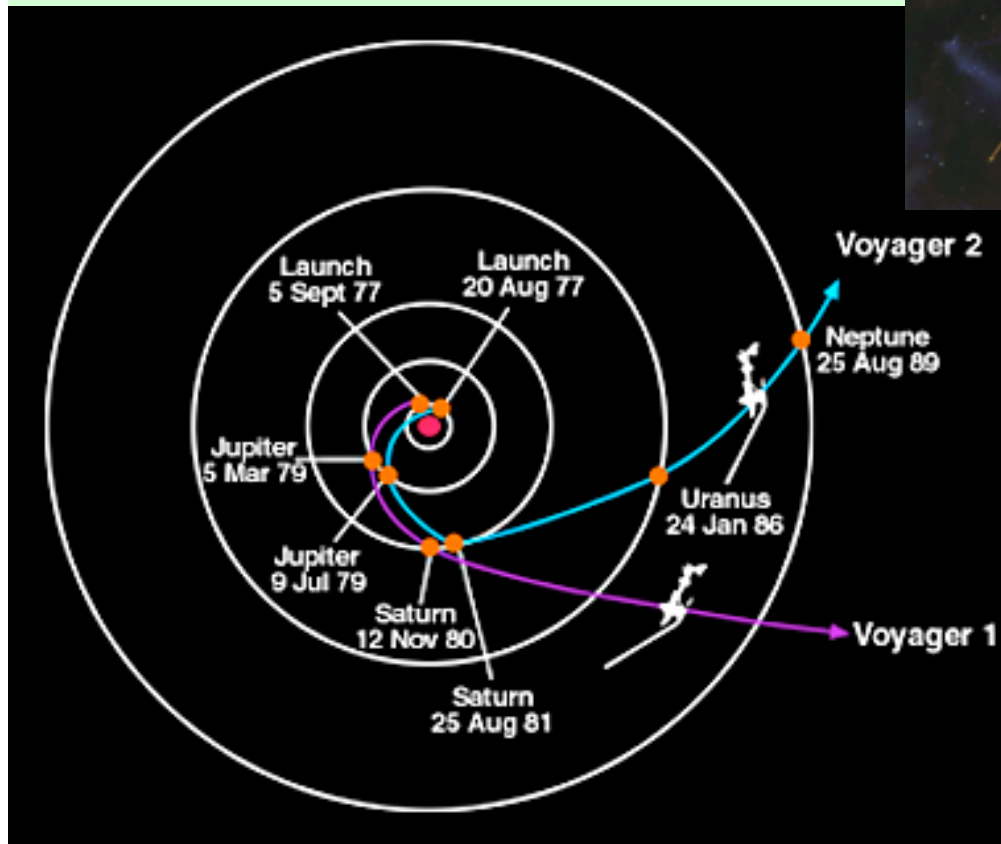
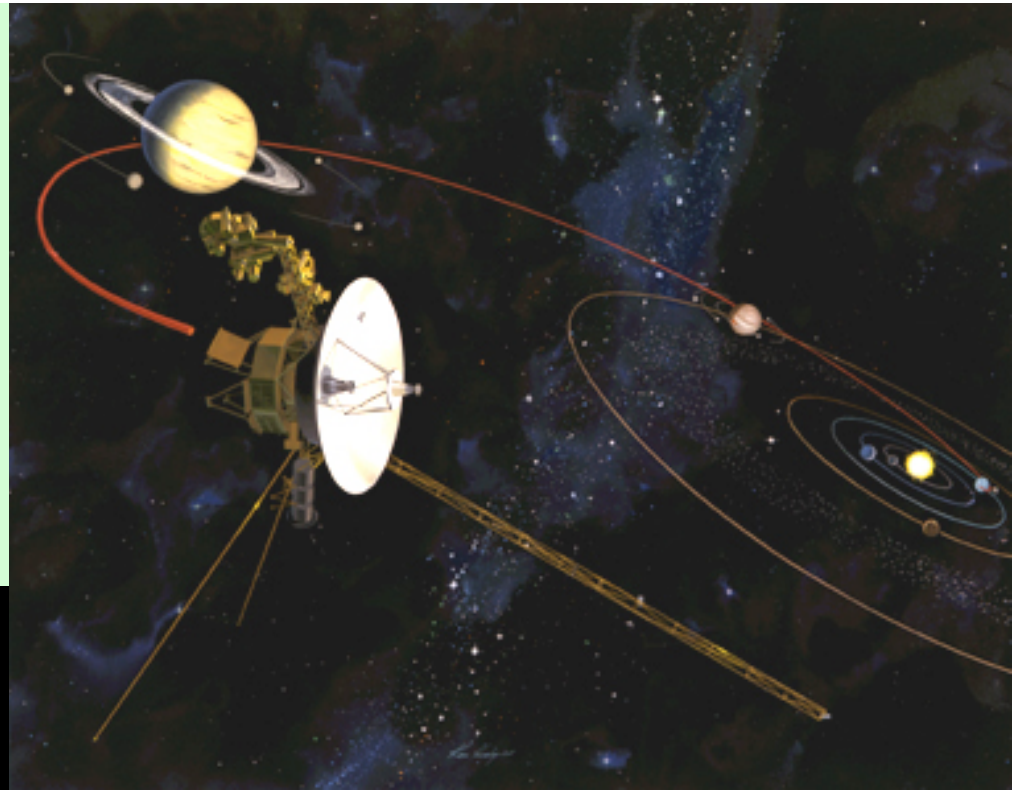


