

Week 2 The Planets

The Solar System

The Origin of the Solar System

- (But first...a quick look at the origin of the universe – there is MUCH more to come!)
- 3 minutes after the Big Bang, protons, neutrons, electrons and the other particles of matter came into existence
- About 75% of the matter condensed into hydrogen, 25% into helium (very very few atoms of heavier materials were made – more on that later...)

The Origin of the Solar System

- Within a billion years years matter began to condense into stars (and groups of stars we call galaxies)
- Stars make heavier materials in their cores (more on THIS later too!) up to iron
- Heavier materials made in supernova

The Origin of the Solar System

- At least two generations of stars are thought to be needed to produce enough of the 'heavier' materials (beyond iron)

Slow or Fast?

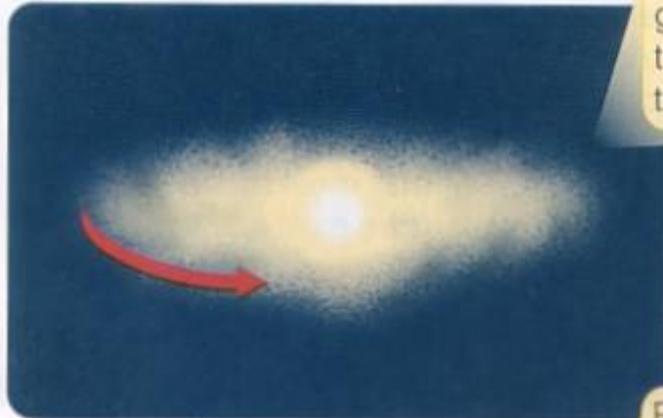
- Two favorite theories = gradual (evolutionary) and catastrophic
- Gradual = Everything is the slow progression from a gas cloud to quiet planets circling a stable star
- Catastrophic = passing stars, intruding gas clouds or shock waves, etc. are responsible for the solar system forming
- Gradual is winning with catastrophes used to explain anomalies

Solar Nebular Theory

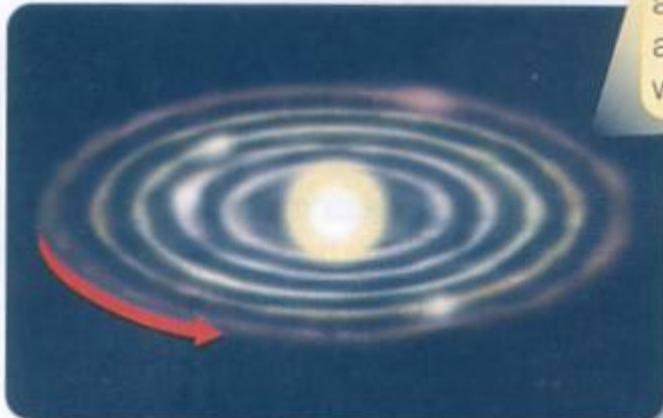
The Solar Nebula Hypothesis



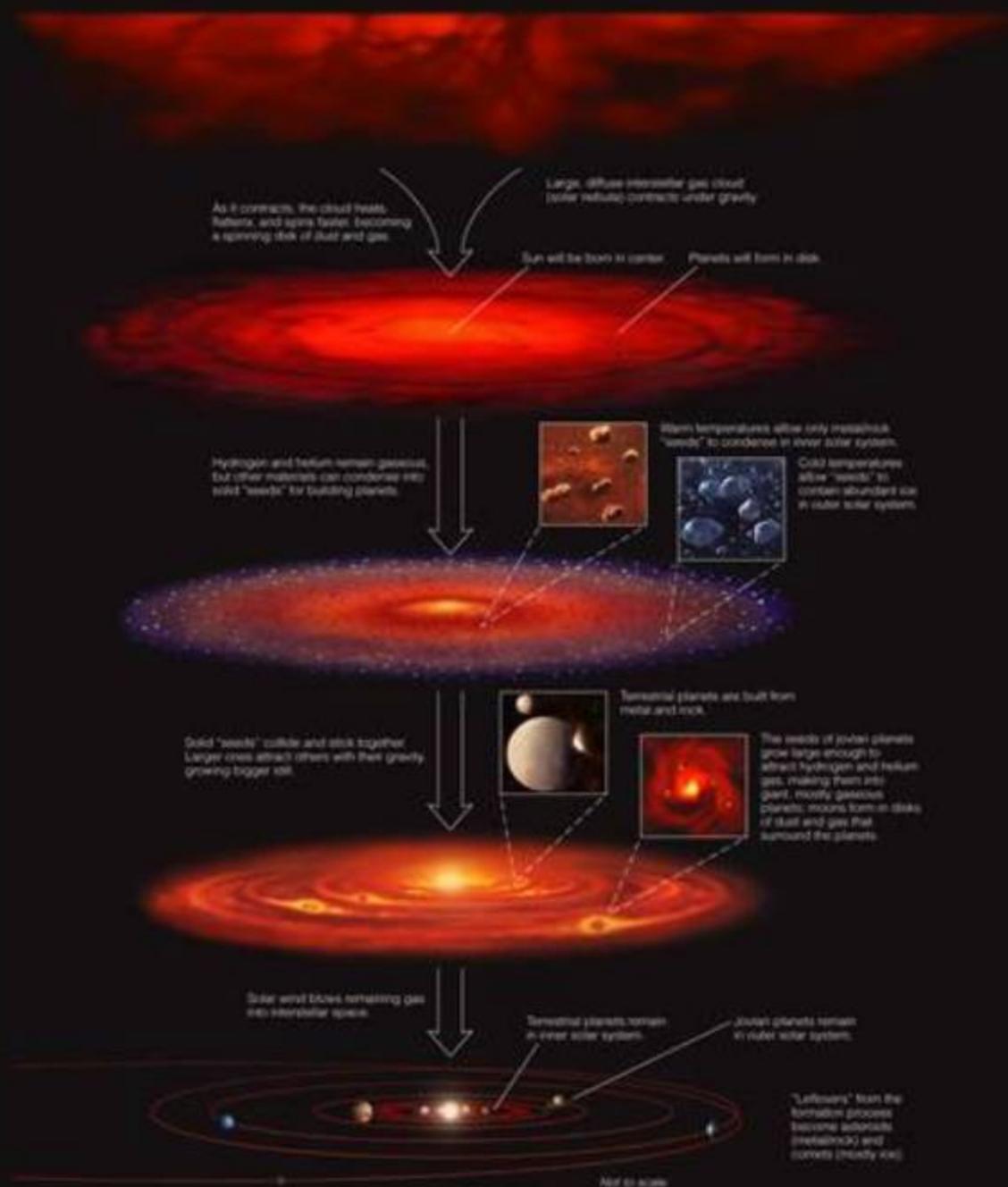
A rotating cloud of gas contracts and flattens...



to form a thin disk of gas and dust around the forming sun at the center.



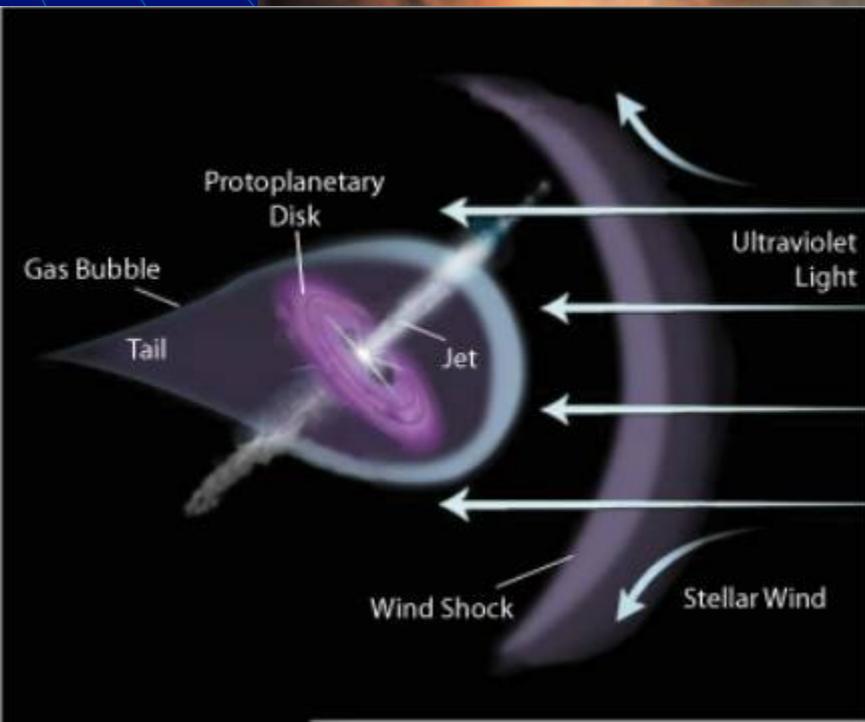
Planets grow from gas and dust in the disk and are left behind when the disk clears.



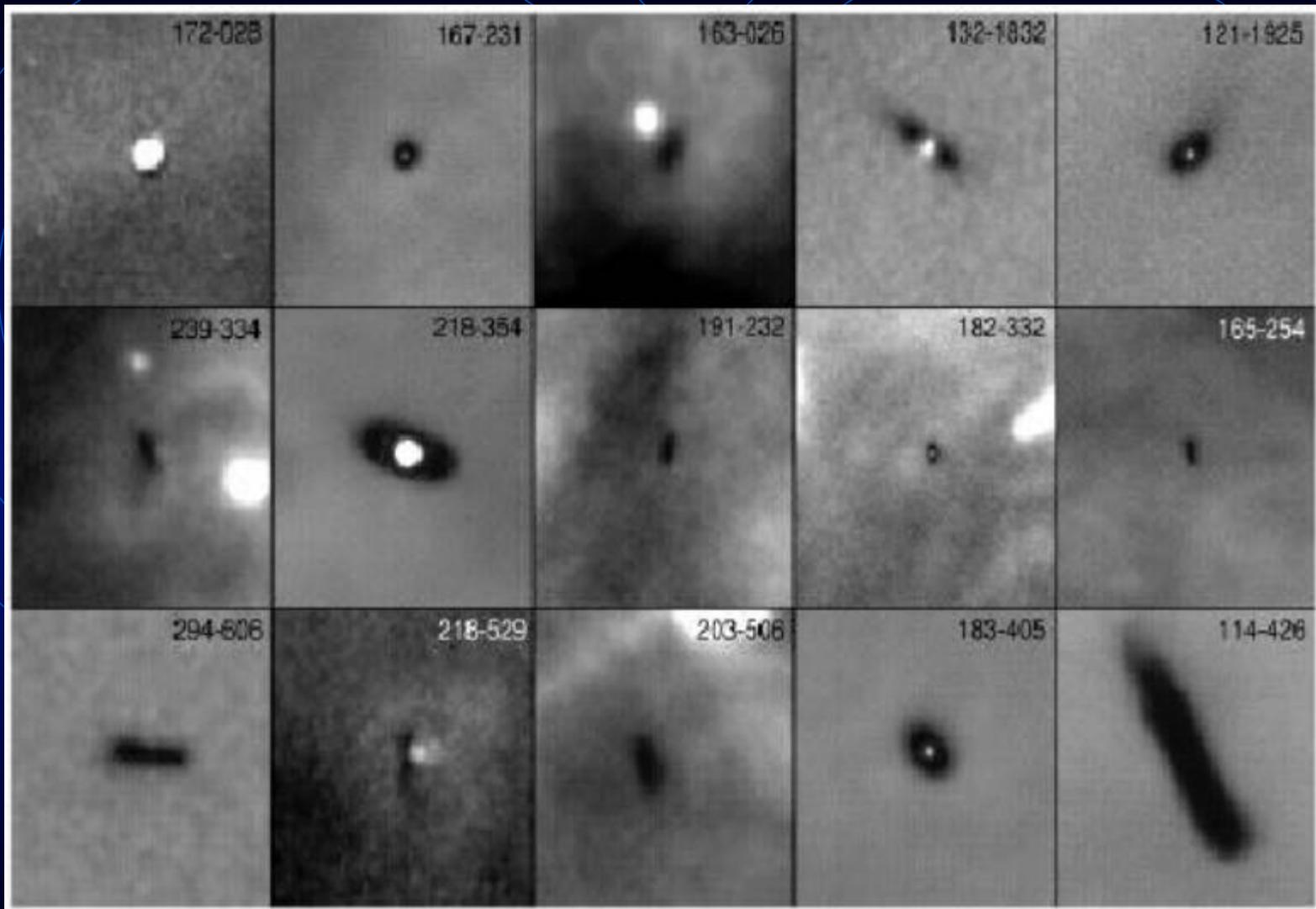


Solar System Origins

- Is there evidence of this theory in the universe...
 - “A Fly’s Life” analogy
- Seeing planets elsewhere is VERY difficult
- Seeing *proplyds* (protoplanetary disks)

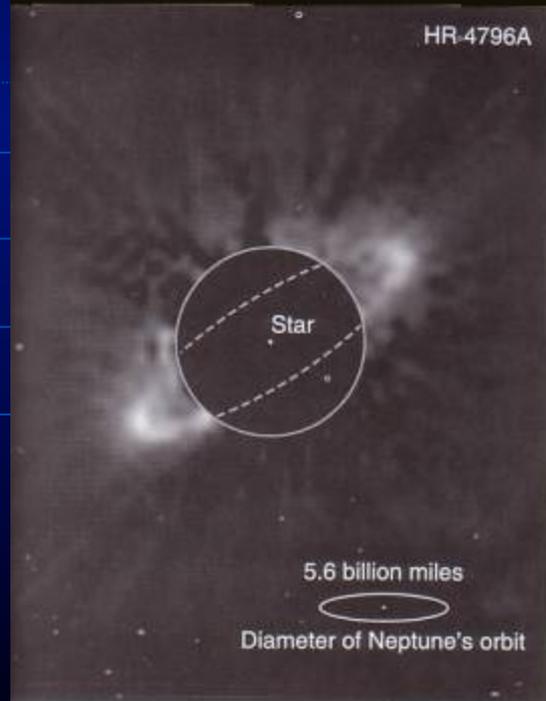
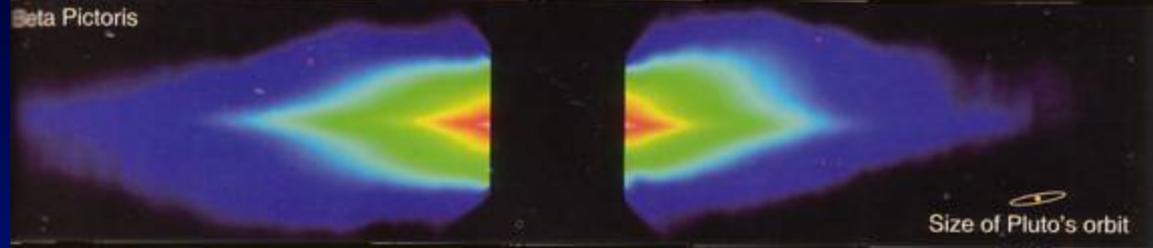


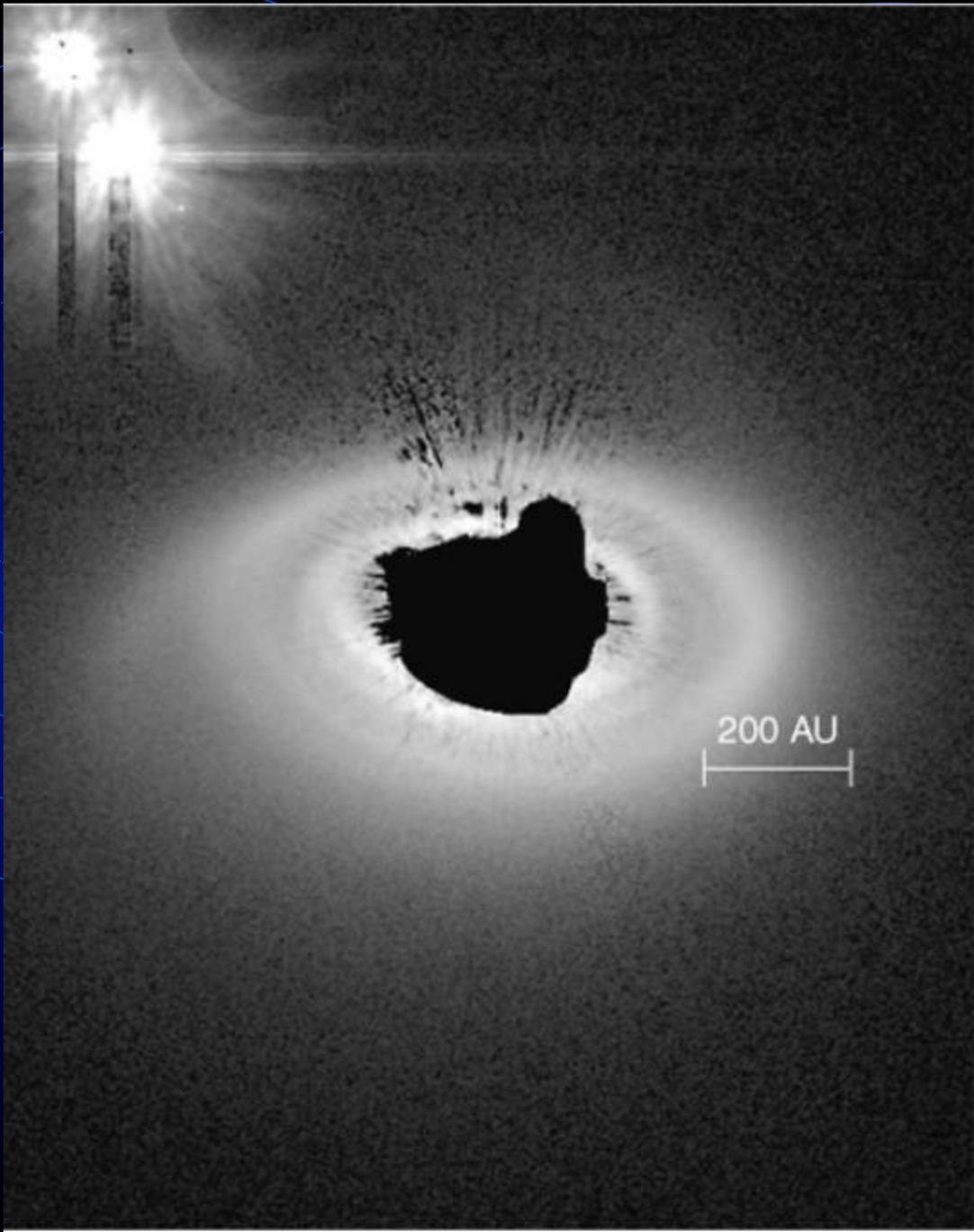




Solar System Origins

- Dust disks –



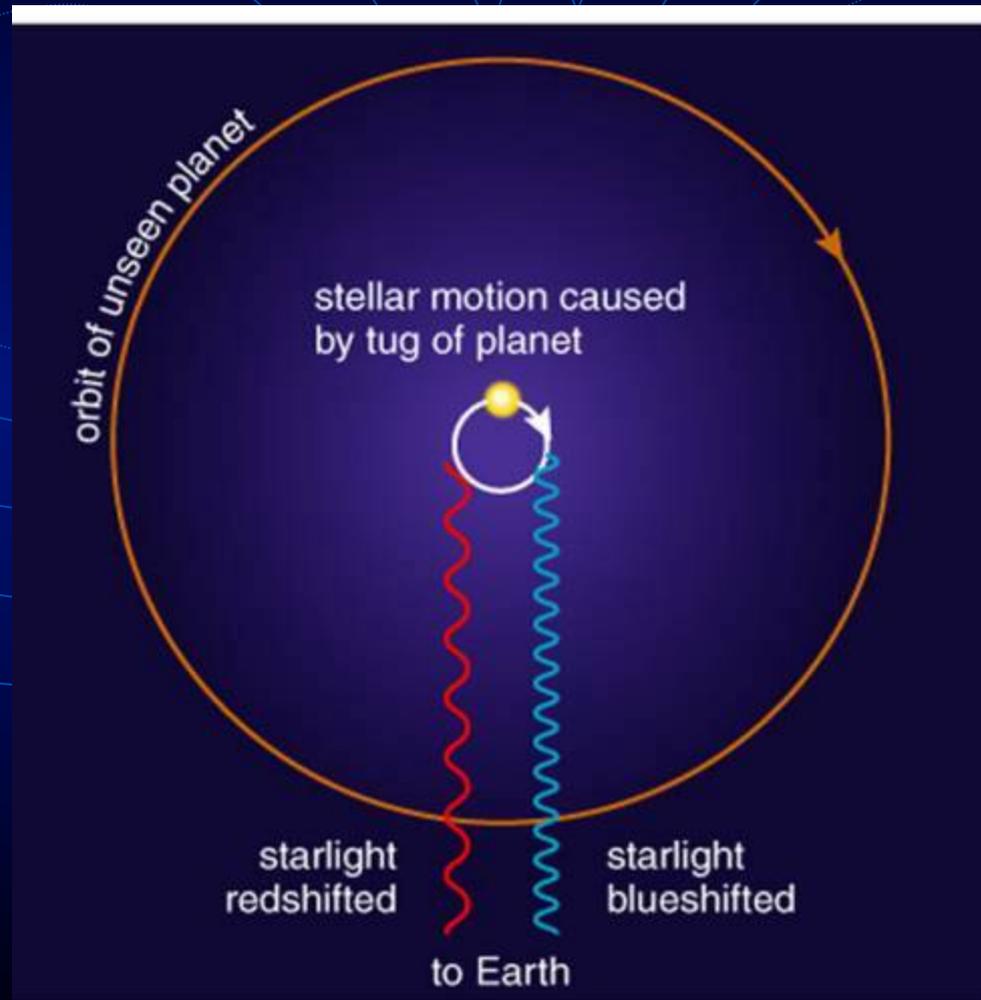


200 AU



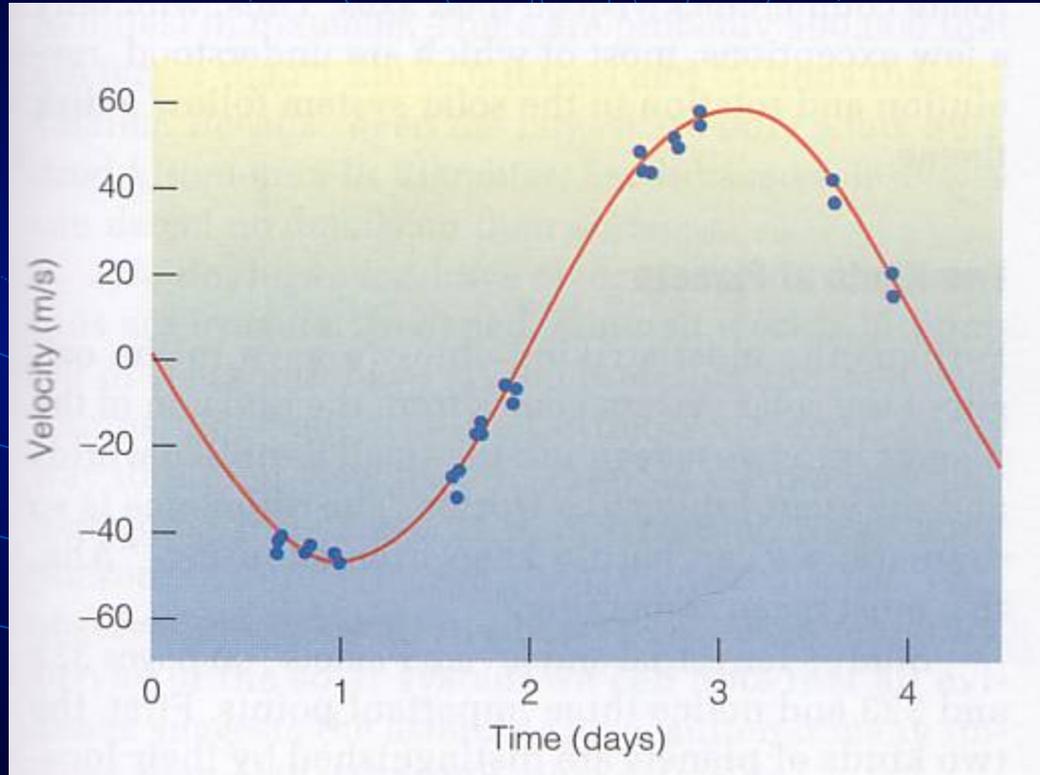
Solar System Origins

- Stellar Motion (Doppler velocity curve)



Solar System Origins

- Stellar Motion (Doppler velocity curve)



- Brightness of star (eclipses?) (HARD!)

An Overview of the Solar System

- What observations can **support or refute** the Solar nebula Theory?
- Volume of material incredibly low in the solar system
 - Volume of Solar system (Pluto's Orbit)/Volume of planets = $2.7 \times 10^{-8} \%$!!!
 - Sun = .00017 % of Solar System by volume
 - Planets = .0016 volume of Sun or 600X the volume of all the plants put together.
 - Where did all the mass go?

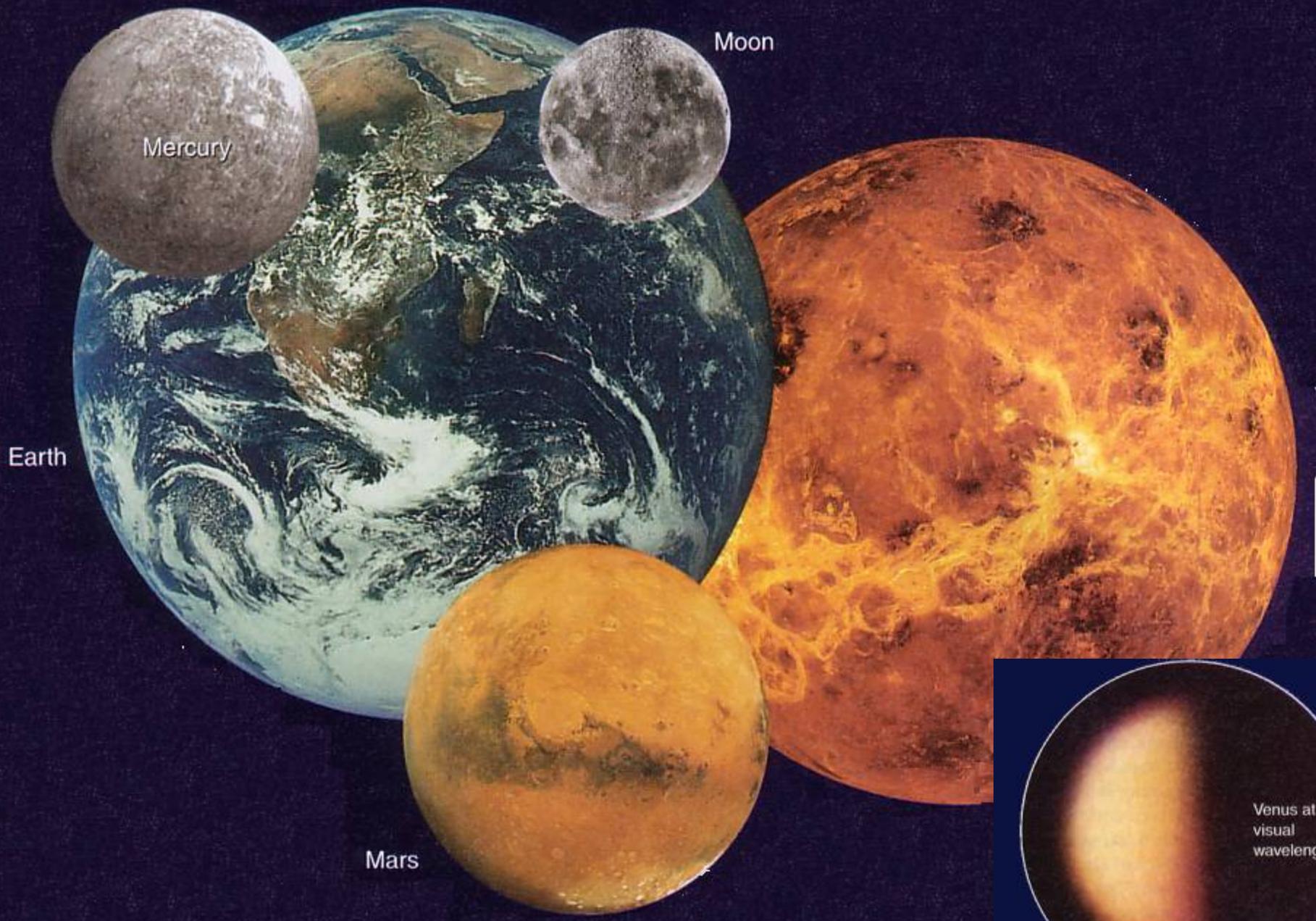
Solar System Observations

- Revolution and Rotations:

- The planets all go around the sun in a nearly flat plane in the same direction... **Supports it! But...**
 - Mercury's orbit is tipped 7 degrees
 - Pluto's is tipped 17.3 degrees
 - The rest are within 3.4 degrees of = pretty good disk
 - All the planets circle the sun (*revolution*) counterclockwise as seen from the North (from the direction away from the sun where the sun seems to be turning counterclockwise)
 - Most of the planets also turn on their axis (*rotation*) counterclockwise (Venus, Uranus, Pluto)
 - All this supports a uniform 'disk' formation picture

The Solar System Breakdown

- The planets fall basically into two classifications
 - Terrestrial Planets
 - “Earth-like” = rocky and small
 - Density 3-5 g/cm³
 - Rock crust and mantle, metallic core
 - Mercury, Venus, Earth, Mars



Earth

Mercury

Moon

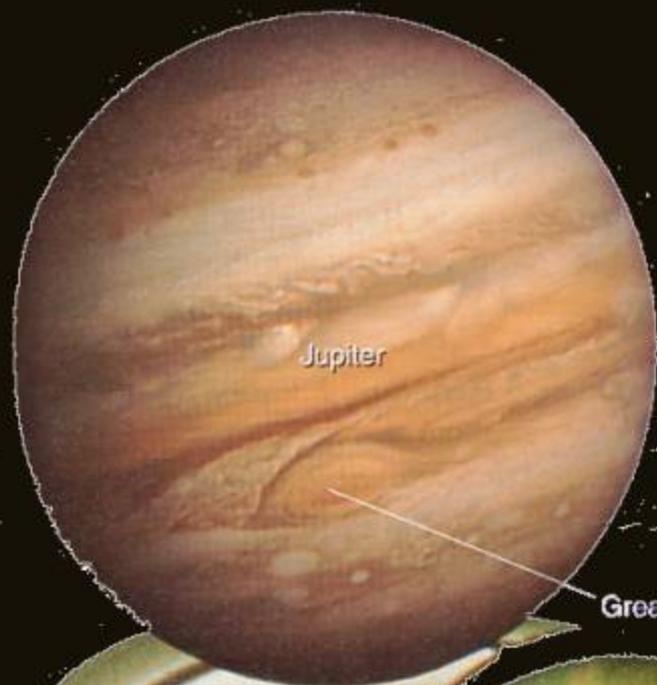
Mars



Venus at
visual
wavelengths

The Solar System Breakdown

- Jovian Planets
 - “Jupiter-like” = gas, rock and large
 - Density about 1.75 g/cm^3 (water = 1 g/cm^3)
 - Gas atmosphere, liquid H_2 , Liquid Metallic H_2 , Core
 - Jupiter, Saturn, Uranus, Neptune

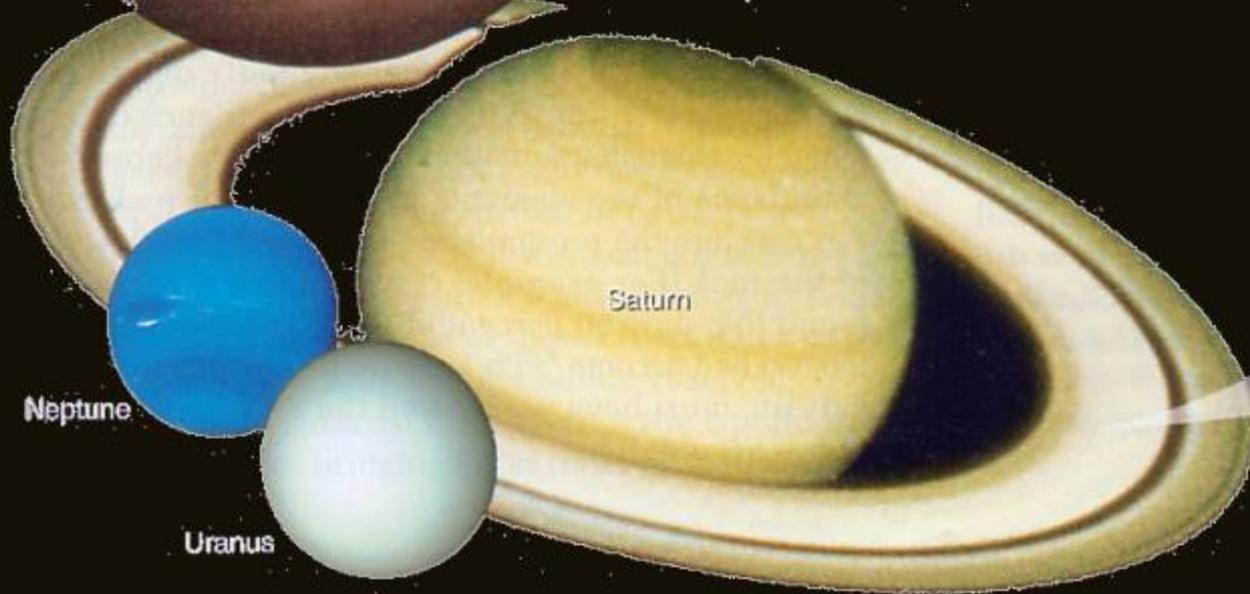


Jupiter



The terrestrial planets to the same scale as the Jovian planets.

