The Cosmos

Planets & Life

PHYS 214

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Please start all class related emails with "214:"

Midterm details

- Walter Light Hall Rm 205 9:30 – 10:30 (so within our usual class slot)
- Half multiple choice, half short answer
  - On the material in weeks 1-5
- On conflicts:
  - "If a conflict arises with one course scheduling their exam outside of their usual slot, then it is the responsibility of the instructor scheduling outside of the slot to make accommodations for students unable to attend due to a conflict"

Homework

- If you haven't already handed in assignment 1 please do so at the end of class
- Assignment 2 will be posted this afternoon
  - Questions on stars, radiation from stars & habitable zones

Remember: no lecture Friday

Today's Lecture

- The Jovian planets
  - Brief discussion of the space-craft we have sent to these planets
  - Physical characteristics of the Jovian planets
  - Possibility of life?

Google video has copies of "Voyage to the Planets" a fact based but ficitional account of the possibility of humans travelling to all the planets. Definitely worth a watch.

We aren't going to the stars soon. If we want to look for life on other planets, then our own solar system is the only place we can send probes.

Mass distribution in the solar system

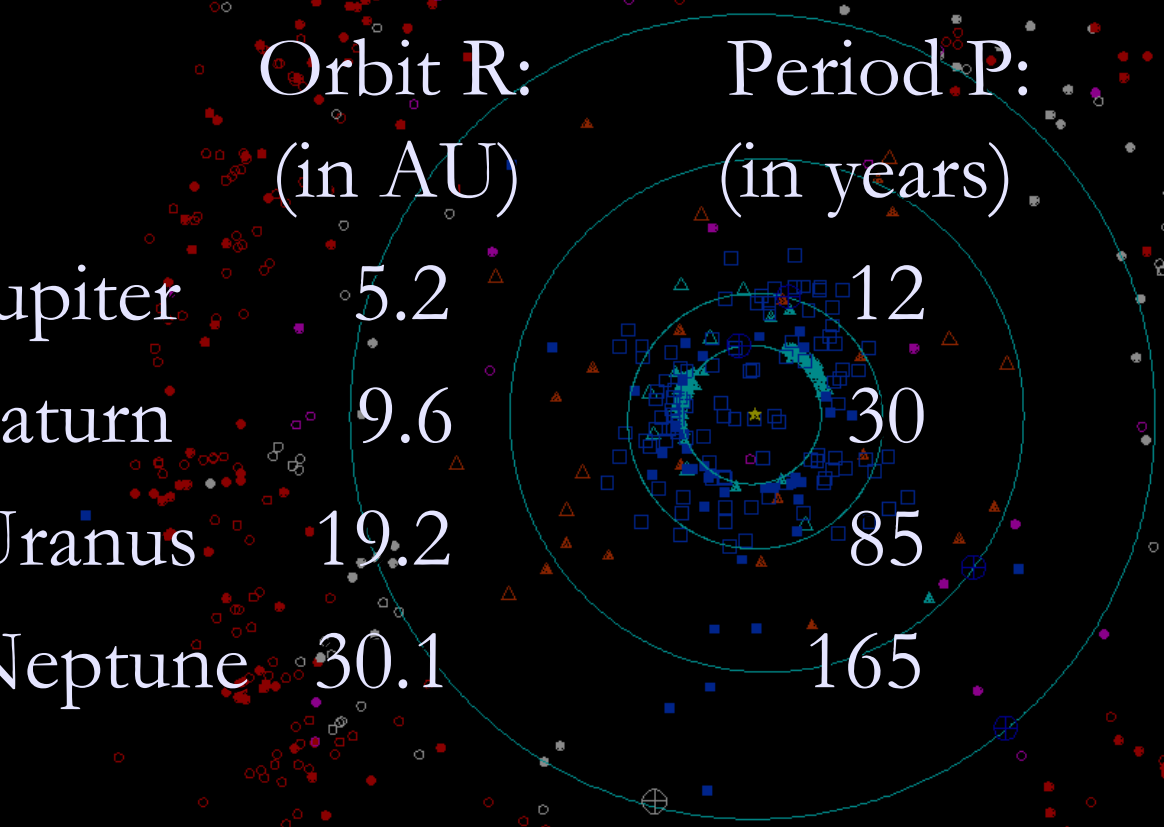
Object	Contribution
Sun	99.85%
Planets	0.135%
Comets	0.01%
Satellites (moons)	0.00005%
Minor planets	0.0000002%?
Meteroids	0.0000001%?
Interplanetary medium	0.0000001%?

Jupiter is more than twice as massive as the rest of the planets combined.

Comparison: Orbital data

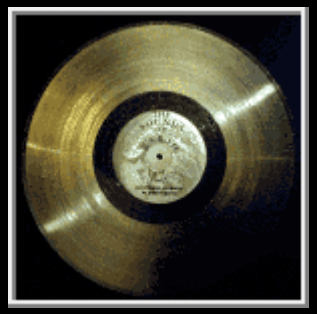
	Orbit R: (in AU)	Period P: (in years)	Mass M: (× Earth)
Jupiter	5.2	12	318
Saturn	9.6	30	94
Uranus	19.2	85	15
Neptune	30.1	165	17

Neptune gets $1/30^2 = 1/900$th of the radiation that the Earth gets



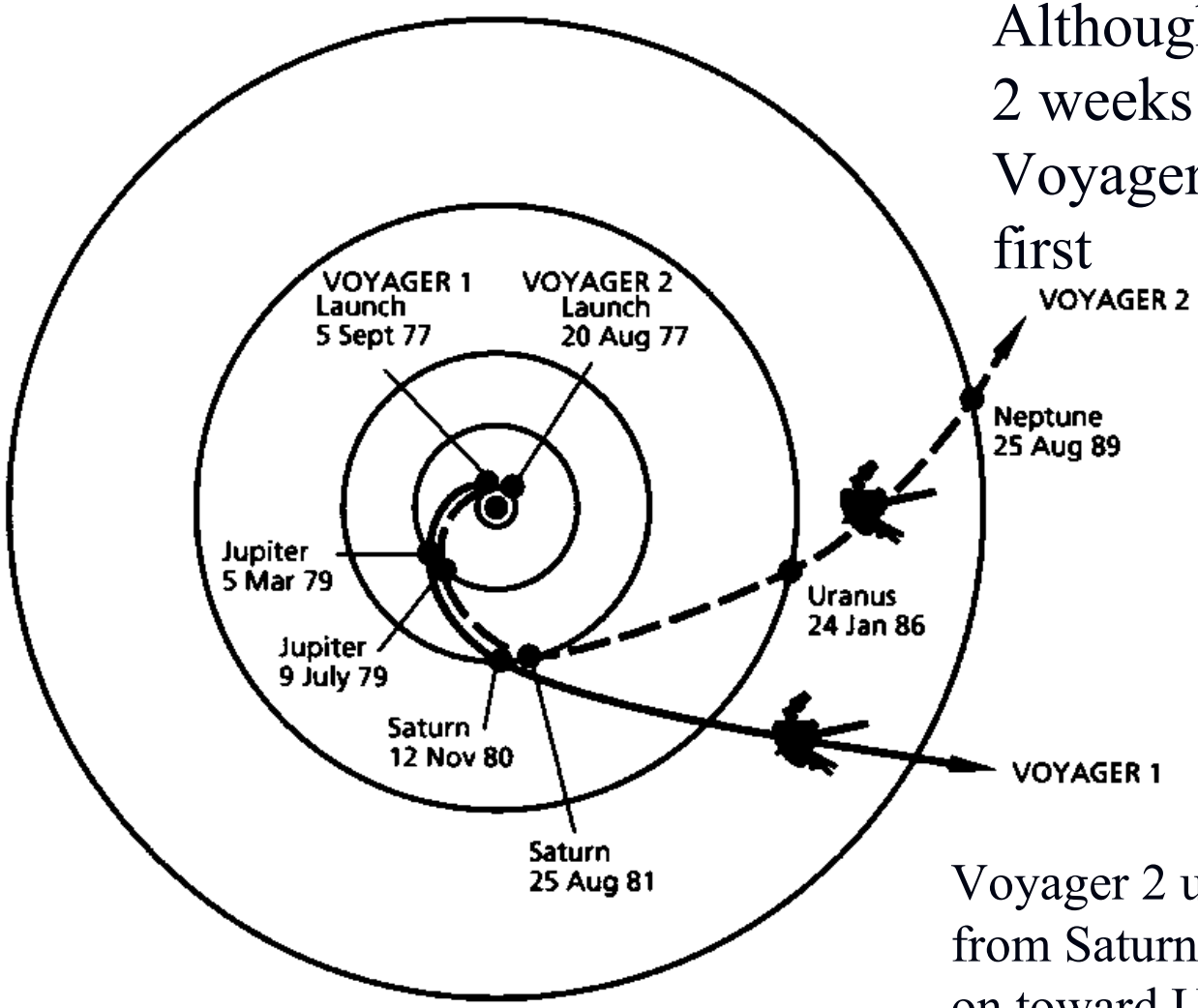
Plot prepared by the Minor Planet Center (2002 Feb 7).