1998

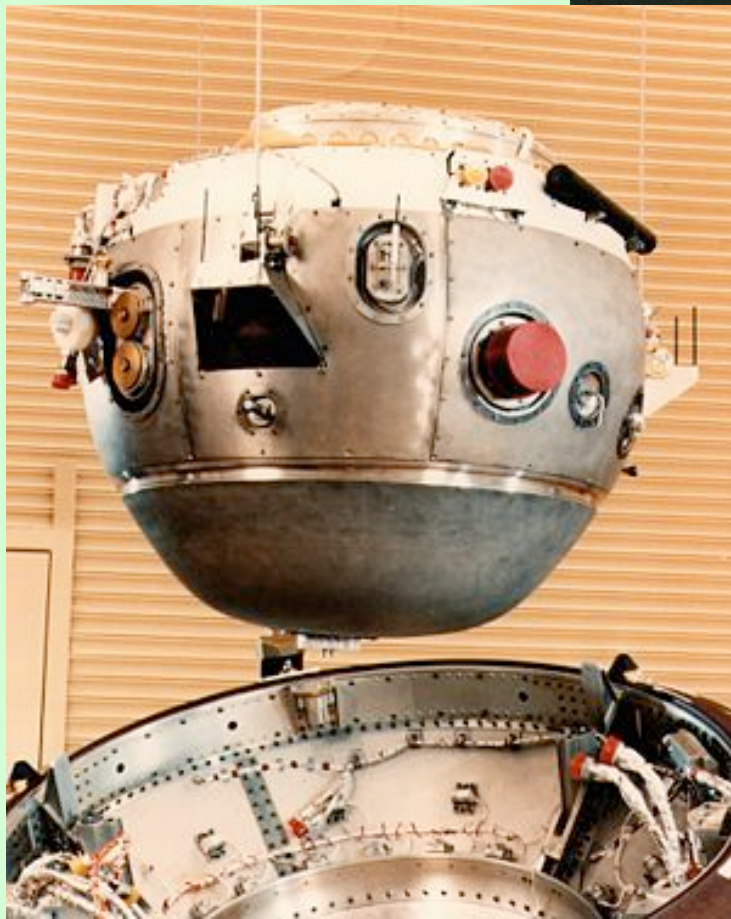
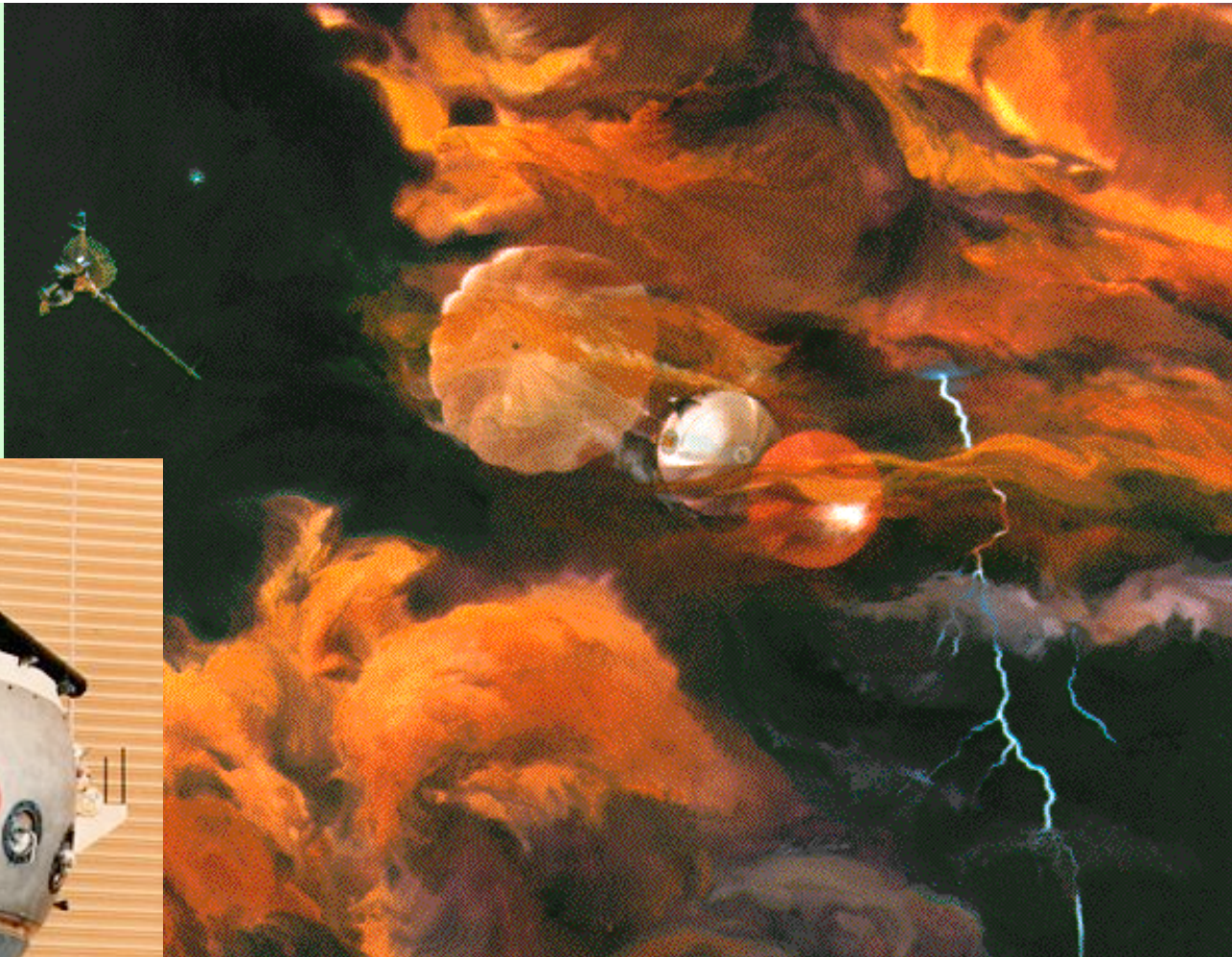


2002

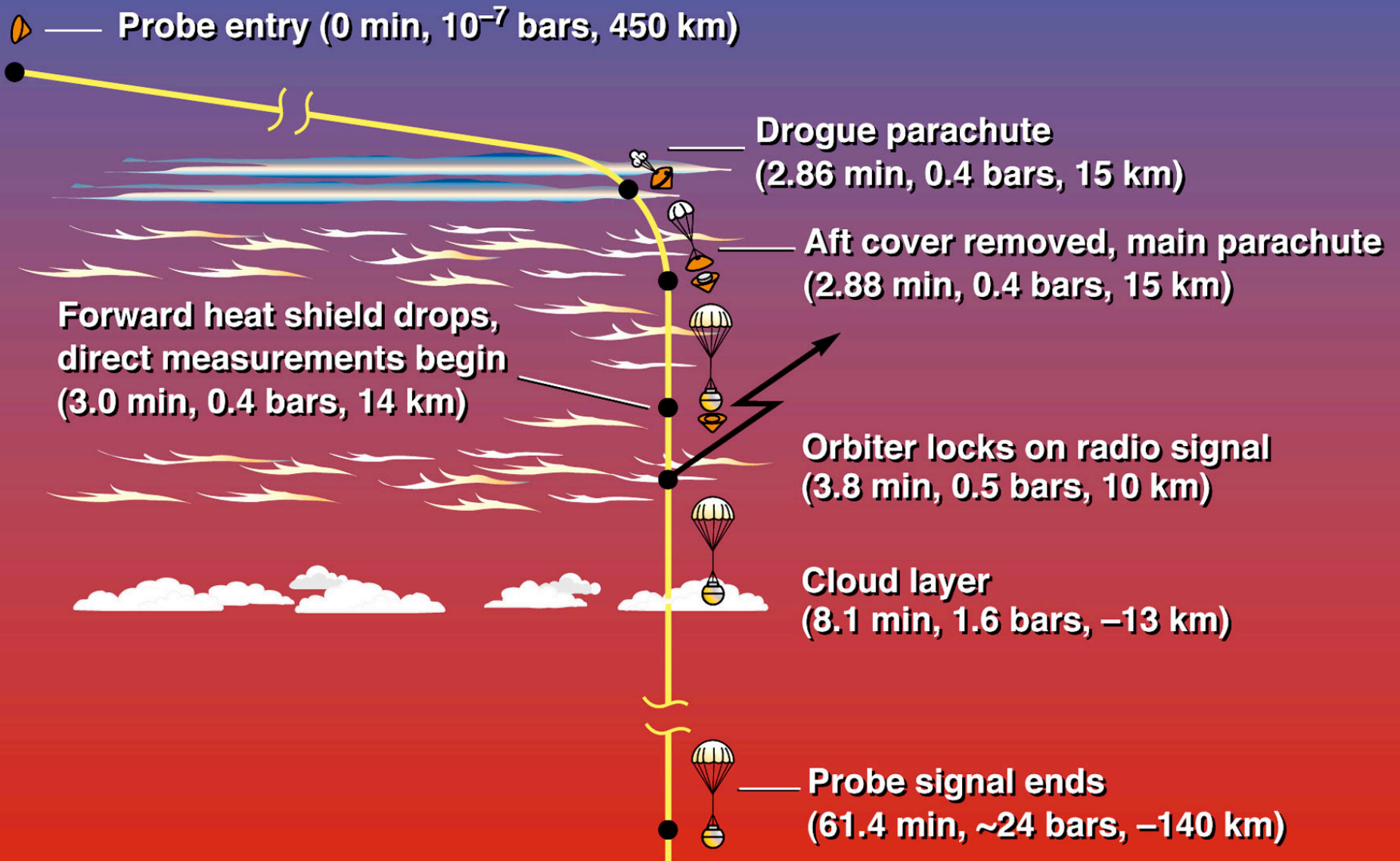
# Voyager: the first "grand tour"