Great Red Spot



Saturn

Neptune

Uranus



Saturn's rings
seen through a small
telescope.

And the rest...

- Space Debris
 - Asteroids, comets, dust (zodiacal light), meteors, planetesimals (Pluto, Sedna, Quaoar [pronounced *kwaɑ'·waar* or *kwow'·ər*], 2003UB etc.)

The Solar Systems Beginning Pt 2

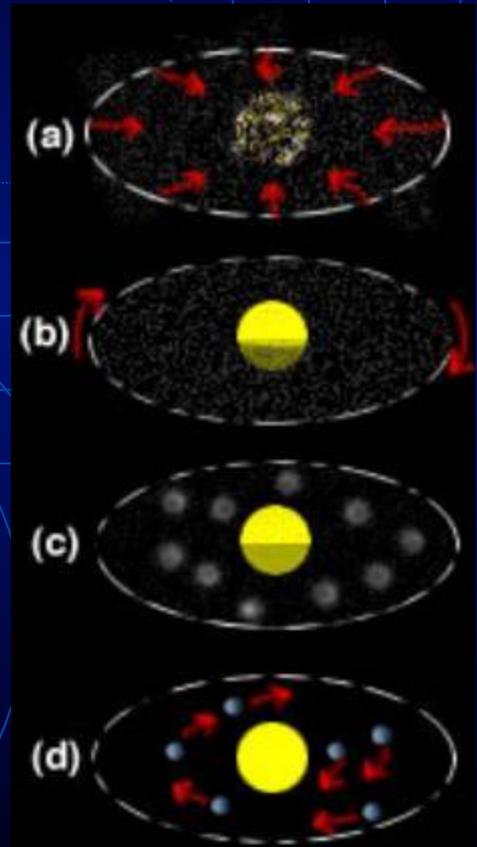
- The Age of the Solar System
 - The universe is about 14 billion years old (est.)
 - The Aging Techniques
 - Original abundances can be inferred from sources such as solar quantities
 - Uranium → Lead (4.5b),
Potassium → Calcium, Argon (1.3b),
Rubidium → Strontium (47b)
 - Oldest Earth Rocks = 3.9 billion years
 - Moon rocks = 4.48 billion years
 - A Mars rock that landed here = 4.5 billion years
 - Meteorites = 4.6 billion years
 - **COMMON AGES** = significant for formation theory...

Solar System Building

- The original composition of the solar system is inferred from the present composition of the Sun
 - 73% hydrogen , 25% helium, 2% heavier elements
 - Unchanged *outer* composition, fusion is in the core (only the outer part is convective)
- Planets form by the left over stuff sticking together then drawing more and more in

Solar System Building

- Only at 15X Earth's Mass can a body pull in and keep hydrogen and helium gas
- Jupiter and Saturn grew faster and dominated the gas trapping (Uranus and Neptune robbed of gas supply = larger % rock and metals.
- The Terrestrial planets are too small and hot to hold onto the gasses (proximity to the sun)

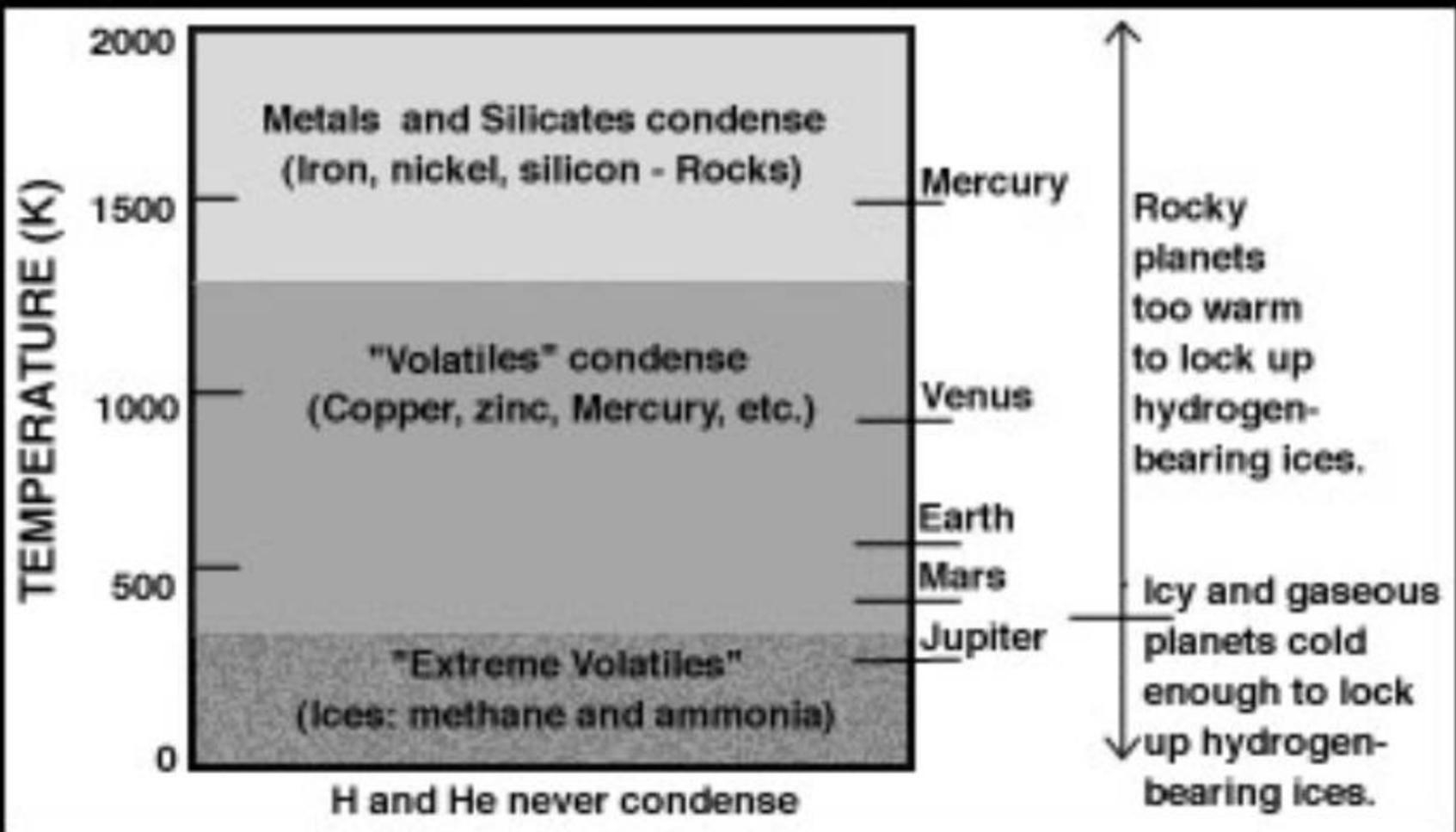


More Solar System Formation

- The condensation sequence
 - Different distances from the sun = different abundances of atoms in the planet makeup
 - Planets closer to the sun = more metal oxides and metals, outer planets formed with more ices and gasses
 - Temperatures near the sun were higher, metals formed grains first, then silicates formed grains in cooler temperatures later in time and further from the sun (earlier) **see next frame**

Table 16-3 The Condensation Sequence

Temperature (K)	Condensate	Planet (Estimated Temperature of Formation; K)
1500	Metal oxides	Mercury (1400)
1300	Metallic iron and nickel	
1200	Silicates	
1000	Feldspars	Venus (900)
680	Troilite (FeS)	Earth (600)
		Mars (450)
175	H ₂ O ice	Jovian (175)
150	Ammonia–water ice	
120	Methane–water ice	
65	Argon–neon ice	Pluto (65)



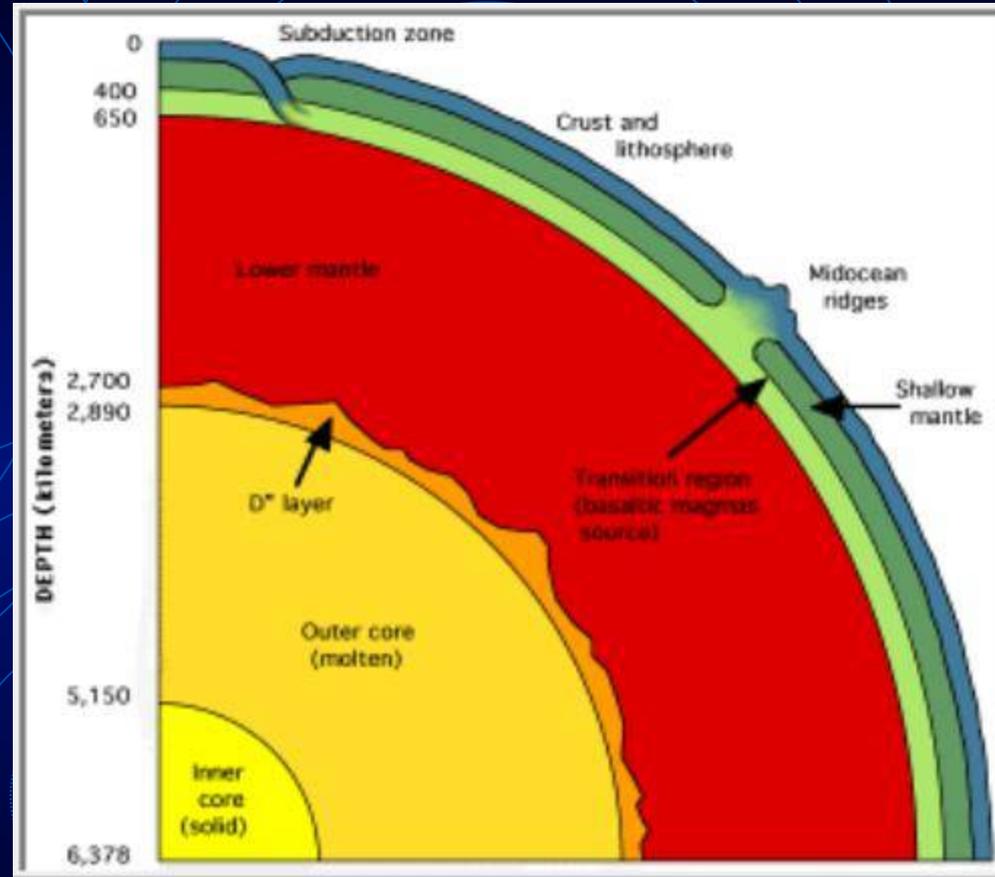
Still More SS Formation

- Planetesimals formed from grains sticking together (called *accretion*), then these stuck together/collided and formed **protoplanets**.
- Protoplanets that formed were hot from the accretion process (collision and compression and short lived radioactive decay) = **melted** all the material



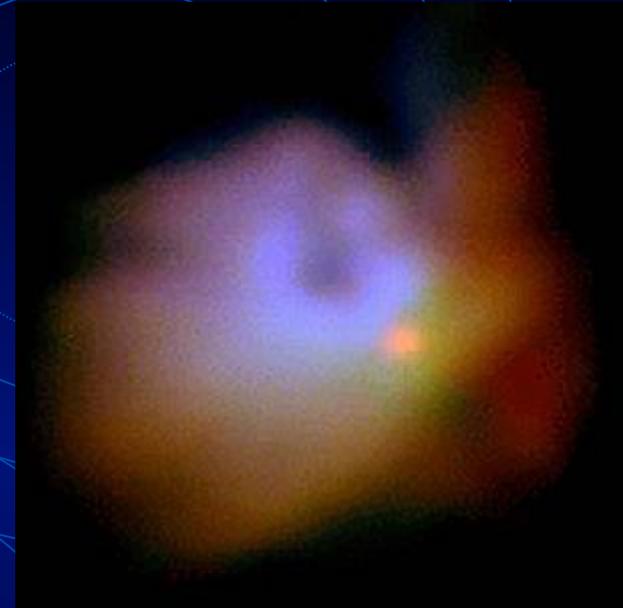
Still More SS Formation

- The hot melted protoplanets differentiated – heavy metals **sank** to the core, silicates **floated** to the surface (crust)
- **Outgassing** released heavier gasses to early atmospheres (Still Terrestrial Planets)



Still More SS Formation

- Out to the Jovian Planets
 - Gas Giants probably formed in 10 million years (due to the age and research on new stars called T Tauri stars). The Sun would have blown the Hydrogen and Helium gas out after about 10 million years
 - The terrestrial planets probably took about 30 million years to form (from computer model simulations); 4 billion years ago the last of the BIG stuff was swept up by the planets = the period of **Heavy Bombardment**



Back to the odd stuff...

- Venus, Uranus and Pluto may be odd balls (their rotation and axis orientation) due to catastrophic events (more later)

Still more SS Formation – the end

- Eventually (10 million years into the process) the gas was swept out by
 - radiation pressure
 - Solar wind
 - Planets sweeping stuff up
 - Planetary ejection (sling shot effect)
- But we still get tons of new stuff a year from dust and meteors – so we are still forming a bit (and a big rock can still hit now and then – see “Deep Impact” or “Armageddon”) ☺

The Earth Like Rocky Planets

- The Rocky Planets

- Earth/Moon as our best studied example
- 4 Stages of formation
 - Differentiation
 - Cratering
 - Flooding (lava)
 - Slow Surface Evolution **see frame after next** (seen elsewhere?)

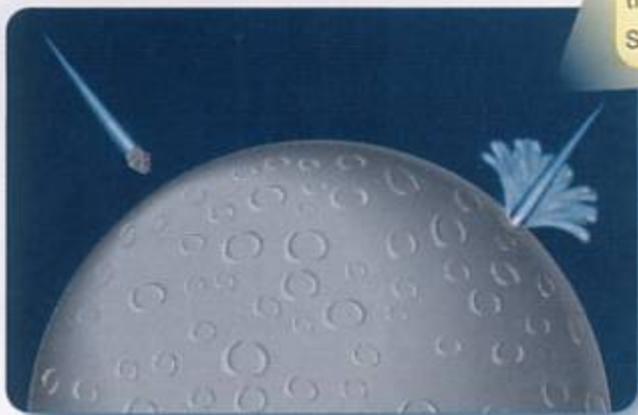
The Earth Like Rocky Planets

- Looking at seismic evidence (Moon and Mars work)
 - Our Earth has a core – solid high density and temperature 14g/cm^3 : High in metals (iron, nickel)
 - Surrounded by a Liquid outer core
 - Above that is the Mantle – rock and metal, plastic like
 - Crust on top
 - Oceanic
 - Continental

Four Stages of Planetary Development



Differentiation produces a dense core, thick mantle, and low-density crust.



The young Earth was heavily bombarded in the debris-filled early solar system.



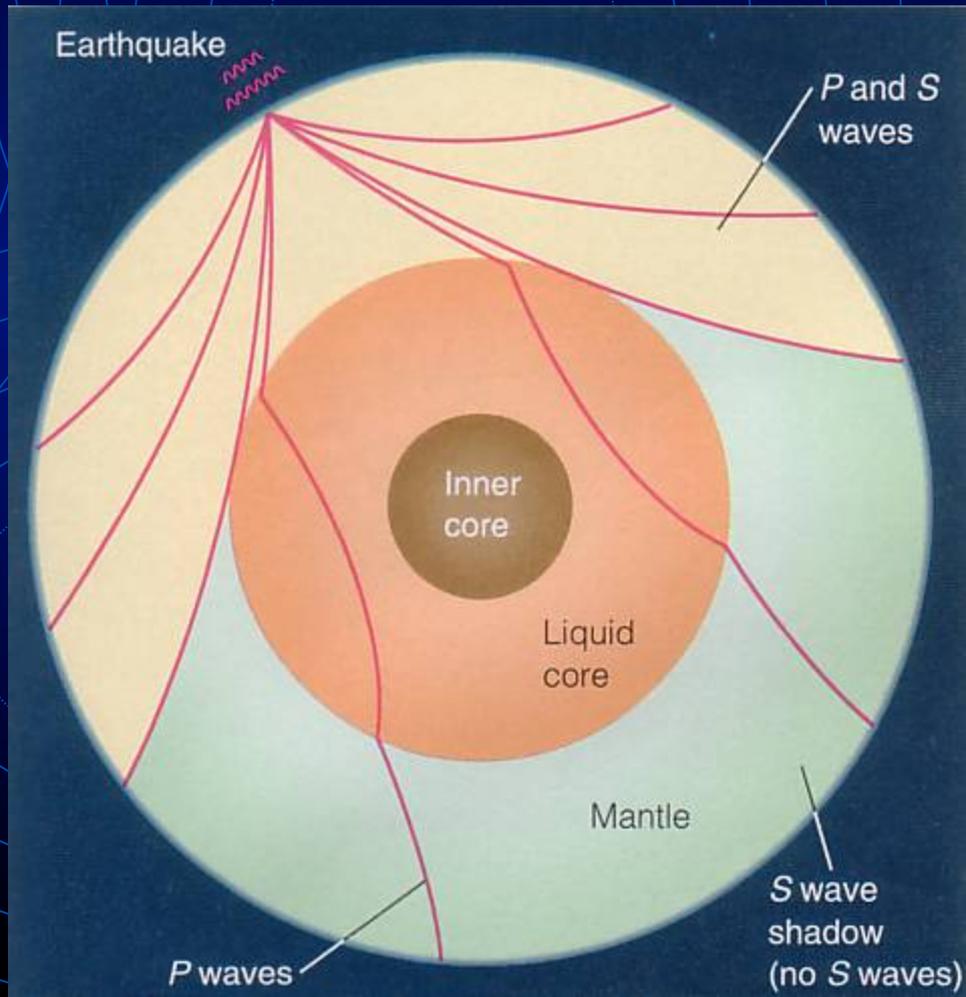
Flooding by molten rock and later by water can fill lowlands.



Slow surface evolution continues due to geological processes and erosion.

The Rocky Worlds - Earth

- Plate Tectonics in detail (analog to Venus and Mars, the moon and Mercury? Io?) **see next page**



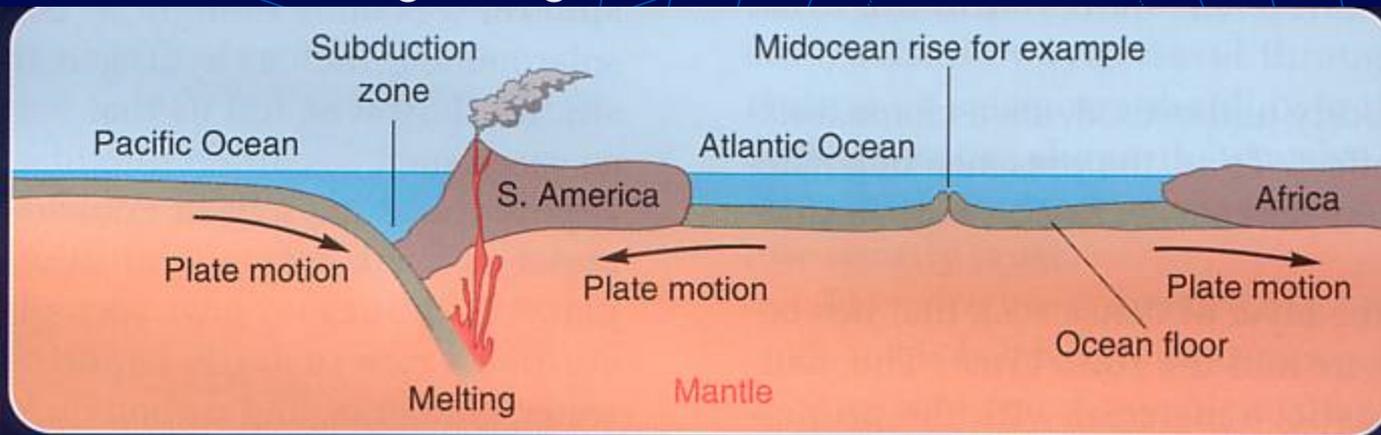


Hot spots caused by rising magma in the mantle can poke through a plate and cause volcanism such as that in Hawaii. As the Pacific plate has moved northwestward, the hot spot has punched through to form a chain of volcanic islands, now mostly worn below sea level.

Folded mountain ranges can form where plates push against each other. For example, the Ural Mountains lie between Europe and Asia, and the Himalaya Mountains are formed by India pushing north into Asia. The Appalachian Mountains are the remains of a mountain range pushed up when North America was pushed against Africa.

Plate Tectonics

- The continental crust is lower density rock that ‘floats’ on the ‘plastic’ mantle **Turn to page 353!!**
- The oceanic crust is higher density rock that easily pitches under then colliding with continental mantle
- Spreading occurs at mid-ocean ridges
- Collision zones = subduction
 - Mid-ocean rise and mid-ocean ridge
 - Subduction zones **below**
 - Folded Mountain Chains
 - Pangea Progression – **next screen**



Continental Drift

Not long ago, Earth's continents came together to form one continent.



200 million years ago

Pangaea broke into a northern and a southern continent.



135 million years ago

Notice India moving north toward Asia.



65 million years ago

The continents are still drifting on the highly plastic upper mantle.



Today

More Rocky Worlds – Earth

- The formation of the Atmosphere (applies to Venus and Mars)
 - Primeval atmosphere = the solar nebula
 - Hydrogen, methane, ammonia + carbon dioxide (CO_2), nitrogen and water vapor cooked out of the rock
 - UV broke down methane and ammonia (Hydrogen and Nitrogen released)

More Rocky Worlds – Earth

- The Planet cooled, oceans formed, CO₂ dissolved in the water
- Limestone formed (precipitate) – Nitrogen was left
- The decreased the CO₂ weakened the Greenhouse Effect (Thermal Blanket Effect)
- Plant life also absorbed CO₂ as well and produced O₂
- Iron in the soil oxidized (red beds) sucking down O₂ until the crust was oxidized
- Now we have 21% oxygen, 79% nitrogen and stuff

The Rocky Planets – the Moon

- When we look at the moon- we see
 - Radial rays made of crater ejecta (sprays from craters)
 - Maria (singular = mare), Latin for seas (man in the moon)
 - Its albedo (reflectivity) is ONLY 6% ! (Earth is 39%)
 - One side is thinner and denser and points towards the Earth



The history of the Moon

- The History of the Moon
 - It has no atmosphere (gravity is too low, temperature is too high)
 - Maybe has water (new discovery)
 - Four Stages of formation
 1. Moon formed (coalesced, or was ejected)
 2. Cratering started when crust solidified - largest impacts = deep/wide craters
 3. filled with molten interior = maria **see next two frames**
 4. Moon cooled, but little happened (no erosion, no tectonics) must minor cratering

Formation of the Imbrium Basin



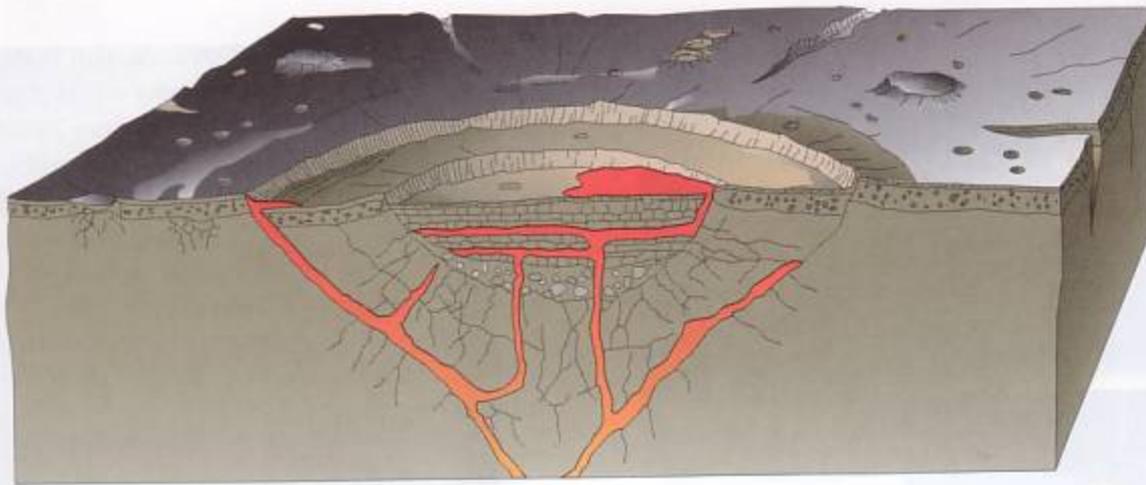
Near the end of the heavy bombardment, a giant impact creates a vast crater basin.



Faulting in the crust produces rings of mountains, and lava flows fill the lowest regions.

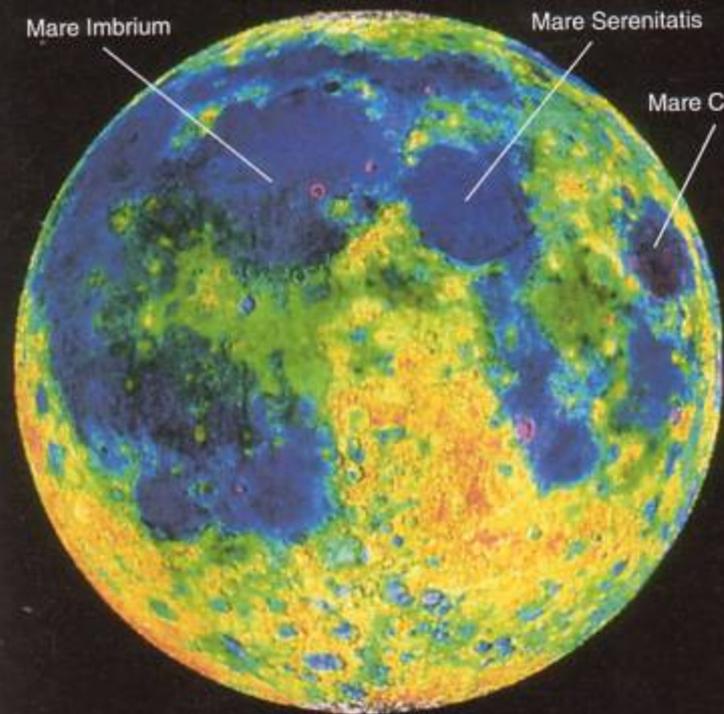


Today all but the outlines of the impact have been covered by dark lava flows.



200 km

a

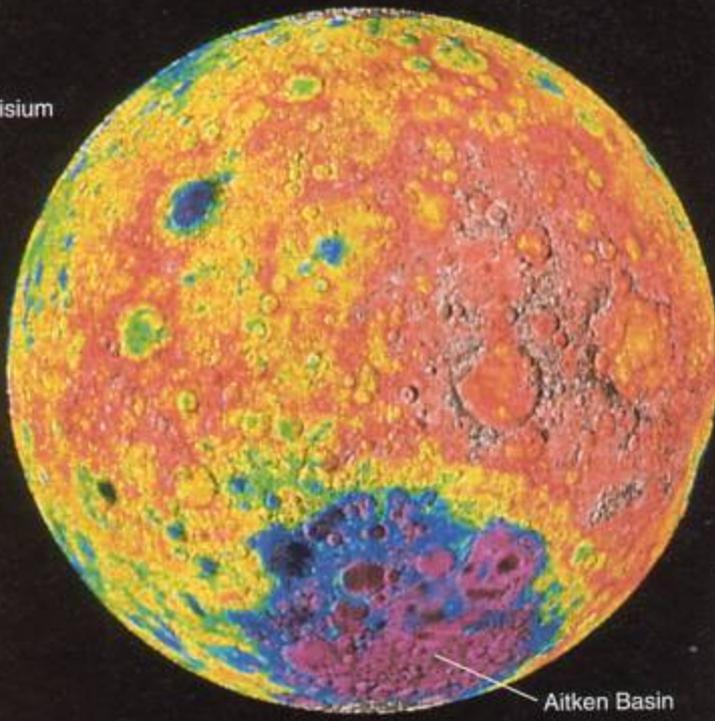


Mare Imbrium

Mare Serenitatis

Mare Crisium

Near side of moon



Aitken Basin

Far side of moon

Lunar Formation

- Capture Hypothesis, Impact Hypothesis

The Large-Impact Hypothesis



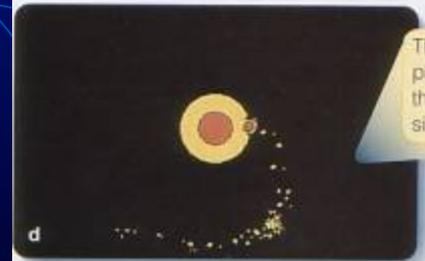
In this model a planetesimal the size of Mars strikes the proto-Earth.



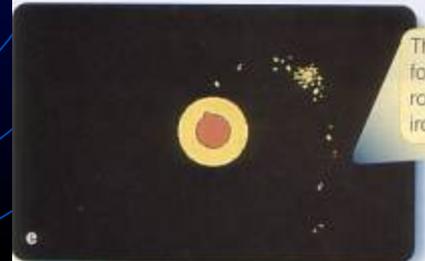
Both bodies have differentiated before the impact.



Material ejected is iron poor, and volatiles are lost in the vacuum of space.



The iron core of the planetesimal falls into the proto-Earth and sinks.



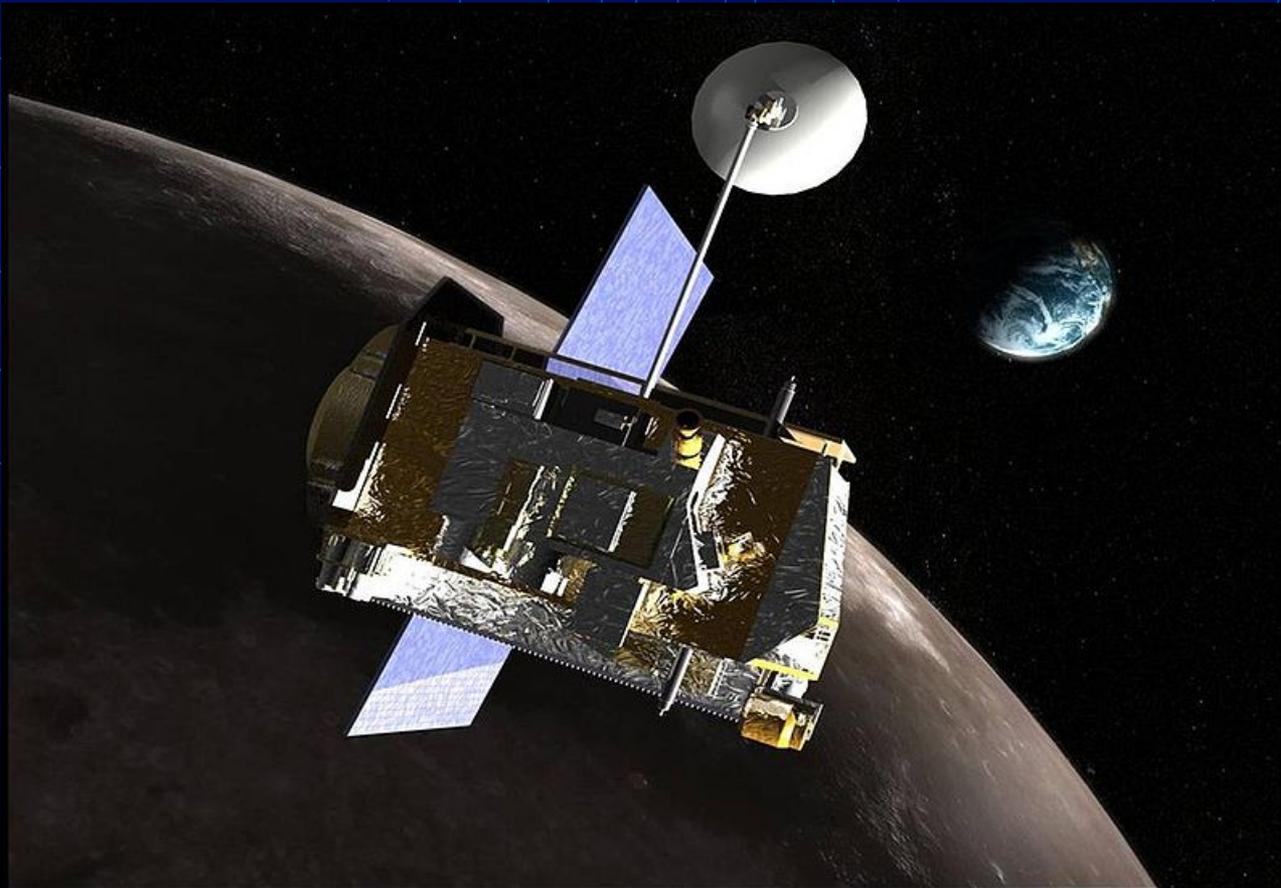
The moon begins to form from volatile-poor rock containing little iron.

Water on the Moon?

- Most likely in the deeper craters at the north and south poles where the sun never shines.
- Billions of years of darkness
- Comets may have deposited a lot of water that is kept cold enough to stay frozen.