Voyagers 1 & 2



- Unmanned probes sent to Outer solar system (launched 1977)
- Voyager 1 visited Jupiter & Saturn
- Voyager 2 visited Jupiter, Saturn, Uranus, Neptune
- Each probe carries a `Golden Record' containing information about the Earth
  - Also includes cartridge and needle needed to make a player for the record

Voyager trajectories



Although launched a
2 weeks after Voyager 2
Voyager 1 reached Jupiter
first

Voyager 2 used a slingshot
from Saturn to propel it
on toward Uranus & Neptune
(took 12 years to reach Neptune!)

The Golden Record

- Content decided upon by a committee headed by Dr Carl Sagan
- 115 images, followed by greetings in 56 languages, a series of sounds of Earth and then 90 minutes of music
- Sounds include
  - Dog…
  - Chimp…

Voyagers still take 40,000 years to travel 1.6 light years! Unbelievably unlikely to be picked up!

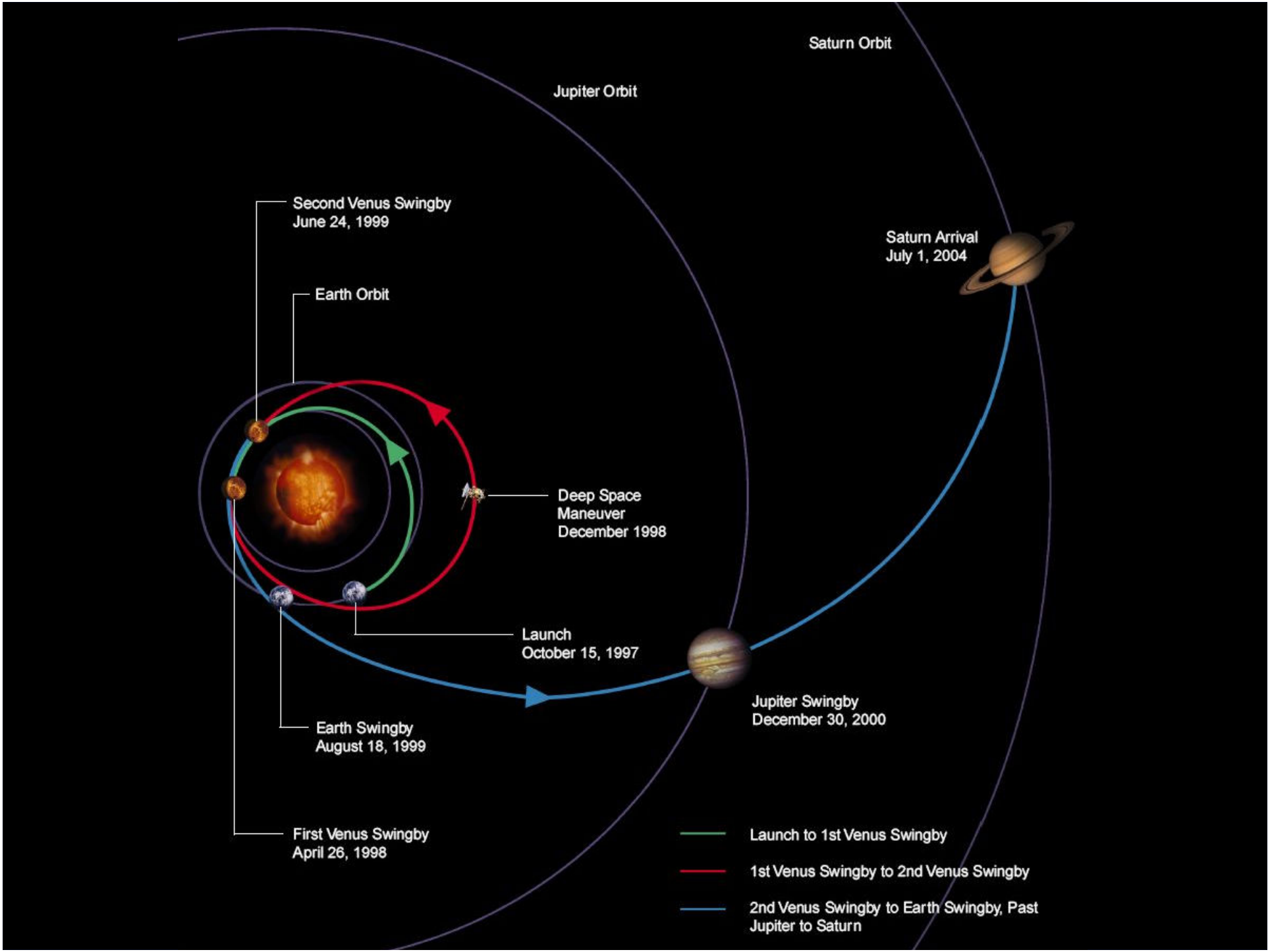
Galileo (Jupiter)

- More recent spacecraft (launched 1989) which orbited around Jupiter until 2003
  - It was destroyed to prevent the possible contamination of the Europa, one of Jupiter's moons that harbours liquid water under an ice surface
- Deployed probe into Jupiter's atmosphere

Even with a damaged antenna it has relayed back some important data and beautiful pictures (right: Jupiter's rings)

Cassini-Huygens (Saturn)

- Collaboration between NASA and European Space agency (ESA)
  - NASA built the Cassini orbiter
  - ESA built the Huygen's lander (landed on Titan)
- Launched in 1997, took 4 gravity assists to get it to Saturn
  - Also included the heaviest payload of plutonium ever launched in a rocket (36.5 kg!)

