

Astronomy 210

Section 1 – MWF 1500-1550
134 Astronomy Building



This Class (Lecture 23):

Giant Planets

**Night Observation Report and
HW 7 due on Friday**

Next Class:

Debris

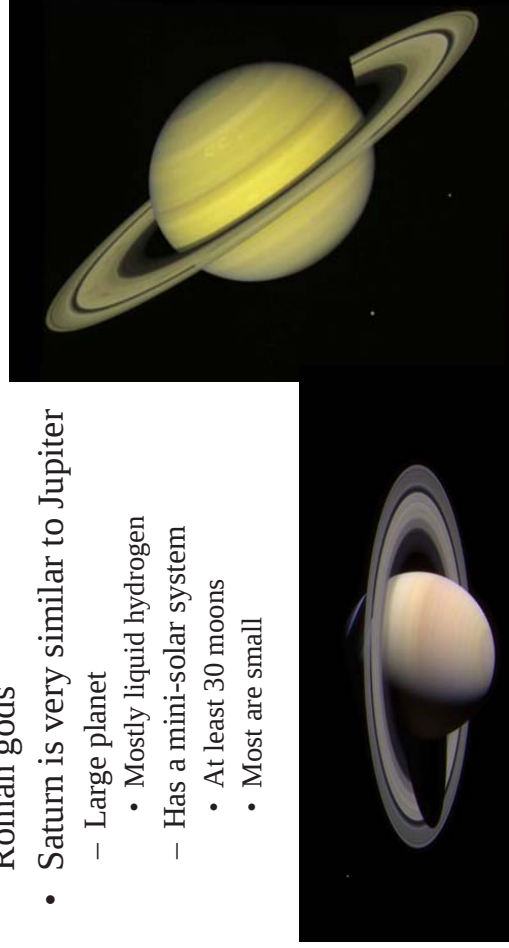
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Saturn, Lord of the Rings



- Named for the father of the Roman gods
- Saturn is very similar to Jupiter
 - Large planet
 - Mostly liquid hydrogen
 - Has a mini-solar system
 - At least 30 moons
 - Most are small



Earth-Saturn Comparison



Outline

- Saturn- The Real Lord of the Rings
- Uranus & Neptune

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Jupiter-Saturn Comparison



Equatorial radius	0.84 Jupiter
Mass	0.30 Jupiter
Density	0.52 Jupiter

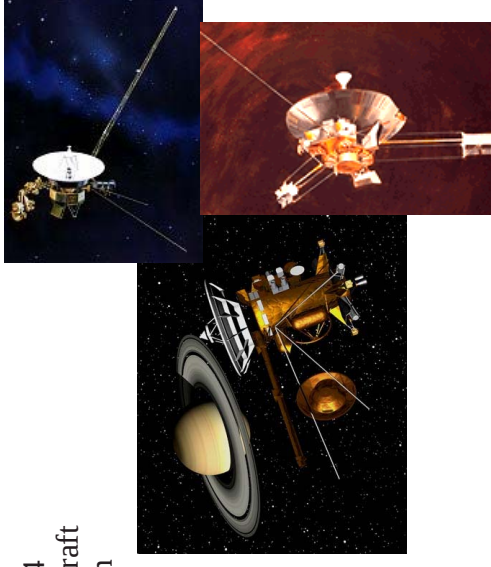
Almost as big as Jupiter, but
Much less massive!

The Cassini Mission

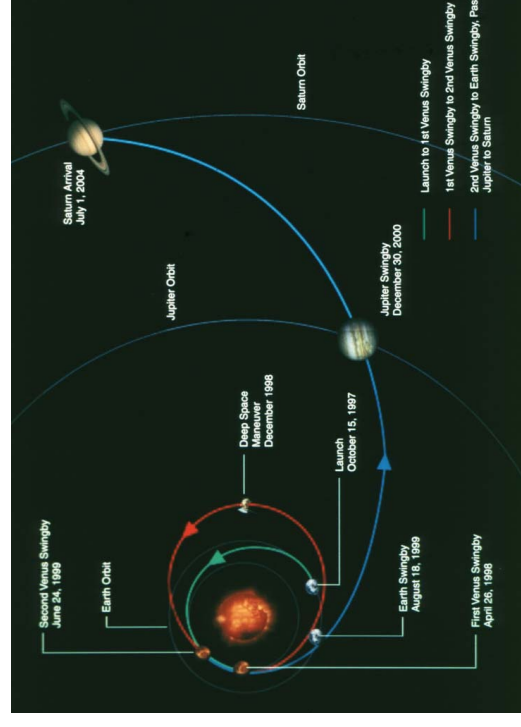
- Launched on October 15th, 1997
- Arrived at Saturn on July 1st, 2004
- Will orbit Saturn for 4 years, making flybys of the planet, its rings, and some of its moons
- Contains 12 scientific instruments
- Also carries the Huygens probe, which was dropped onto Titan, Saturn's largest moon, at the beginning of the semester. Remember?

Missions to Saturn

- There have been 4 unmanned spacecraft missions to Saturn
 - Pioneer 11
 - Flyby 1979
- Voyager 1
 - Flyby 1980
- Voyager 2
 - Flyby 1981
- Cassini-Huygens
 - Arrived last year



The Road to Saturn



Saturn's Atmosphere



- Composition similar to Jupiter
 - Mostly hydrogen and helium
- Atmosphere more “spread out”
 - Less gravity
 - Contrast of cloud bands reduced
- Wind speeds fastest at the equator
 - 1000 km per hour!