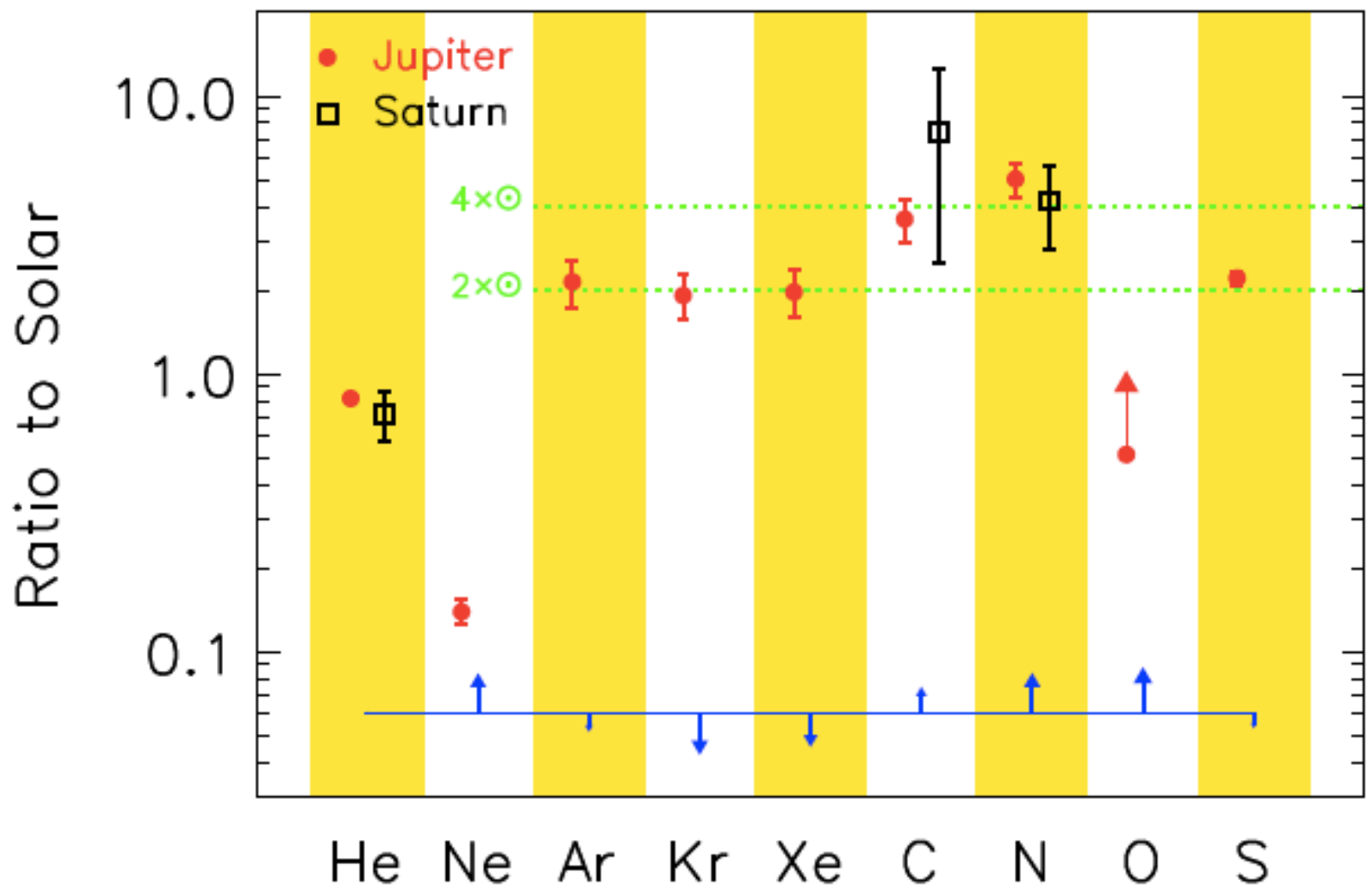


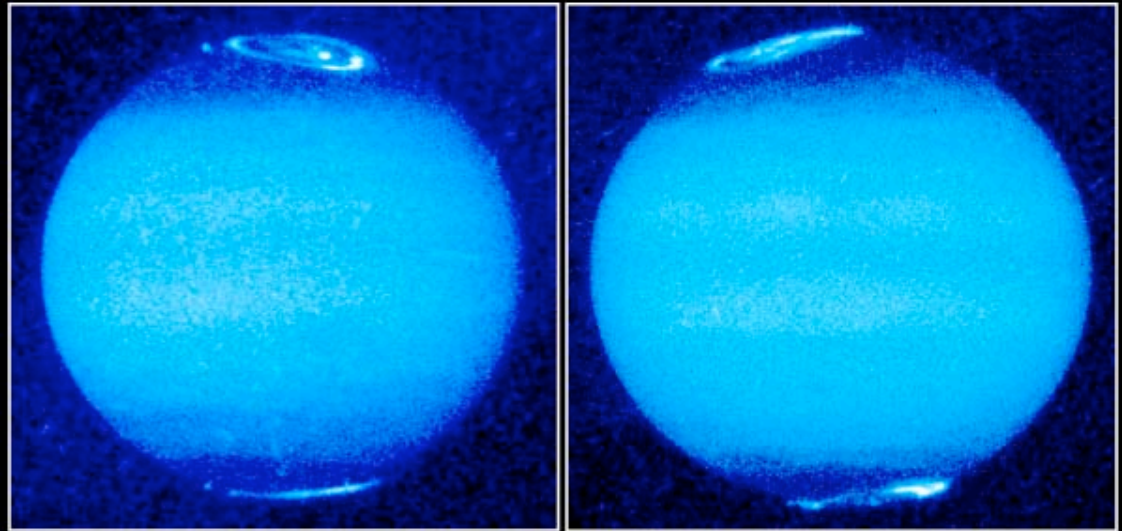
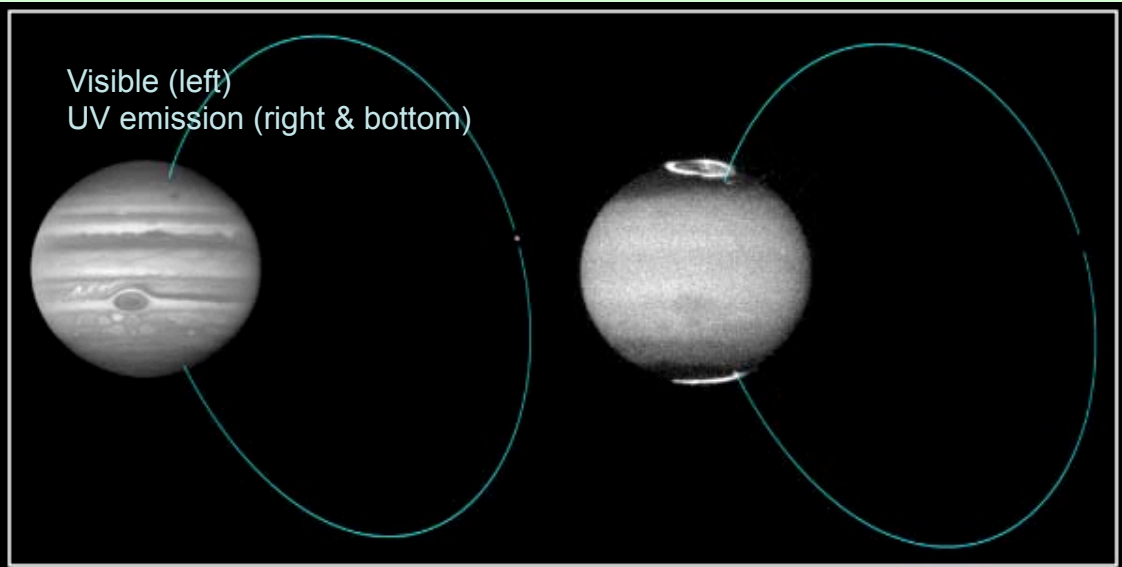
# Galileo Entry Probe, 1995