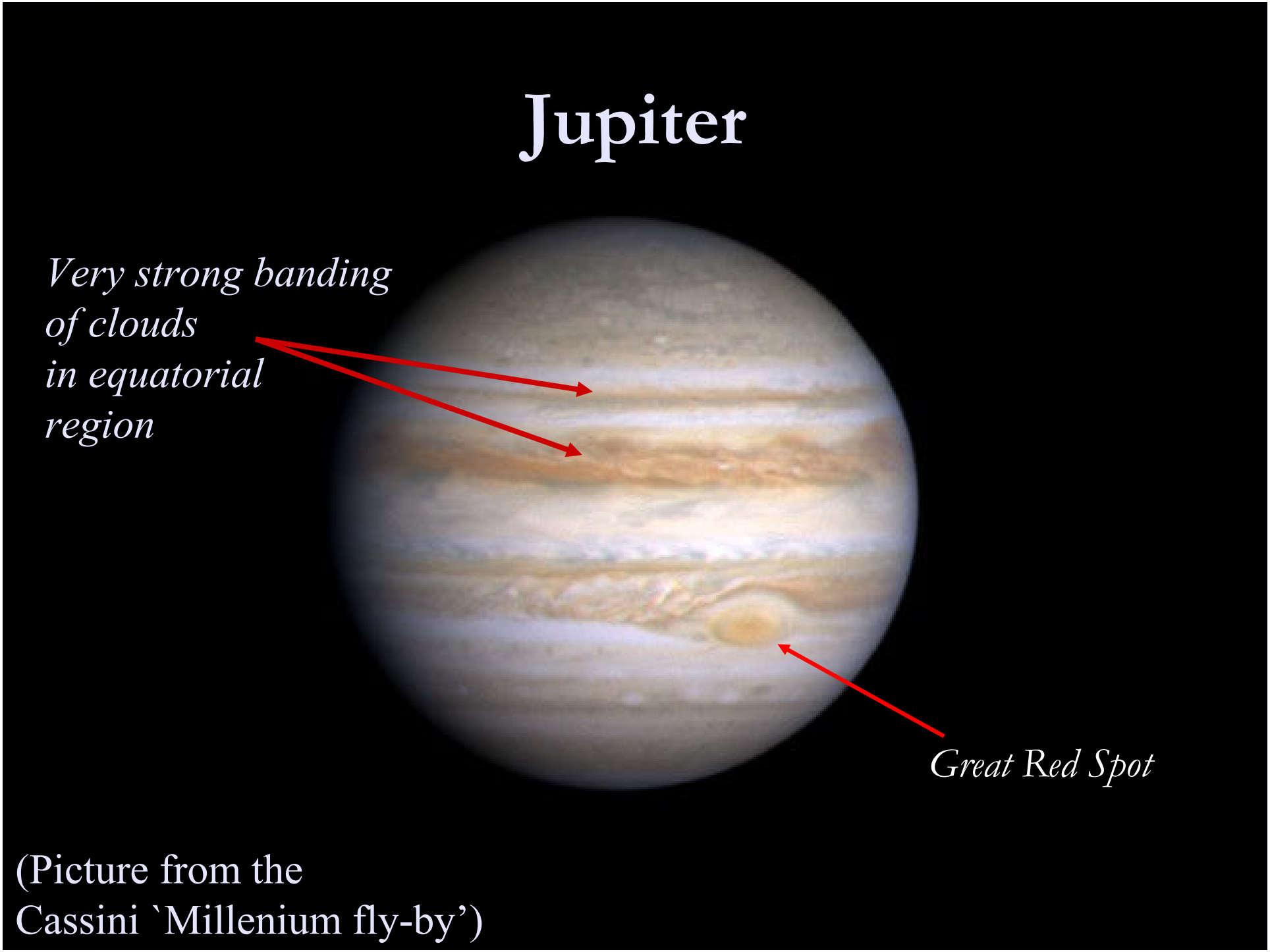

Saturn Orbit
Jupiter Orbit
Second Venus Swingby
June 24, 1999
Saturn Arrival
July 1, 2004
Earth Orbit
Deep Space
Maneuver
December 1998
Launch
October 15, 1997
Jupiter Swingby
December 30, 2000
Earth Swingby
August 18, 1999
First Venus Swingby
April 26, 1998
Launch to 1st Venus Swingby
1st Venus Swingby to 2nd Venus Swingby
2nd Venus Swingby to Earth Swingby, Past
Jupiter to Saturn

A few thoughts about interplanetary exploration – is it expensive?

- Cost of Galileo mission ~ $1.5 billion (over 10 years)
- Cost of Cassini-Huygens mission = $3.26 billion (over a similar period)
- US annual GDP ~ $10 trillion
  - US defense budget around $400 billion
  - NASA Budget per year around $16 billion
  - Cost of entire Apollo project ~ $150 billion in today's dollars

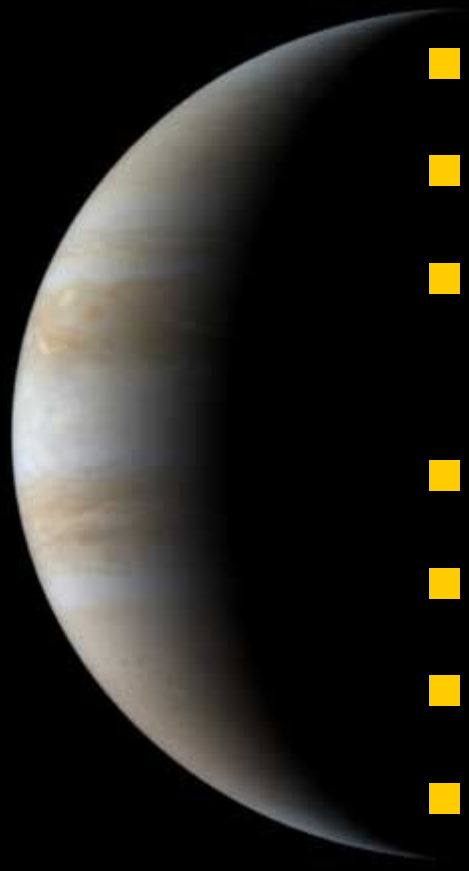
You decide…

Jupiter



(Picture from the Cassini `Millenium fly-by')