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Driving Saturn's Weather



- As on Jupiter, Saturn's internal heat drives weather
 - Saturn radiates 80% more heat than it receives from the Sun
 - Like Jupiter, Saturn is still contracting!
 - As is contracts, heat is produced
- As on Jupiter, storms are produced between cloud bands
 - No long lasting storm like the Great Red Spot

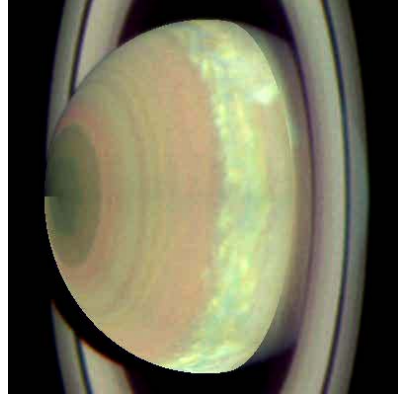
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The Great White Spot



- A seasonal storm!
 - Unlike Jupiter, Saturn does have seasons
- An ammonia bubble that forms in the northern-hemisphere summer
 - Lasts a few months
 - Gets wrapped around the planet by the equatorial winds



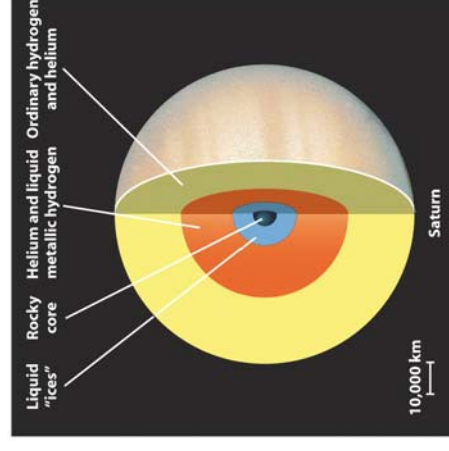
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Saturn's Interior



- Similar structure to Jupiter's
 - But Saturn is less massive
 - The interior is less compressed
- Liquid metallic hydrogen creates a magnetic field
 - 30% weaker than Earth's

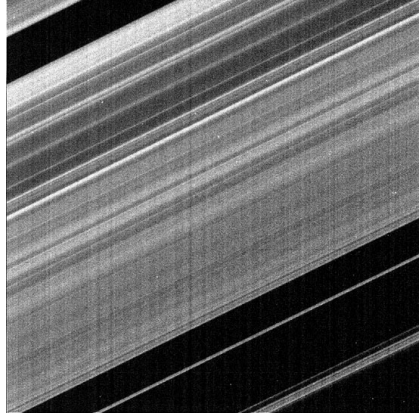


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Saturn's Rings



- Two main rings
 - Several fainter rings
 - Each ring is divided into *ringlets*
- The rings are **thin**
 - Only a few tens of meters thick– razor thin!



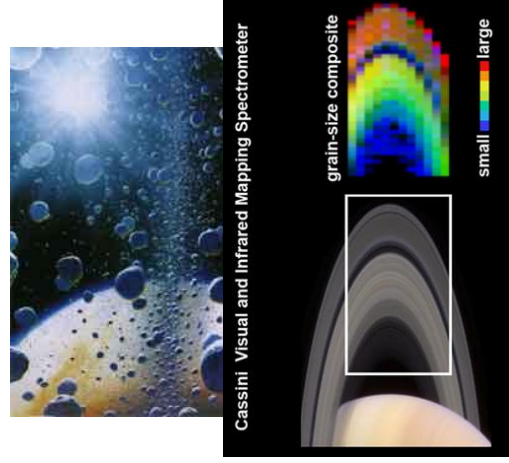
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Makeup of the Rings



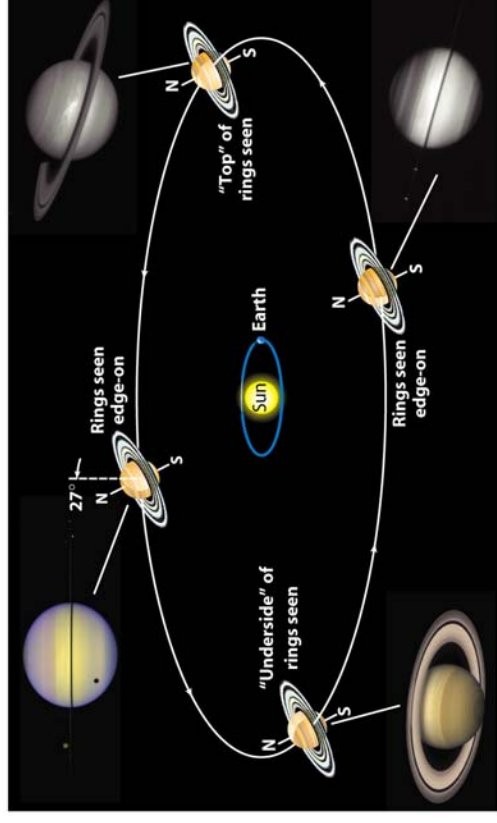
- The rings of Saturn are **not** solid rings
 - Made of icy rocks
 - 1cm to 10m across
- New Cassini data shows ring particle size varies with distance from Saturn
 - Note the gap is filled with small particles