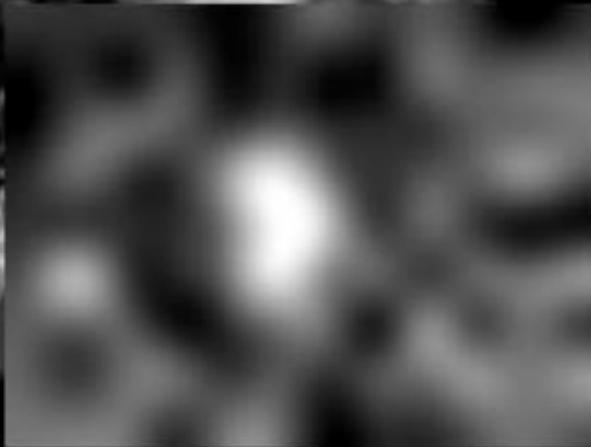
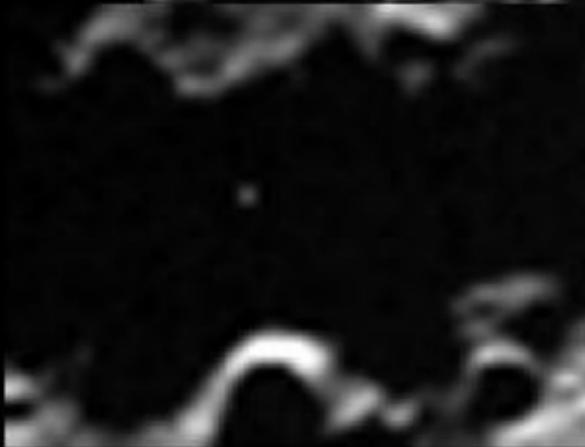
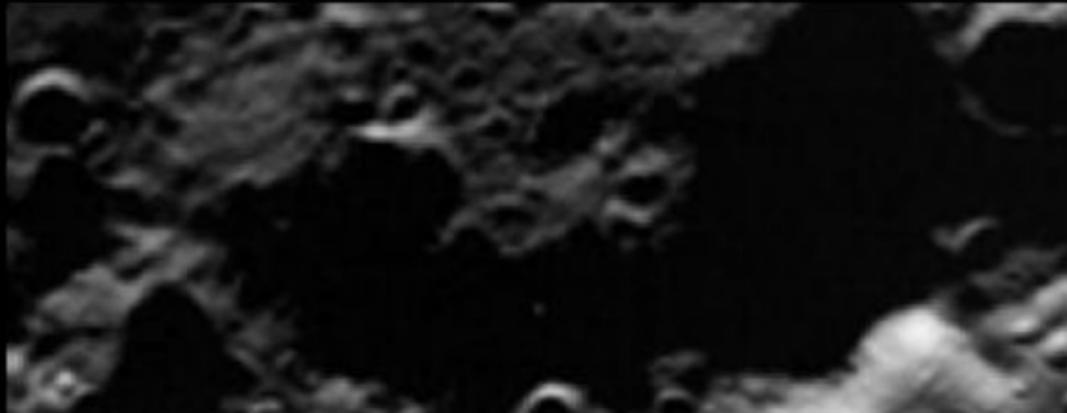
LCROSS Mission Oct 2009

- Lunar Reconnaissance Orbiter



Impact of 1st piece of ship

MIR Flash Detection

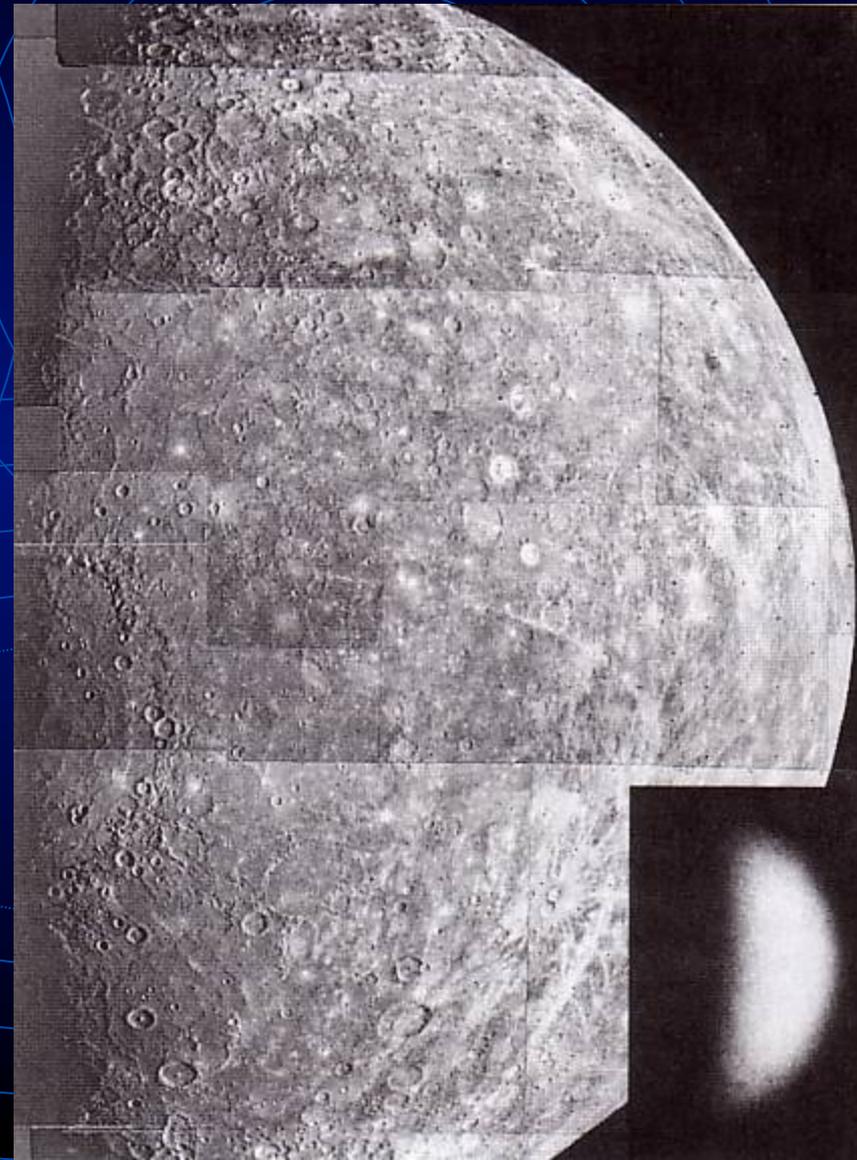
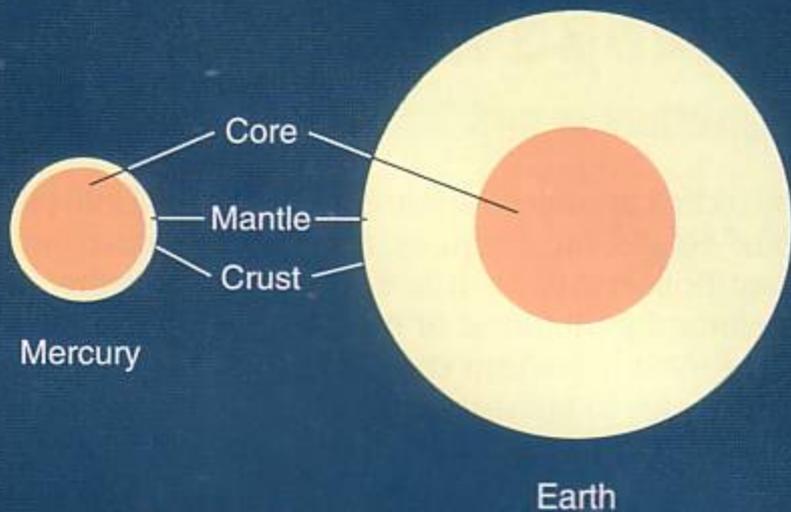


A planet *like* the moon...

- Mercury...
- Now we being with planets!

Rocky Planets – Mercury

- The innermost planet
- Airless and cratered (much like the moon)
- Revolves around sun in 87.969 days
- Rotates in 58.646 days

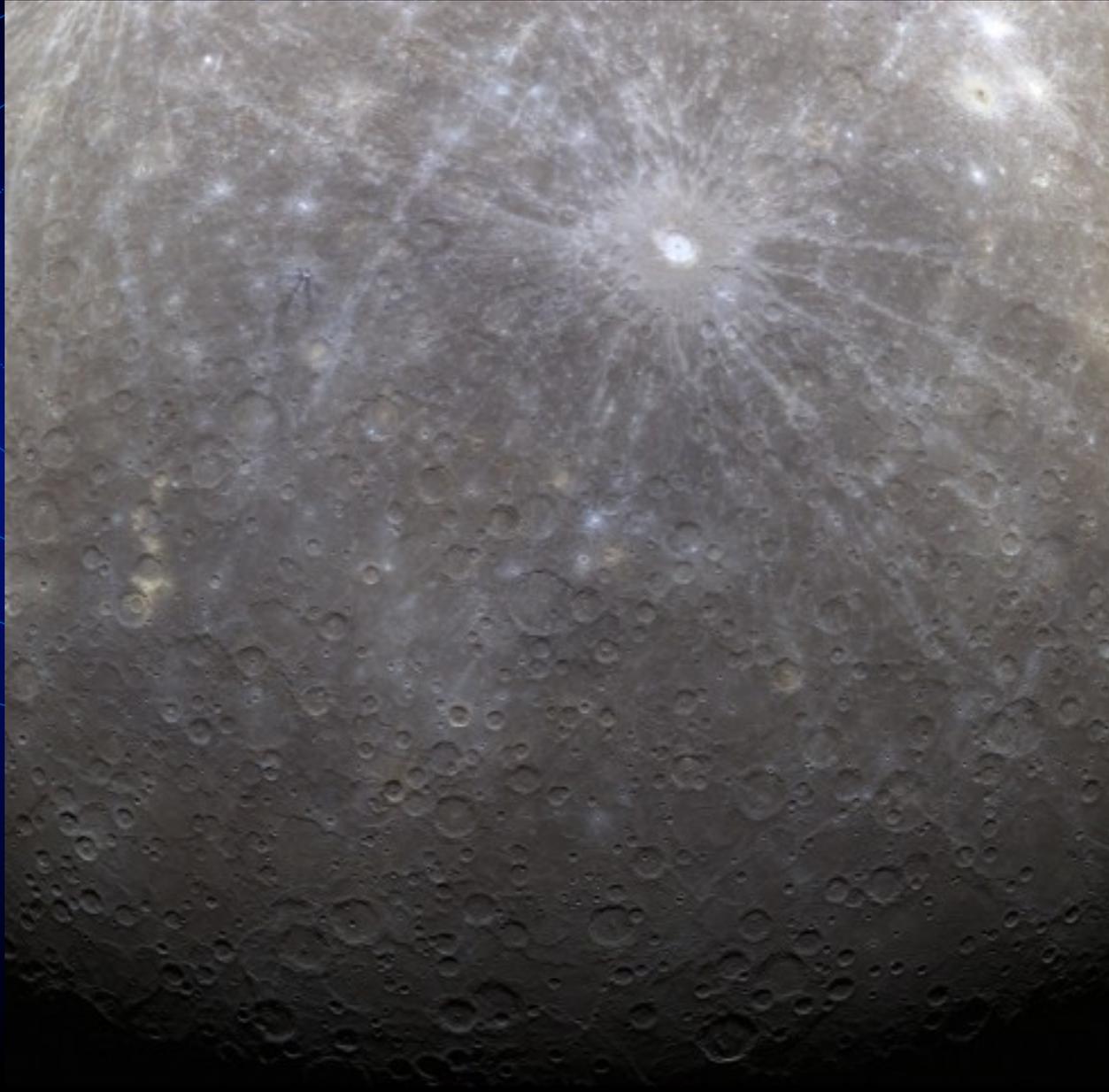




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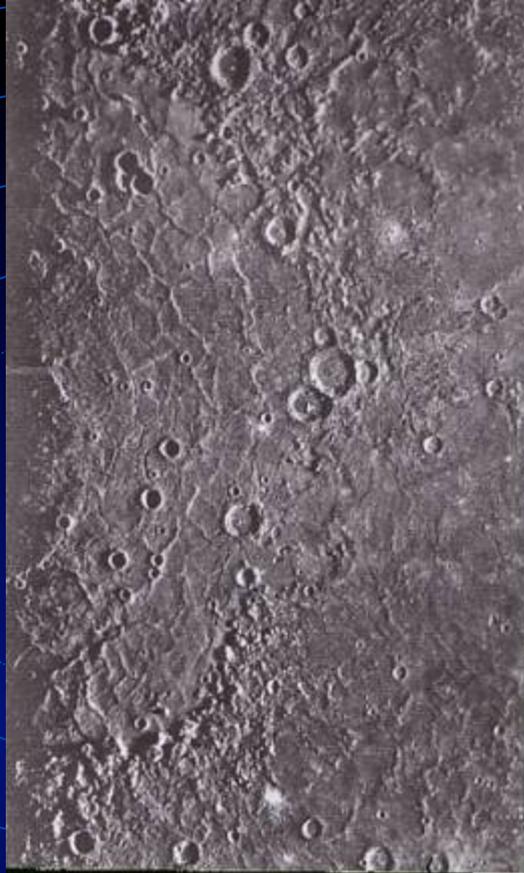
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1st image from 1st orbiter March 29, 2011



Mercury

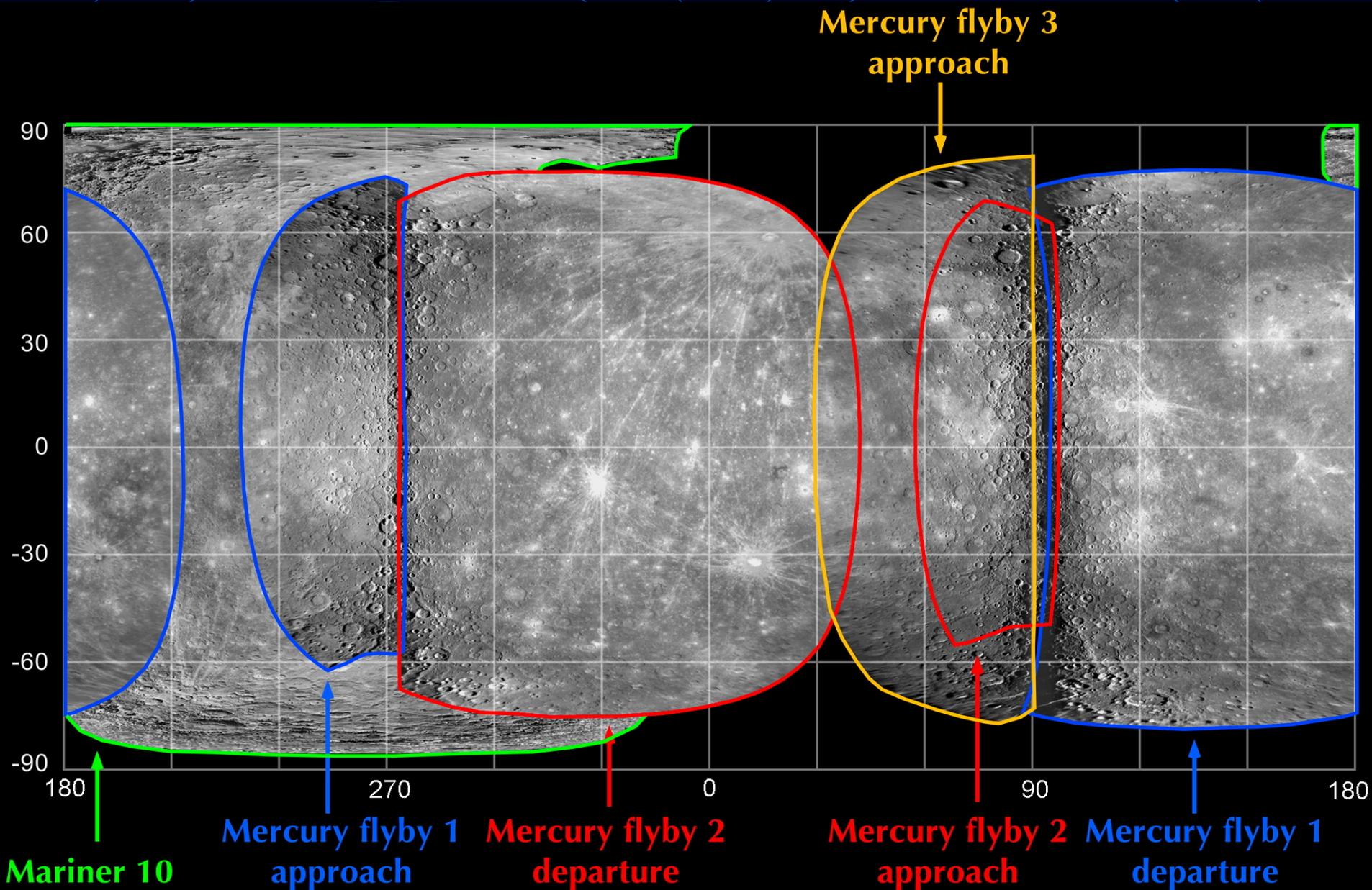
- Ratio = 2/3 day/yr (locked to sun similar to Moon locked to Earth)
- Has lobate scarps **see next screen** even through craters- shrinking of core
- Largely metallic core- larger than it should be
 - Large impact in the past might have blown the early crust away leaving more iron core
 - The remaining collisional remains reformed Mercury

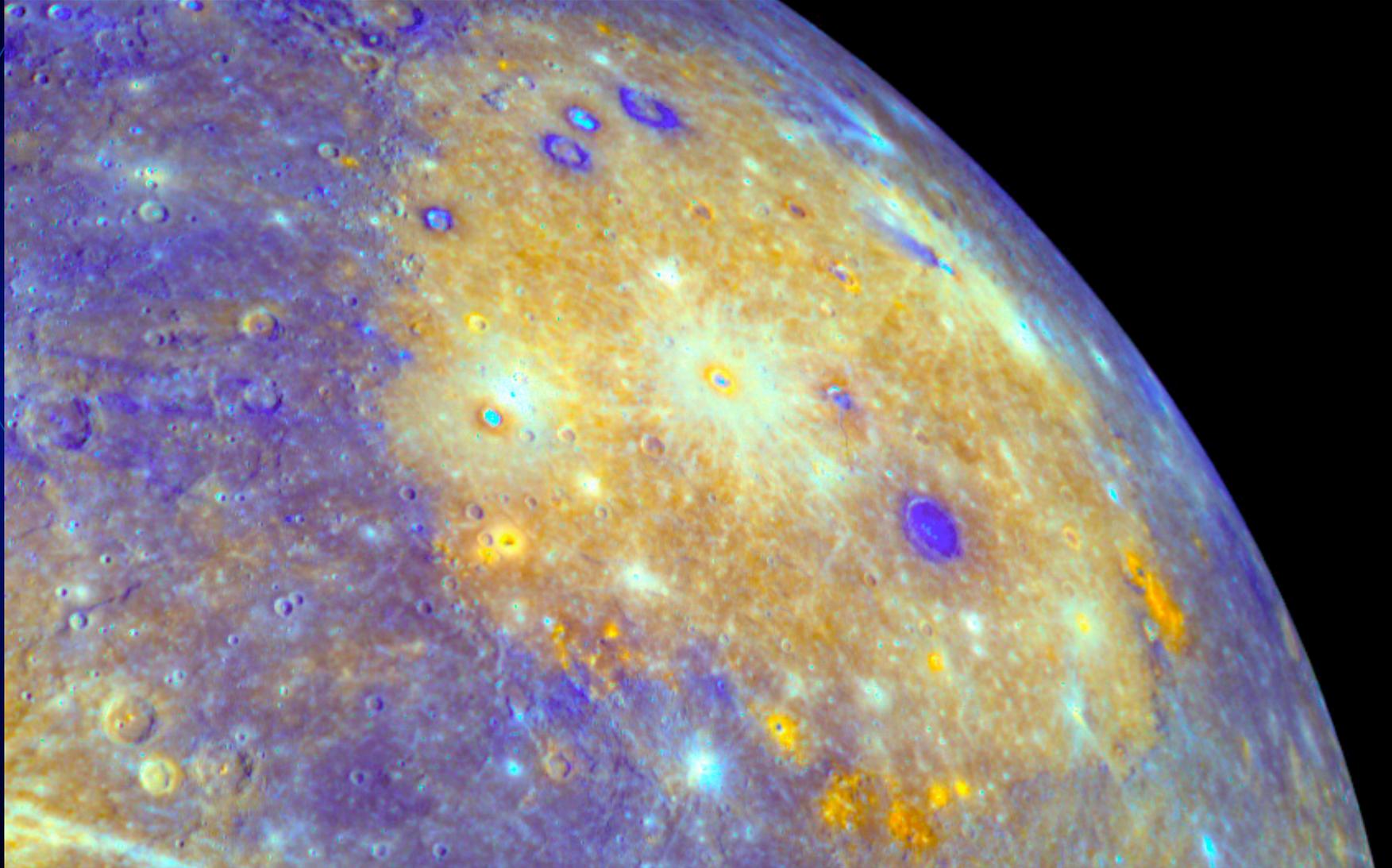


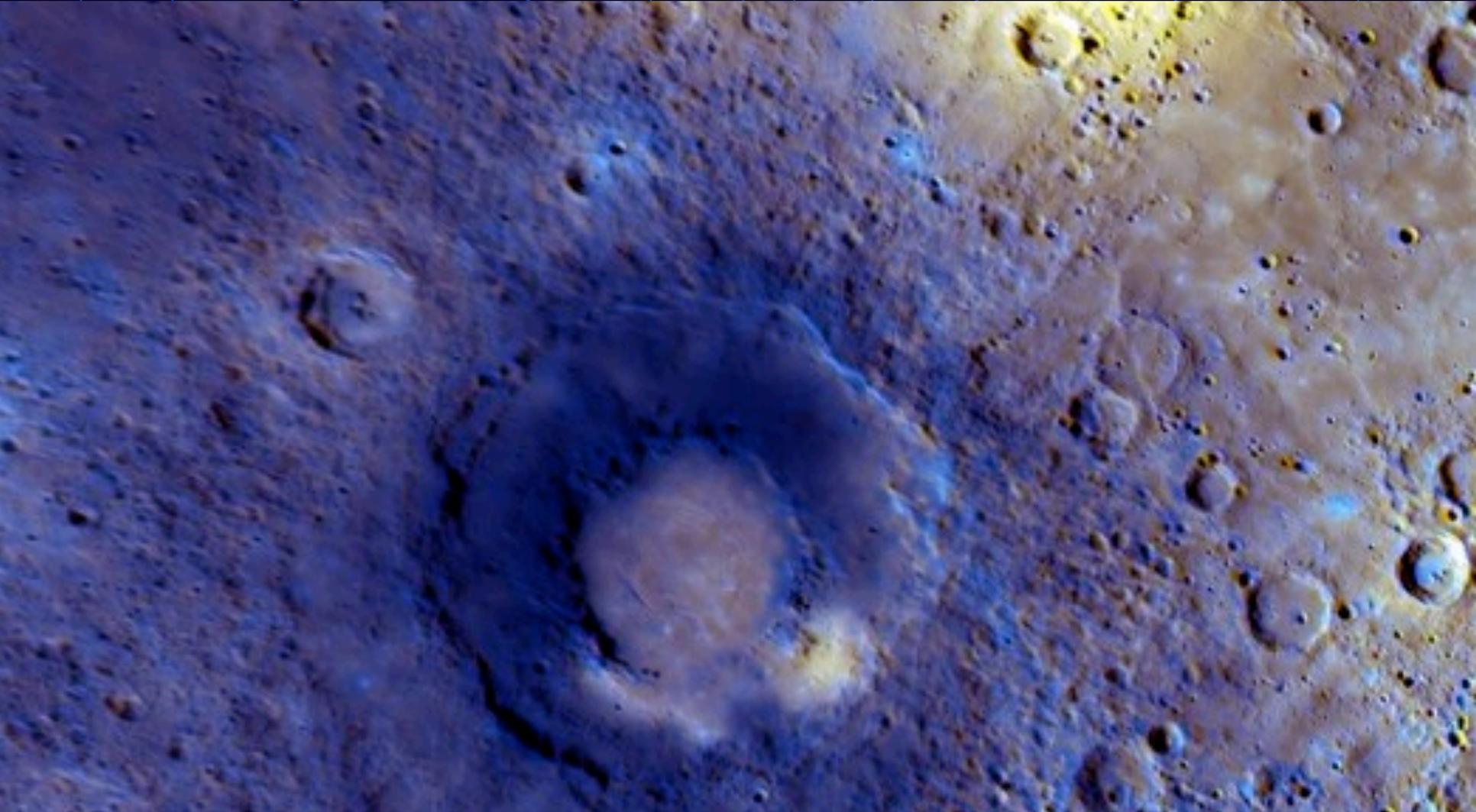
Previously Unseen side of Mercury from the NASA Messenger Mission



Pre Orbit Pass in Oct 2009







Venus

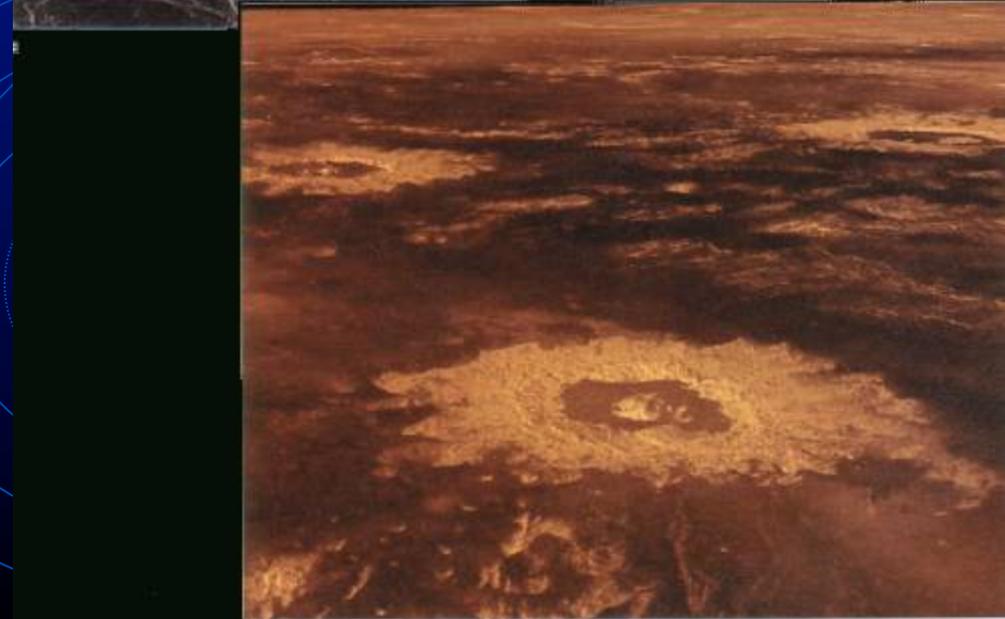


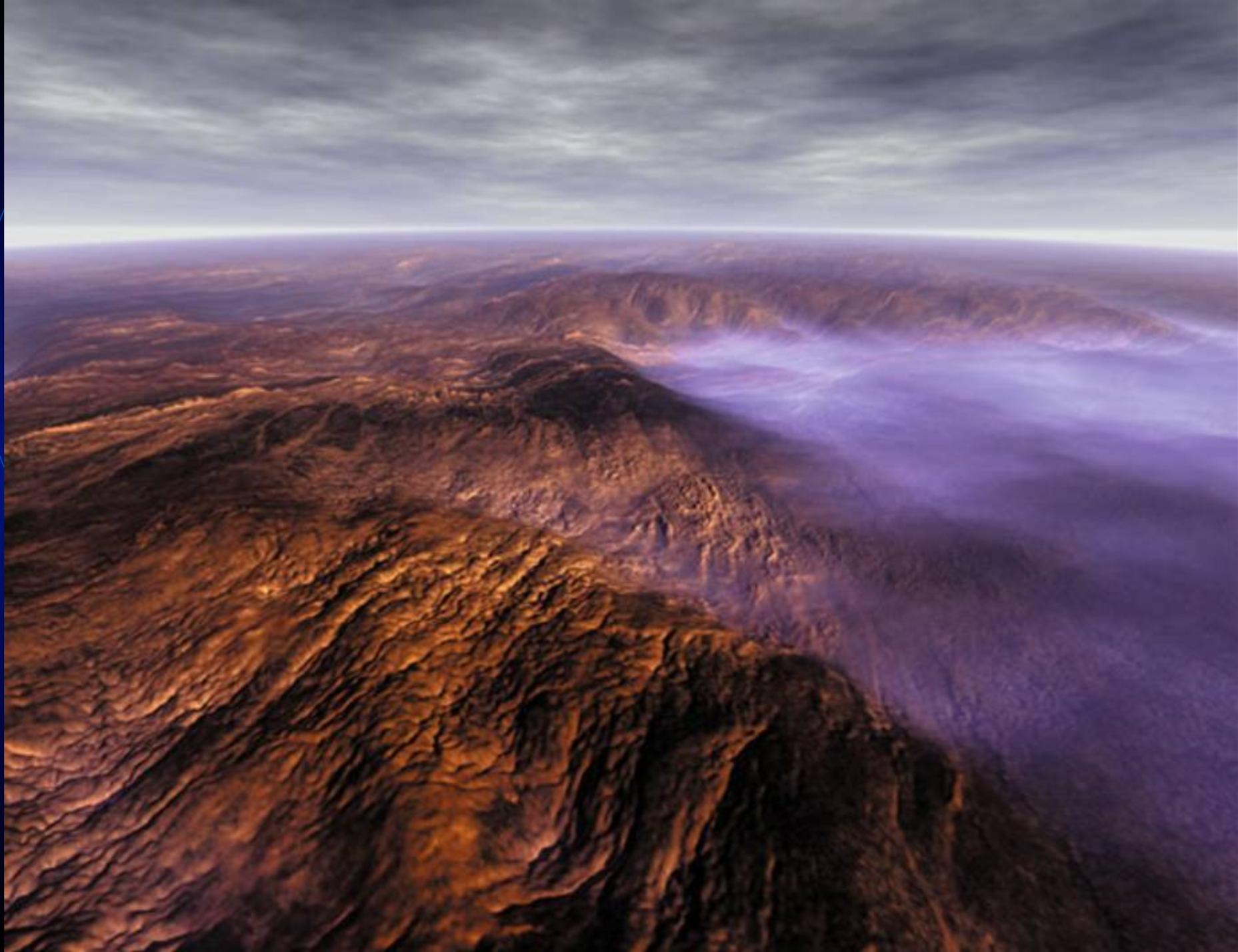
Venus

- Very similar to Earth in size = 95% our diameter
- 30% closer to the Sun
- Year = 224d, Day=243d (retrograde) = Axis tilt 177deg
- The atmosphere is 100X the density of Earth's and 96% CO₂, some Argon, Sulfur Dioxide, hydrochloric acid, hydrofluoric acid with clouds of sulfuric acid droplets and crystals of sulfur
- The atmospheric density is only 10X less than that of water
- 882deg F temp = hot enough to melt lead

Venus

- Surface is characterized by large shield volcanoes
- Coronae = solidified bubbles of magma – dome shaped with cracks around them
- Large craters are visible – little weathering or plate tectonics: also no rift valleys