Jupiter Facts

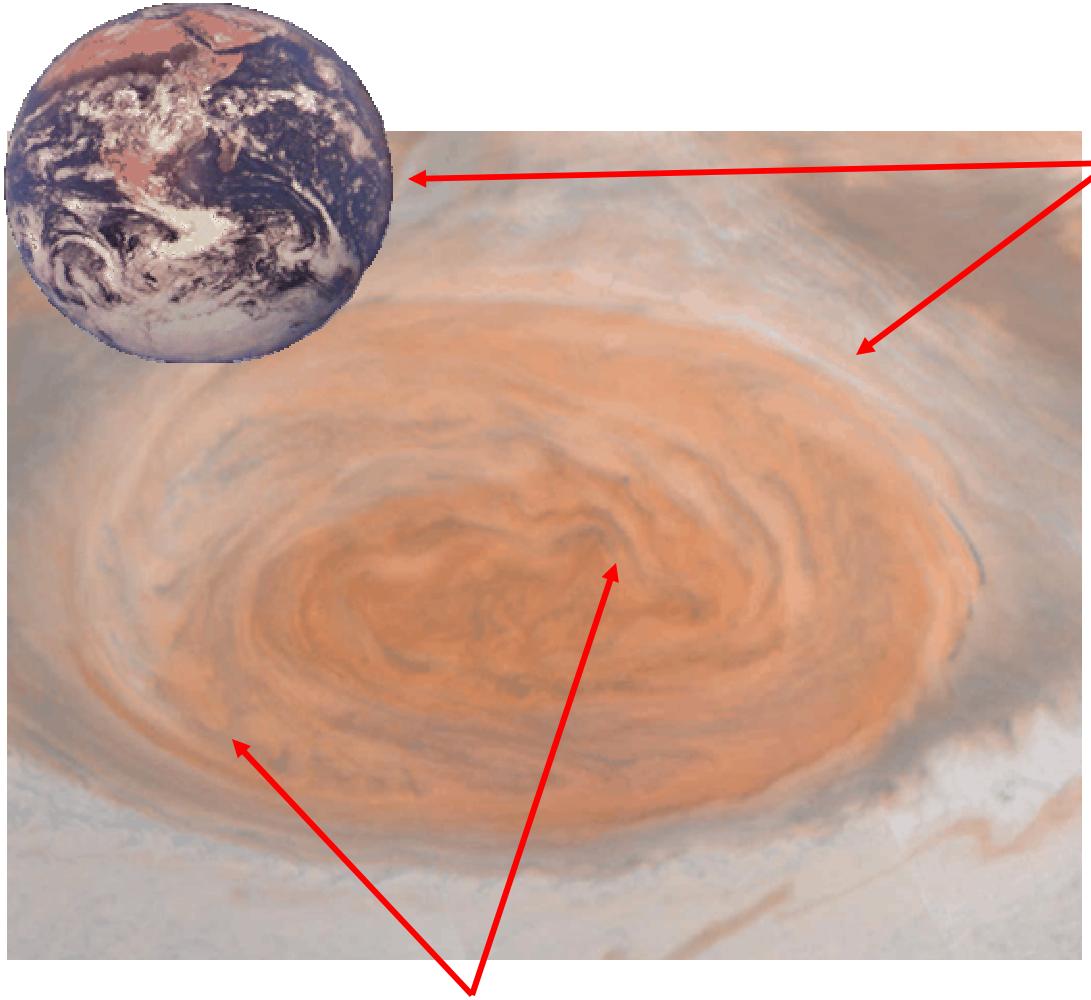


- Diameter: 142,000 km (11× Earth)
- Rotation period is *about* 9.8 hours (very fast)
- Different latitudes rotate at different rates (slower at poles, faster at equator)
- `Surface*' gravity is 2.5× that of Earth
- Escape velocity is 6 times that of Earth
- Magnetic field is 14× stronger than Earth's
- Radiates more energy at infrared wavelengths than it receives from the Sun – slowly collapsing and releasing energy

*gravity at the top of the atmosphere

Origin of colour is not fully understood, may be down to red phosphorus

Great Red Spot



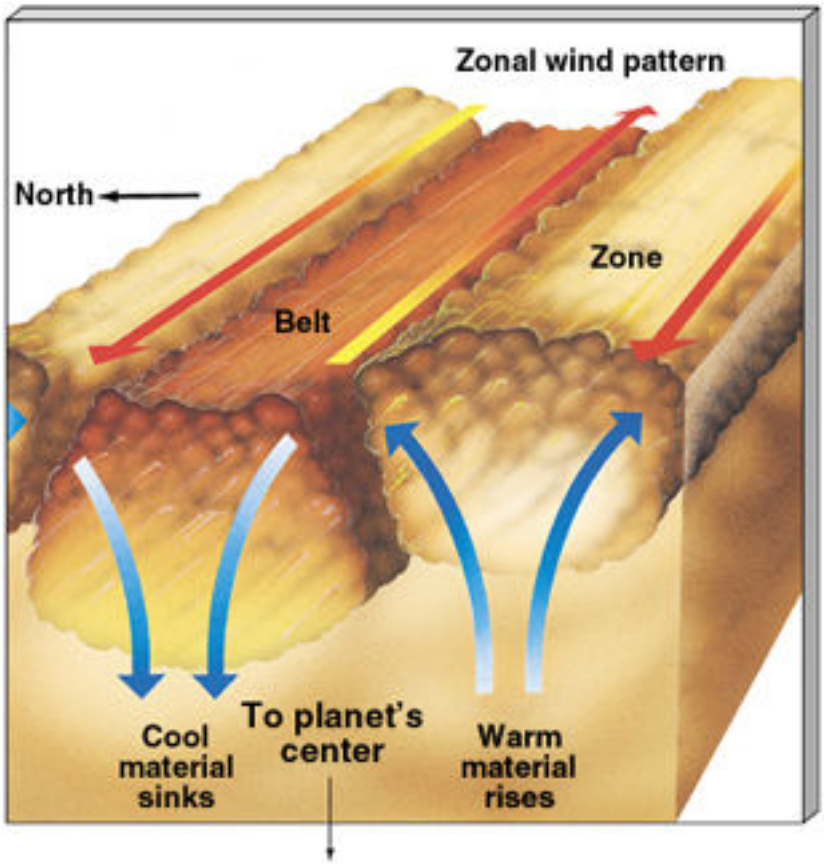
Great Red Spot and Earth (to scale)

Diameter is over twice that of Earth

Red Spot is an ancient *hurricane* in Jupiter's atmosphere – Wind speeds 650 km s^{-1}

Circulation bands show it is rotating

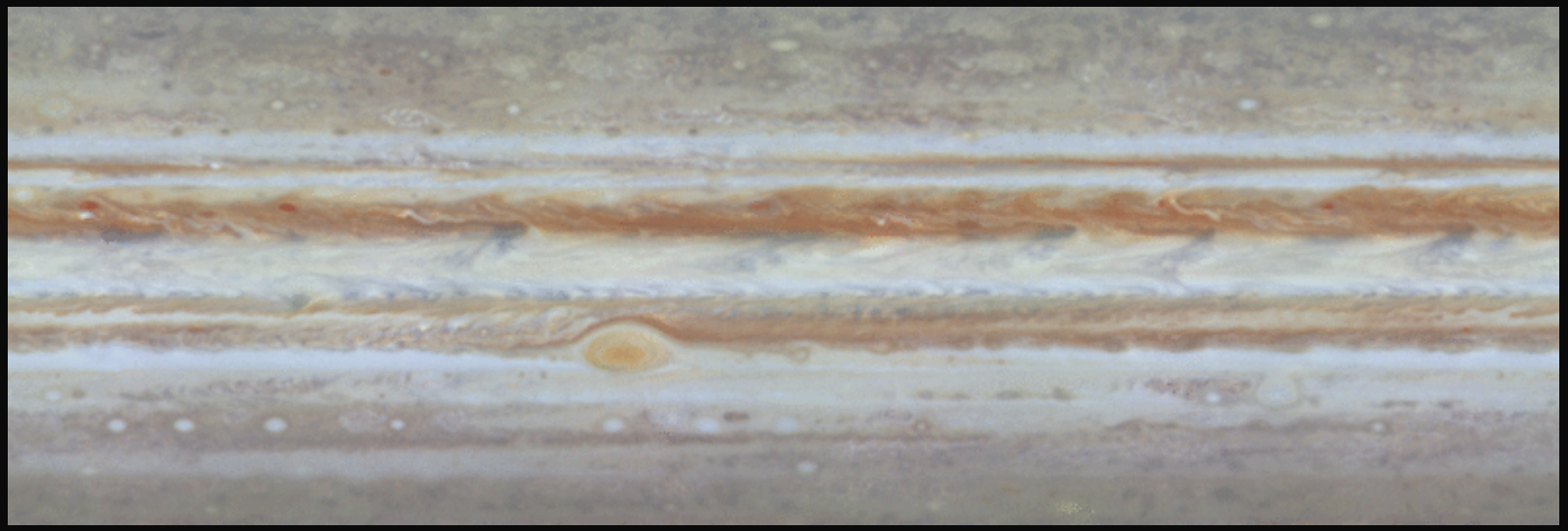
Jupiter's Atmosphere: Convection



- Zones - light (heating, high pressure), Belts - dark (cooling, low pressure)
- Zones flow in the opposite direction to belts