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The View of Saturn's Rings



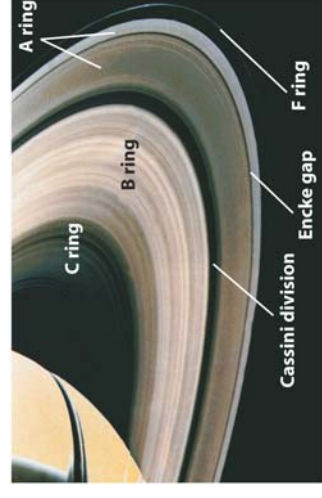
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Gaps in the Rings



- There are two prominent "gaps" in the rings
 - Cassini division
 - Encke gap
- What causes these gaps?
 - Cassini division
 - Gravitational interactions with Mimas, a moon of Saturn
 - Encke gap
 - Swept free by a small moon in the gap



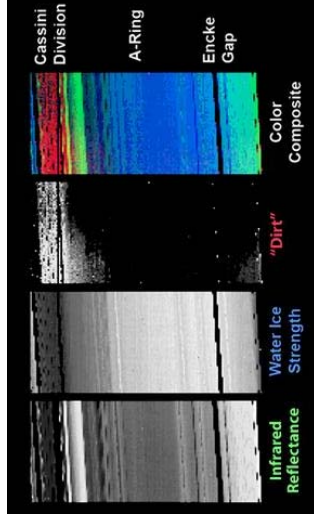
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Dirty Gap



- The Cassini gap in Saturn's rings is **not** completely empty
- Contains ringlets of "dirty dust"
- Much less reflective than the main rings



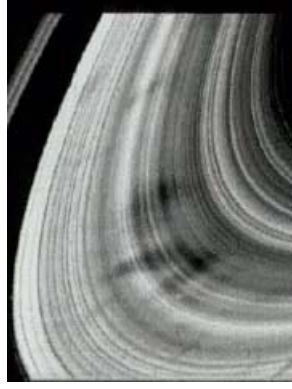
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"Spokes" in the Rings



- Saturn's magnetic field can "lift" particles out of the ringplane
- Decreases reflectivity in parts of the rings
- Creates a "spoke" effect



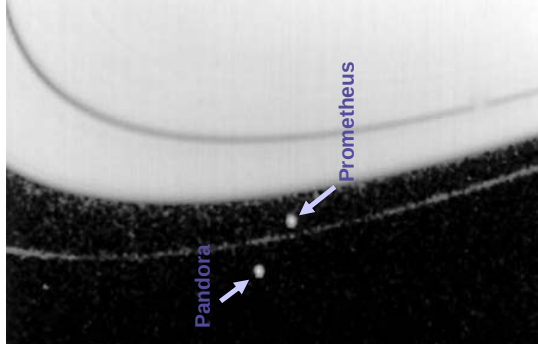
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Shepherding the Rings



- The F ring is extremely narrow
- It is kept that way by a pair of moons that flank the ring
- Keep the ring particles in line



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Why so Ringy?



- Time to play more with tidal forces.
- Imaging a rubble pile of small rocks that is only held together by gravity, total mass m with radius r .
- Now, put your pile in the gravity field of a large object, mass M and radius R at a distance d
- When does the tidal forces pull it apart?

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Totally Tidal, Again



- Competition of self-gravity and outward tides
- Compare forces on a test particle at surface of pile

$$F_g = G \frac{mm_{\text{test}}}{r^2} \quad F_t = 2G \frac{Mm_{\text{test}}r}{d^3}$$

$$G \frac{mm_{\text{test}}}{r^2} = 2G \frac{Mm_{\text{test}}r}{d^3}$$

$$d^3 = 2 \frac{M}{m} r^3$$

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Totally Tidal, Again



- Competition of self-gravity and outward tides
- Compare forces on a test particle at surface of pile

$$d^3 = 2 \frac{M}{m} r^3$$

- If densities are similar $\frac{M}{R^3} \approx \frac{m}{r^3}$

- Then $d^3 = 2R^3 \Rightarrow d = 1.3R$

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Roche Limit



- If do a more detailed analysis $d = 2.4R$
- Anything inside this limit is torn apart.
- Note that the rings are inside this limit, while the moons are outside of it.
- Rings are captured moon or proto-moon that never coalesced

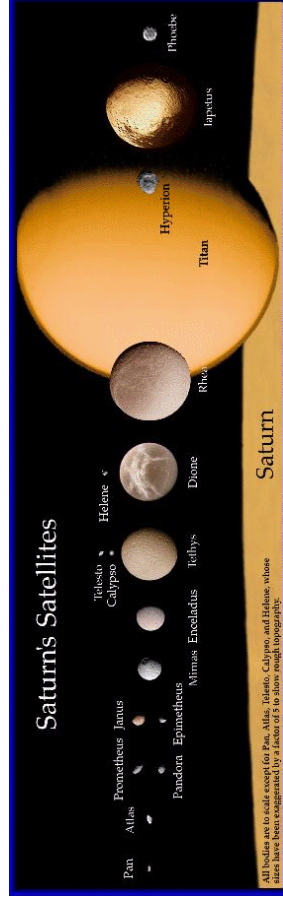
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Saturn's Moons



- Saturn has a large number of moons
 - At least 30
- Only Titan is comparable to Jupiter's Galilean moons
- Smaller moons are mostly ice, some rock