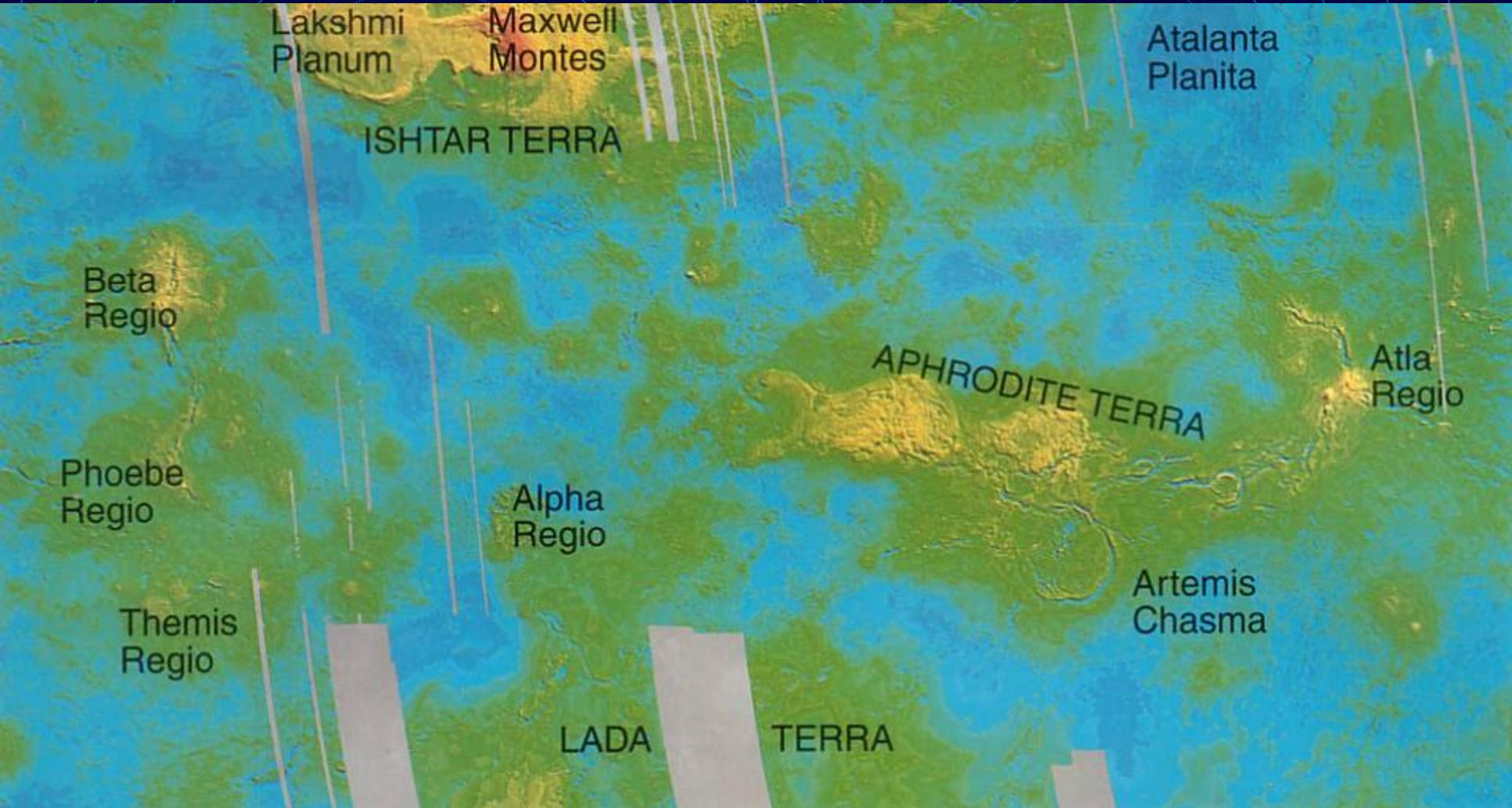


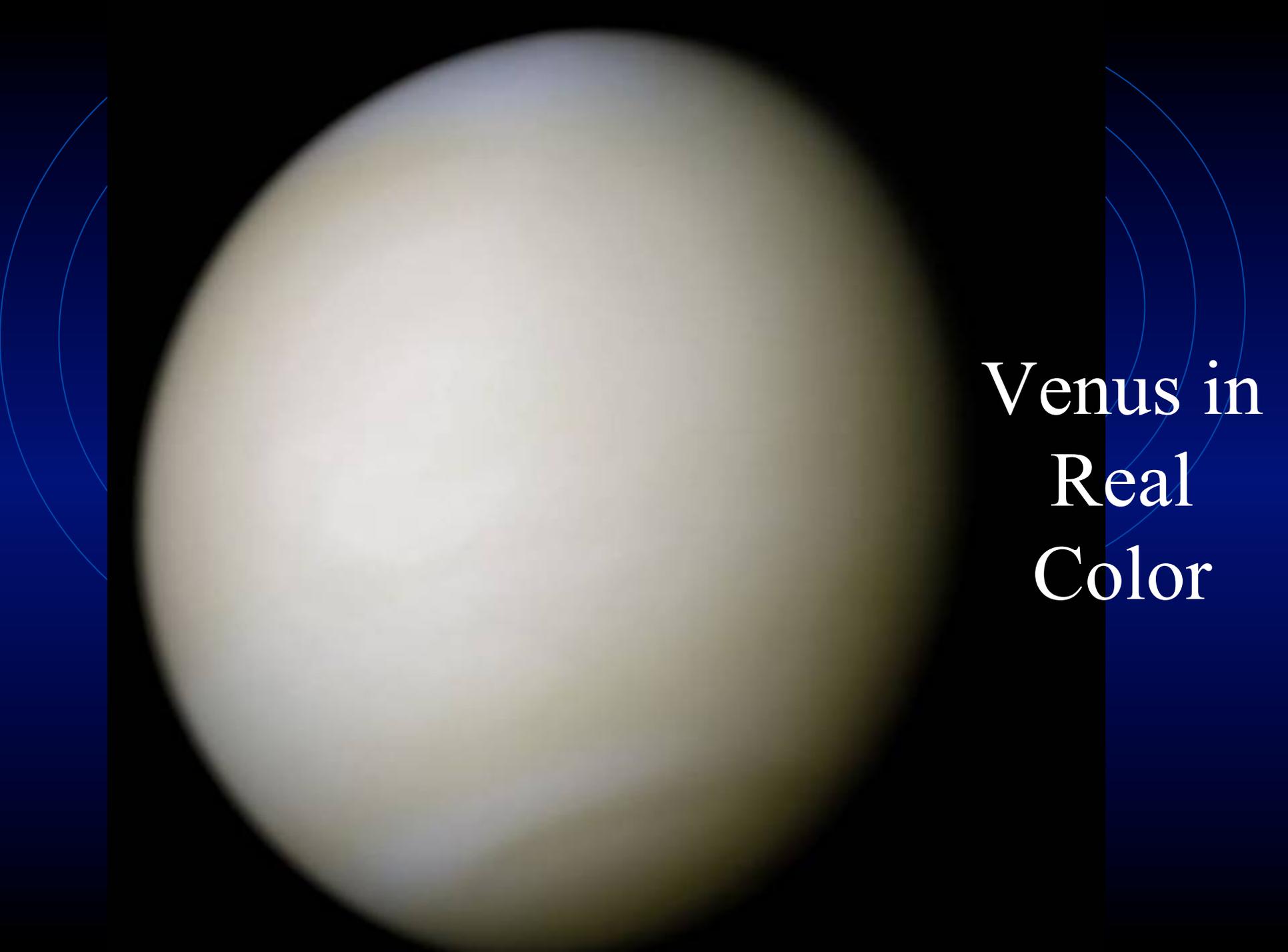


Venus Continued

- Earth and Venus probably out-gassed the same amount of CO₂ in their early history- but on Earth it is all locked up in limestone
- The difference is the lack of water oceans on Venus
- Venus had a ‘runaway greenhouse effect’
- No oceans = no plate tectonics – no crustal density differences = just large volcanic regions and uplift (highlands) **see next frame**
- The planet surface has about 900 large craters – more than the Earth but less the moon, and largest mountains don’t have the ‘roots’ that they do on Earth (magma support) = overturning of the crust

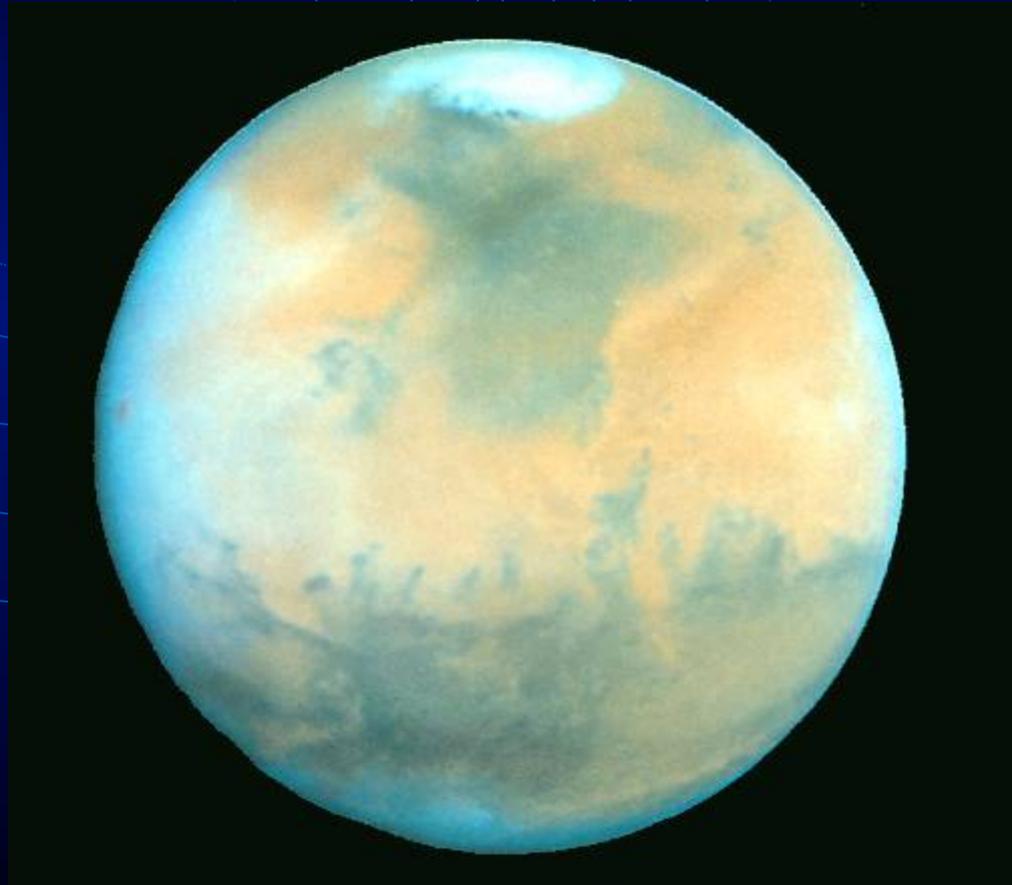
Venus

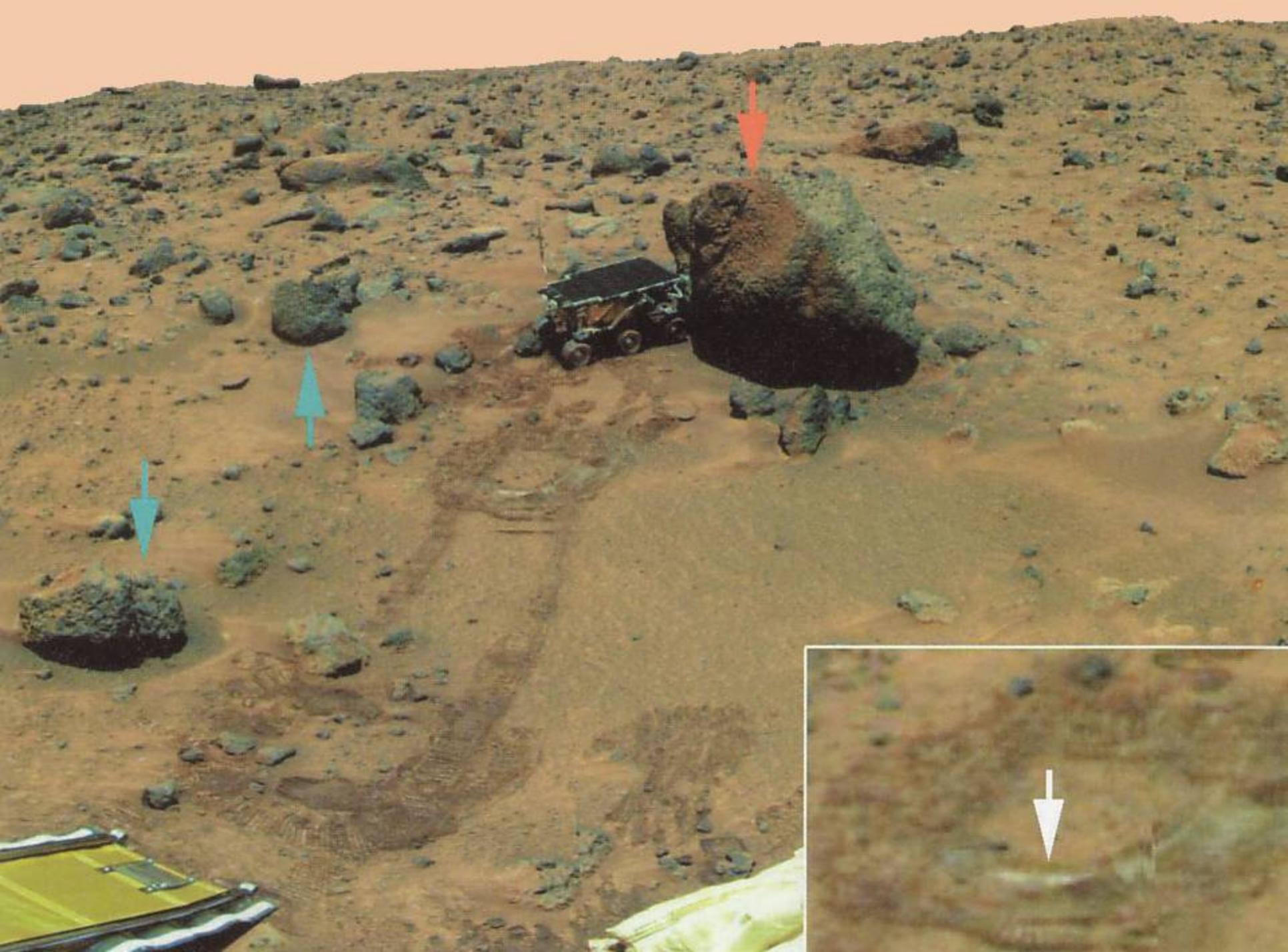




Venus in
Real
Color

Mars





Mars

- Diameter is 53% that of Earth (intermediate between our Moon and Earth)
- 1 Day = 24h 37m, 1 Year is 1.88, Axis tilt = 24deg
All very Earth like
- Atmosphere = 95% CO₂ but only 1% the density of Earth's
- Max Temperature about 75deg F, Min-220 deg F
- Polar caps made of water AND frozen carbon dioxide
- Low pressure would make our blood boil (at 98F)



Mars

- BUT we see evidence of water on the surface at one point!!
- Low gravity = it could not hold onto it's gasses
- No free oxygen = no ozone layer (O_2 lock in crust)
- Red planet = iron oxides, iron peroxides
- Water ways
 - Short term event channels – simple- few tributaries
 - Long term flow channels – complex – many tributaries



a



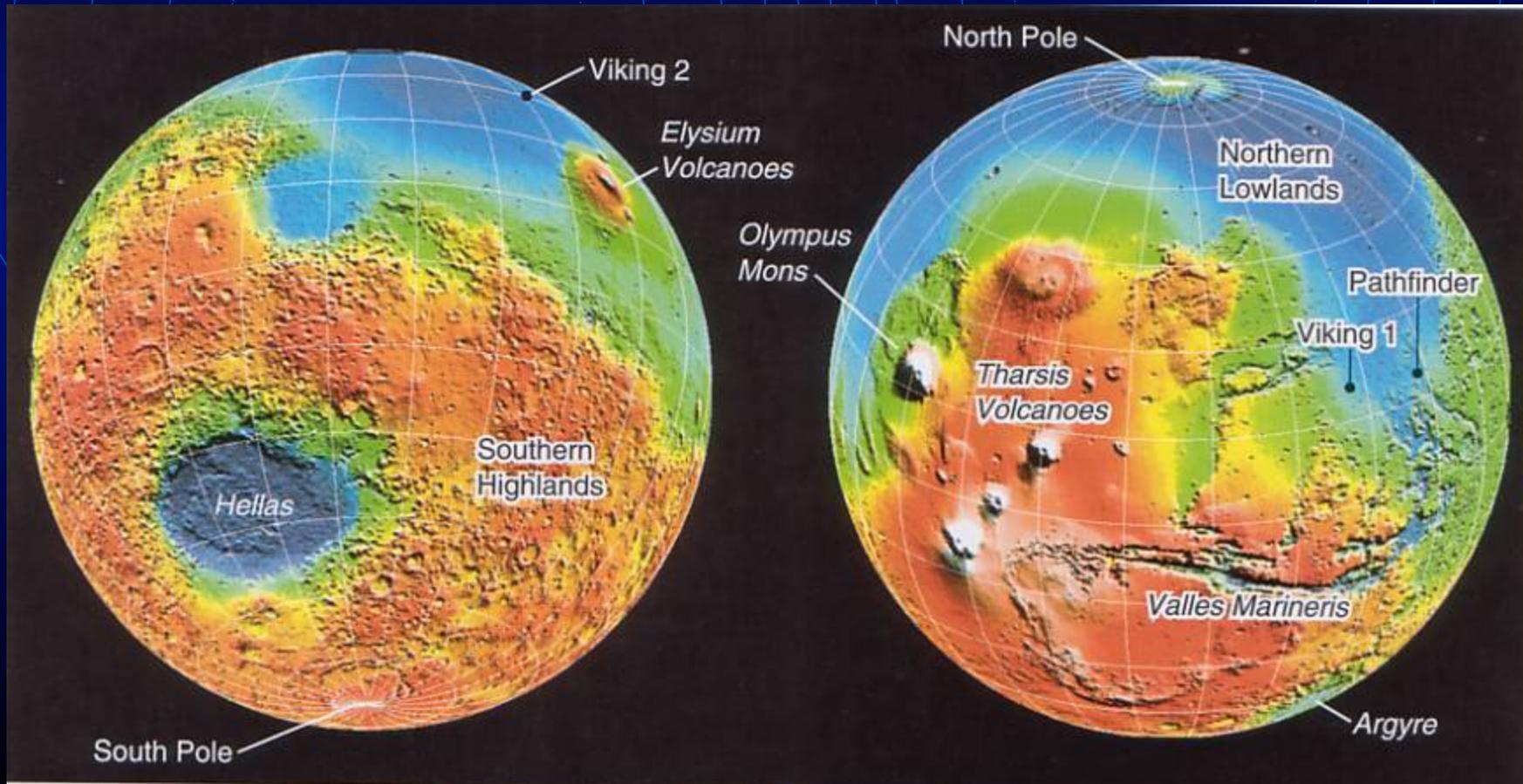
b



More Mars

- Geology

- Highlands (older and cratered)
- Lowlands (younger – water covered once?)



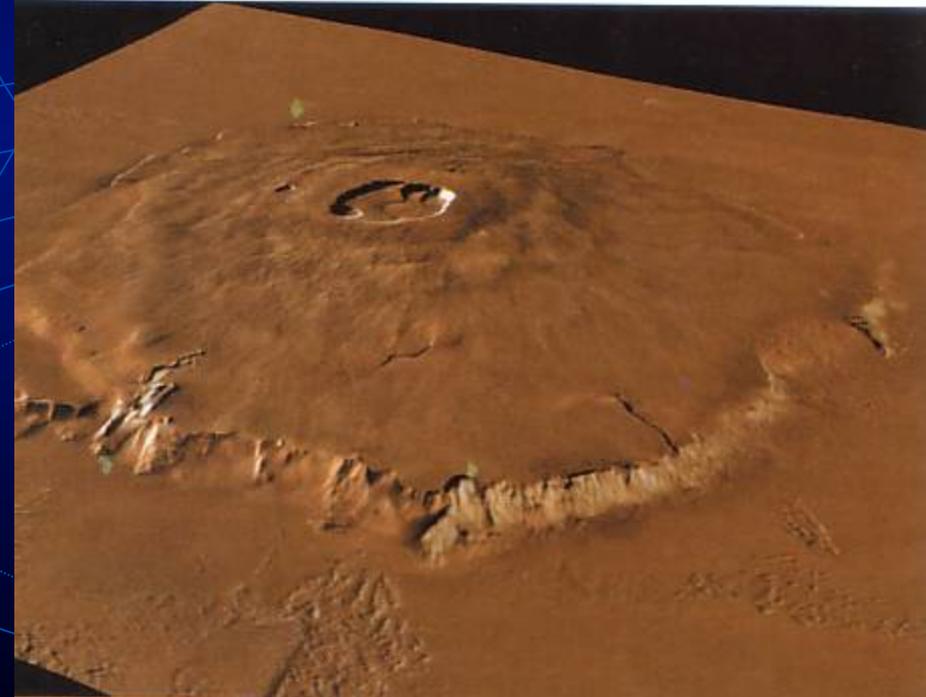
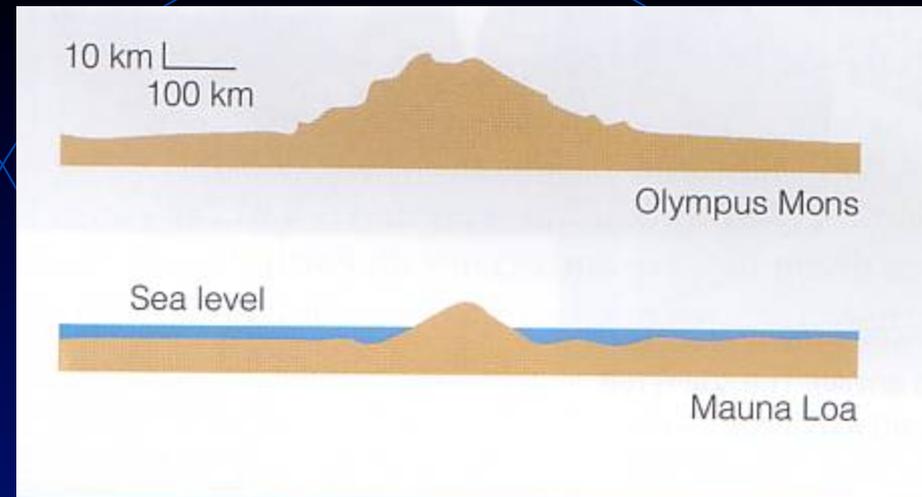
Mars Geology

- Volcanic regions

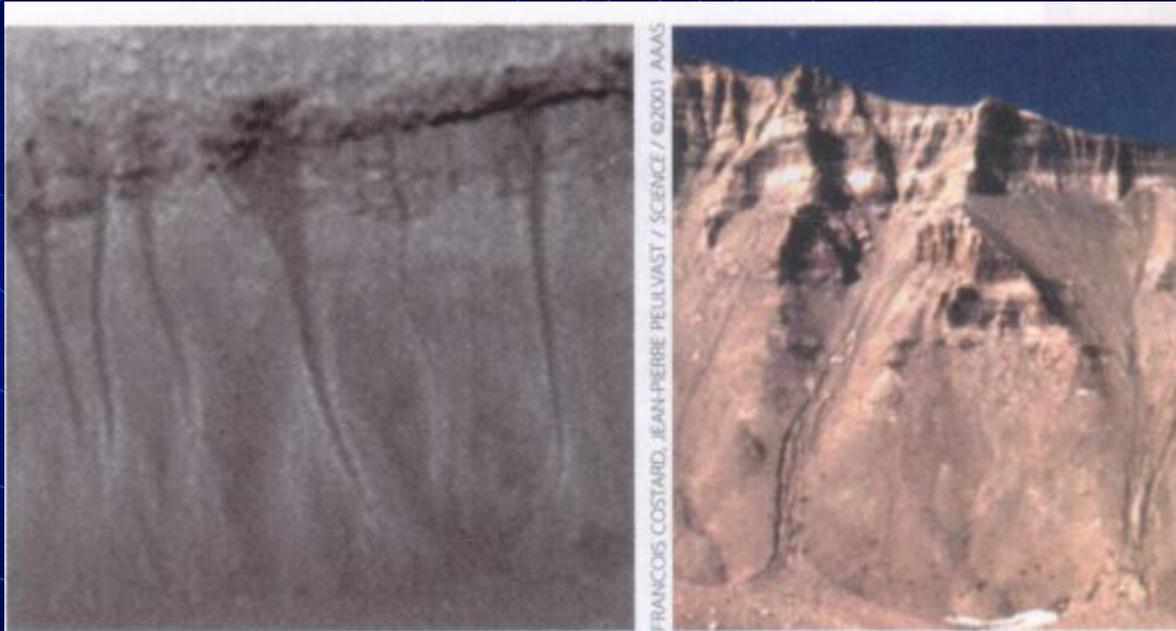
- Olympus Mons

- 370 miles in diameter and 16 miles high (Mauna Loa = 6 miles high above ocean floor)

- Mauna Loa has sunk a bit into the Earth's crust- Olympus Mons has not = strong crust on Mars

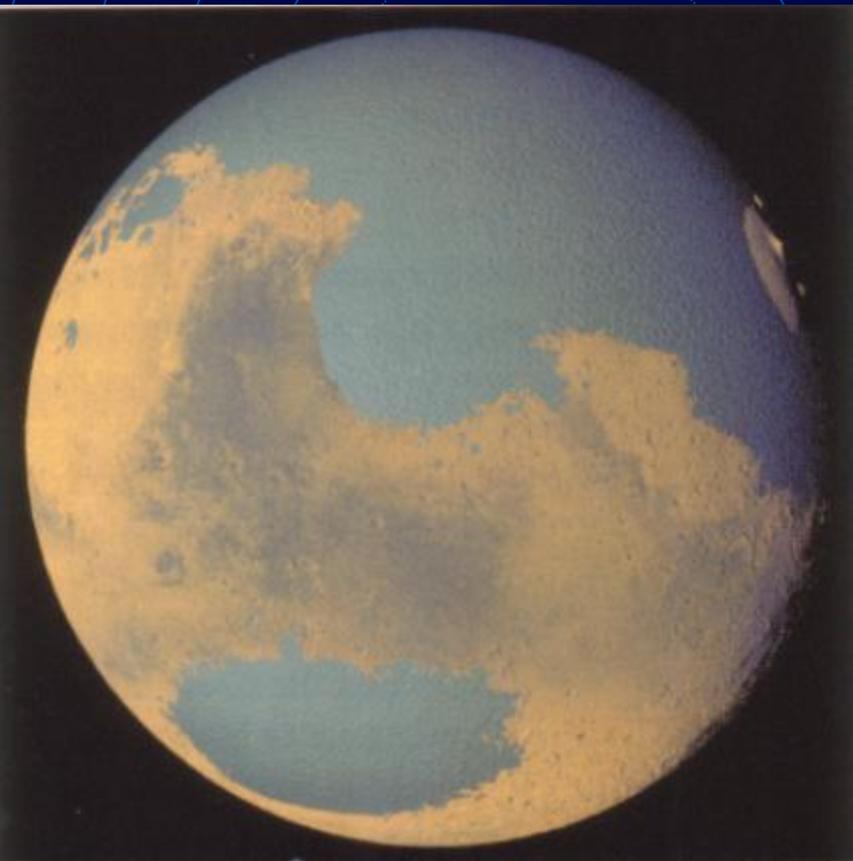


Mars and Water (hot off the press)



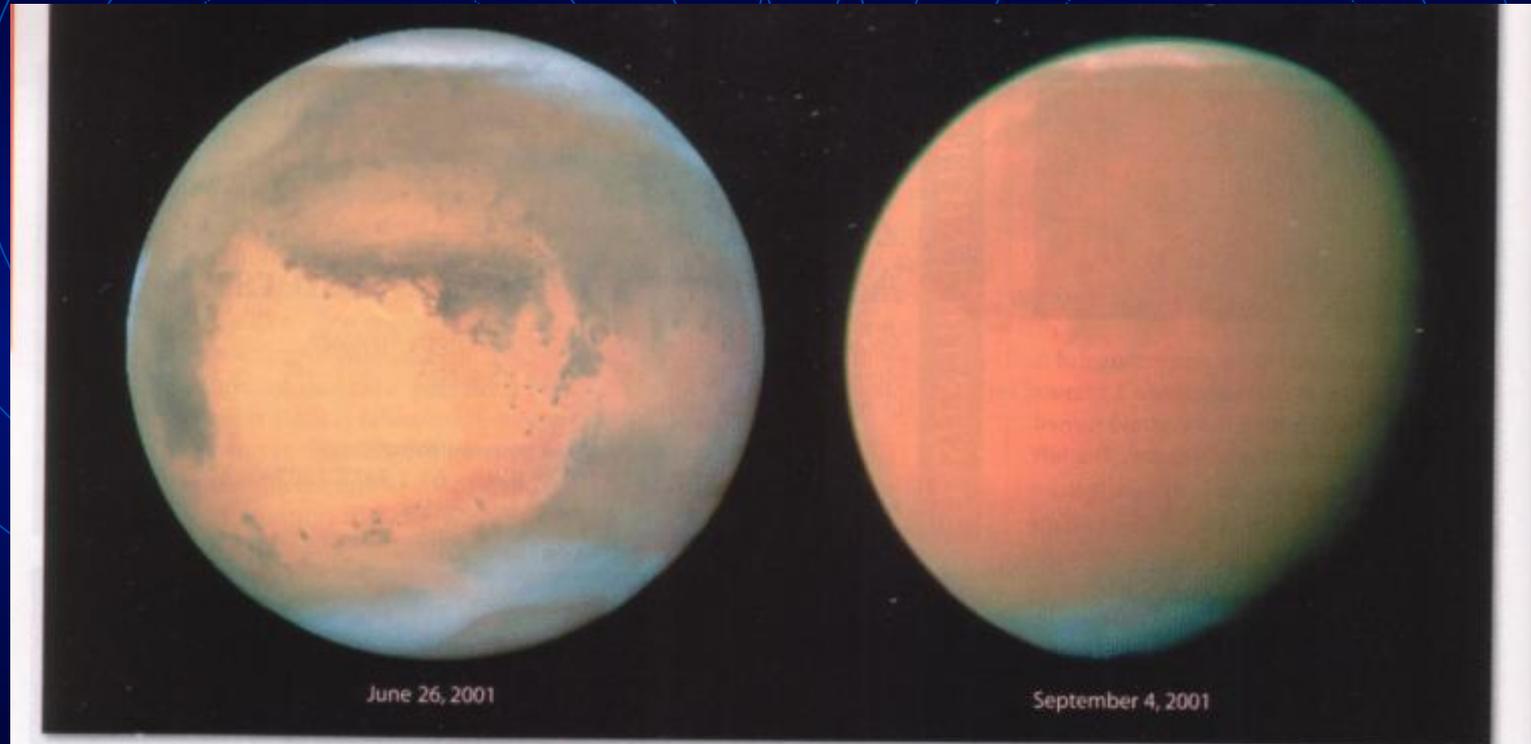
How did the Martian gully features form? Changes in Mars's polar tilt may hold the answer. Prolonged Sun exposure near the poles could have melted the top of a Martian permafrost layer and led to outflows of rubble and mud (*left*), just as happens in Greenland (*right*).

Mars and H₂O



Mars and Dust storms

- Seem to happen every southern hemisphere Spring with varying strengths



Mars in a Dust Cocoon

The dust-storm wipeout of Martian surface features that disappointed amateur telescope users starting last July (*S&T*: November 2001, page 22) is dramatically displayed in this pair of natural-color Hubble Space Telescope images. When the first picture was taken, yellow-brown dust clouds were already beginning to shroud the Hellas basin (the medium-bright area at the 10 o'clock position on the limb) and the North Polar Cap (bottom). They soon spread and multiplied to envelop the globe. Both images show nearly the same Martian hemisphere, with dark Sinus Sabaeus and Sinus Meridiani near center. — A. M.

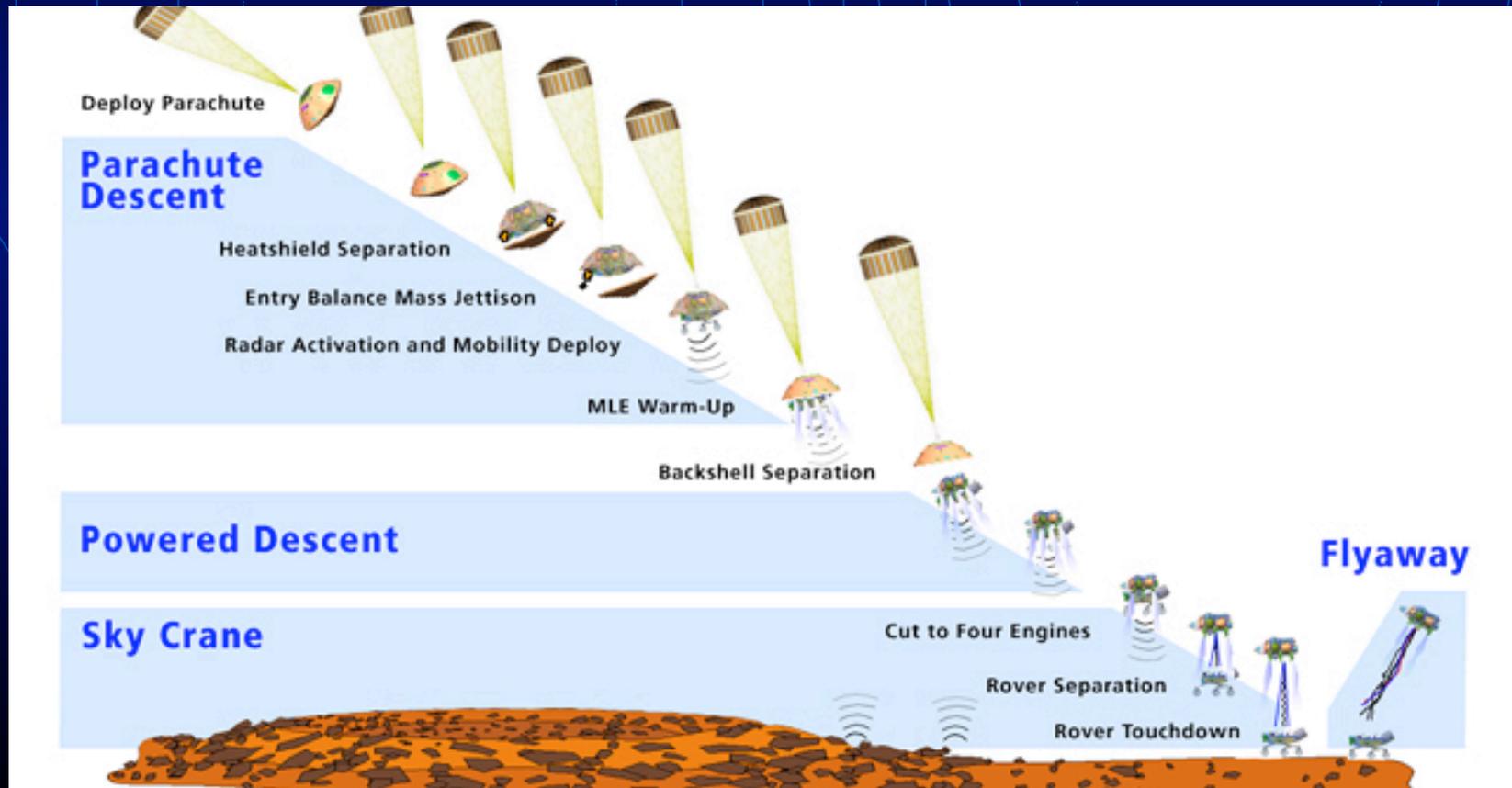
Hubble
Image
of Mars



Curiosity Rover (Mars Science Laboratory)



7 minutes of terror: Aug 5, 2012 11:31PM MT



Sky Crane



Still More on Mars

- Plate Tectonics?
 - No – the small planet cooled quickly and the crust became immobile
- Moons
 - 2= Phobos and Demos
 - Dusty, with grooves(?). **Next frame**

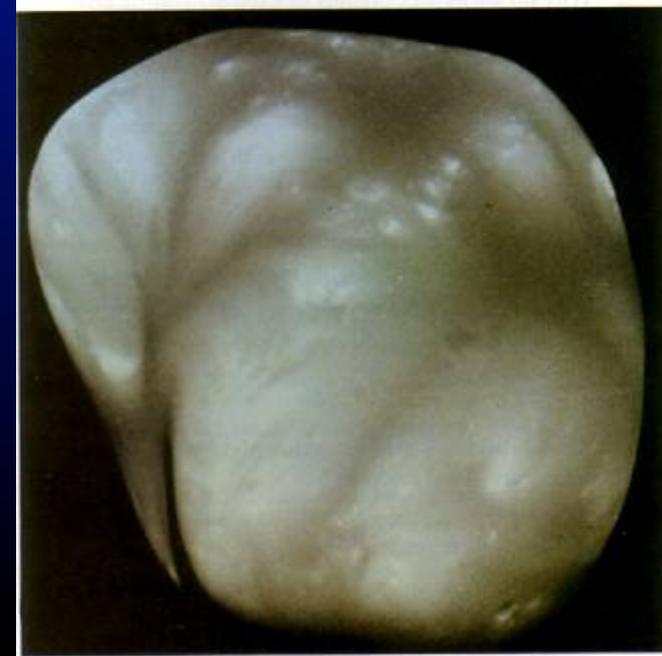
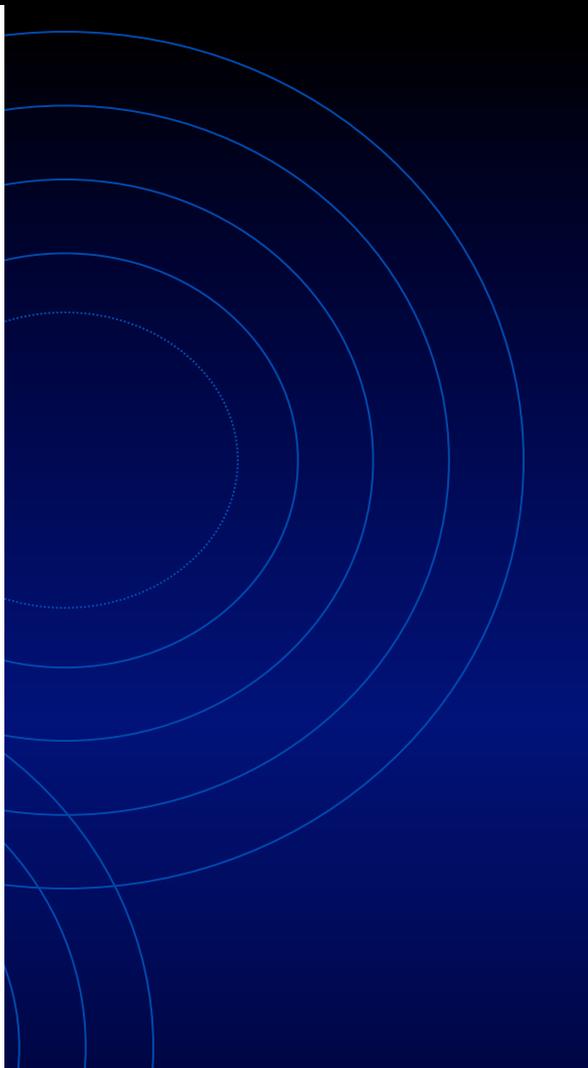


Figure 17-24
The moons of Mars are too small to pull themselves into spherical shape. (a) Phobos has an impact crater 10 km in diameter at one end with grooves radiating away. (*Damon Simonelli and Joseph Ververka, Cornell University/NASA*) (b) A photo from the Mars Global Surveyor spacecraft shows features as small as 8 meters in diameter. (*Mallin Space Science Systems/ NASA*) (c) Deimos, smaller than Phobos, looks more uniform because of dusty soil covering the smaller features. (*NASA*)



A comparison before we go on...