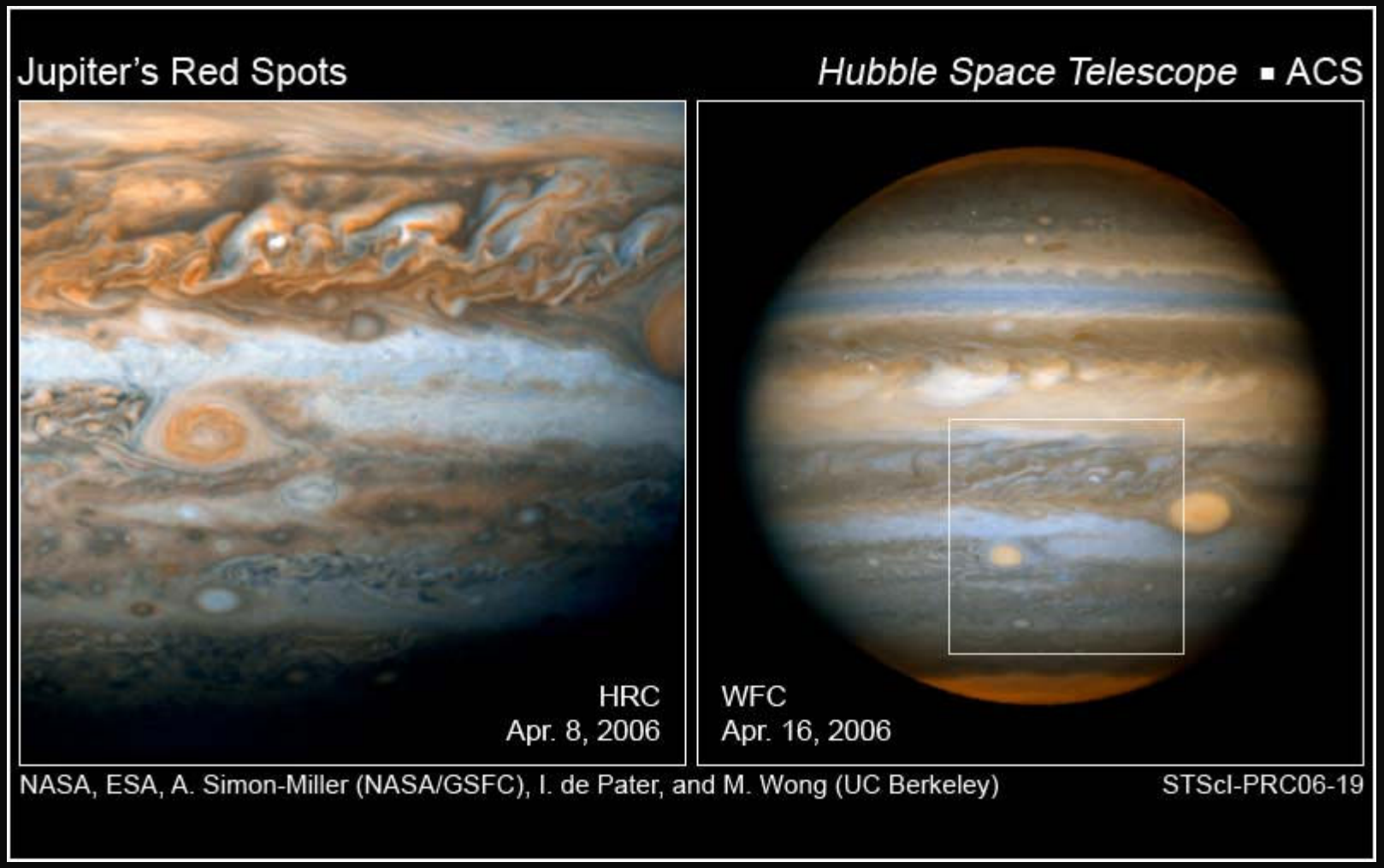
Zones, belts wrap around the planet because of the fast rotation

Cloud motion



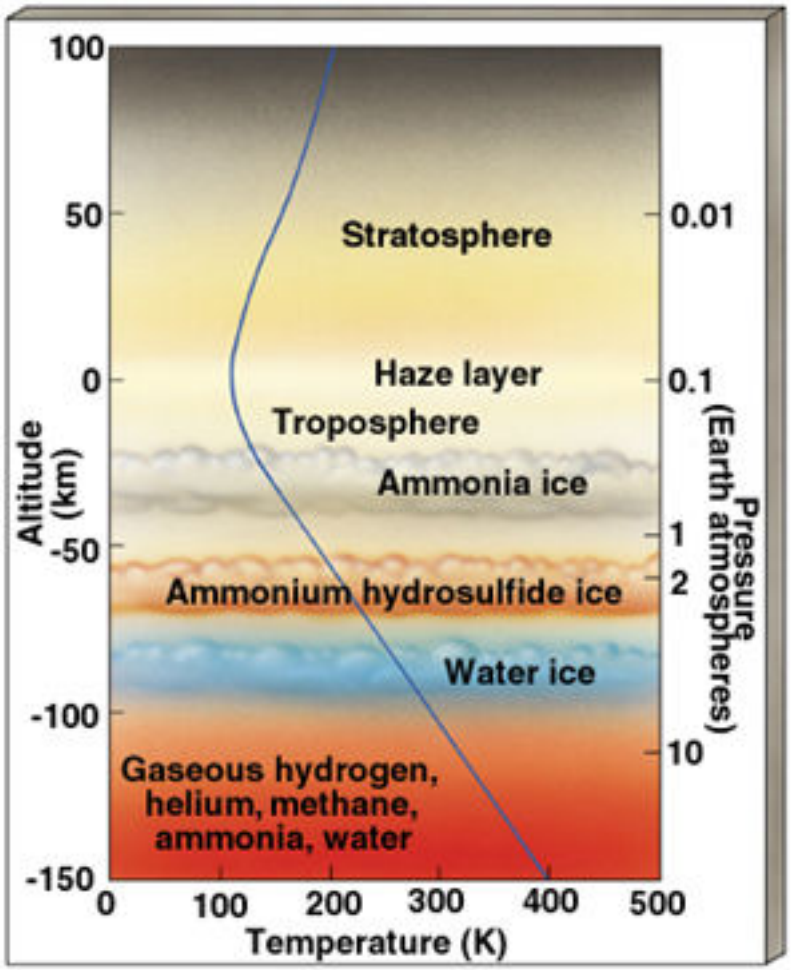
- Clip shows projected surface of Jupiter over 10 days, as shot by Cassini-Huygens probe

New "Junior" Red Spot



Appeared in 2006, and seems to have been formed by the merger of two other storms

Jupiter's Atmosphere



- 84% Hydrogen, 15% Helium
- Very chemically complex, subtle reactions depend on temperature and pressure
- We see the upper NH_3 (ammonia) ice clouds as white regions
- The ammonium hydrosulfide (NH_4HS) ice clouds are seen as dark regions

Life on Jupiter?

- In the 1970's (prior to Voyager missions) Sagan & Salpeter hypothesized that ammonia based life could evolve in Jupiter's atmosphere
  - The idea was adopted by many science fiction authors but quickly Voyager data proved the hypothesis fundamentally flawed
- In practice this seems incredibly unlikely for the following reasons:
  - Winds range from 200 to 1600 km h^{-1}
  - Temperature ranges are vast, from -167° C to 0° C
  - Where the temperature reaches 0° C the pressure is equivalent to being under 2 miles of water on the Earth
  - Large amounts of electrical discharge