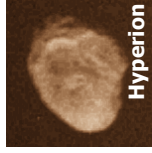
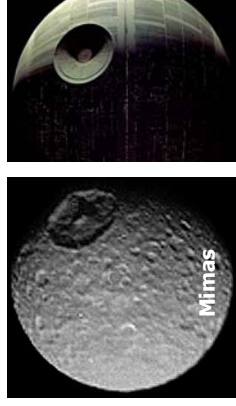
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Saturn's Odd Moons

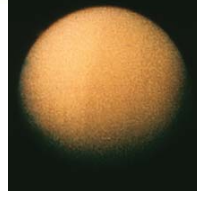


- **Mimas** - Crater two-thirds its own radius
- **Enceladus** - Fresh ice surface, water volcanoes?
- **Hyperion** - Irregularly shaped
- **Iapetus** - Half its surface is 10x darker than the other half
- **Phoebe** - Orbits Saturn backwards



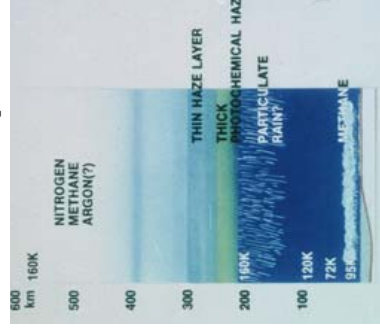
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Titan



Titan's atmosphere

- Saturn's largest moon- bigger than Mercury.
- 2nd largest moon in the solar system after Ganymede.
- Only moon to have a dense atmosphere
 - Dense nitrogen/methane atmosphere (basically smog)
 - Small greenhouse effect
 - 85% nitrogen
- composition of ancient Earth



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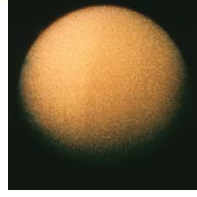
Saturn's Odd Moons



Brand new images from March 9th Enceladus has a tenuous atmosphere

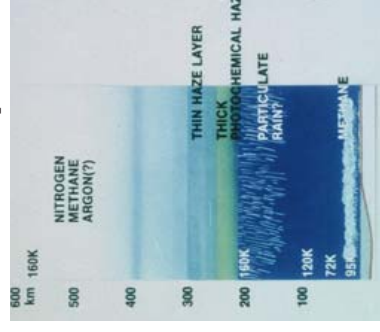
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Titan



Titan's atmosphere

- Atmospheric pressure is 1.5 times Earth's
- Liquid/ice hydrocarbons?
- Organic compounds – life?
 - Probably not – too cold: 95 K
 - May be a “deep freeze” of the chemical composition of ancient Earth



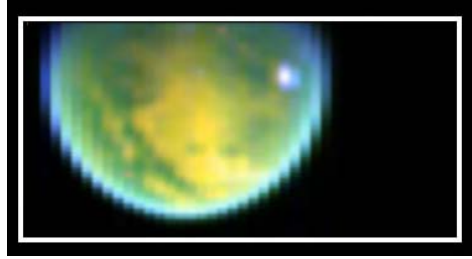
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Piercing the Smog

- Cassini has special infrared cameras to see through Titan's smog
- Green areas are water ice
- Yellow-orange areas are hydrocarbon ice
- White area is a methane cloud over the south pole

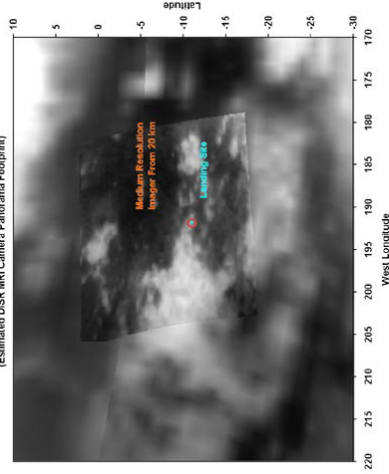
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Cassini-Huygens

Cassini VIMS True Ty, Blue Map, and Huygens DSR Image Coverage
(Estimated DSR MRI Camera Footprint)