# Probe Mission



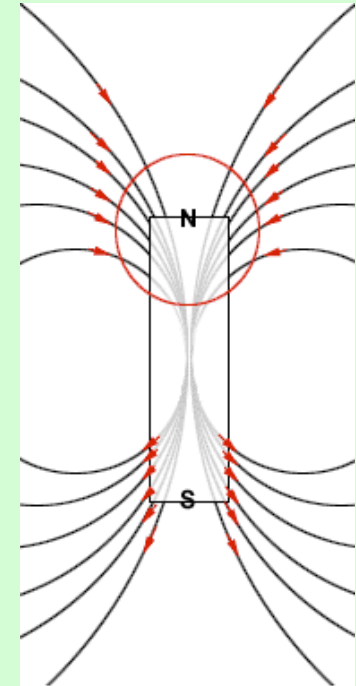




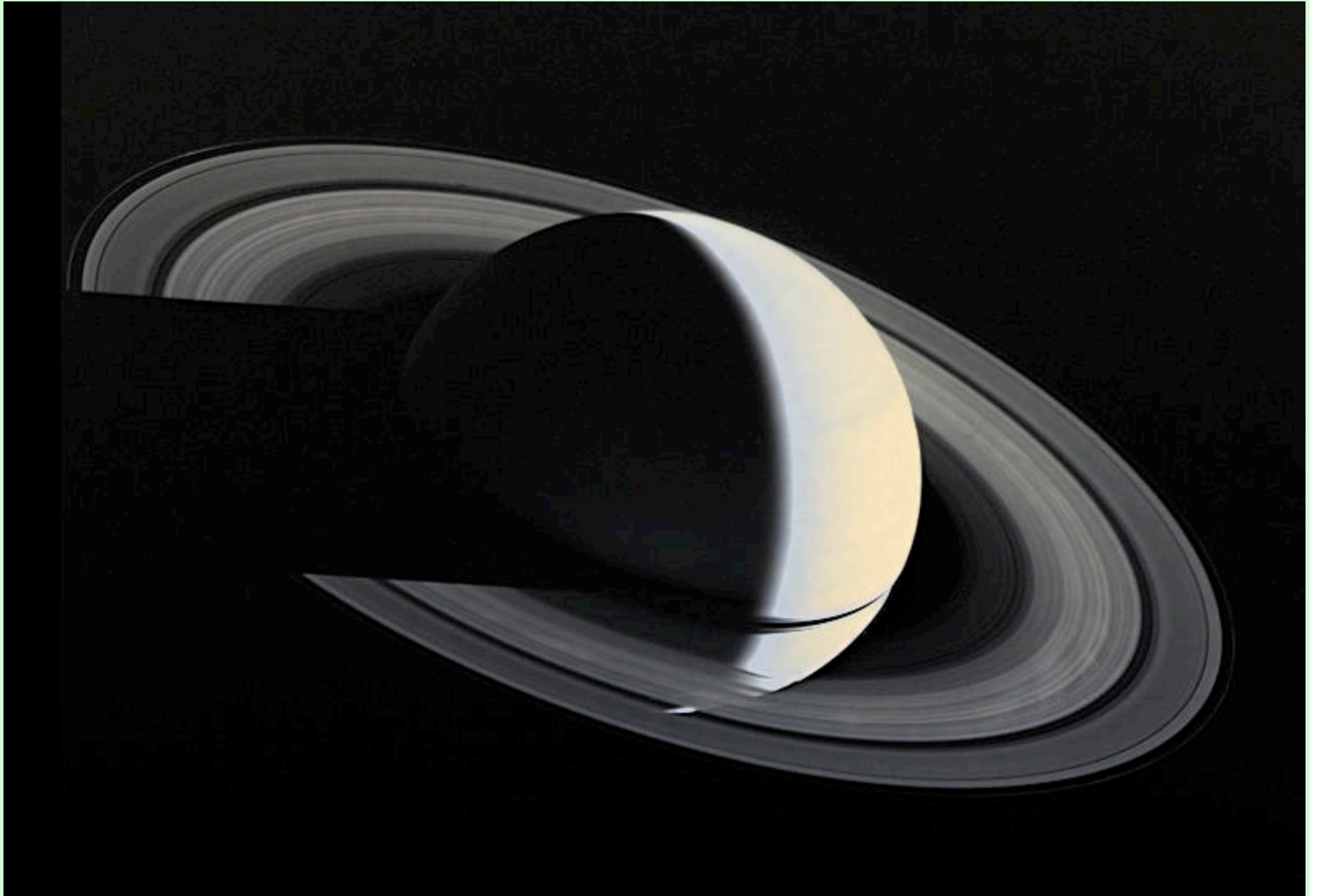
## Jupiter Aurora

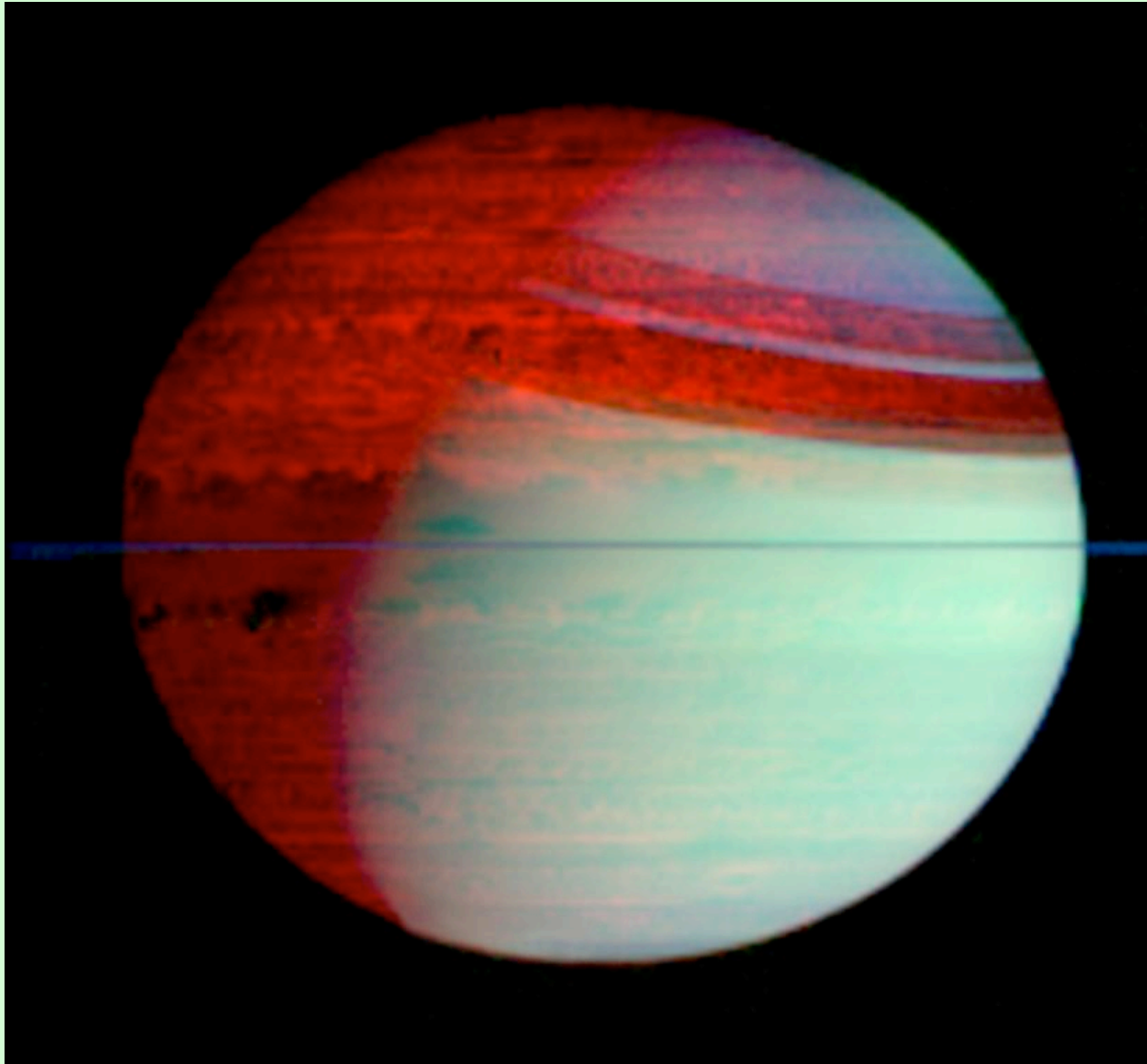
HST · WFPC2

PRC96-32 · ST ScI OPO · October 17, 1996  
J. Clarke (University of Michigan) and NASA