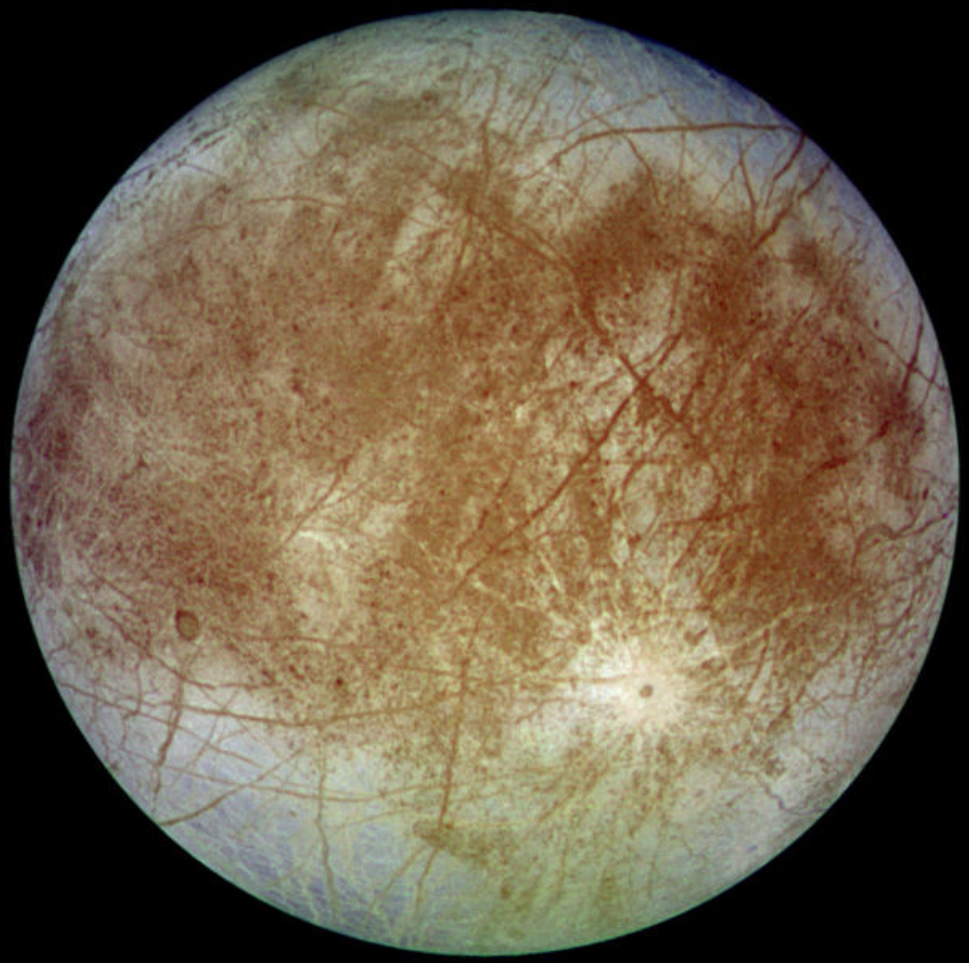
Contribution of Jupiter to life on Earth

- Jupiter's gravitational pull is sufficiently large to deflect a large fraction of comets and planetesimals heading for the inner solar system
- This helps reduce the probability of an impact event that could wipe out life on Earth
- However, Jupiter cannot be too massive as some comets must reach the primordial Earth to supply it with water
  - The balance between having enough mass and having to much mass is part of the Rare Earth hypothesis

Jovian Satellites

- Jupiter has at least 60 moons of sizes greater than 3km
- However there are 4 major satellites (diameter greater than 3000km)
  - Io, Europa, Ganymede, Callisto
- Io shows extreme volcanic activity due to stresses caused by Jupiters tidal field
- Ganymede, Callisto and Europa all show evidence of liquid water beneath their surfaces
- The presence of trace amounts of organic molecules have been found on Ganymede and Callisto

Europa



- Frozen surface of water ice (100 km thick?)
  - Surface temperature ~ -160 C
- Very few surface craters indicates a fairly new surface
- No organic molecules have been detected on surface, but we don't know about under the ice sheet
- Possibility of subsurface ocean due to heat from tidal heating of the planet caused by Jupiter
  - Requires a probe to be sent to test the idea
- Water + heat + organic molecules= possibility of life?