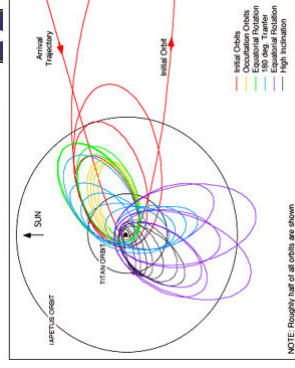
Arrival at Saturn

July 1, 2004

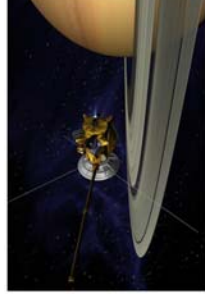
Huygens Probe descent to Titan

Jan 14, 2005

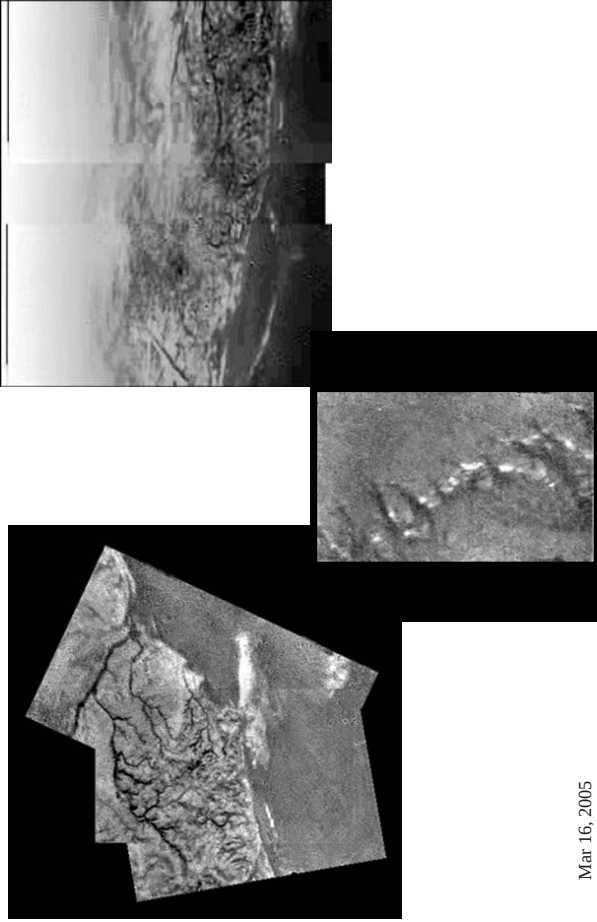
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NOTE: Roughly half of all orbits are shown

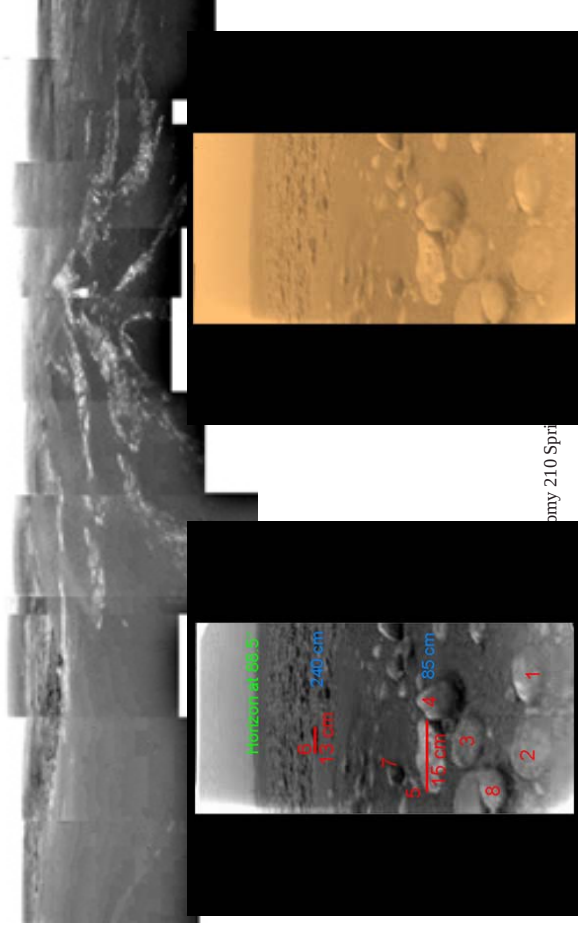


Mapping Titan



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Mapping Titan

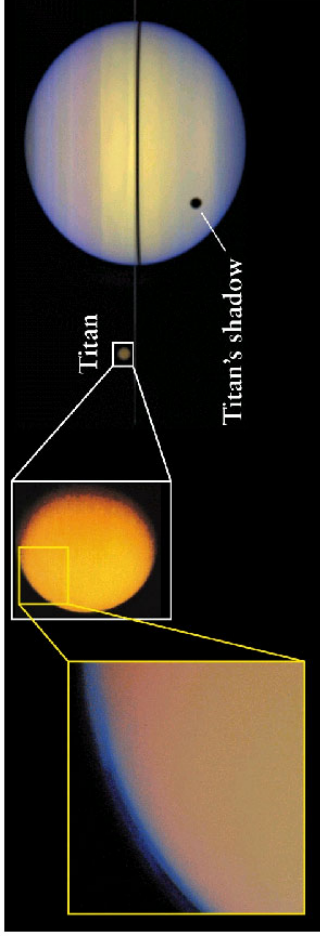


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Titan



- N_2 came from ammonia (NH_3) – common in outer solar system
- Second most abundant component is methane (natural gas)
 - One option is $UV + \text{methane} \rightarrow \text{hydrocarbons (e.g., ethane)}$
 - Then, ethane condenses and rains down on Titan's surface
- So, it might have liquid ethane or methane lakes/oceans?
- Many organic compounds should be in atmosphere– reducing atmosphere.
- If life exists here, then it will change our water–chauvinistic ideas.



Discovery of Uranus



- Discovered by accident by William Herschel in 1781
- Named for the father of Saturn
- First planet discovered since ancient times



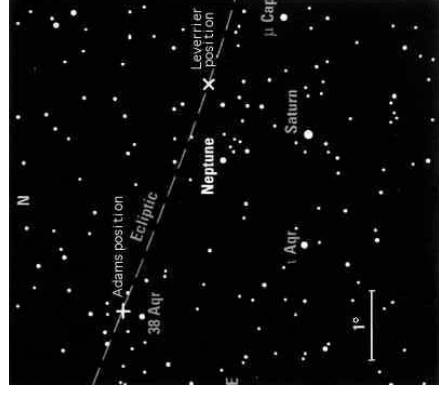
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Discovery of Neptune



- Observations showed that Uranus was not orbiting the way Newton predicted
- Two scientists predicted a new planet, Neptune
 - Within 1 degree of where it was found in 1846
- A triumph of Newton's Laws!