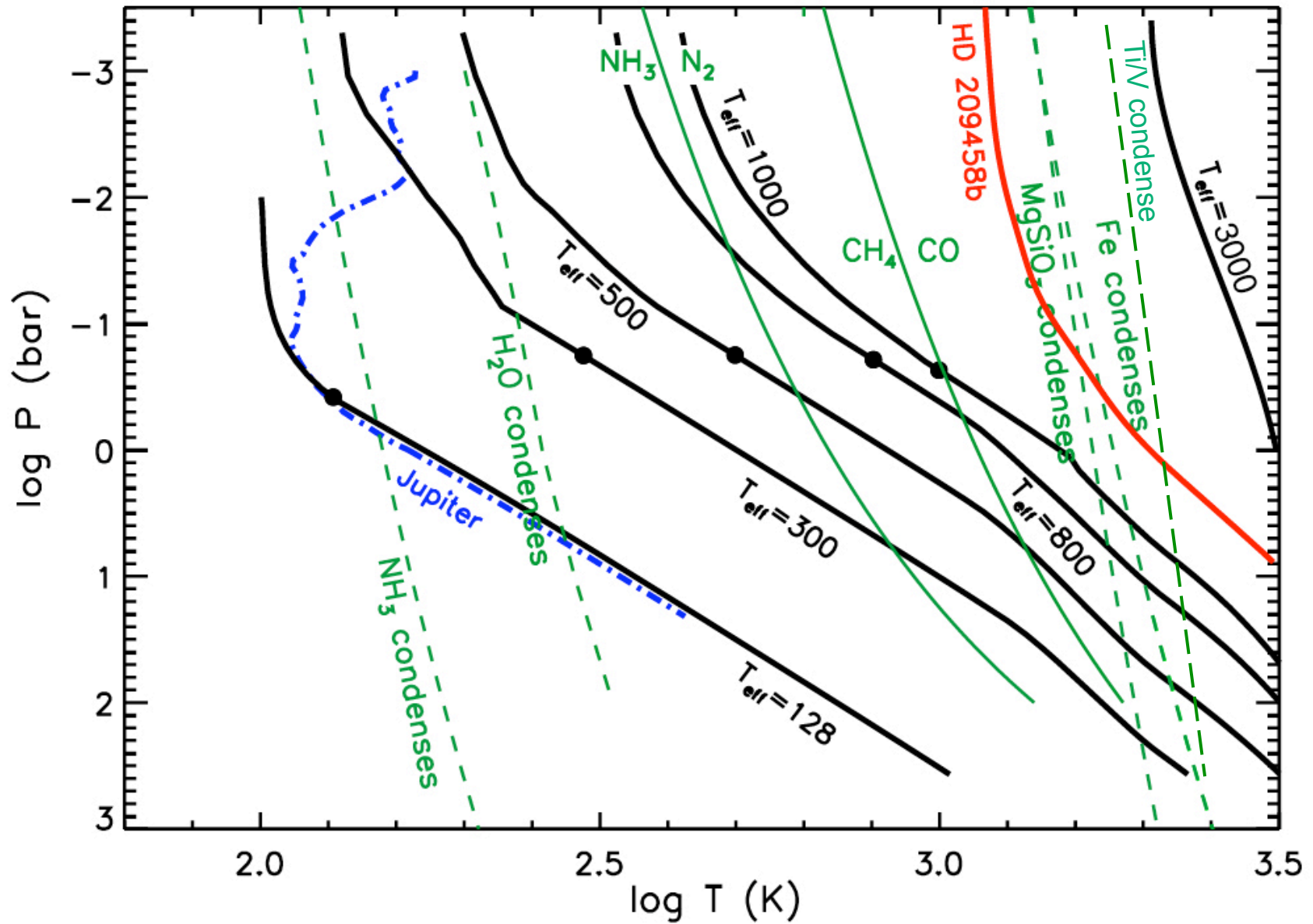


Isolating a single pole of a magnet is not possible. According to Maxwell's equations, there are always as many field lines going into an isolating sphere as the number coming out.



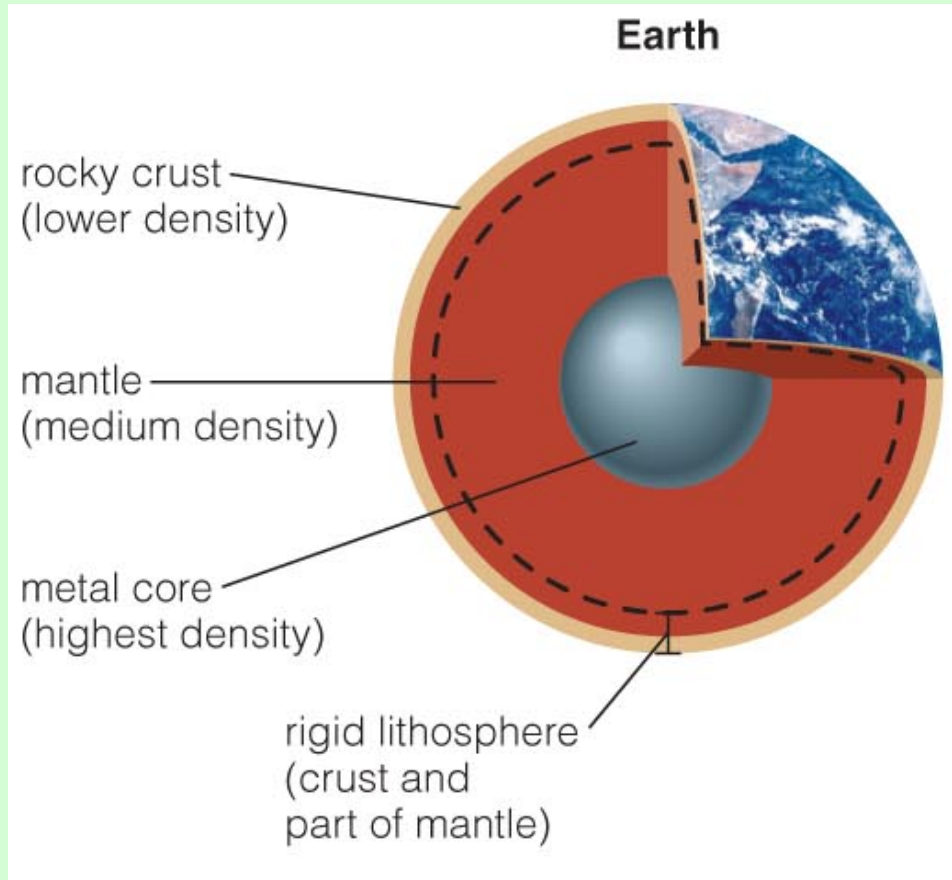


While Saturn looks visibly blander than Jupiter, it has very similar atmospheric structure



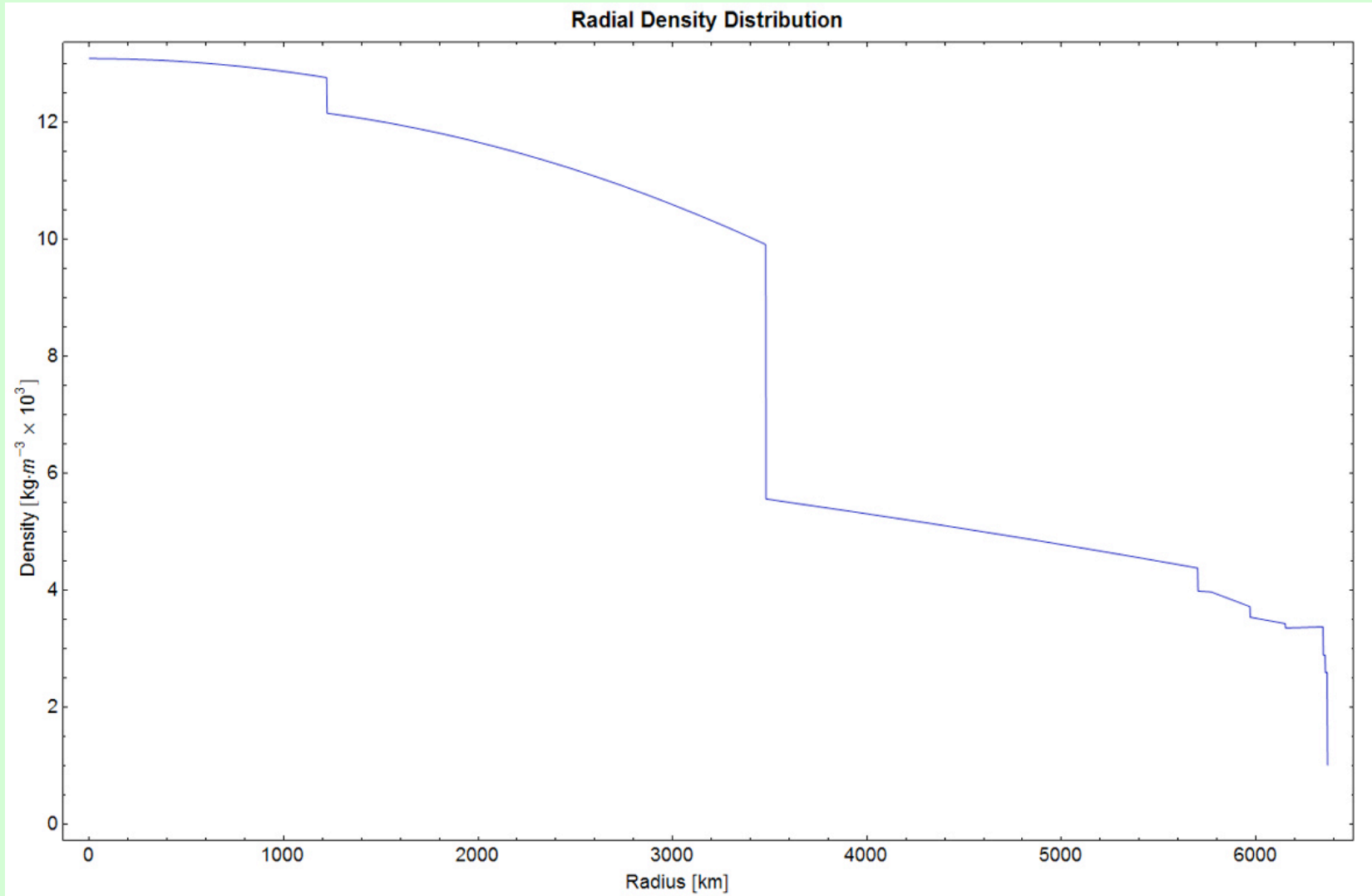
Pressure-Temperature ( $P$ - $T$ ) profiles from Jupiter to a 3000K M dwarf star