We'll spend a lecture looking at this possibilty…

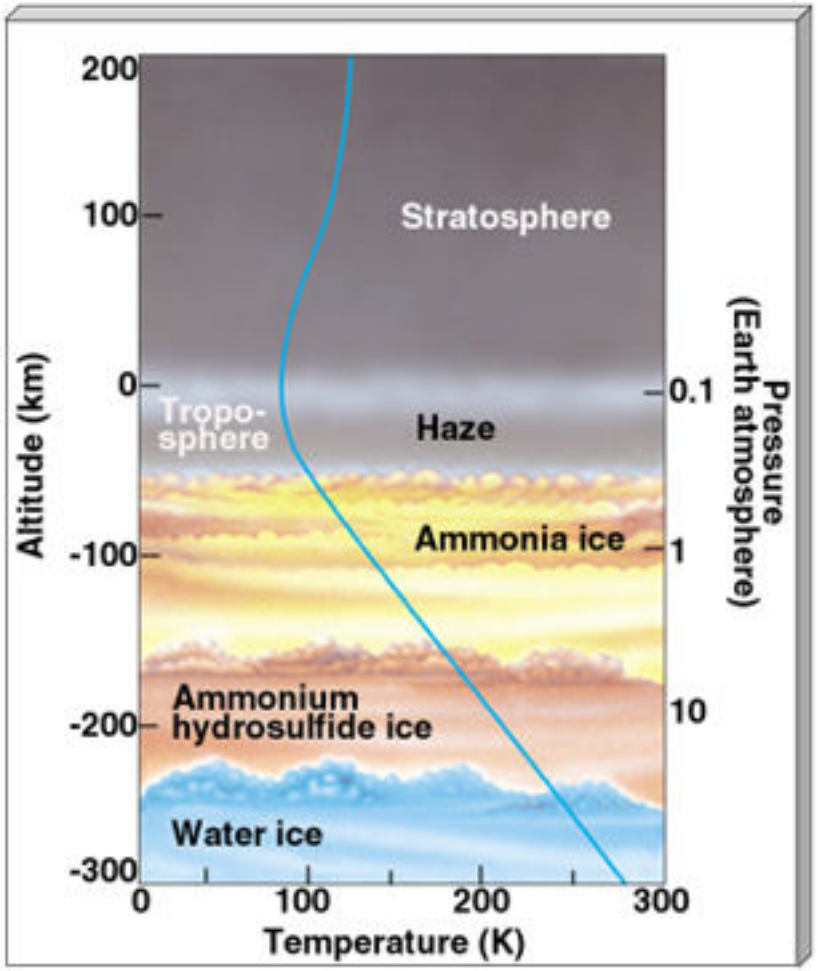
Saturn

Saturn from Voyager 1 after it's fly-by

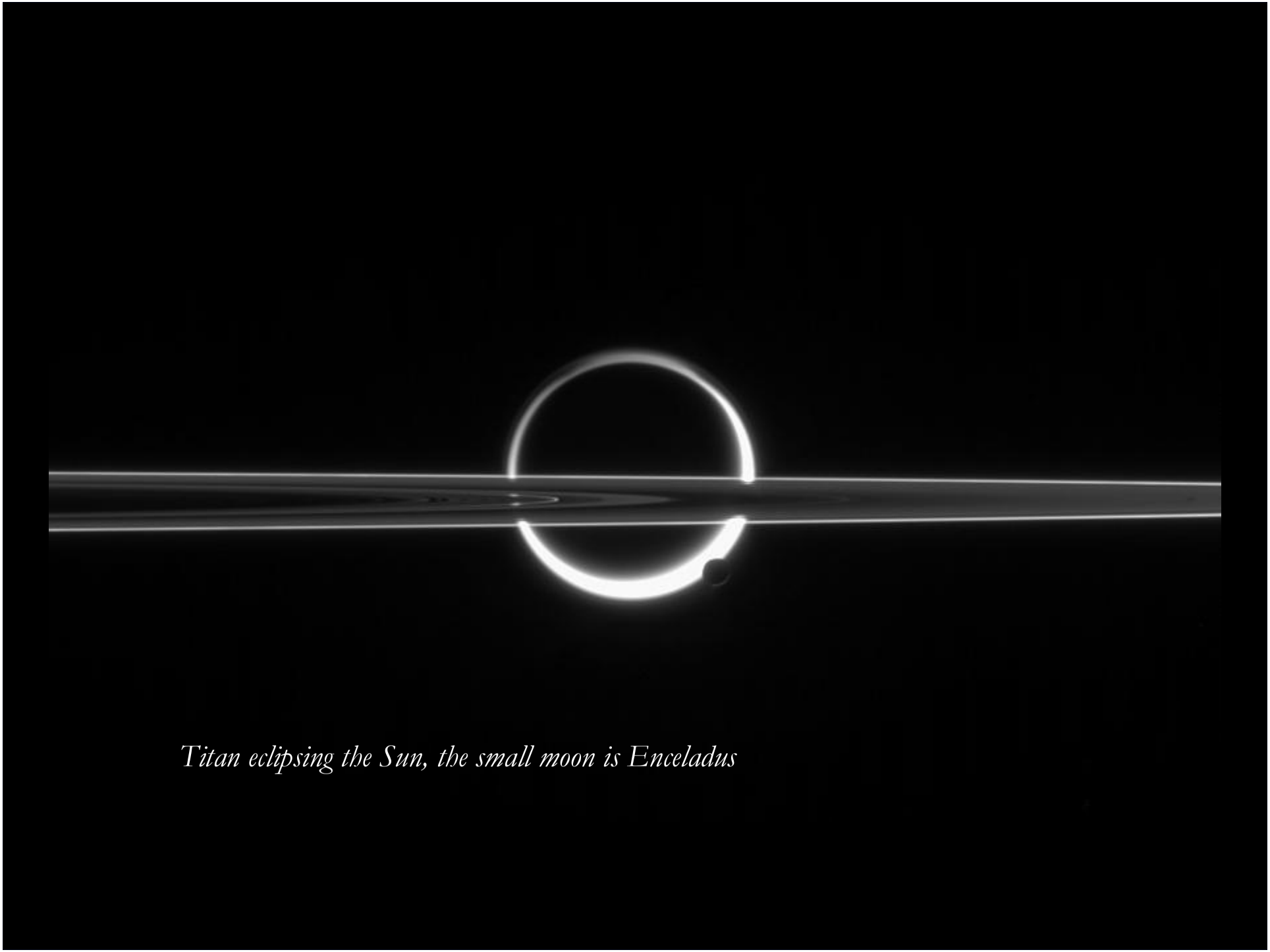
Saturn Facts

- Diameter 120,000 km
- Saturn is *less dense* than water
- Rotation period about 10 hours
- Escape velocity is about 3× Earth's
- `Surface' gravity: approx same as Earth
- Ring system formed from break-up of planetesimals
- Has very large satellite system like Jupiter and also emits more energy at infrared wavelengths than it receives from the Sun

Saturn's Atmosphere



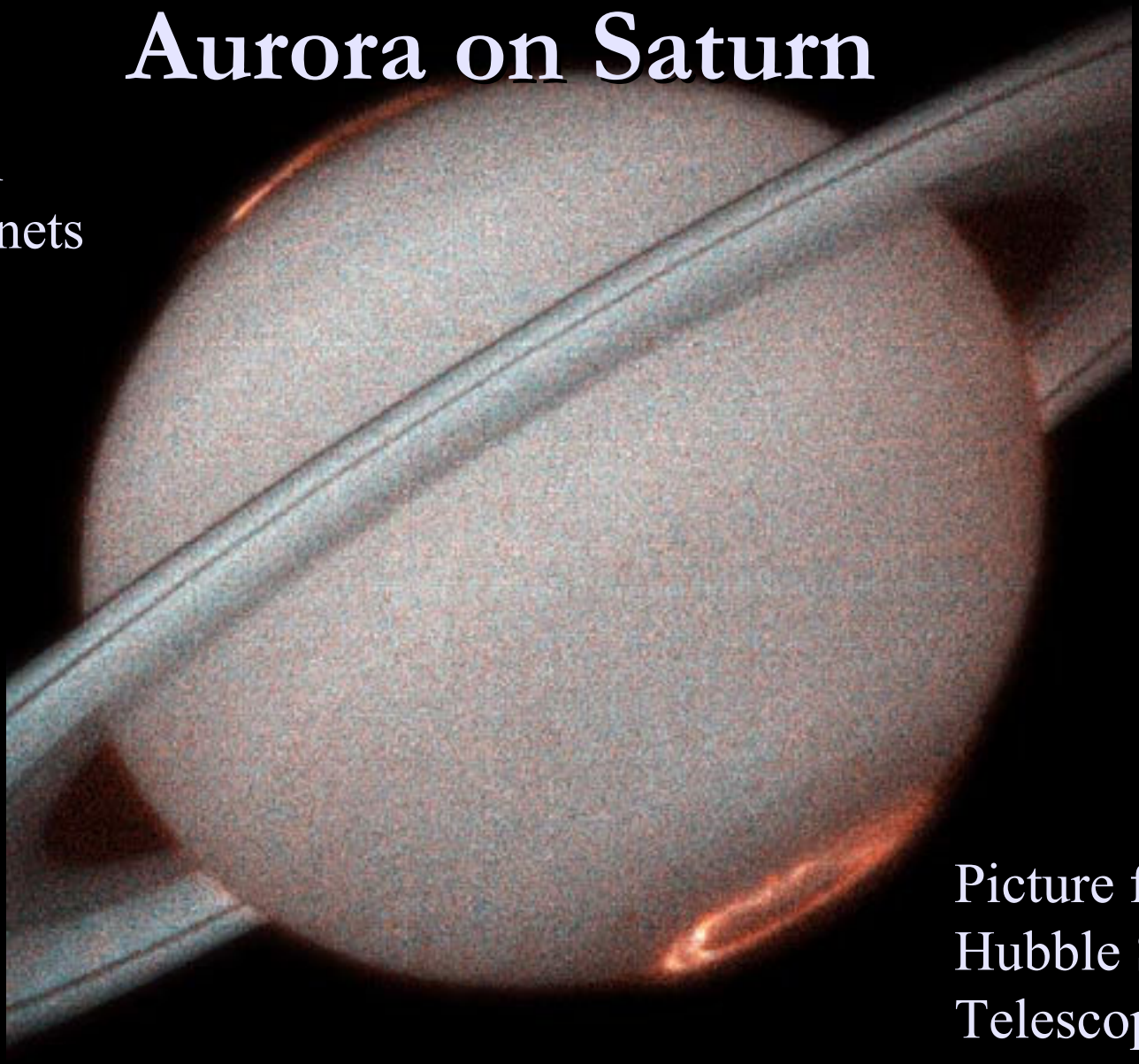
- 92.4 % Hydrogen, 7.4 % Helium
  - Less Helium because it is condensing out and raining down on the center of the planet
- Very similar to the Jovian atmosphere
  - Equally inhospitable
- Less dense, so pressure does not rise as fast with depth