Jupiter – King of Planets



Another Comparison:

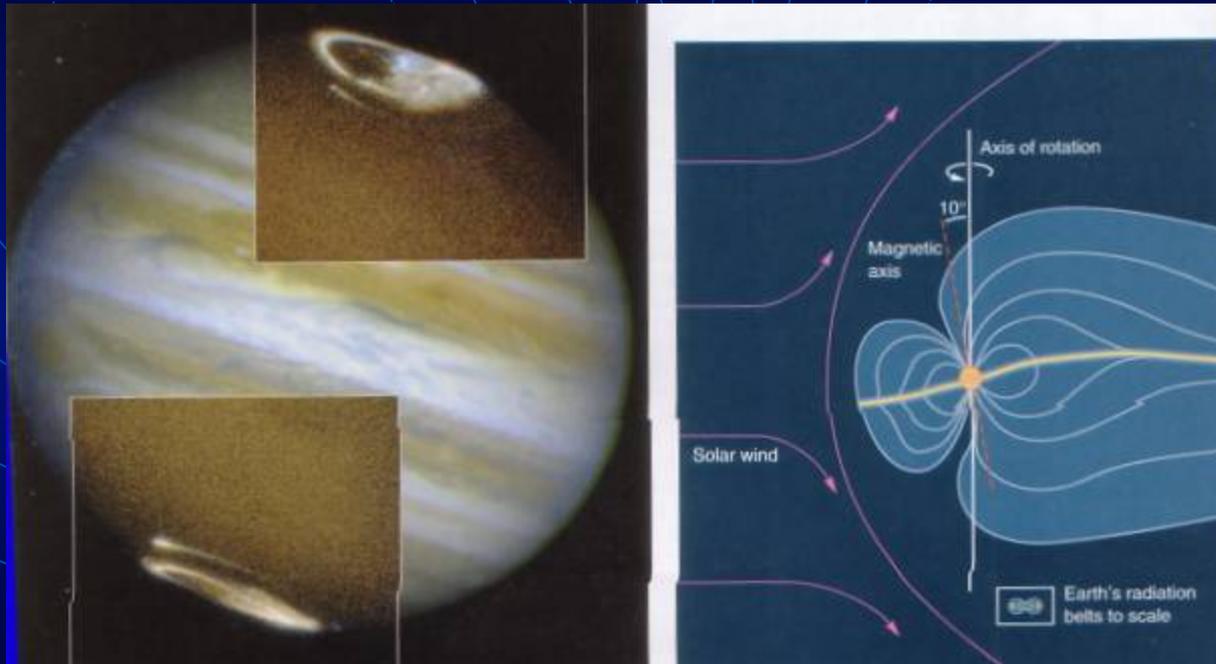


The Gas Giants – Jupiter

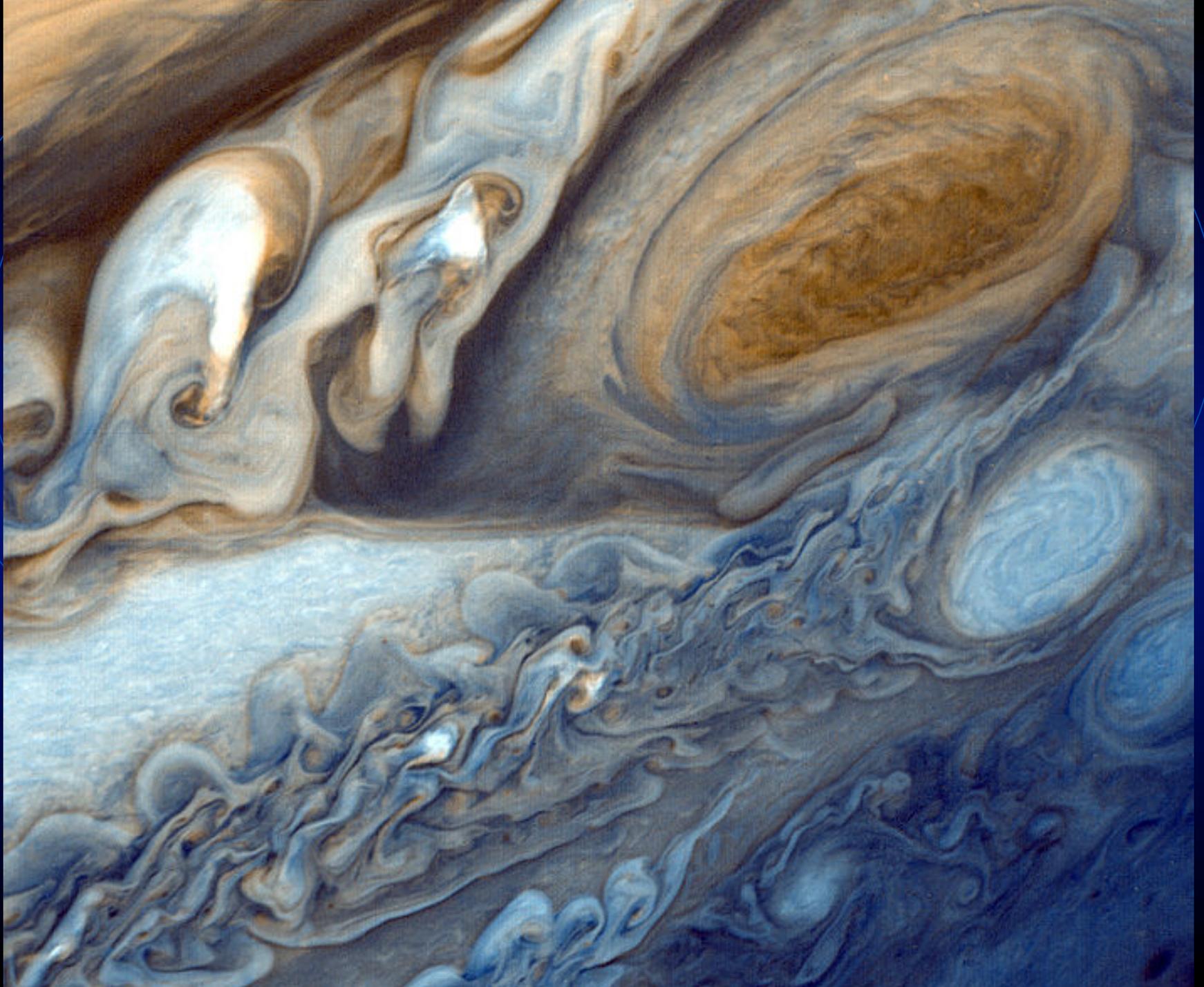
- The four gas giants do not have surfaces
- Rapid rotation flattens them out (oblateness)
- Studied by Pioneer 10, 11, Voyager 1,2, Galileo spacecraft
- **Jupiter** is the most massive planet = 318 Earth's in mass
- Composed mostly of hydrogen (liquid) and helium
- It emits 2X more heat than it gets from the sun (left over from planet formation we think)

More Jupiter

- Much of interior is liquid metallic hydrogen = STRONG magnetic field = 400X stronger radiation belt around the planet than that needed to kill a human



- Atmospheric circulation belt like (similar to Earth)
- Even lightning and aurora
- **Great Red Spot next slide:**



Jupiter

- Rings = thin and dark – inside the **Roche limit**

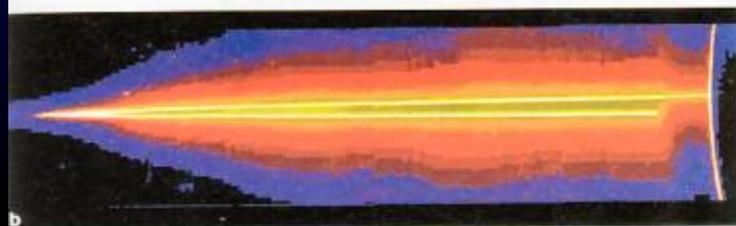
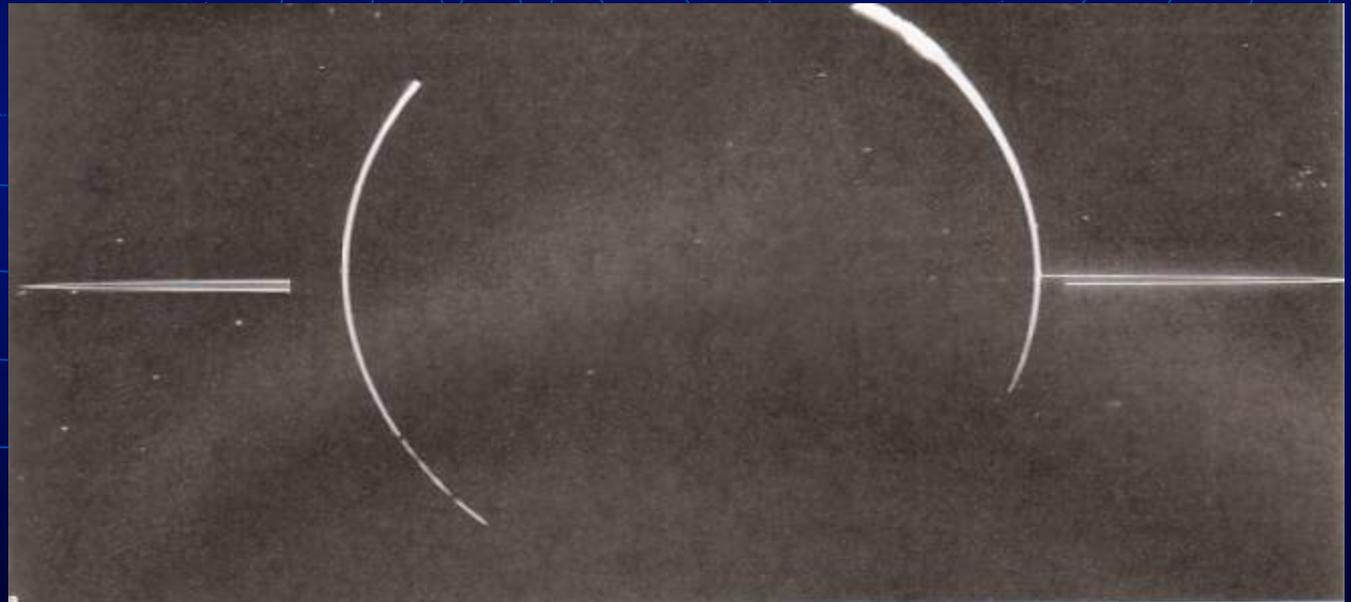
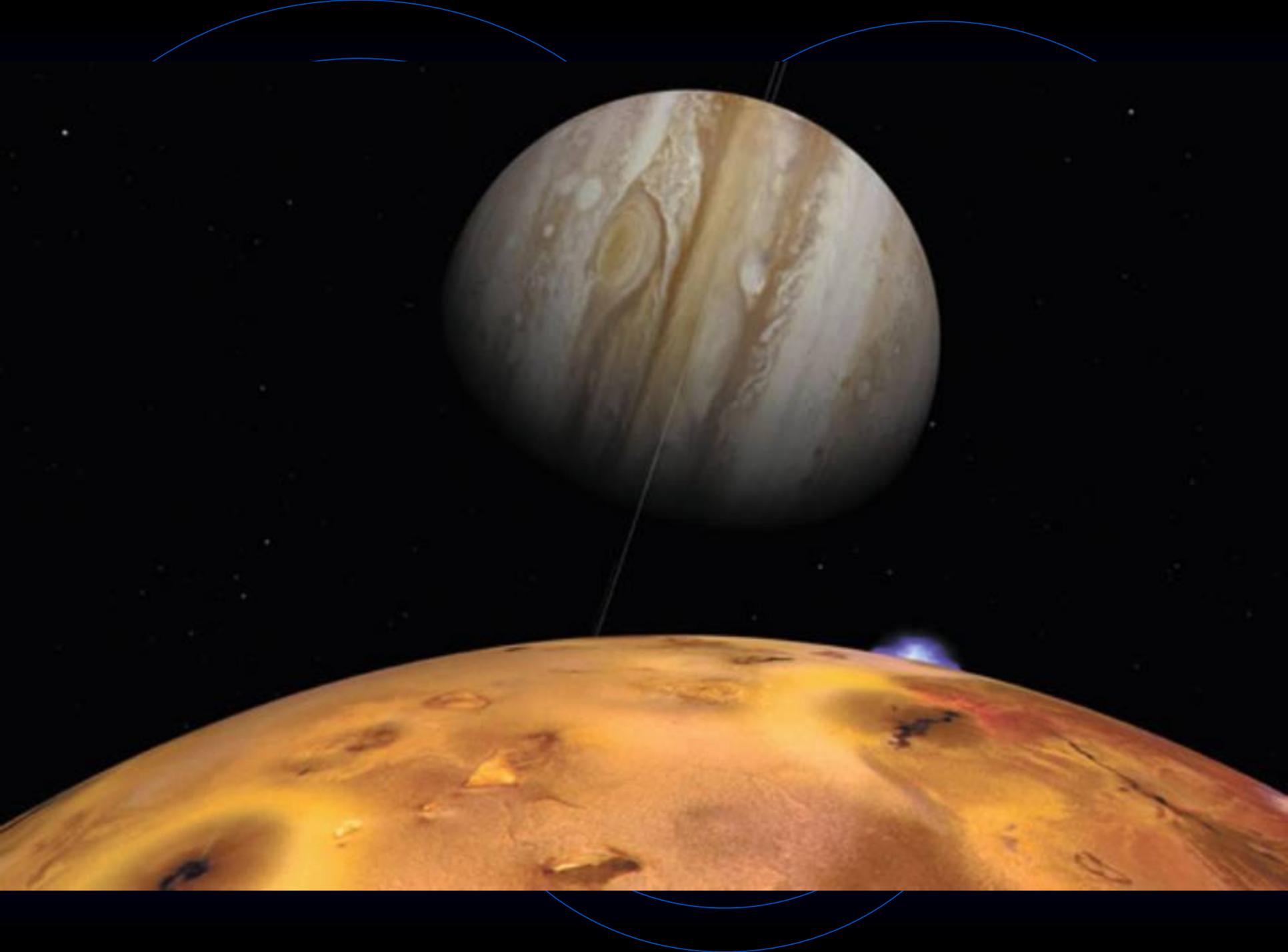


Figure 18-6

(a) The main ring of Jupiter, illuminated from behind, glows brightly in this photo made by the Galileo spacecraft from within Jupiter's shadow. (b) Digital enhancement and false color reveal the halo of ring particles that extends above and below the main ring. The halo is just visible in part a. (NASA)



Gas Giants – Jupiter's Moons

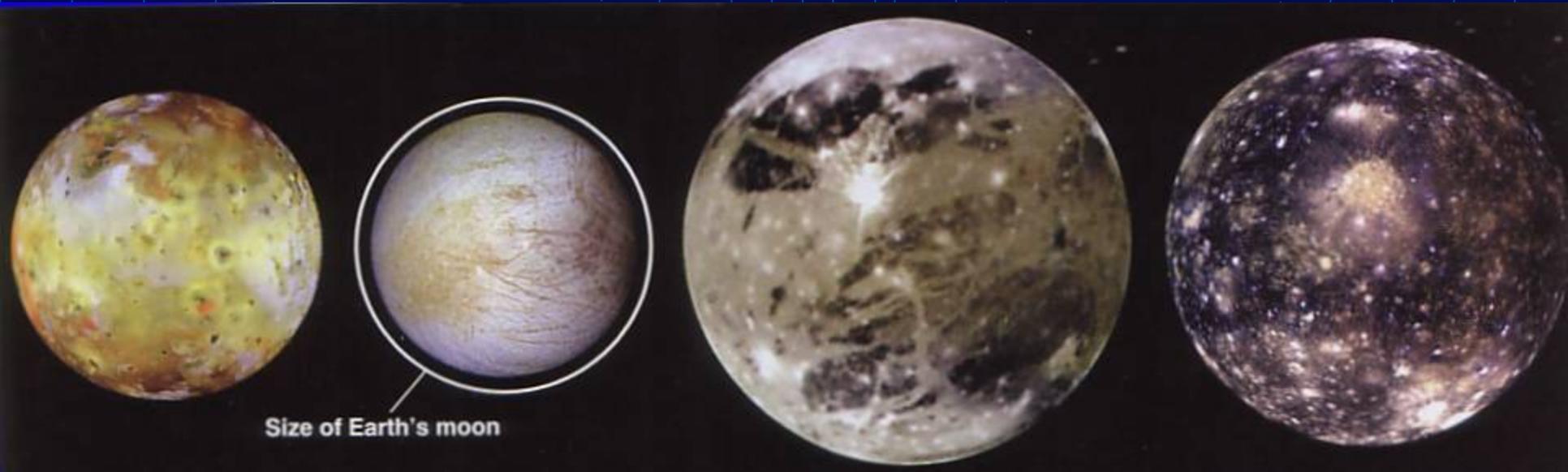
- Jupiter has 63 (currently) moons (captured asteroids)
 - 47 are < 10 km (or 6 miles)
- 4 of these are the Large Galilean Moons:
- The outermost is Callisto (1.5x Earth's Moon)
next frames
 - Low density 50/50 ice/rock
 - Mineral rich liquid water ocean 100km below it's crust
- Next in is Ganymede **next frames**
 - Similar density
 - Darker surface
 - Grooved terrain – faults in a brittle crust

Gas Giants – Jupiter's Moons

The outermost is Callisto (1.5x Earth's Moon) **next frames**

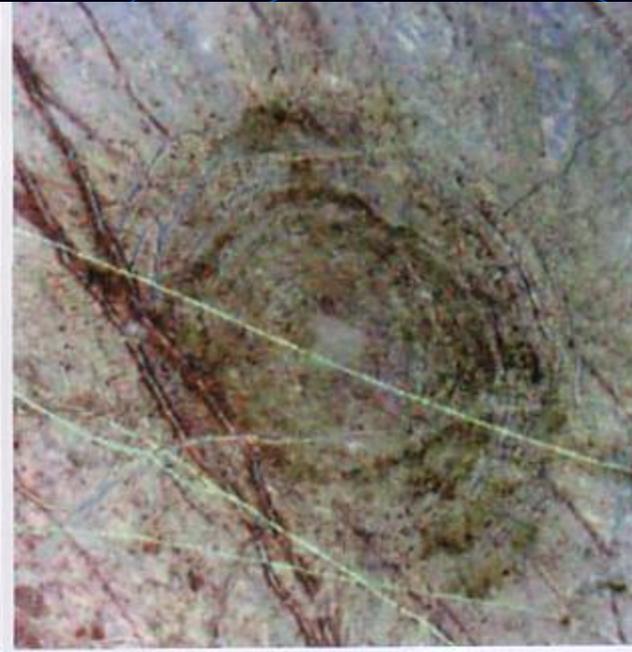
- Europa **next frames**
 - Denser = mostly rock with thin icy crust
 - Surface is very clean ice with cracks
 - Tidal stresses may heat and liquefy the water below (life?)
- Io **next frames**
 - Geologically active = volcanoes
 - Tidal stresses high
 - Surface remade by the volcanism over time

Io, Europa, Ganymede, Callisto



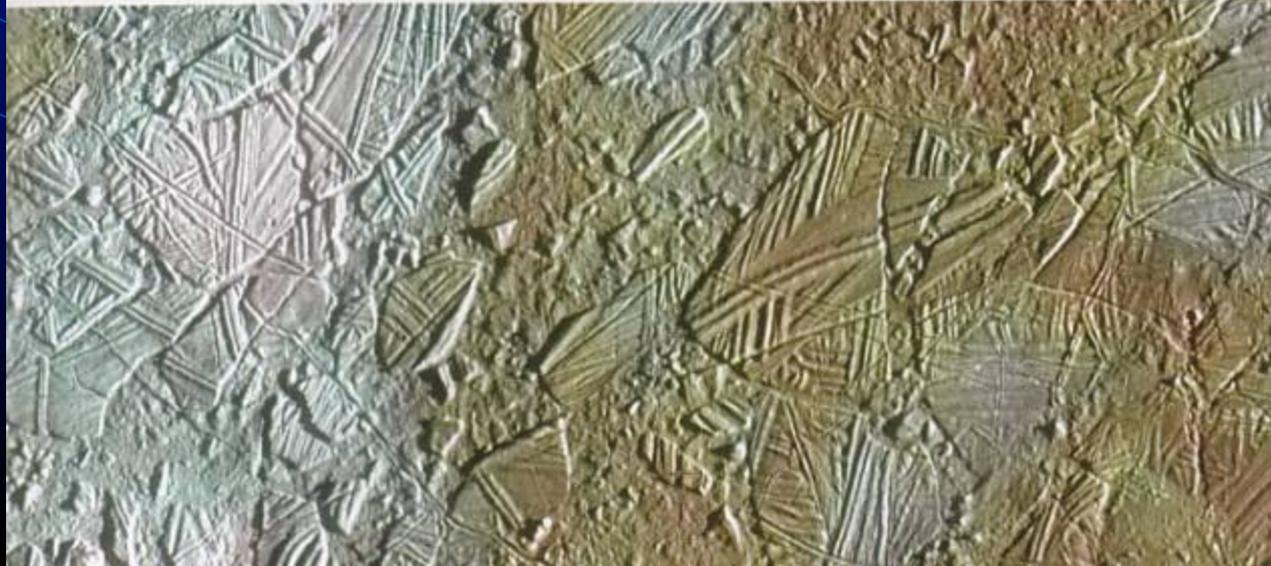
Size of Earth's moon

Europa in Detail

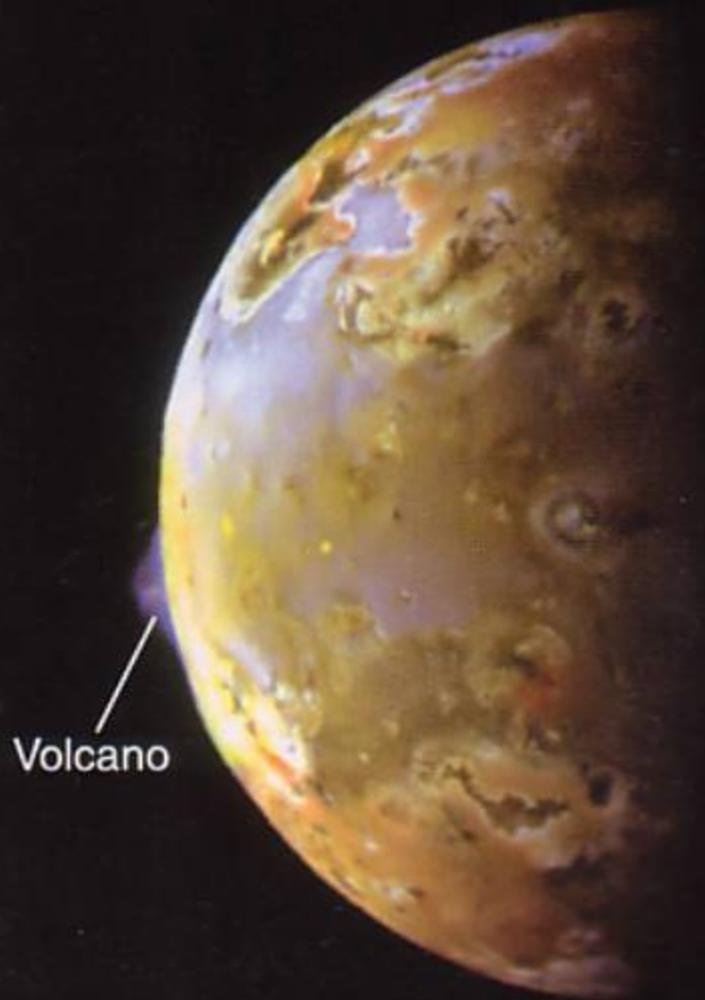


a

b



Io in Detail



Volcano

Enlarged view



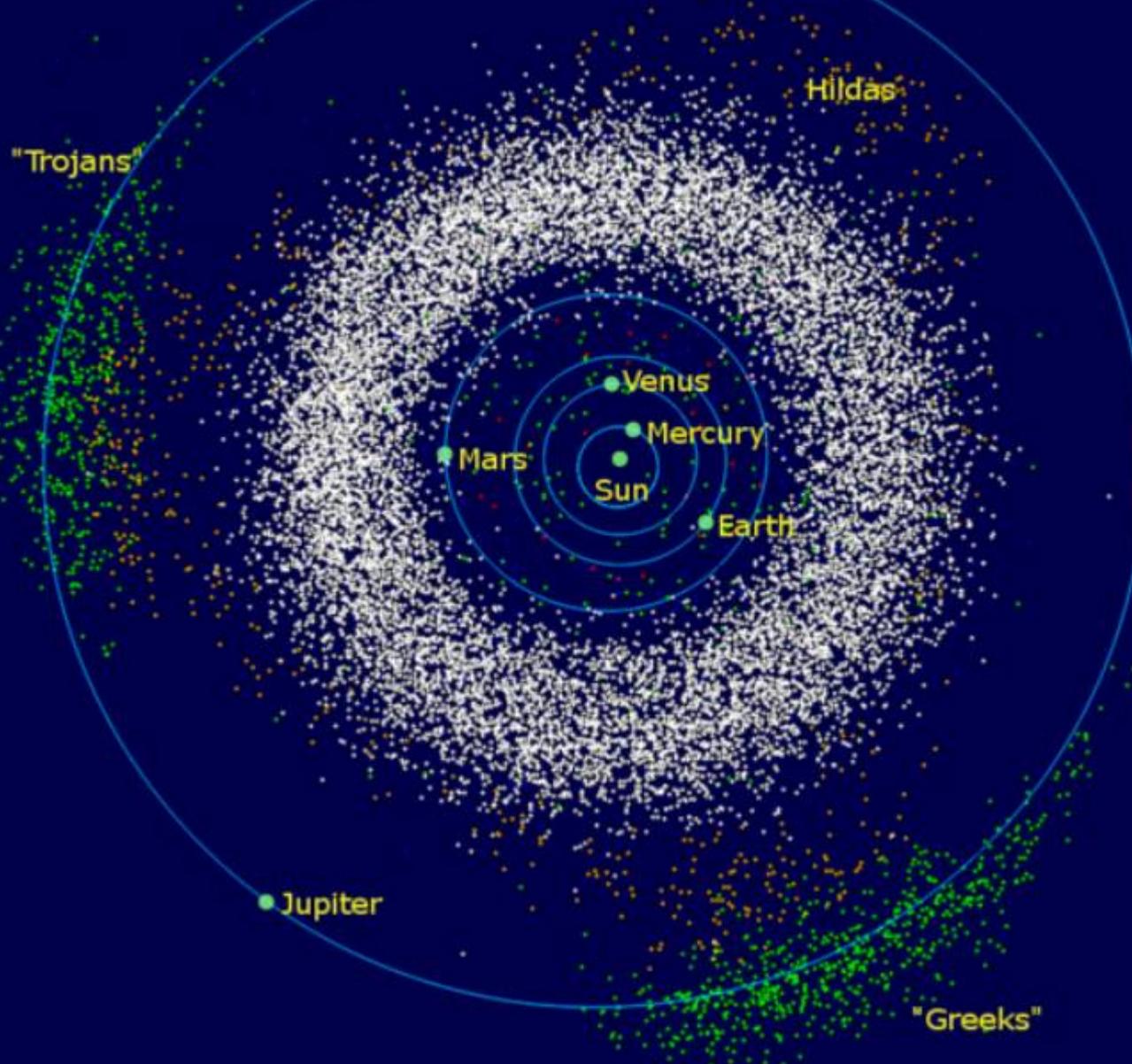
Prometheus from above

Juno Spacecraft Arrives August 2016



Microwave radiometer, Jovian Infrared Auroral Mapper, Advanced Stellar Compass, Jovian Auroral Distribution Experiment, Jovian Energetic Particle Detector Instrument, Radio and Plasma Wave Sensor, Ultraviolet Imaging Spectrograph, JunoCam