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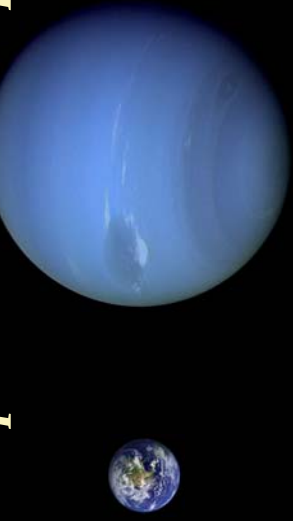
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Uranus-Earth Comparison



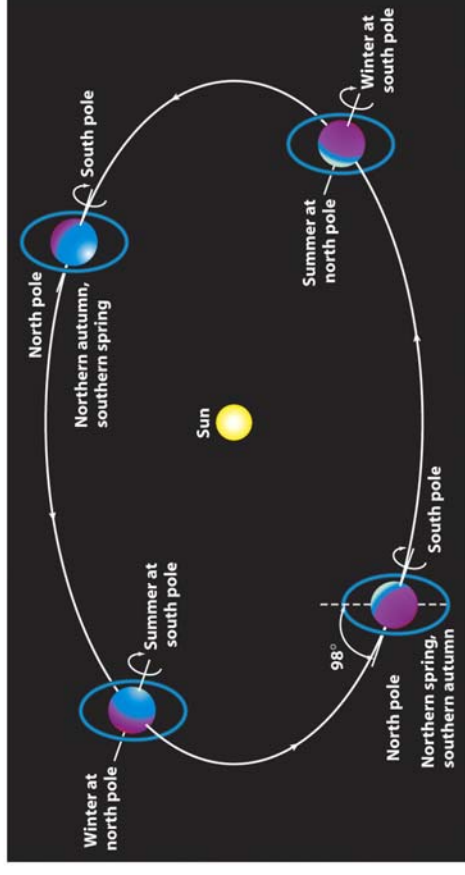
Equatorial radius	4.01 Earth
Cloud-top gravity	0.79 Earth
Mass	14.5 Earth
Distance from Sun	19.2 AU
Tilt of rotation axis	98 degrees
Year	84 Earth years
Solar day	17 hours 14 minutes (on its side)

Neptune-Earth Comparison



Equatorial radius	3.88 Earth
Cloud-top gravity	1.12 Earth
Mass	17.1 Earth
Distance from Sun	30.1 AU
Tilt of rotation axis	29.6 degrees
Year	164.8 Earth years
Solar day	16 hours 7 minutes

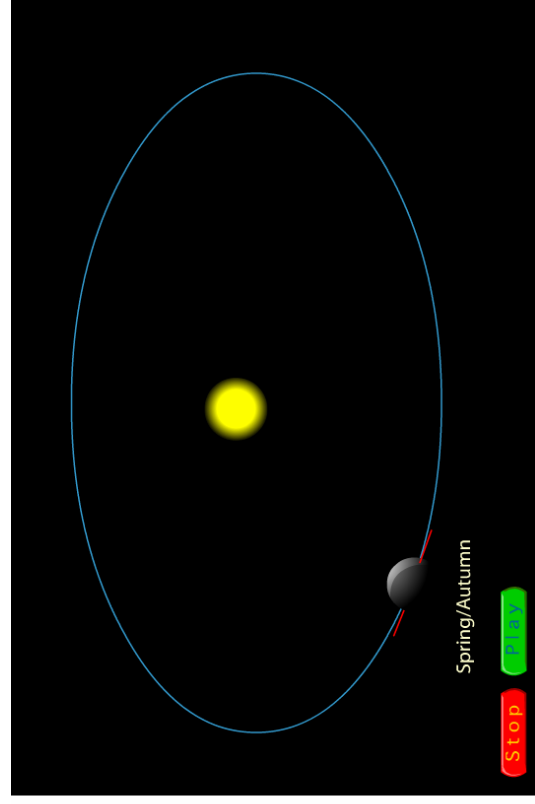
The Orbit of Uranus



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The Orbit of Uranus



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Atmospheres of Uranus and Neptune

- Composed of about 90% hydrogen, 9% helium, 1% methane and small amounts of acetylene and other hydrocarbons
- Temperatures are so low, that methane ice crystals form clouds
- Methane absorbs red light, making the planets appear bluish
- The atmospheres are arranged into cloud bands running at constant latitudes
 - Similar to the orientation of the cloud bands seen on Jupiter and Saturn

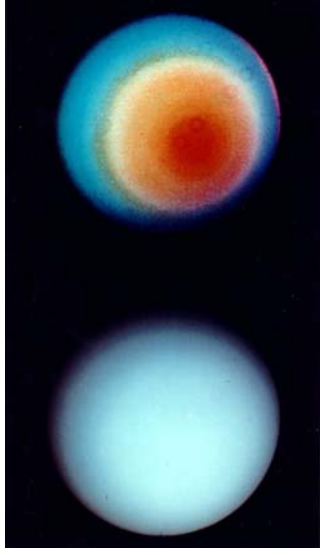
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Atmosphere of Uranus



- When Voyager 2 visited Uranus in 1986, it saw a featureless pale blue cloud layer
- High contrast images show cloud banding
- Wind speeds of 350 km/hr



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Storms on Uranus



- In the 1990's, Hubble observations of Uranus found storms!
- Why none before?
- Uranus' odd seasons may be the cause
- Triggered by sunlight reaching a region of the planet for a first time in decades?