# Earth's Interior

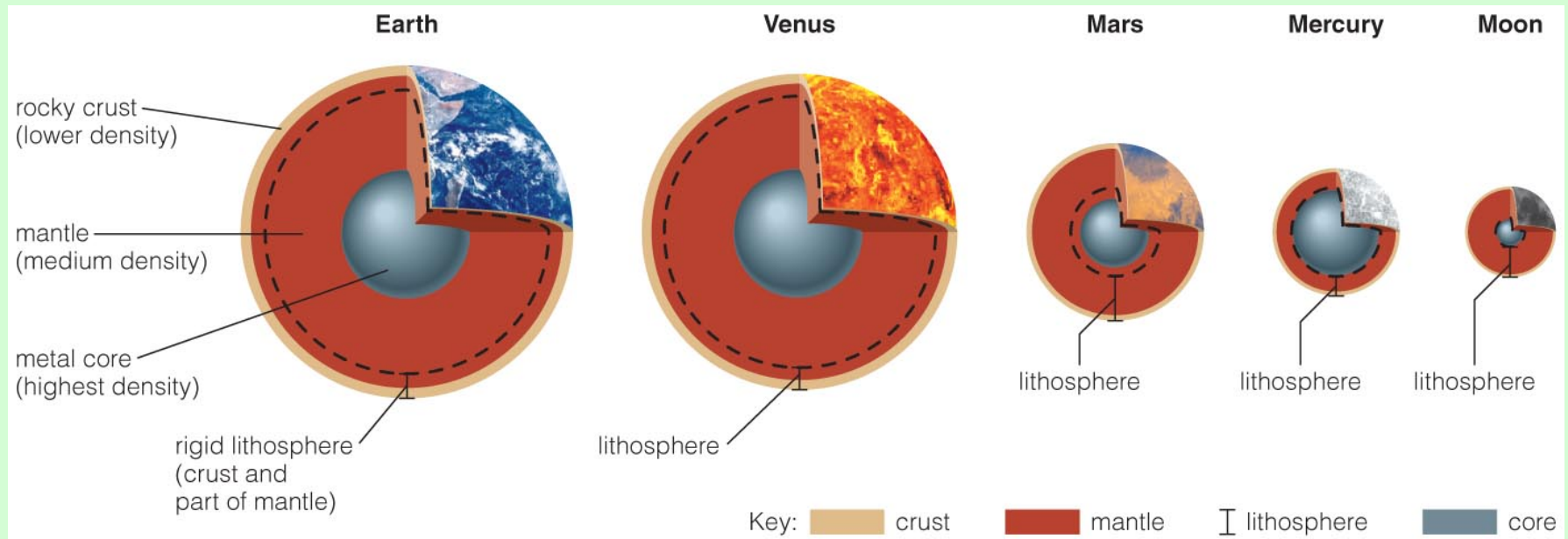


- **Core:** highest density; nickel and iron
- **Mantle:** moderate density; silicon, oxygen, etc.
- **Crust:** lowest density; granite, basalt, etc.