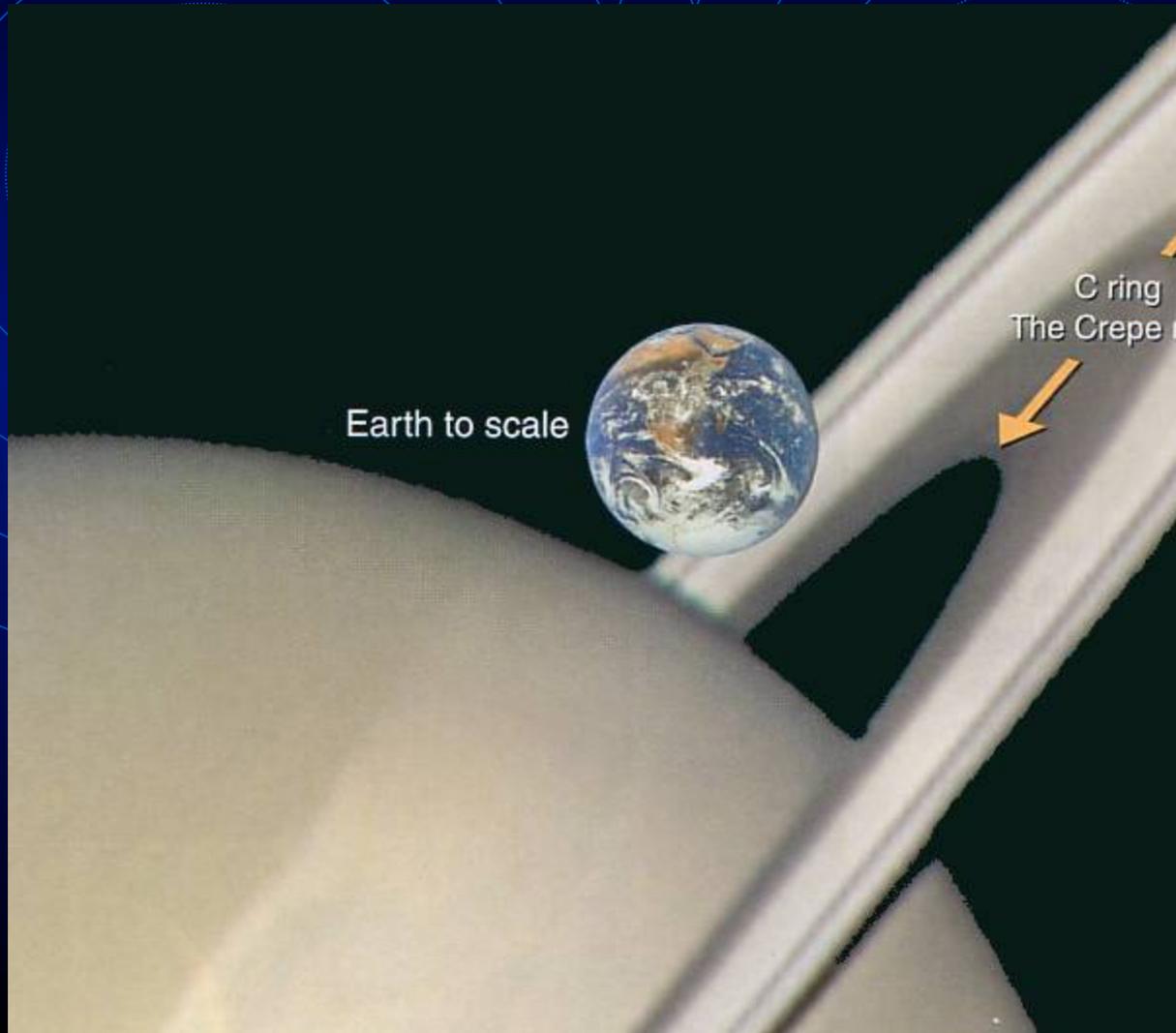
Jupiter and Rocks



Saturn

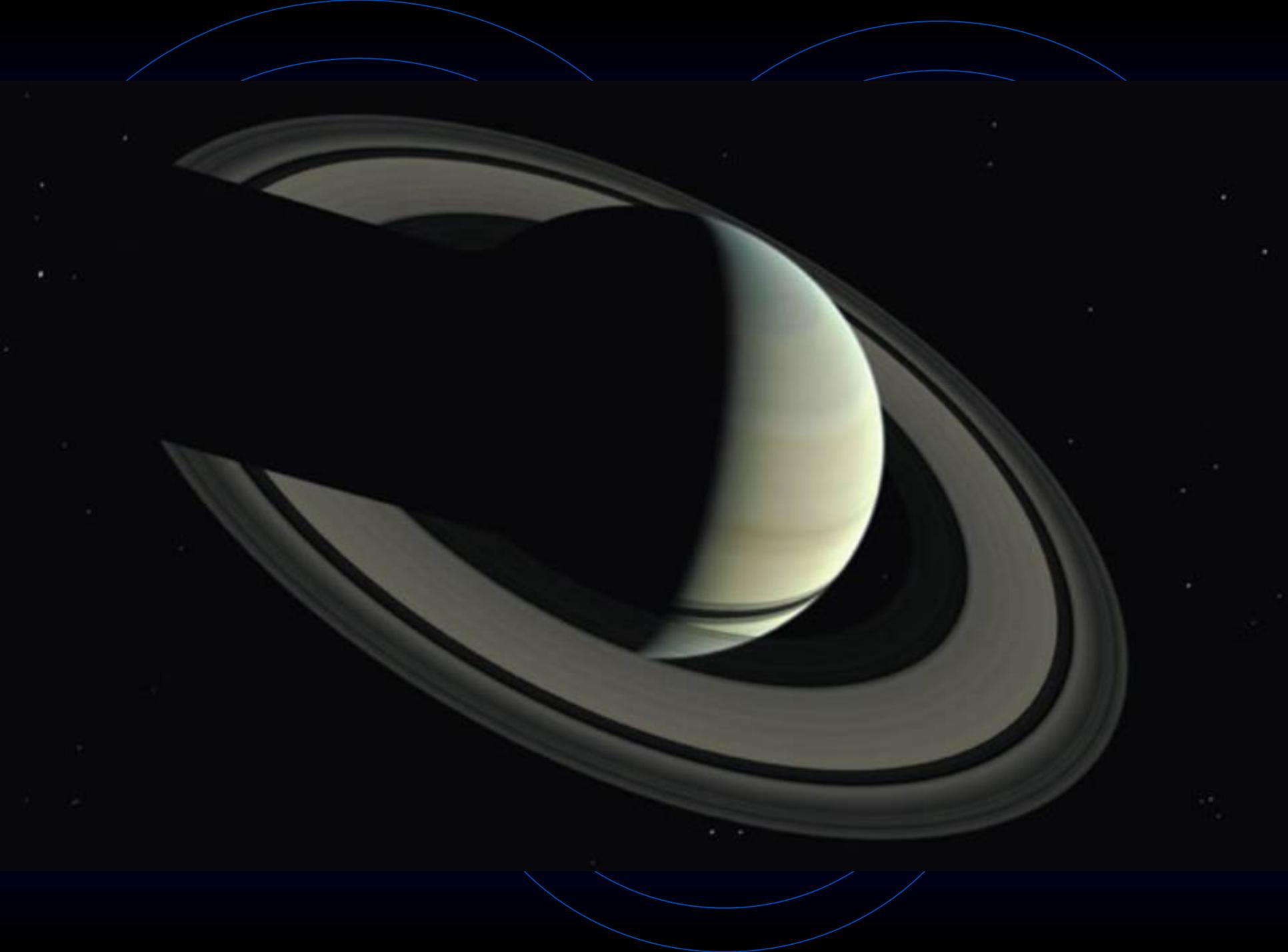


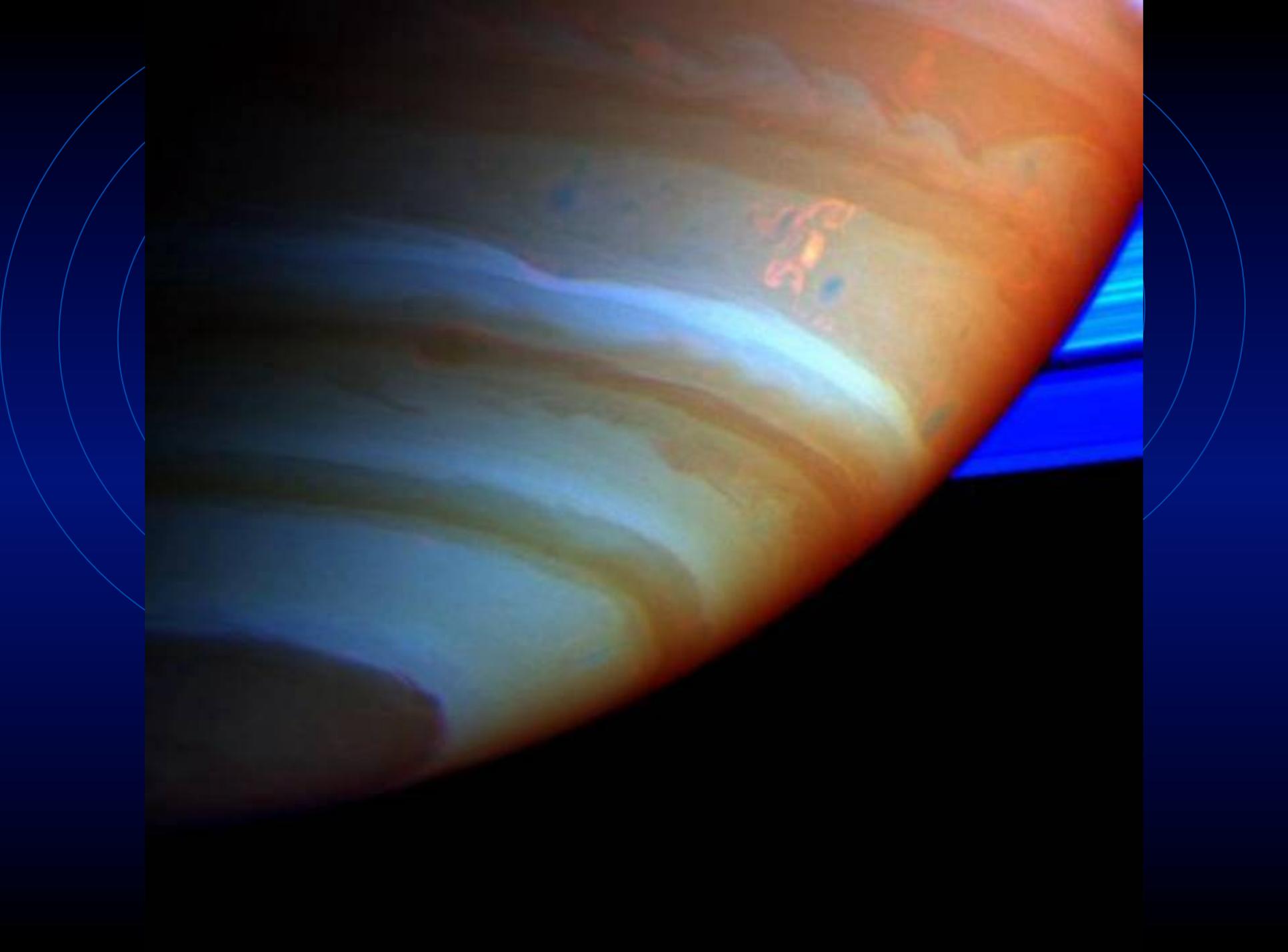
Saturn to Scale



Saturn

- The Planet with RINGS!
 - First seen by Galileo – Planet with Ears (secret)
 - Smaller core of metallic hydrogen = 20x weaker magnetic field than Jupiter
 - Possible cloud structure H₂, Methane, Ammonia, Ammonia Hydrosulfide, Water
 - Density is less than that of water! (mostly hydrogen – gas and liquid)

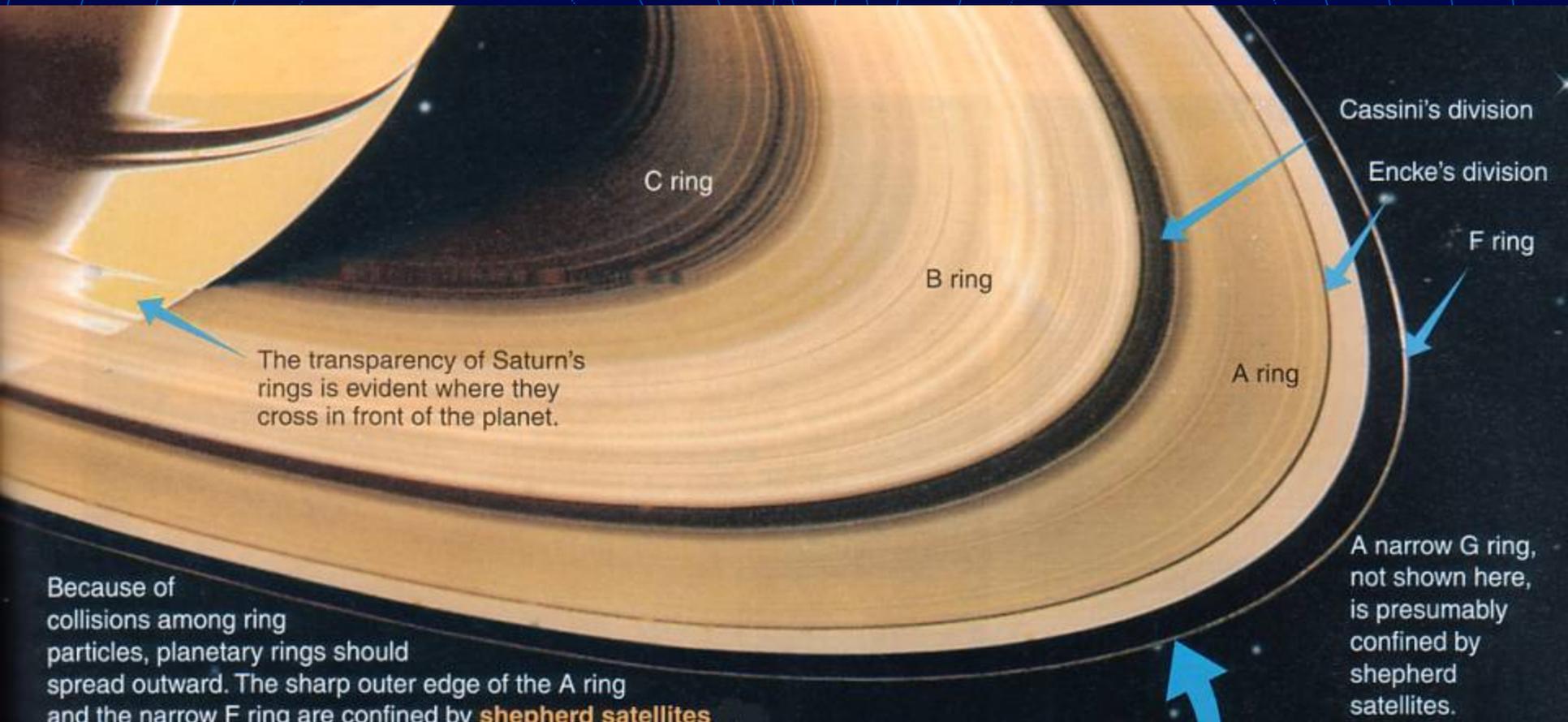


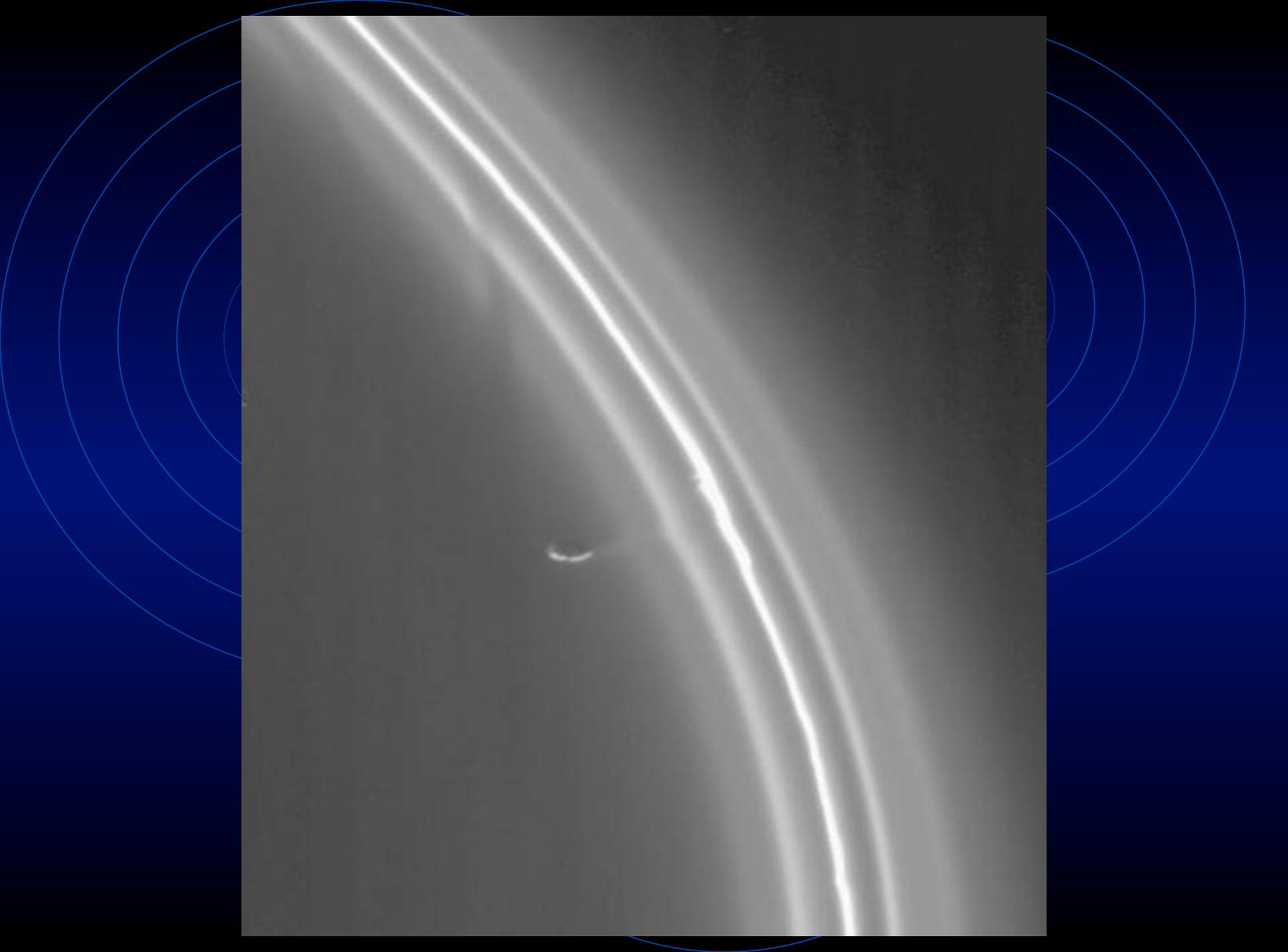


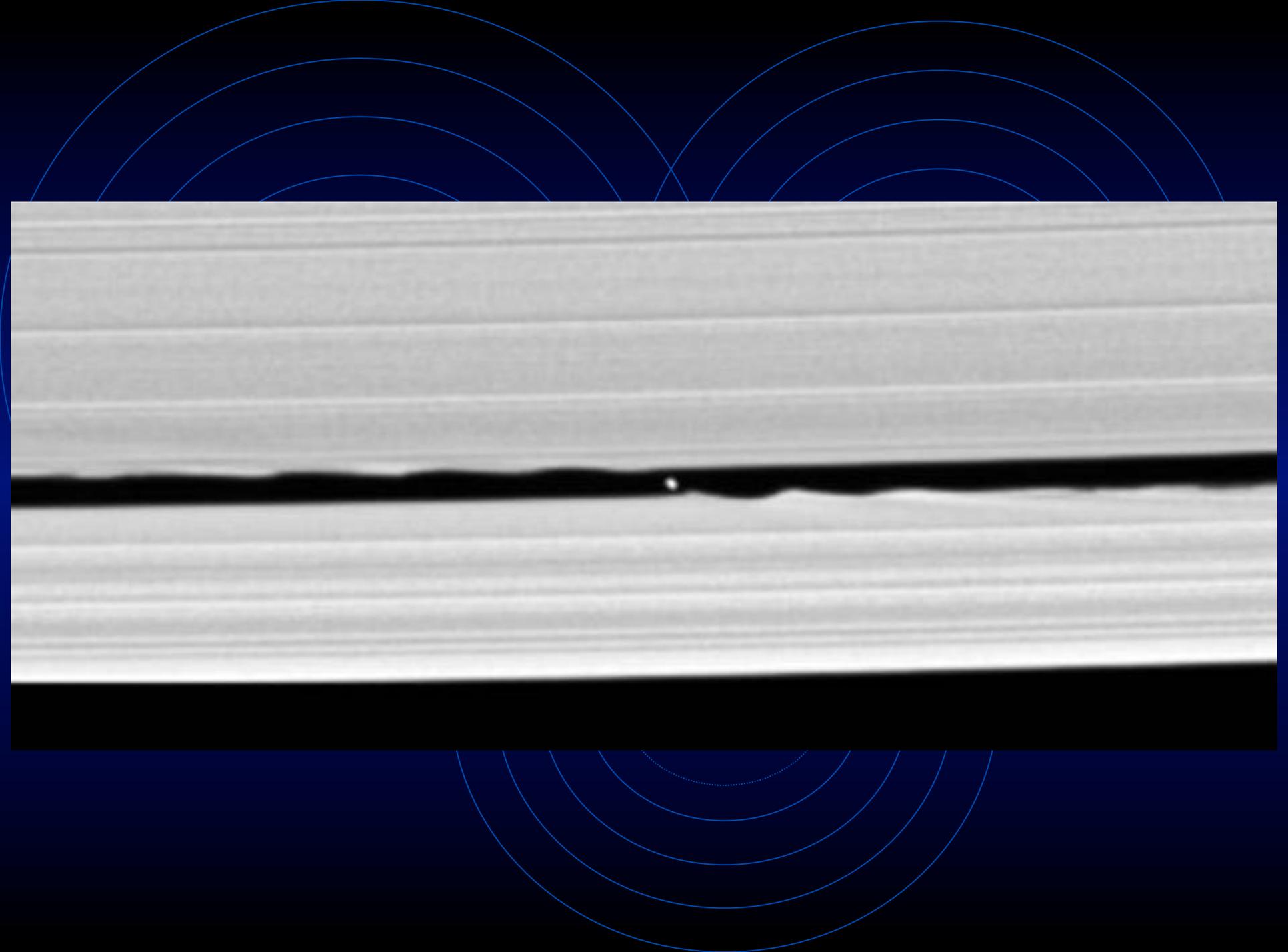
Saturn

- RINGS
 - Made up of 1000's of ringlets
 - Very bright – bright as snow – frozen gasses
 - Shepherd satellites corral lanes open (integral orbits with nearer moons)
 - Rings must be young, 100 million years = darkened
 - Must be replenished every few 10's of millions of years by comets (?!)
- Cassini spacecraft on its way (probe to moon Titan) [2004]

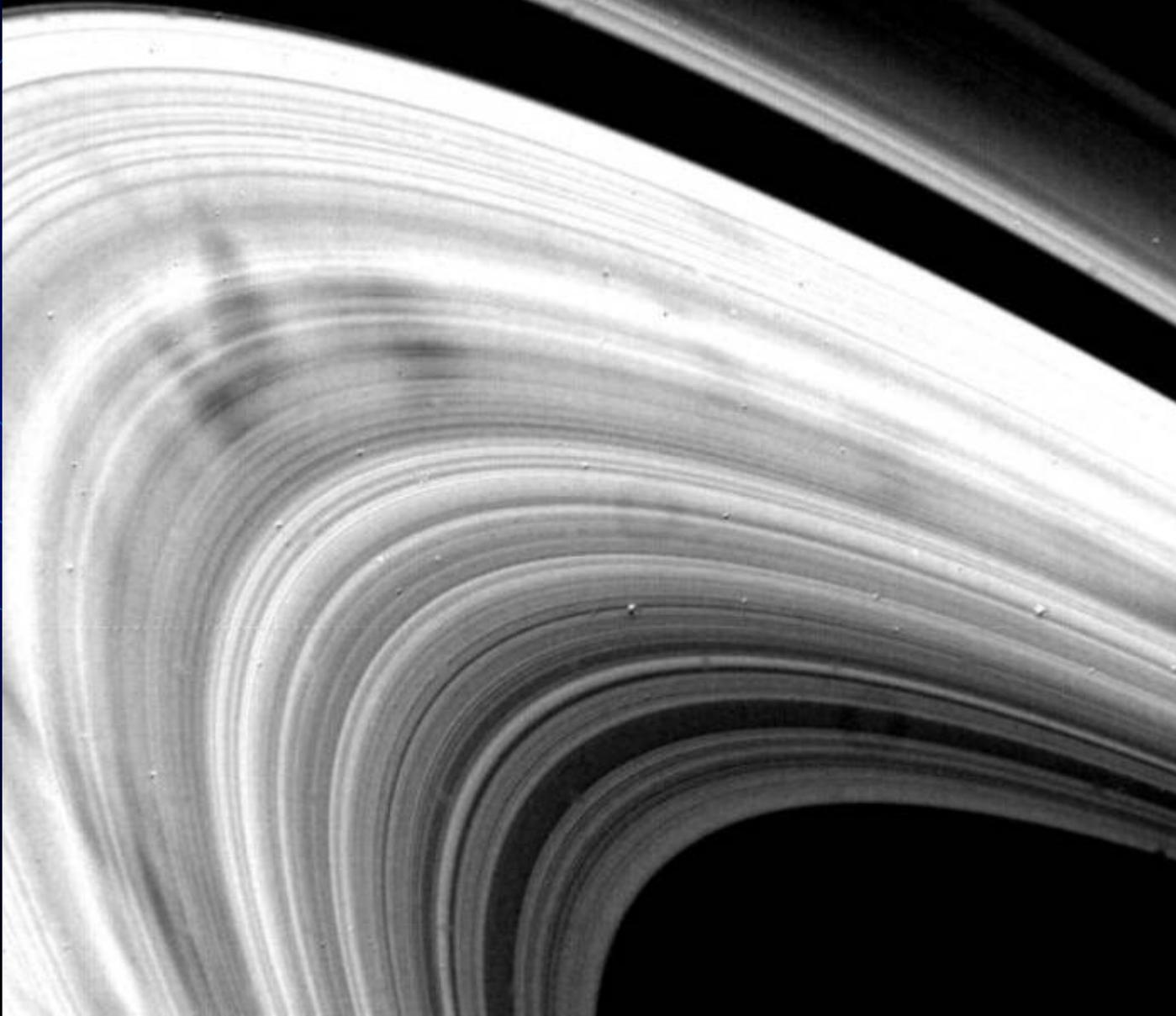
Saturn's Rings







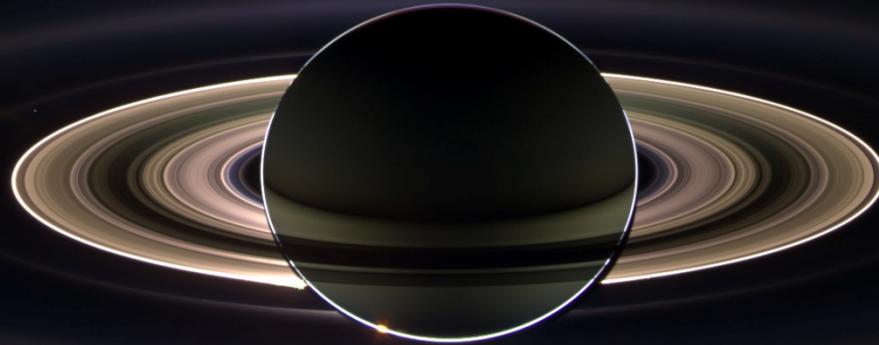
Strange Spokes (Voyager 2)



Ring Swimming



Saturn in Eclipse — Can you find the Earth?

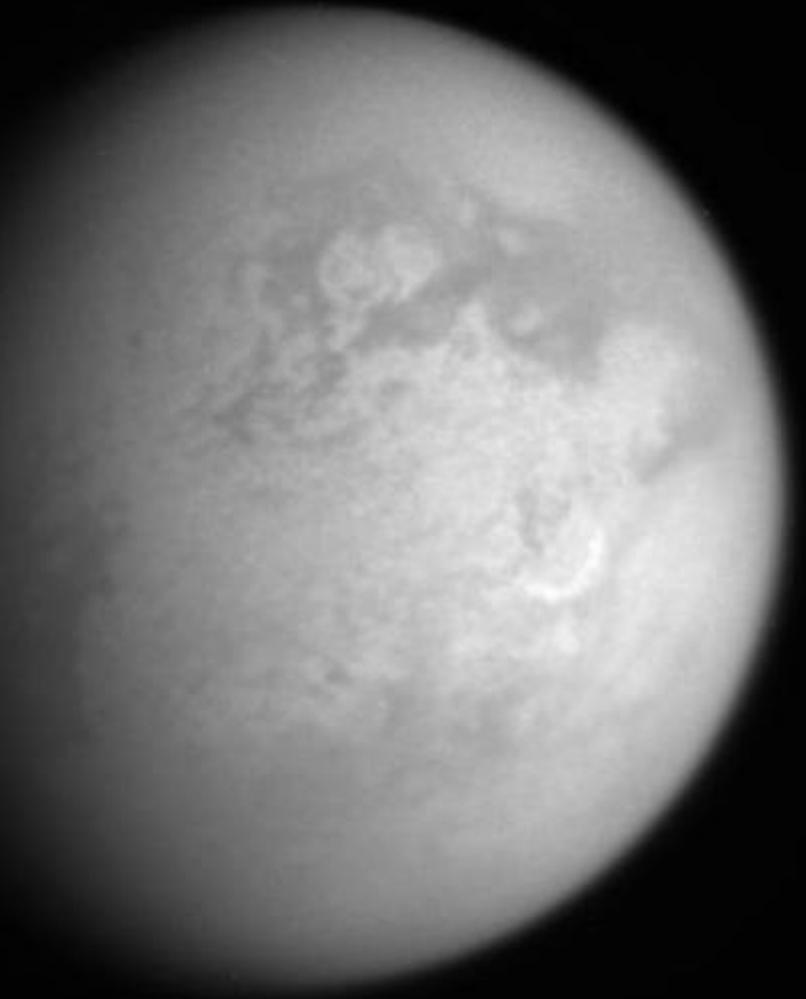


Saturn's Moons

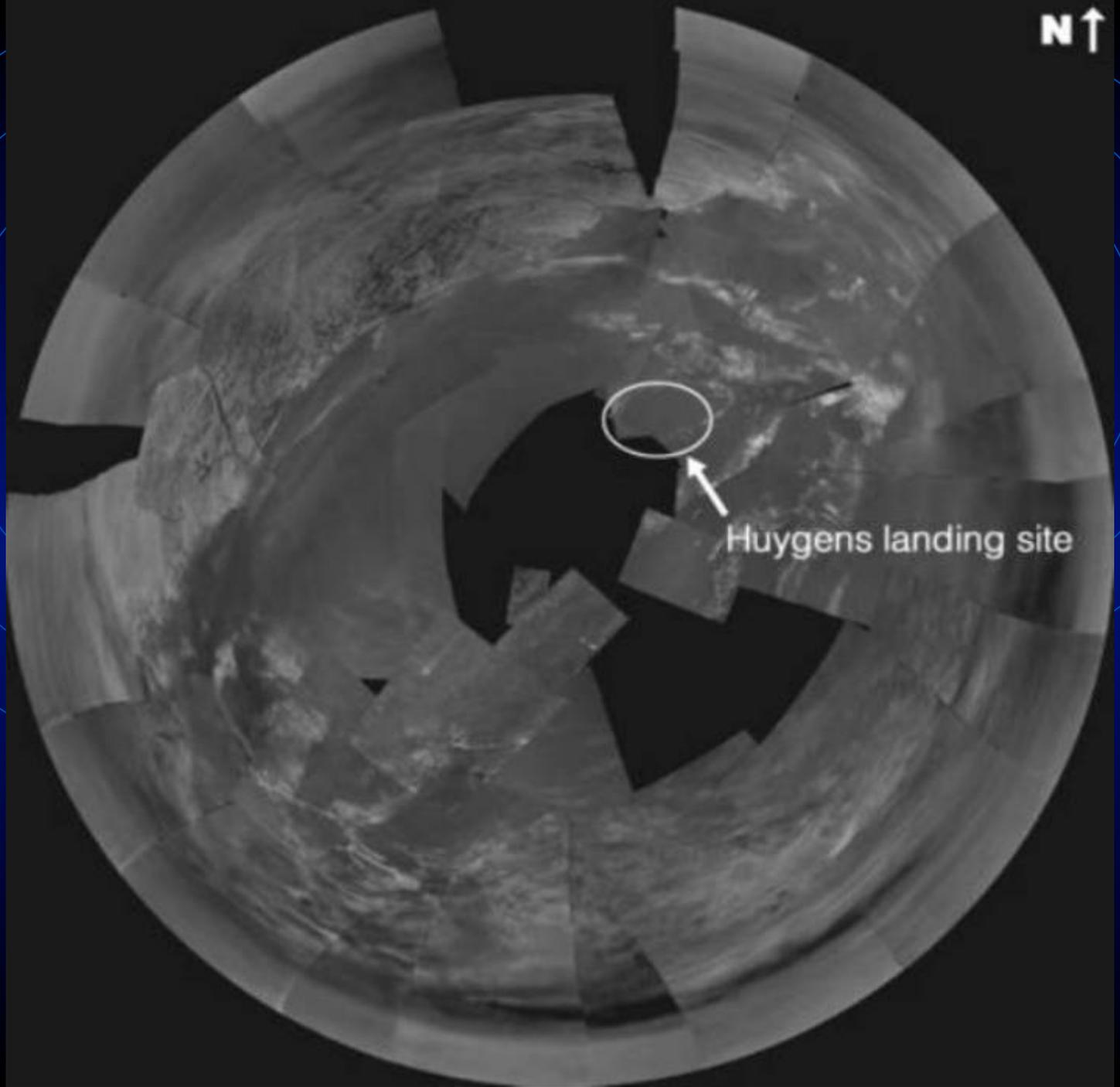
- Titan – largest Moon in the Solar System
 - A few % larger than the planet Mercury!
 - -290deg F surface
 - Atmosphere! 90% N₂ and 10% Argon, Liquid methane, ethane
 - Organic smog (hydrocarbons) from sunlight
 - Inverse Greenhouse – smog keeps light out lets IR leave (cooler and cooler)
 - The rest of the moons (60 to 63) are smaller, airless, largely ice and rock- show evidence of expanding when they froze (cracks) some might be captured asteroids