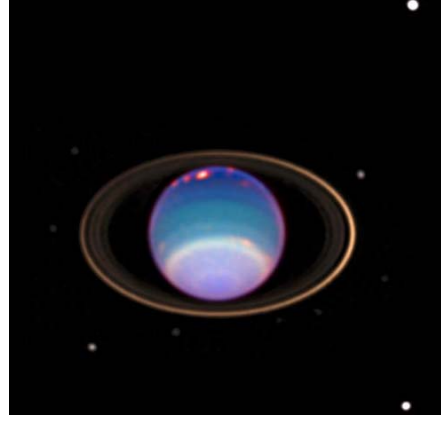
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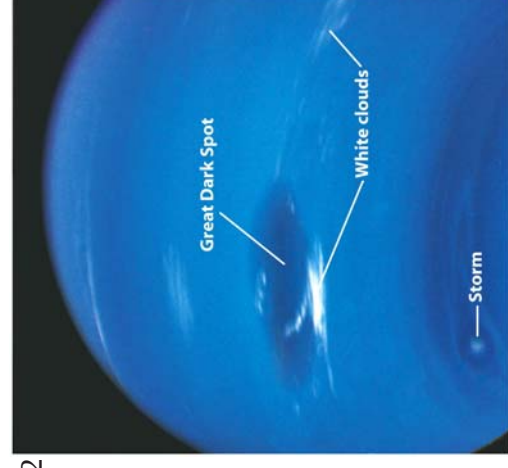
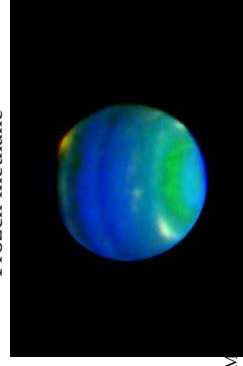
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Neptune's Atmosphere



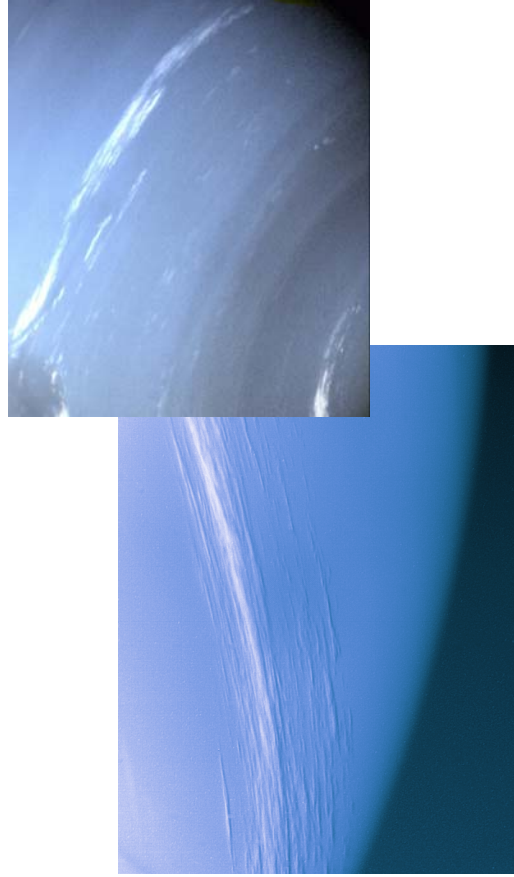
- When visited by Voyager 2 in 1989, Neptune showed more features than Uranus
- Large storms
 - Great Dark Spot
 - Like the Great Red Spot?
 - Disappeared by 1994
- White clouds
 - Frozen methane



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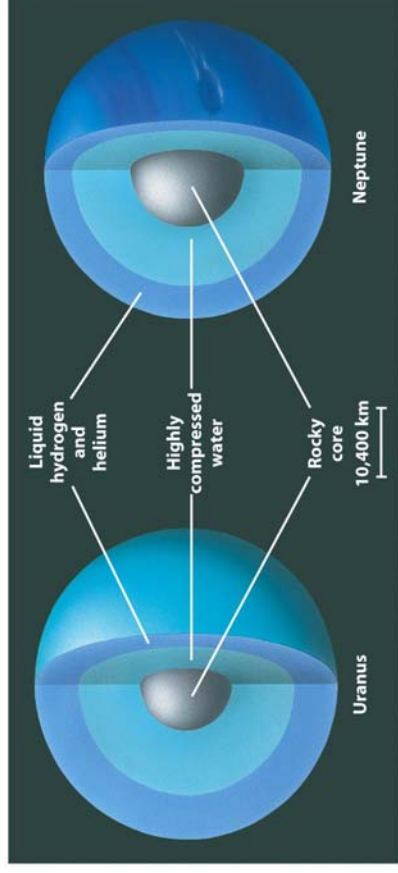
Methane Clouds of Neptune



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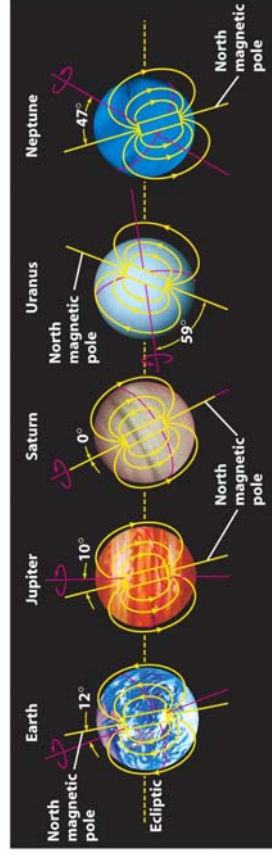
Water Worlds