Titan eclipsing the Sun, the small moon is Enceladus

Aurora on Saturn

Occur on other planets too



Picture from the Hubble Space Telescope

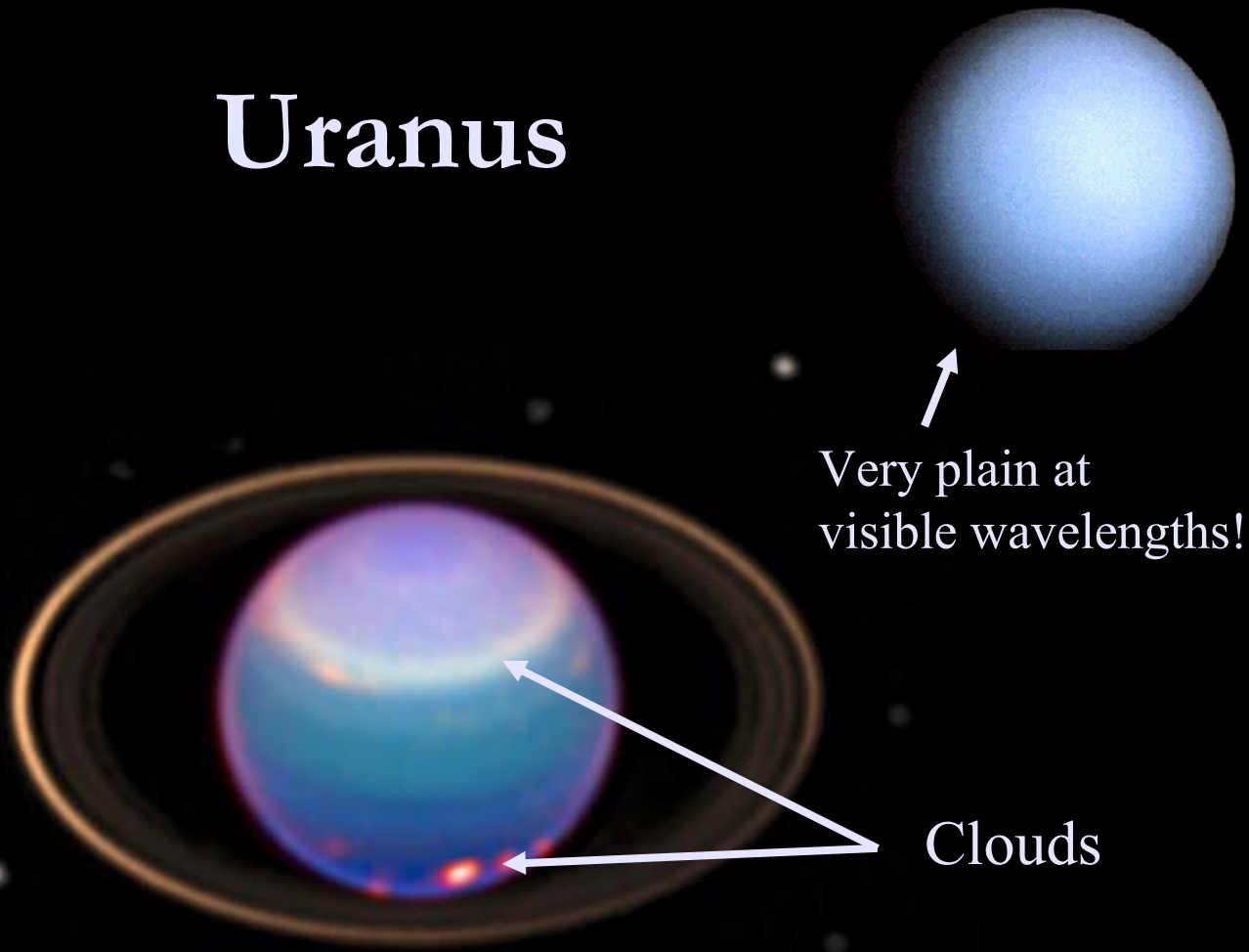
Sound of Titan from Huygens probe

Titan

- Titan is the only moon in the solar system with a thick atmosphere
  - Visible wavelengths do not penetrate the haze – high albedo so Titan is colder than we might expect
    - Surface temperatures around -179° C
  - Liquid methane precipitation?
- The Huygens probe landed on the surface and sent some stunning images back
  - Strong evidence for lakes of hydrocarbons – first liquid bodies observed beyond Earth
  - Evidence of erosion
- Other than temperature Titan has a number of similarities with primordial Earth – we'll spend a lecture looking at this in more detail

Artist's impression of Titan's surface

Uranus



- HST picture at infrared wavelength

Uranus Facts

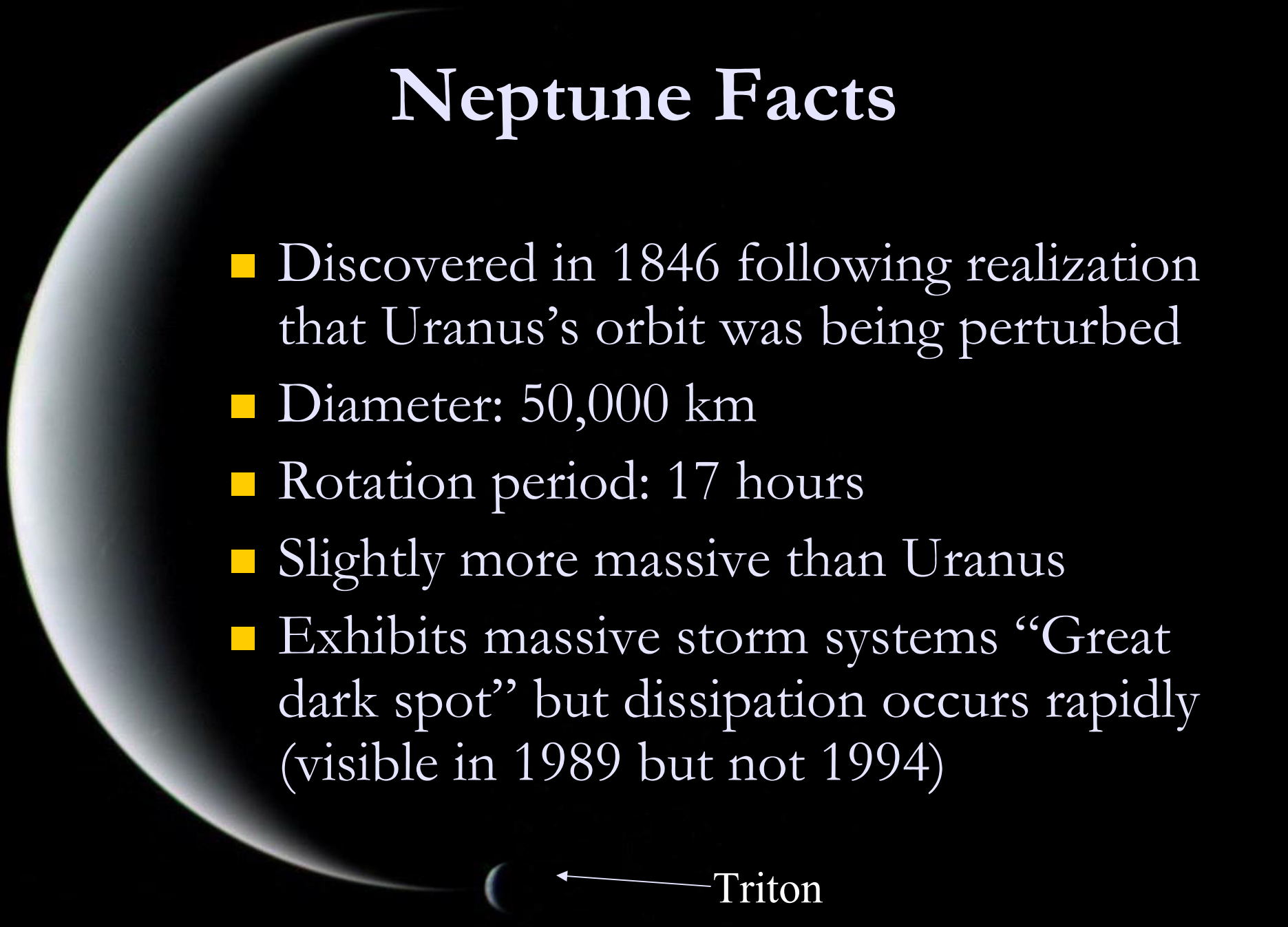
- Axial tilt 98° - poles almost lie on ecliptic
- Diameter: about 50,000 km
- Rotation period: about 17 hours
- Escape velocity about 2× Earth's

Neptune

Ring system not
visible on this picture

Neptune Facts

- Discovered in 1846 following realization that Uranus's orbit was being perturbed
- Diameter: 50,000 km
- Rotation period: 17 hours
- Slightly more massive than Uranus
- Exhibits massive storm systems "Great dark spot" but dissipation occurs rapidly (visible in 1989 but not 1994)



Summary of lecture 13

- Life evolving in the Jovian planets themselves seems virtually impossible
- However, a number of satellites show evidence for liquid water, heat and organic monomers which together could form the basis of life

Next lecture

- Terrestrial planets