Cassini-Huygens

- Titan

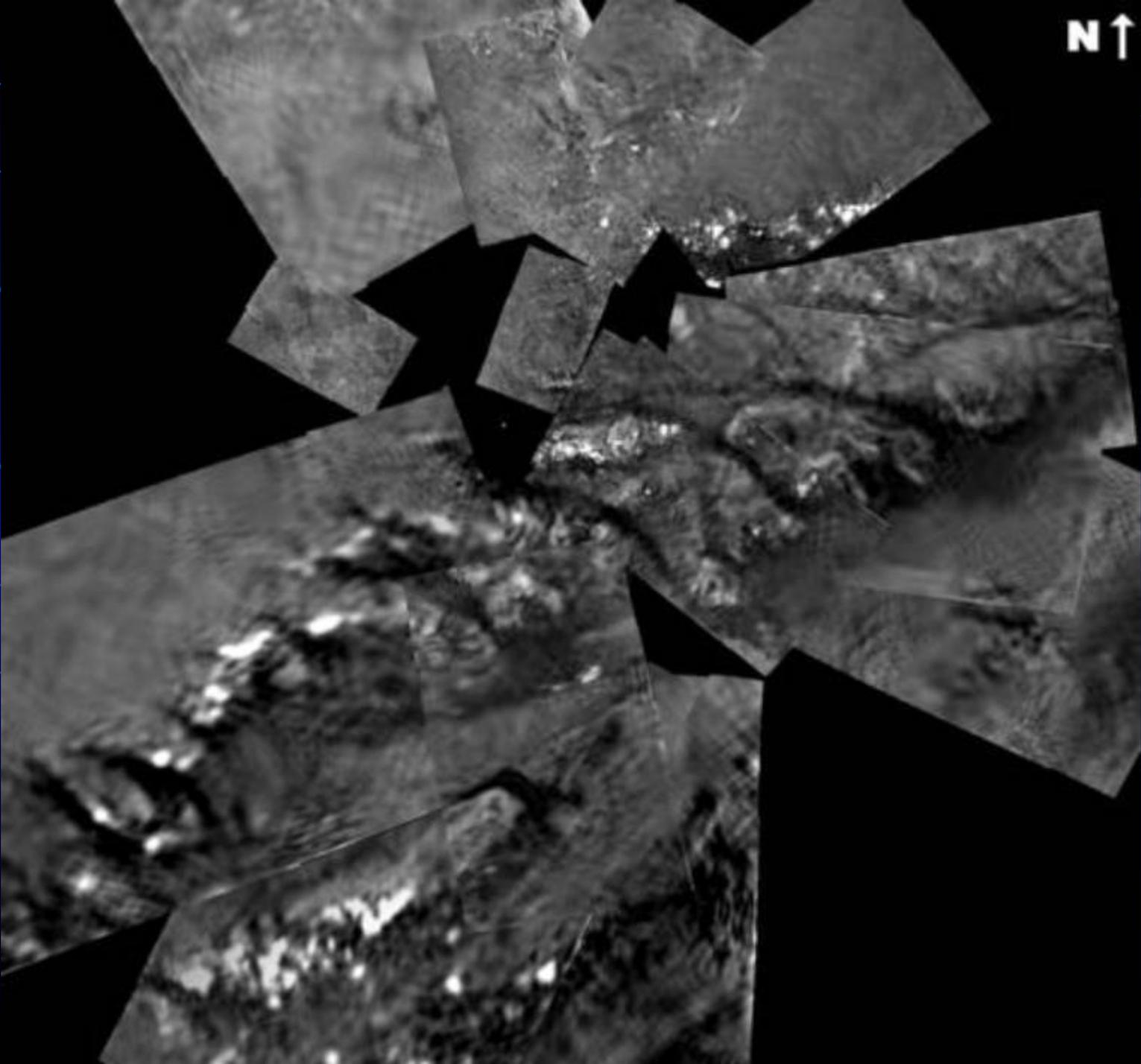


N ↑

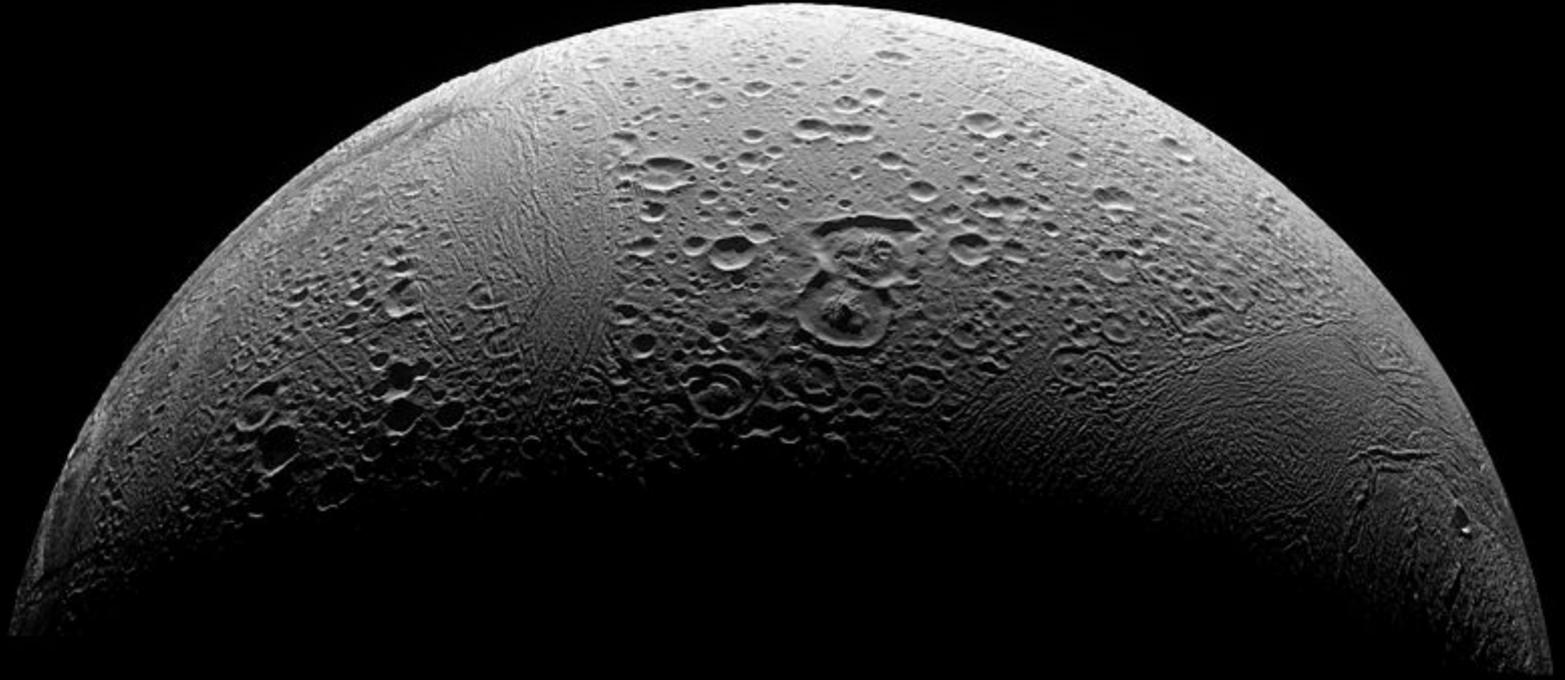


Huygens landing site

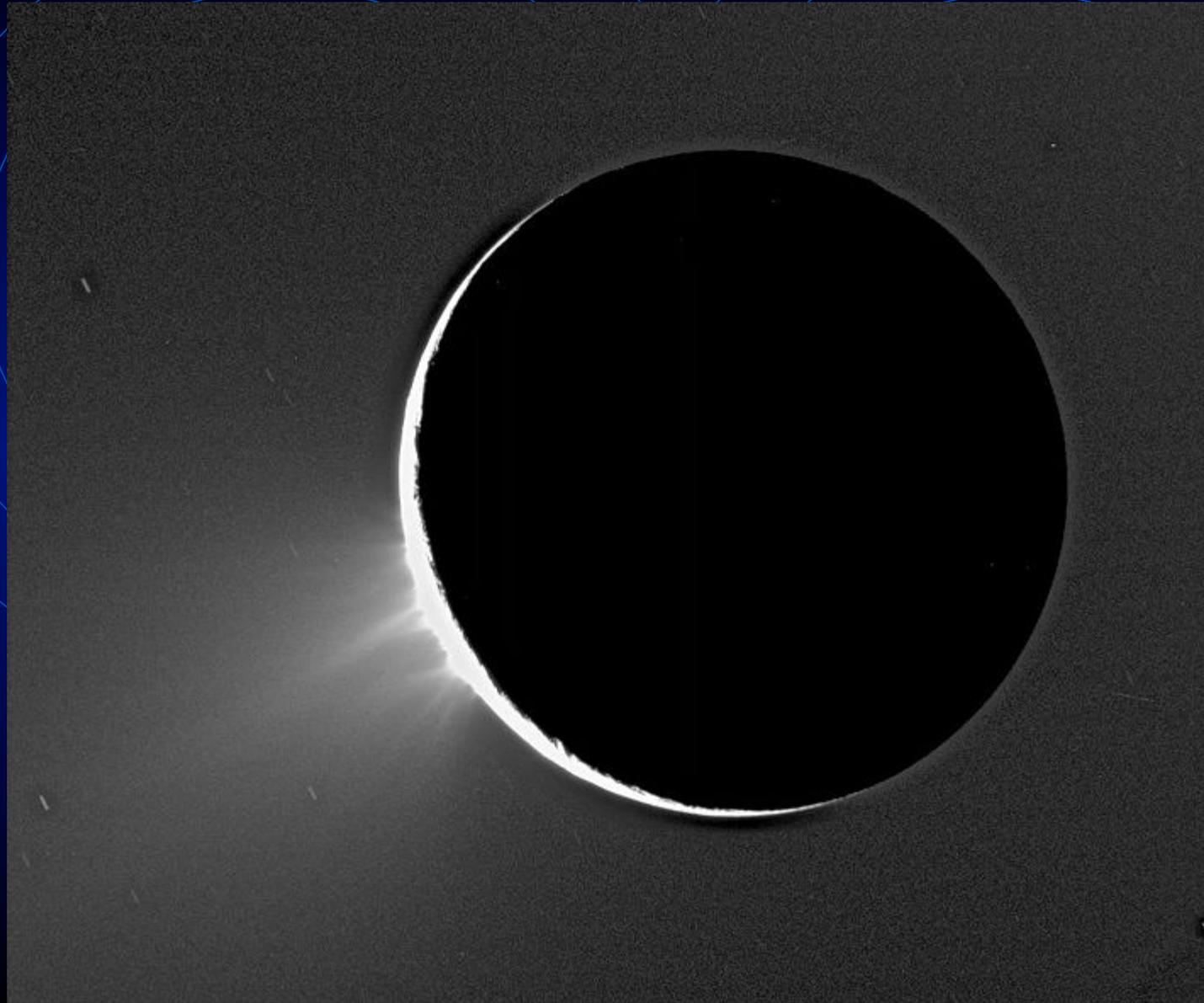
N ↑



Enceladus

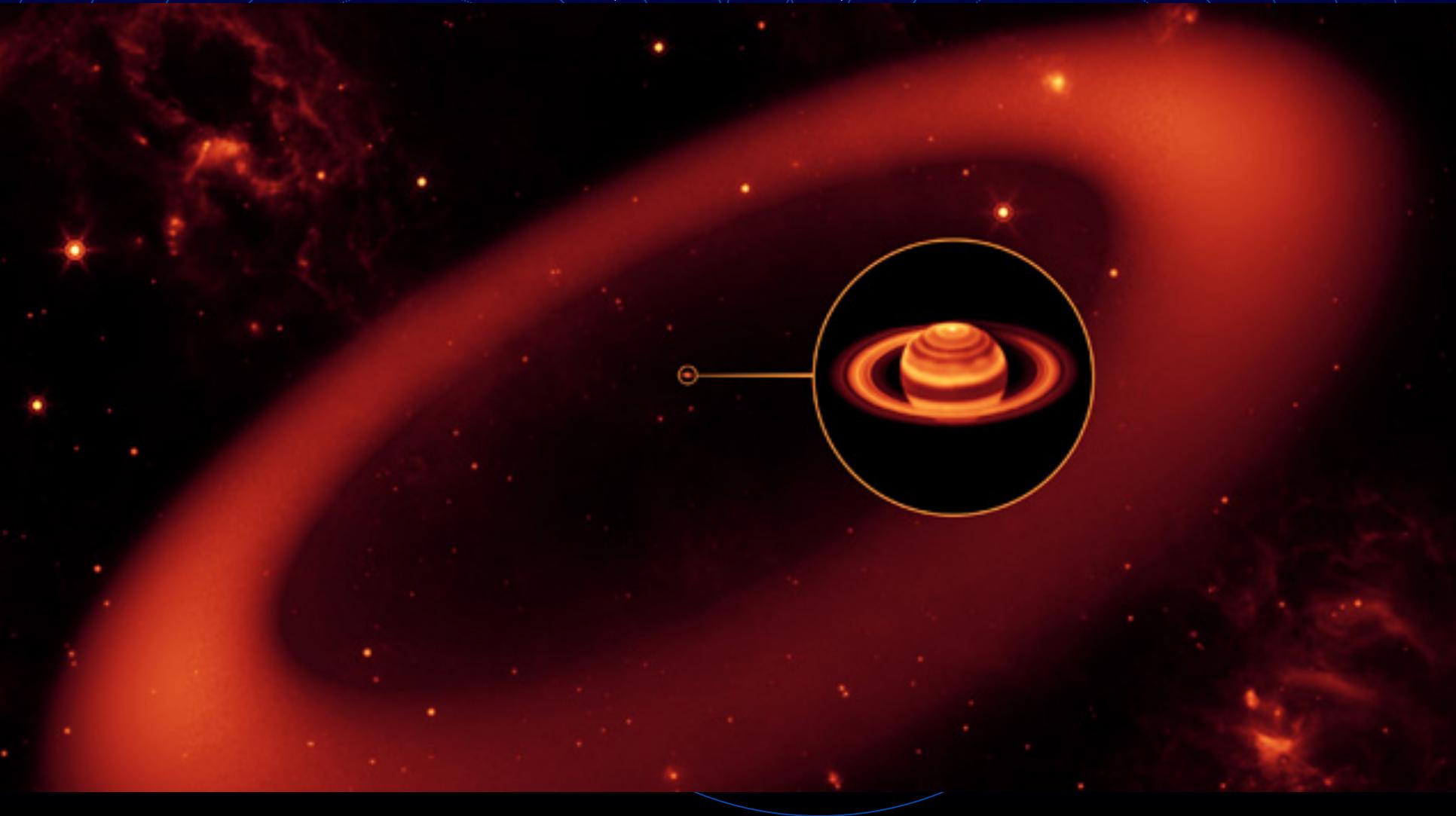


The Geyser - Cryovolcanism

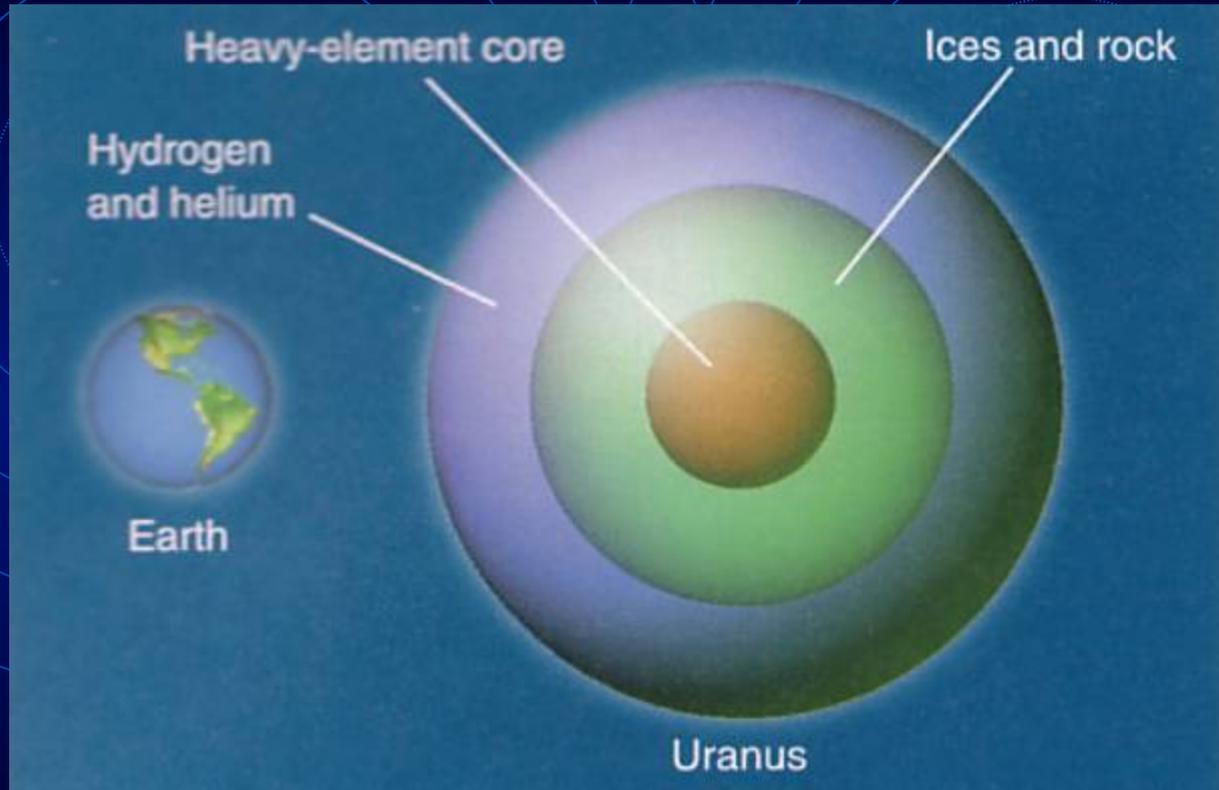


Phoebe + New Ring!

(not “Friends”)

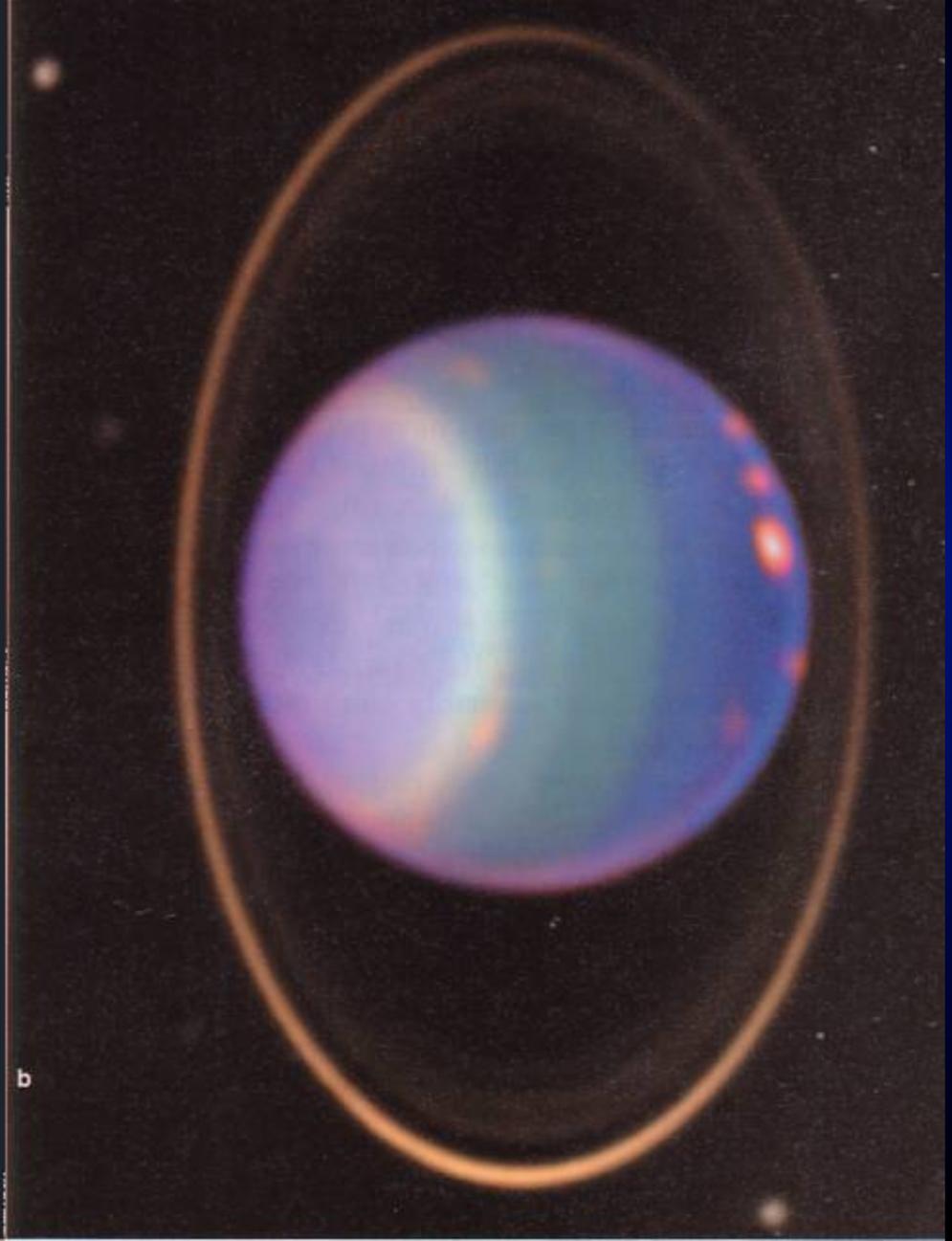
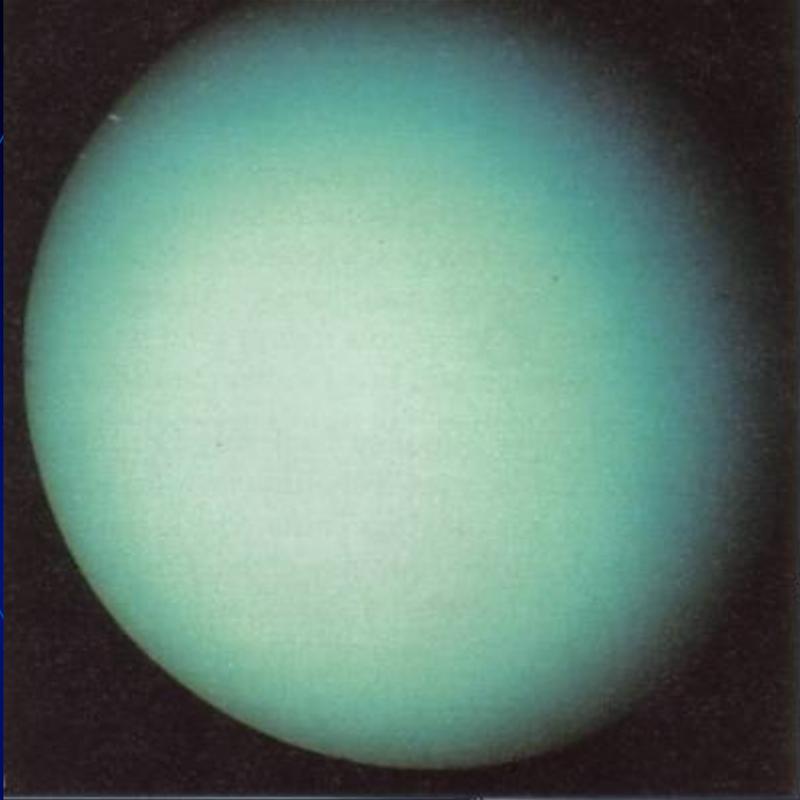


Uranus



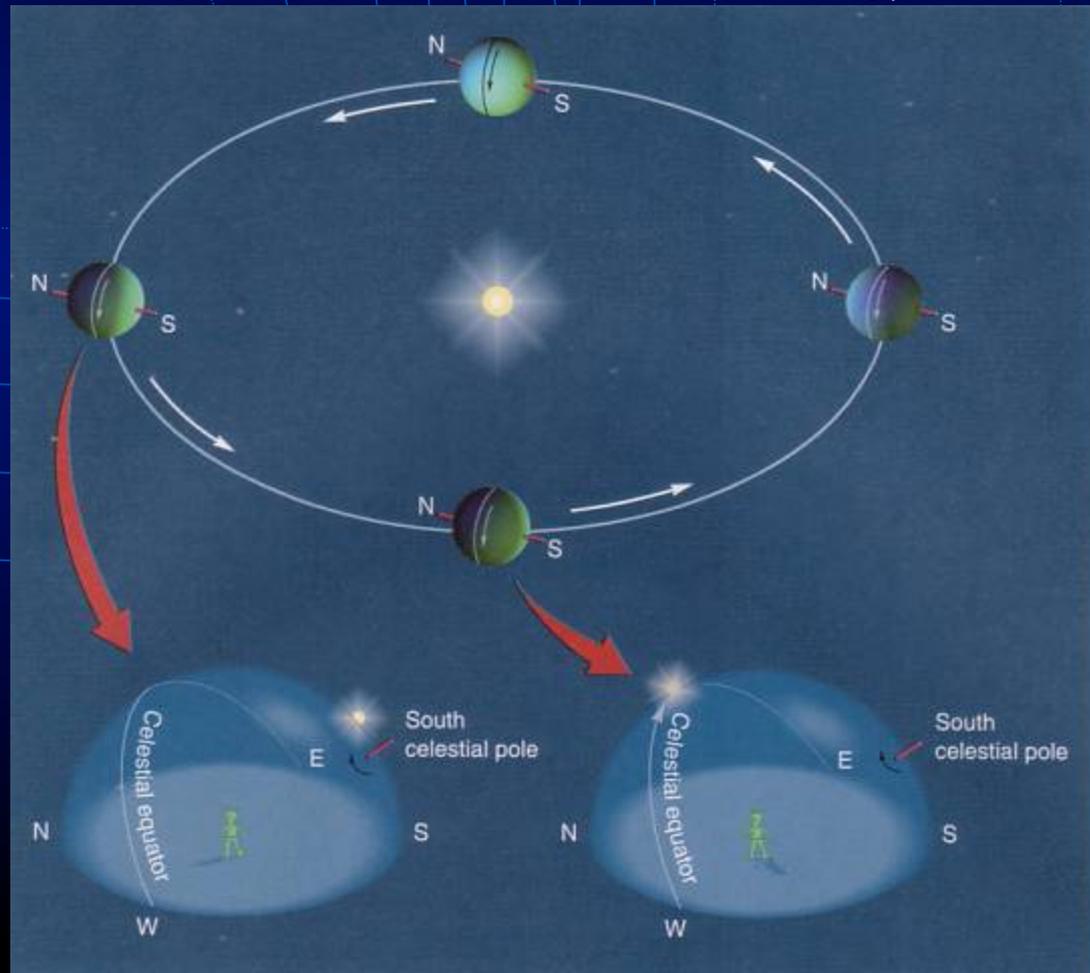


Uranus



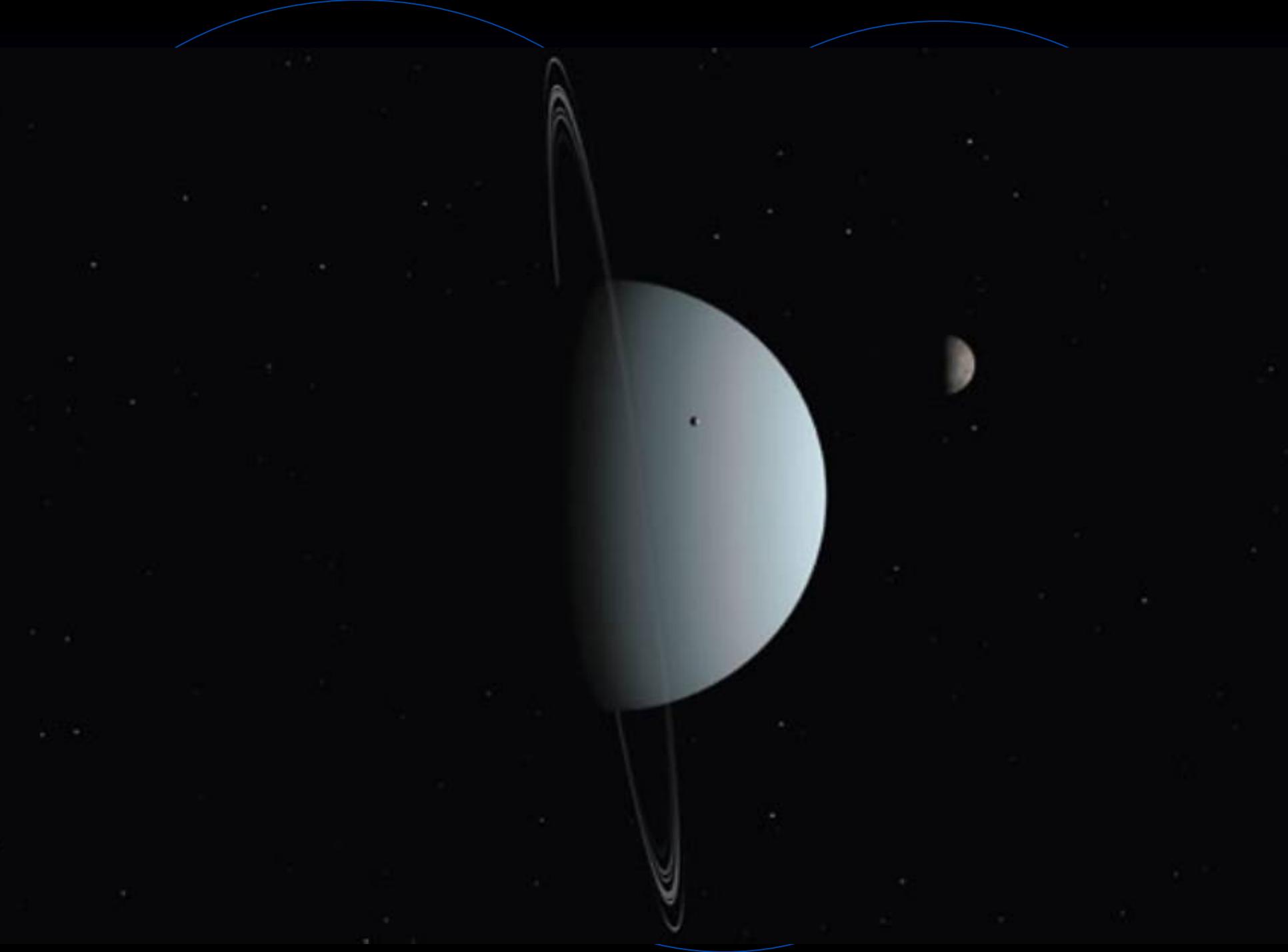
Uranus

- You-ran-us (not correct but safe 😊)
- Discovered by accident (wrong place right time)
- 1/3rd the diameter of Jupiter, 100 deg C colder
- Uranus rotates on its side (inclination of 98 deg)

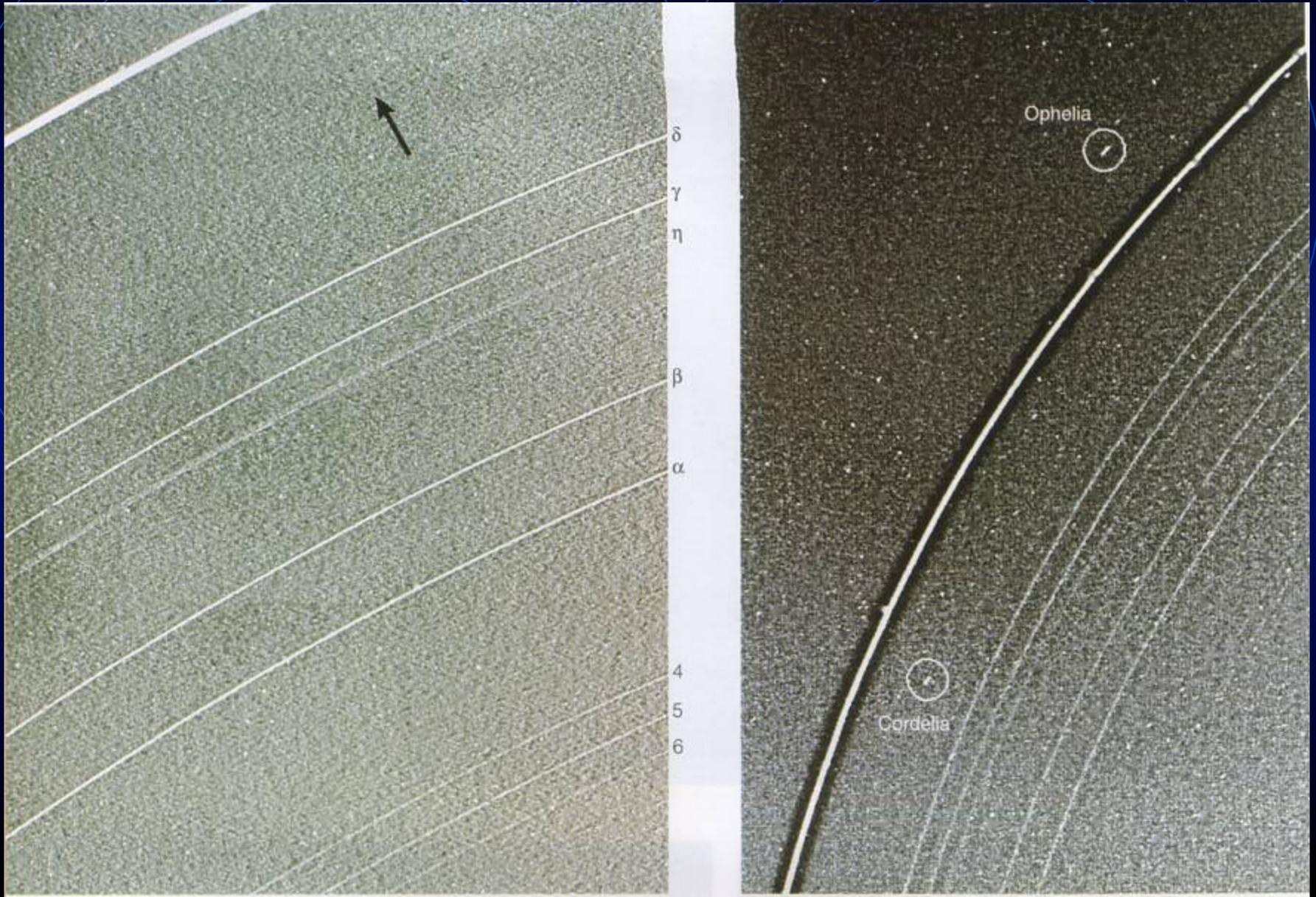


Uranus Details

- Revolves around the sun in 84 years
- Each season lasts 21 years (pole, equator, pole, equator)
- Impact by a large planetesimal
- Hydrogen & Helium, water below that heavy element core (metal/rock)
- RINGS (100-1000x more substantial than Jupiter's- they have less mass than the material in Cassini's Division)
- Small moons are shepherding these rings