# Preliminary Reference Earth Model (PREM)

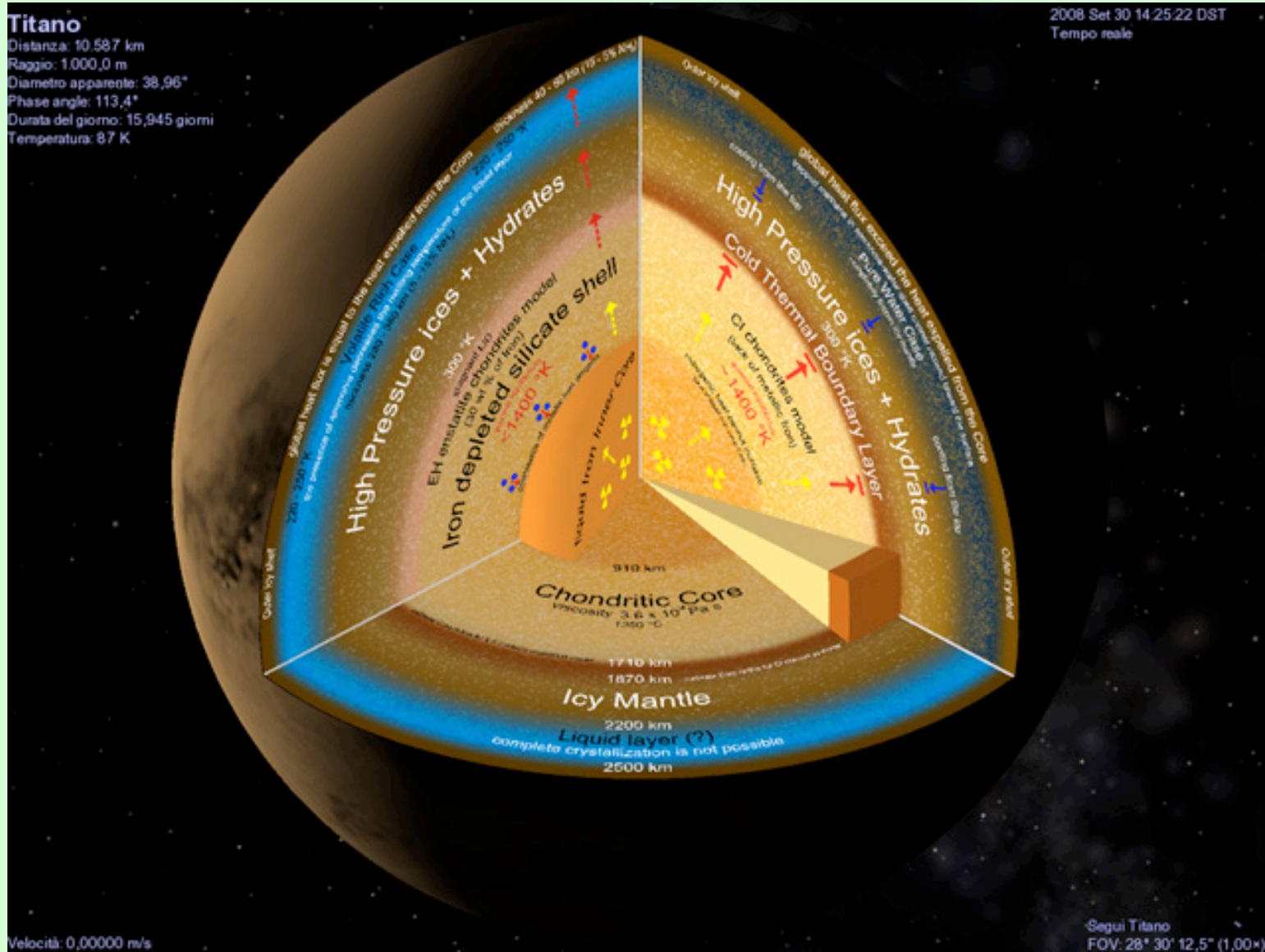


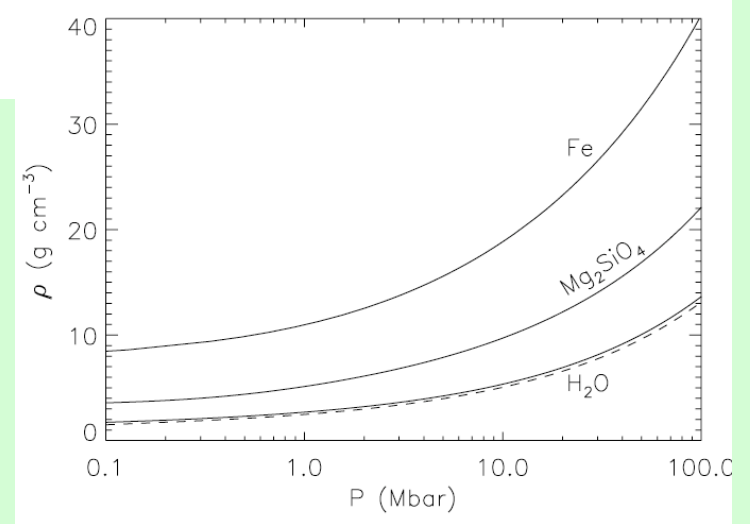
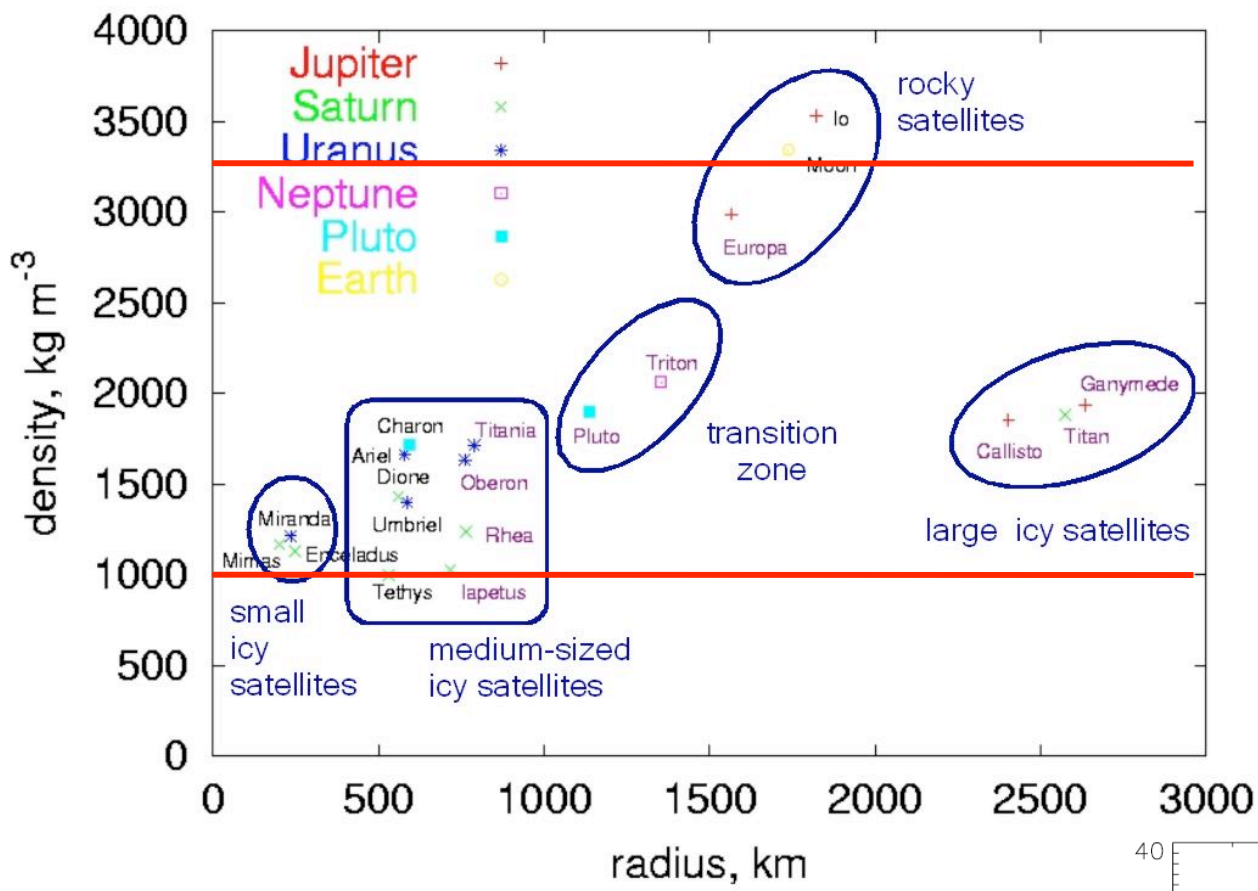
# Terrestrial Planet Interiors



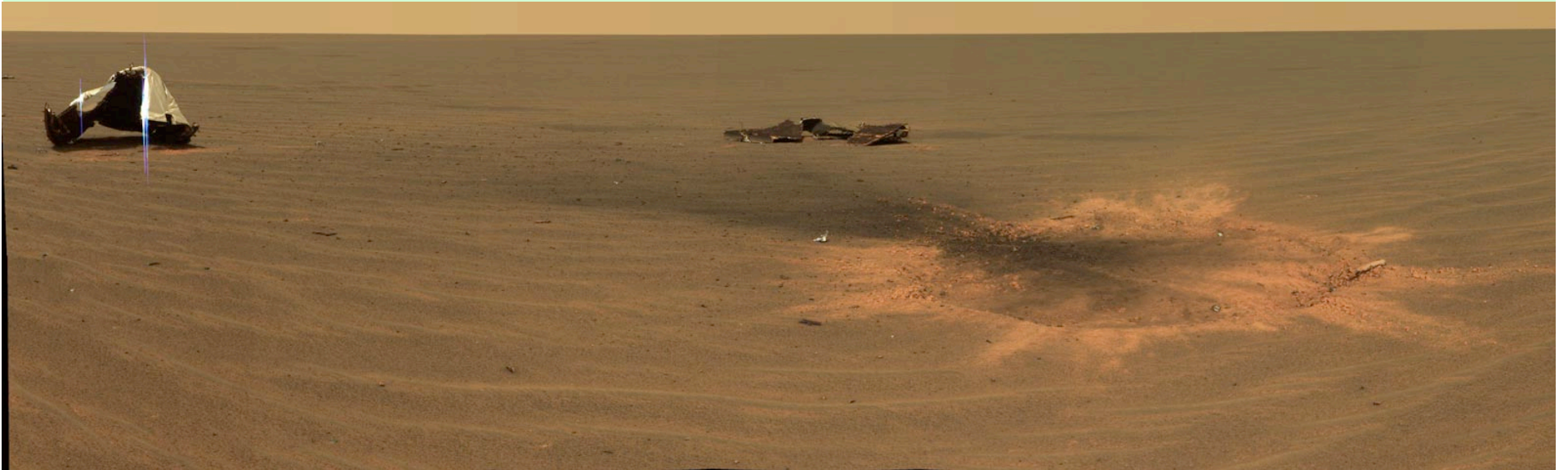
- Applying what we have learned about Earth's interior to other planets tells us what their interiors are probably like.