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Magnetic Fields



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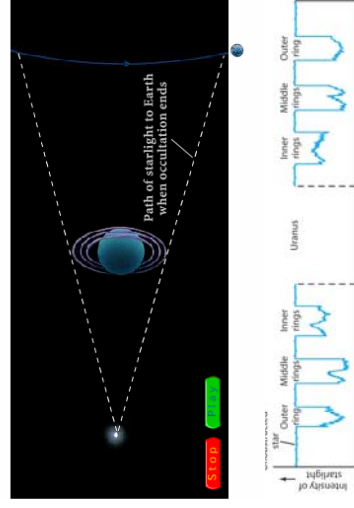
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- On both Uranus and Neptune
 - Compressed water mantle conducts electricity
 - Rapid rotation (about 17 hours)
- Generates very odd magnetic fields
 - Off-center & highly tilted to the planets' spin axes

Uranus' Rings

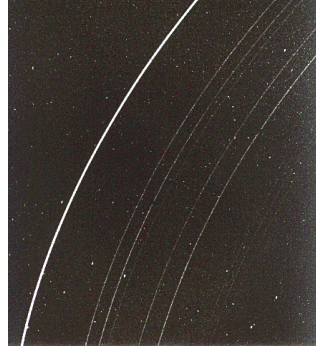


- Discovered 1977 from Earth during occultation of a star
- Later observed close-up by Voyager 2 (1986)
- Rings are dark, narrow, dusty



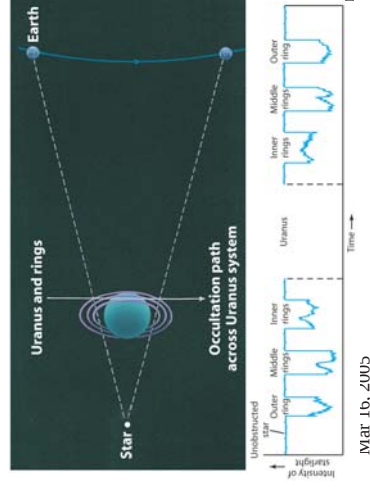
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Uranus' Rings

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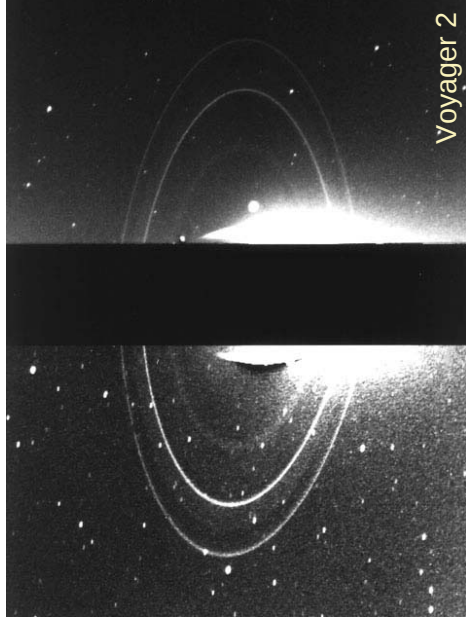


Neptune's Rings

- Thin and dark
- Like Uranus' rings
- Seen by Voyager 2 in 1989

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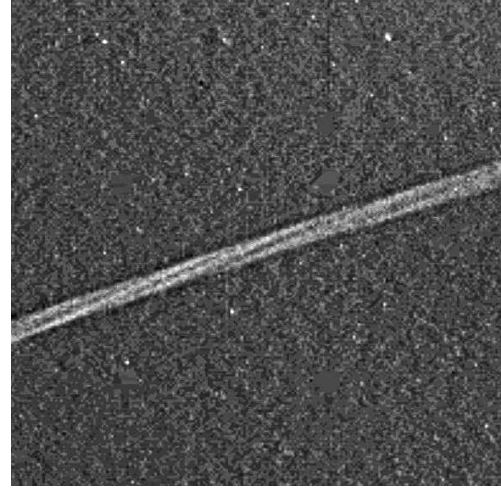


Neptune's Rings

- Neptune's outermost ring appears to be twisted!
- Caused by a gravitational interaction with one of its moons

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Moons of Uranus

- 5 intermediate satellites, none Galilean-sized
 - Titania, Ariel, Umbriel, Oberon, Miranda
 - Composed of 50% rock, 50% ice
- 10 minor ones discovered by Voyager 2
- 5 additional minor ones discovered since then

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Titania (largest)

Miranda (smallest of the majors)



Moons of Uranus



- Miranda's patchwork appearance suggests a catastrophic impact
- Miranda was completely shattered, then reassembled itself
- Did a similar impact flip Uranus on its side?



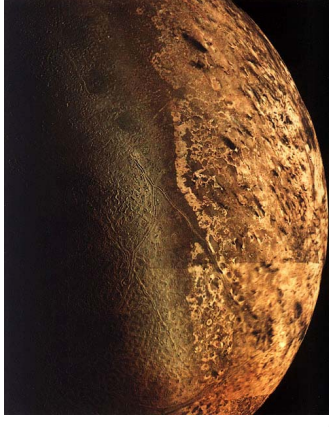
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Moons of Neptune



- Eight moons known
 - 2 intermediate sized, Nereid & Proteus
- 1 Galilean-sized, Triton
 - Thin nitrogen atmosphere
 - 50% rock, 50% ice
 - Surface frozen methane/nitrogen
 - Evidence of geologic activity (few craters)
 - Orbits Neptune backwards



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