# Titan: A Model Icy Moon





My favorite image of Mars



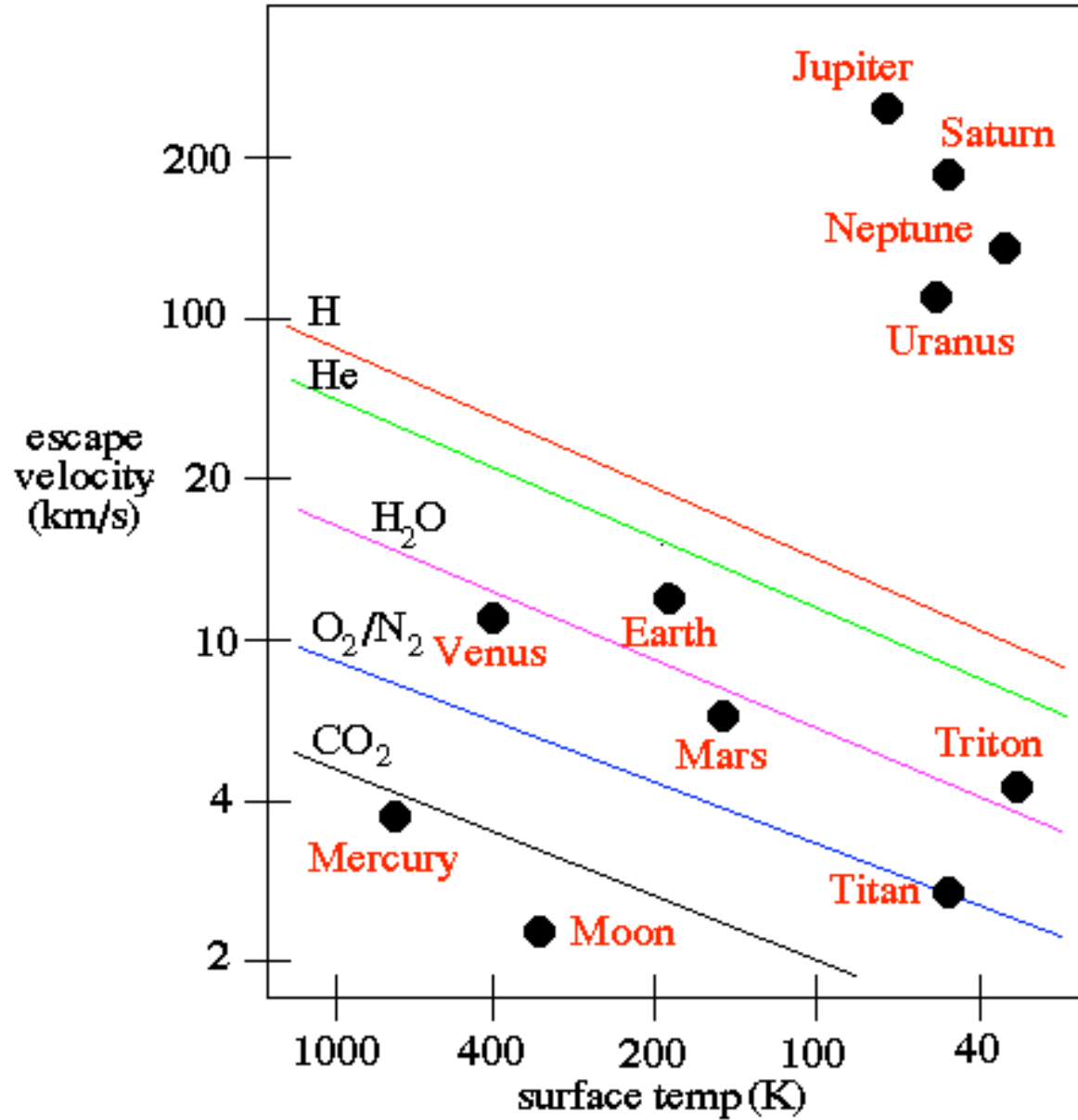
2005, Opportunity rover heat shield

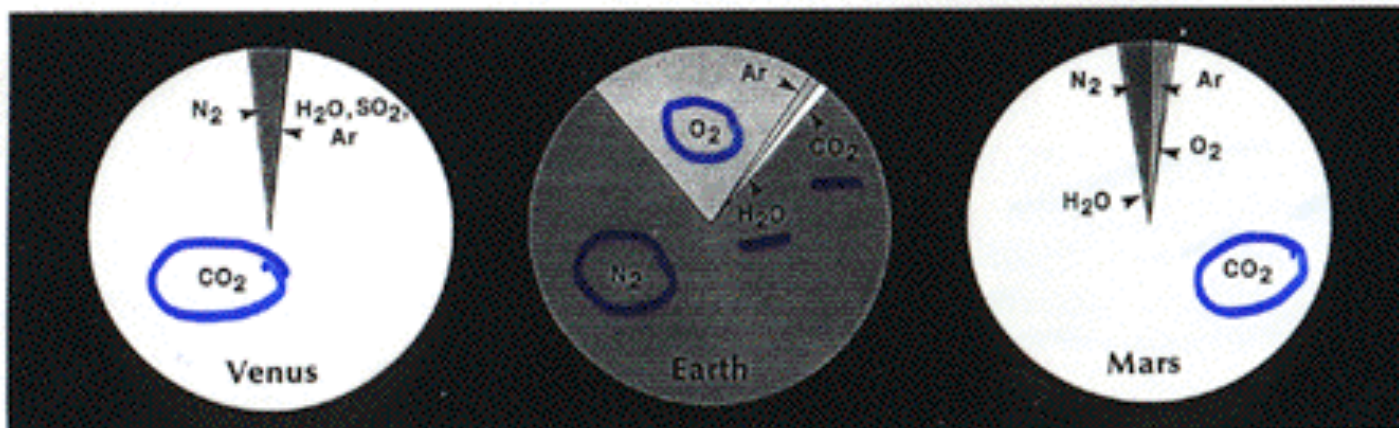
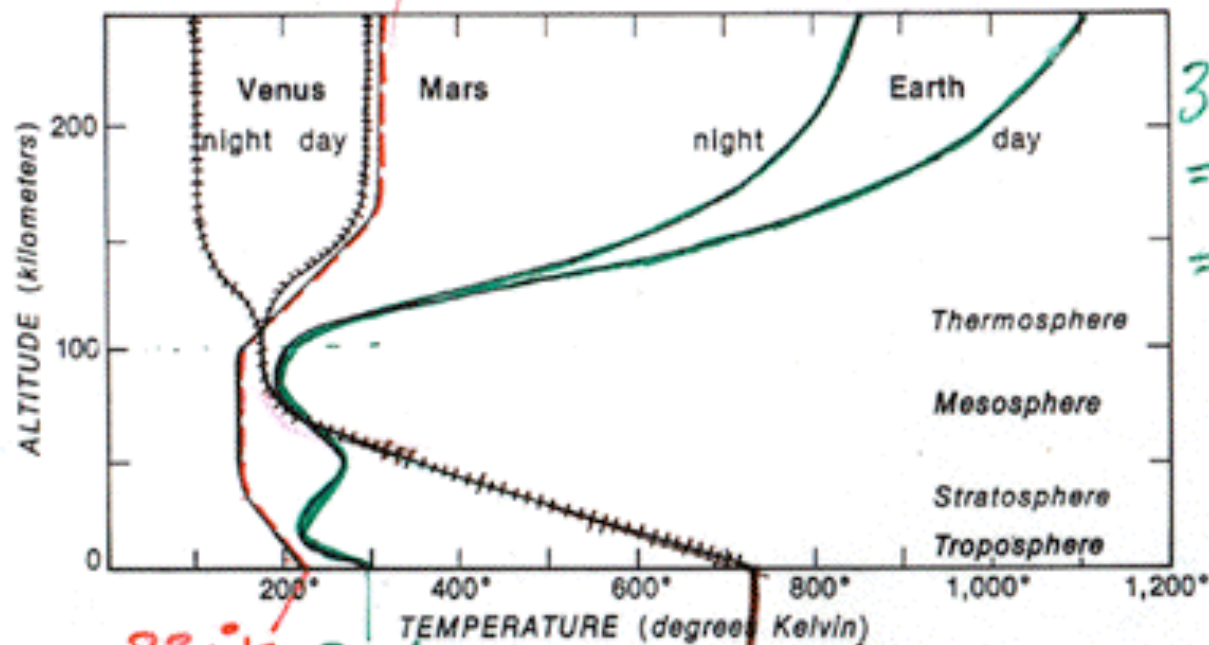
# “No Greenhouse” Temperatures

**TABLE 10.2** The Greenhouse Effect on the Terrestrial Worlds

World	Average Distance from Sun (AU)	Reflectivity	“No Greenhouse” Average Surface Temperature*	Actual Average Surface Temperature	Greenhouse Warming (actual temperature minus “no greenhouse” temperature)
Mercury	0.387	12%	163°C	day: 425°C; night: -175°C	—
Venus	0.723	75%	-40°C	470°C	510°C
Earth	1.00	29%	-16°C	15°C	31°C
Moon	1.00	12%	-2°C	day: 125°C; night: -175°C	—
Mars	1.524	16%	-56°C	-50°C	6°C

\*The “no greenhouse” temperature is calculated by assuming no change to the atmosphere other than lack of greenhouse warming. For example, Venus has a lower “no greenhouse” temperature than Earth even though it is closer to the Sun, because the high reflectivity of its bright clouds means that it absorbs less sunlight than Earth.





SURFACE PRESSURE 90 ATMOSPHERES

1 ATMOSPHERE

0.006 ATMOSPHERE