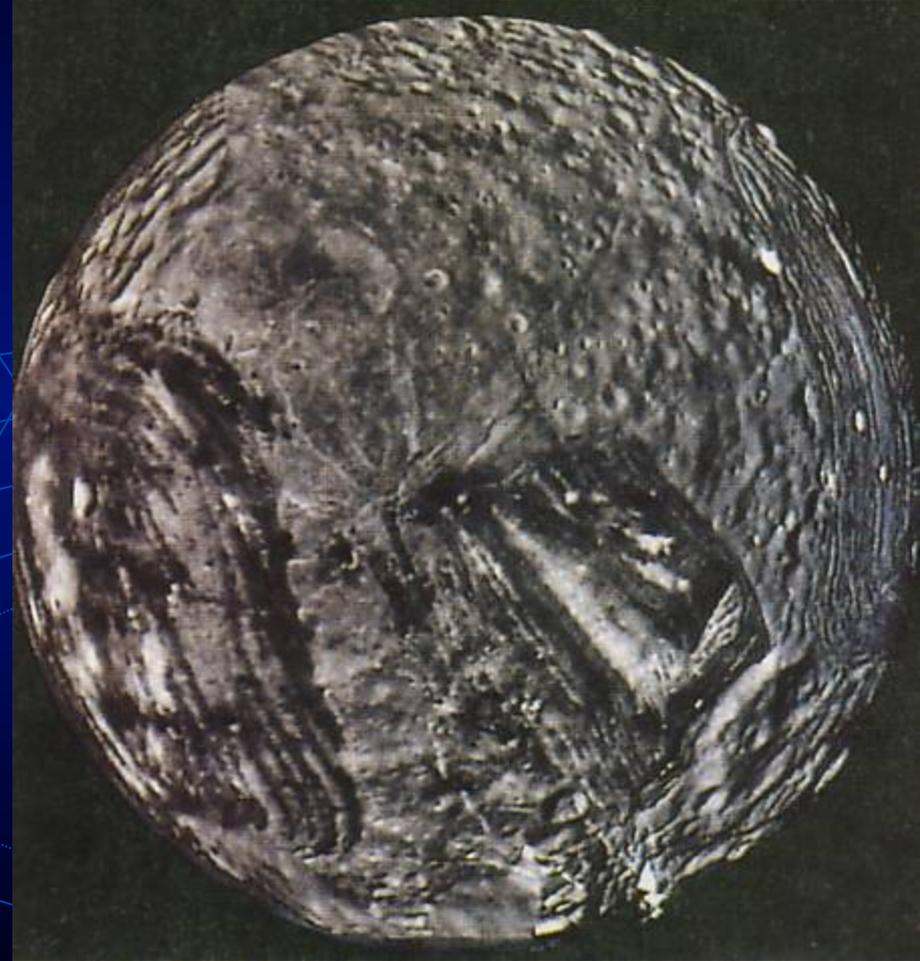
Uranian Rings



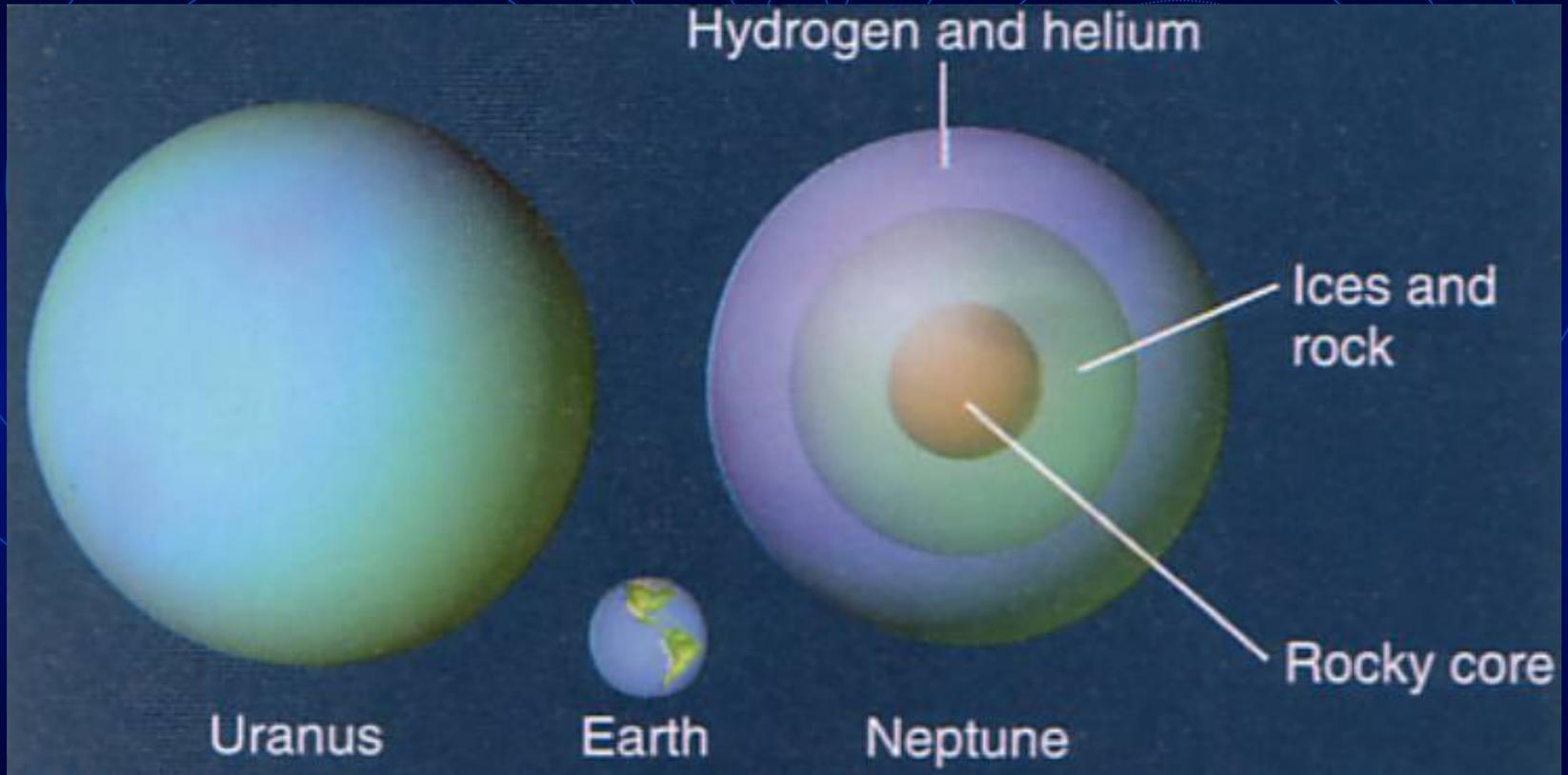
Uranian Moons

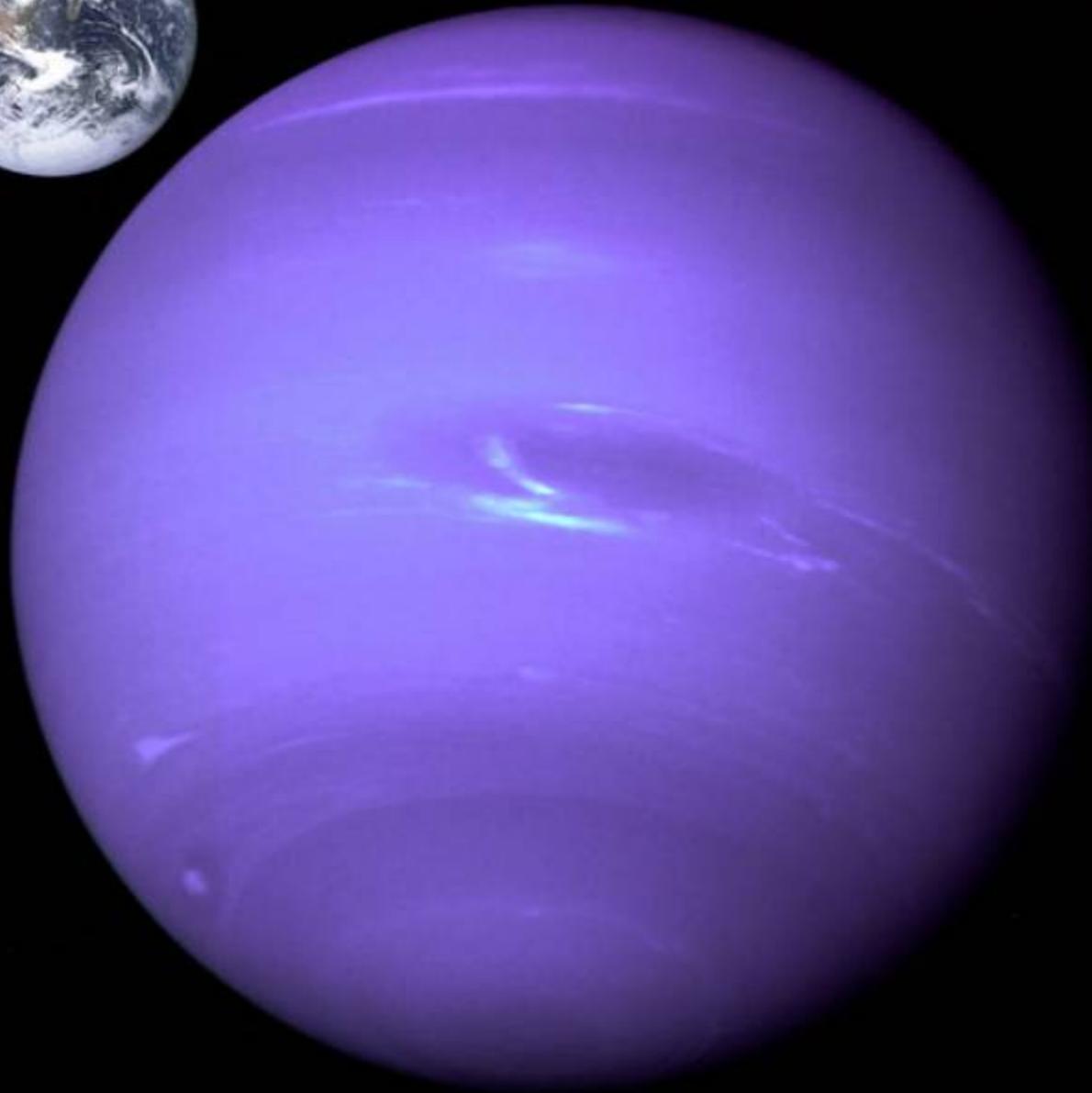
- 5 Major moons, 22 small moon/rocks
 - Oberon, Titania – old outer moons 45% Earth's Moon – they have faults and water 'lava' flows
 - Umbriel = 33% of Earth's Moon- just craters
 - Ariel = a bit smaller than Umbriel –flowing ice in lowlands (glacier like)
 - Miranda = 14% of Earth's Moon in size

The moons

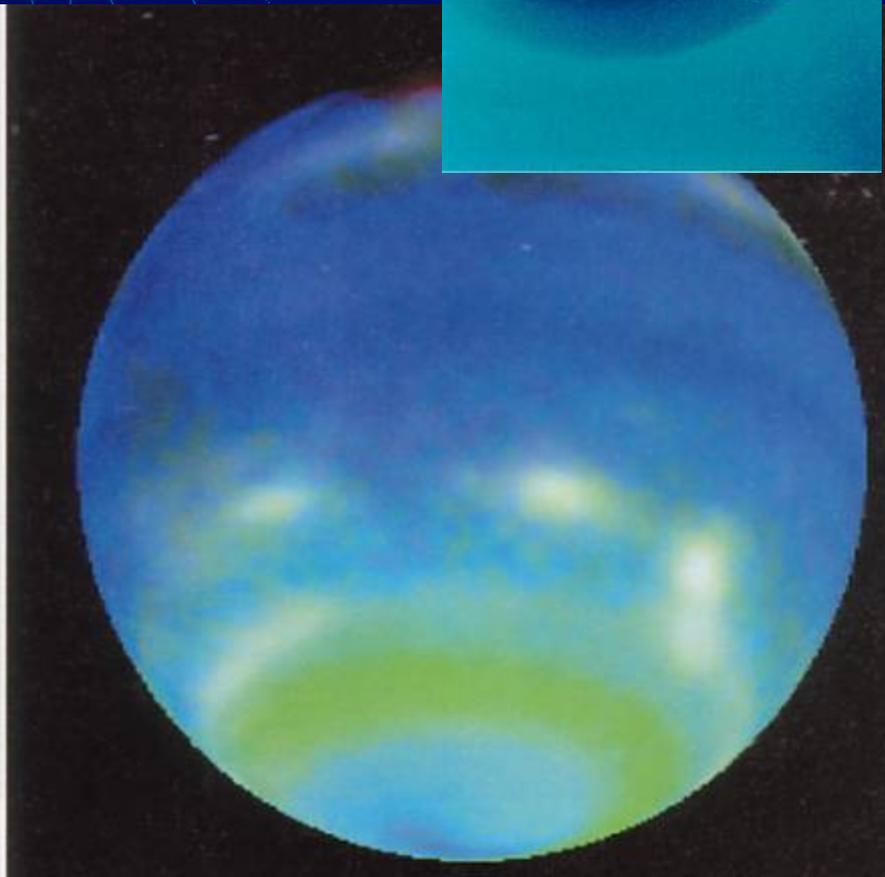
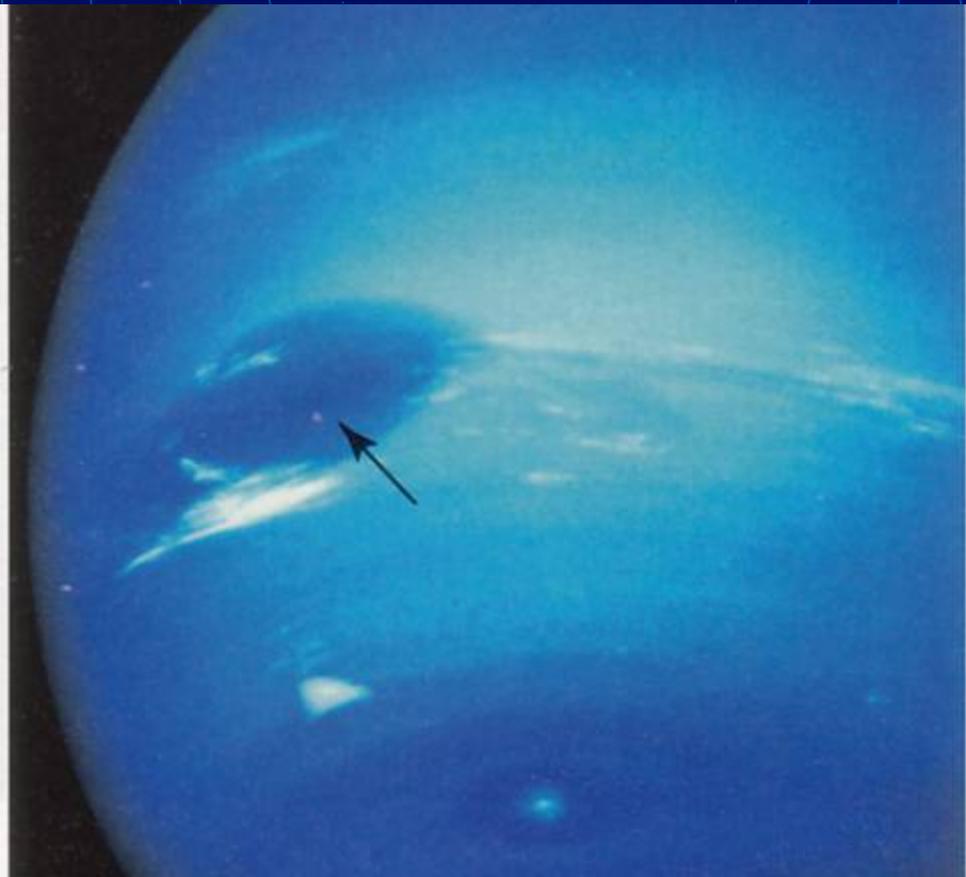
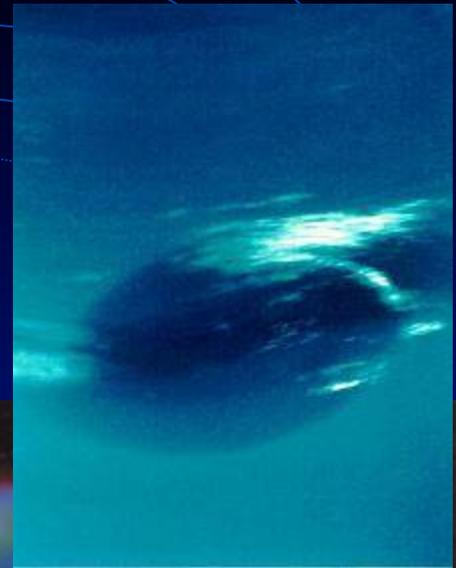


Neptune





Neptune



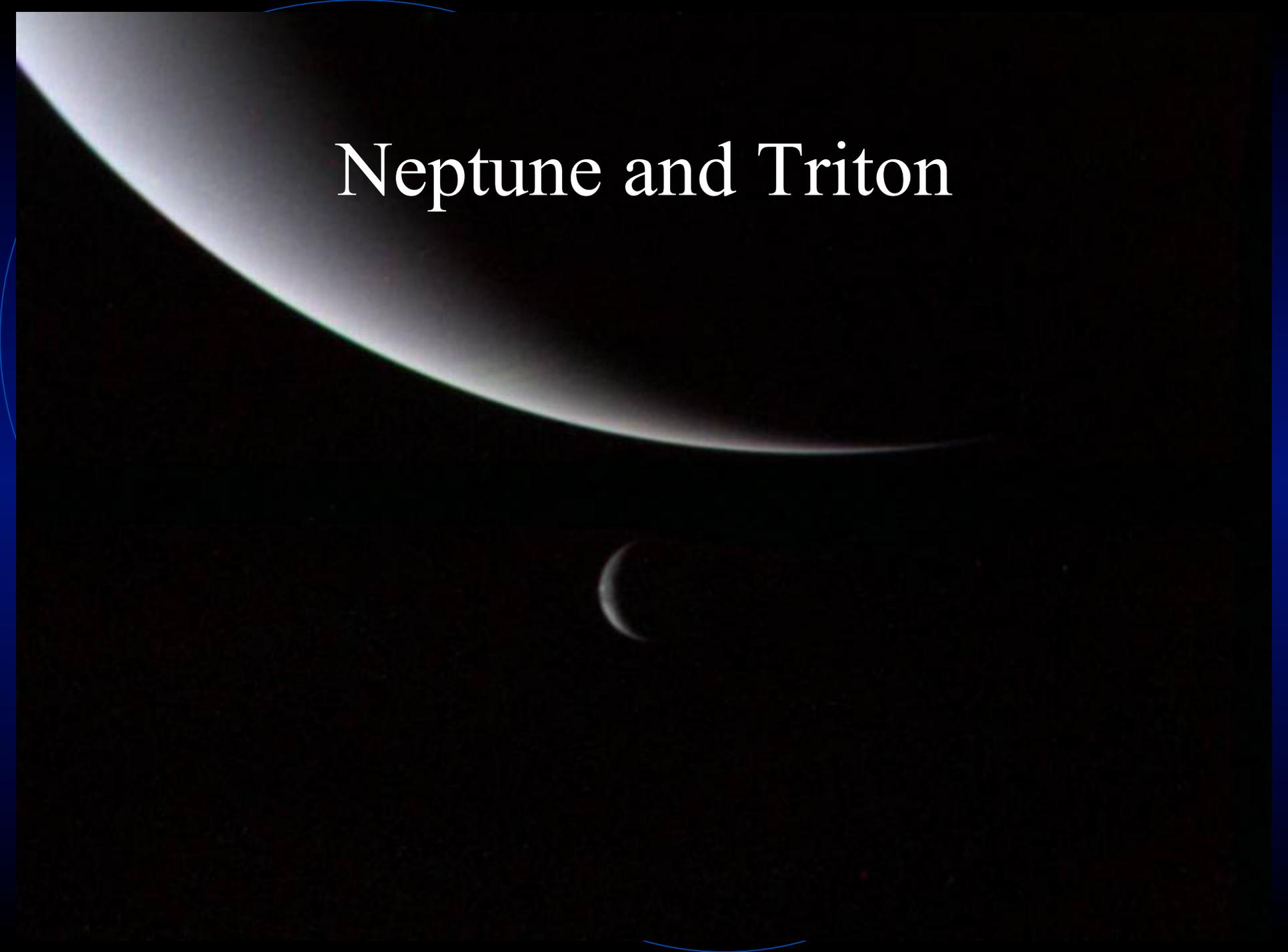
Neptune

- Discovered by prediction (right place, right time)
- Only 4% smaller than Uranus
- Very similar chemically to Uranus
- 165 year = 'year', day = 16h (also oblate)
- Has a great Dark spot (only lasted a while)
- Like Uranus – has a tilted magnetic field axis

Neptune

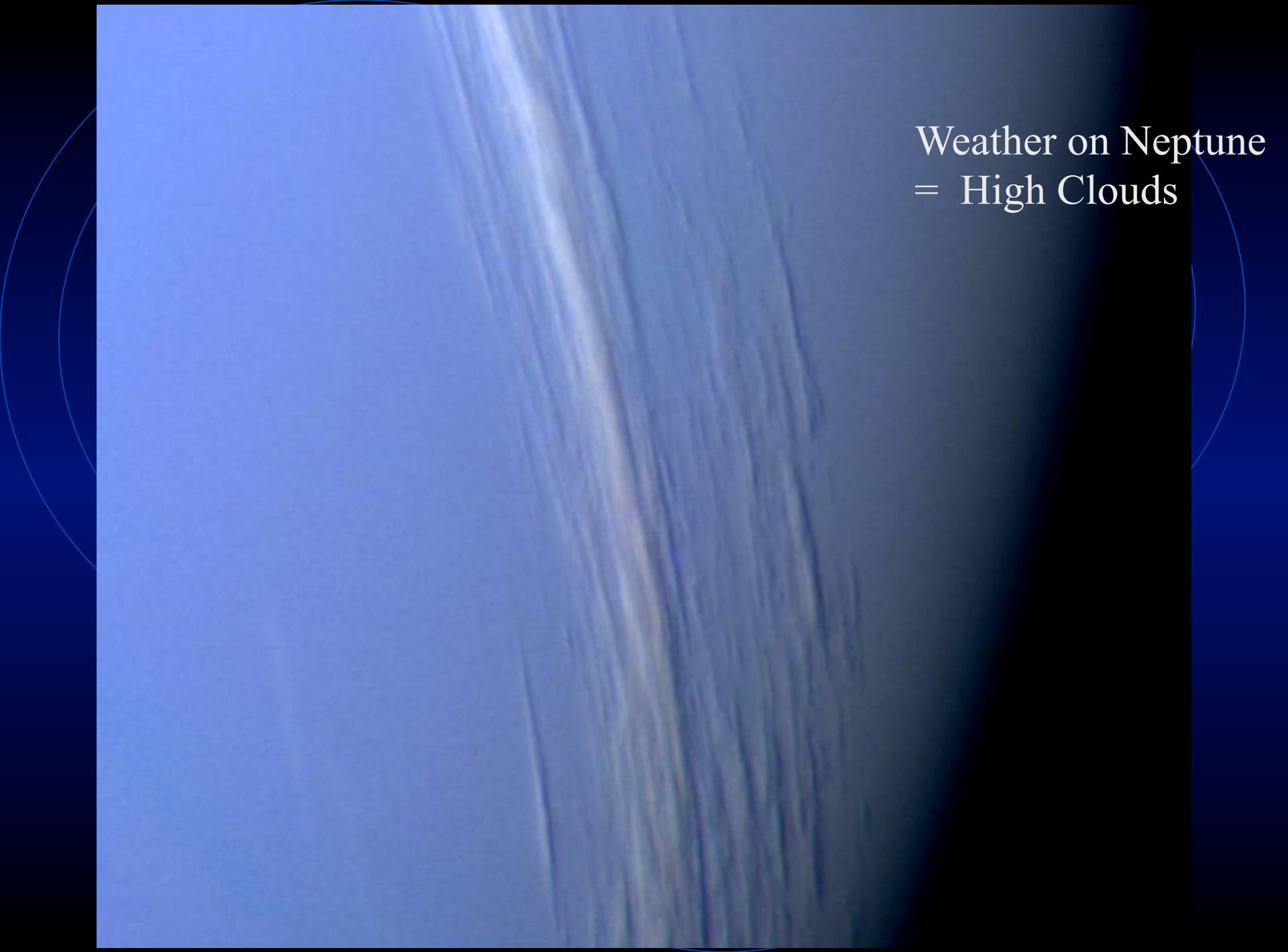
- Neptune also has rings (also very dark and widely separated)
- Two moons are visible from Earth – Nereid and Triton (orbits backwards – impact? Capture?)
- + 11 smaller moons
- Triton has a N_2 atmosphere very thin compared to earth
- Methane geysers make it another geologically active body

Neptune and Triton

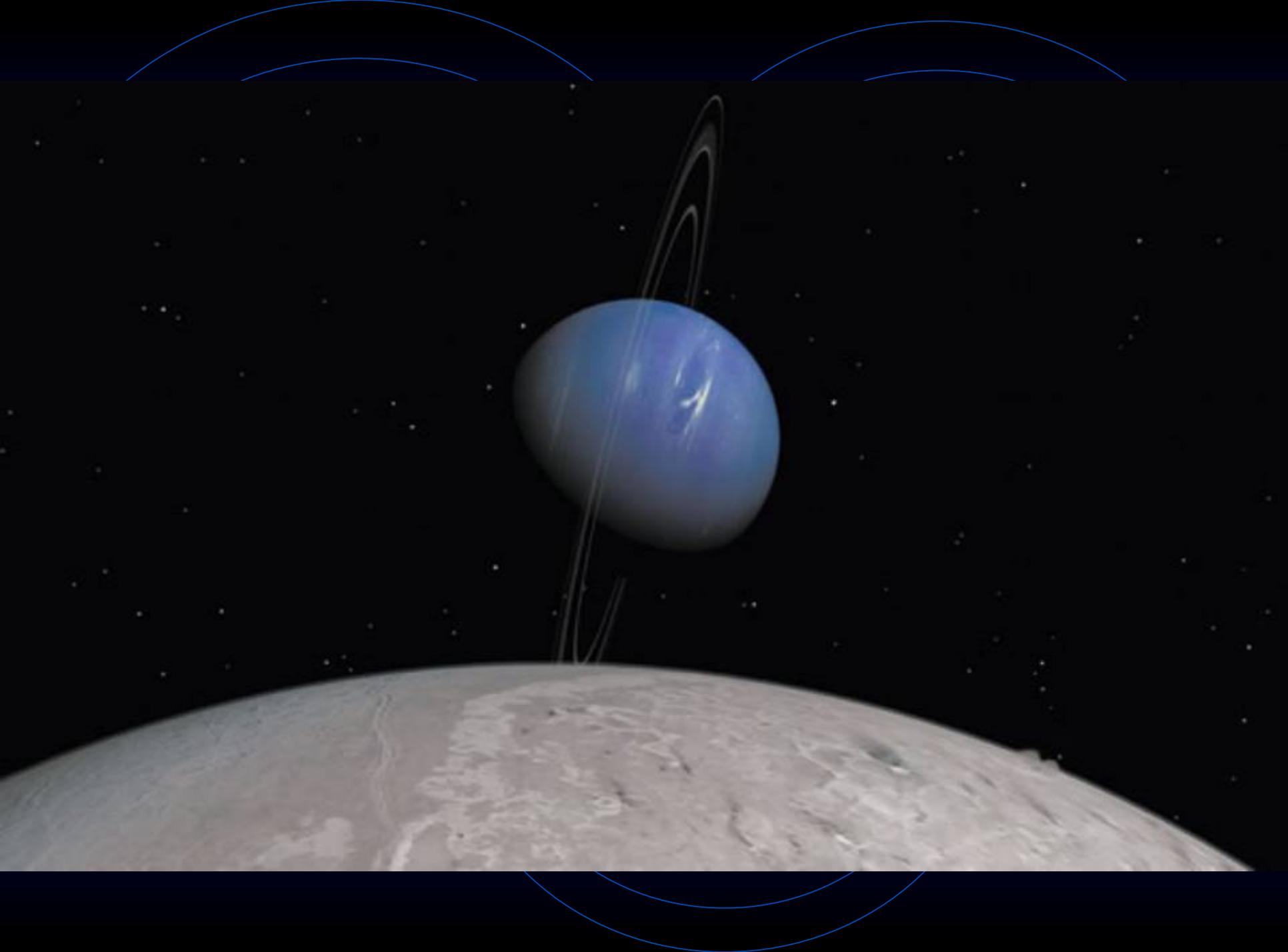


Neptune's Moon Proteus

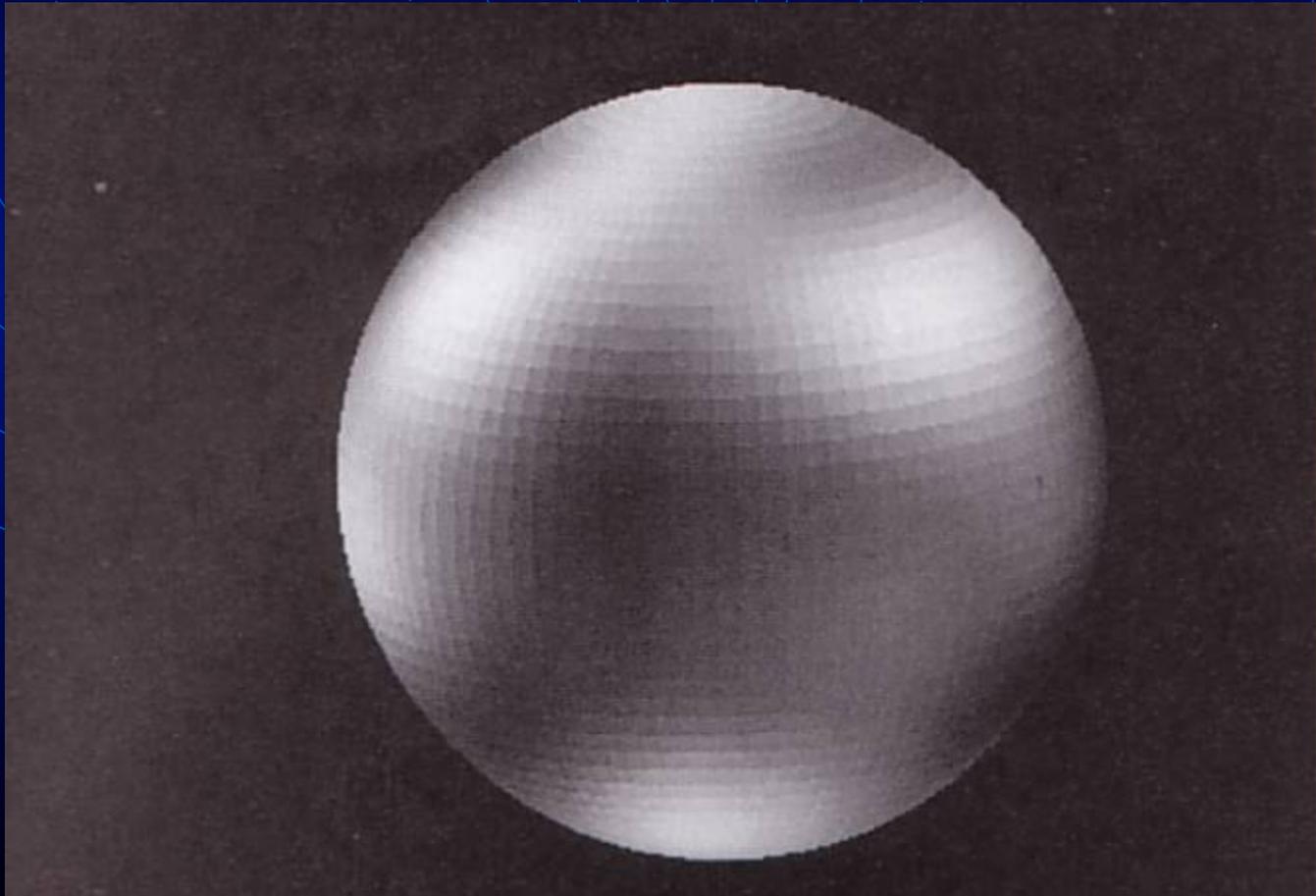


The image shows a close-up of Neptune's atmosphere, characterized by a deep blue color. A prominent feature is a bright, vertical band of high-altitude clouds that runs diagonally across the frame. The clouds appear as a series of parallel, slightly wavy lines, suggesting a dynamic weather system. The background is a uniform, darker blue, which makes the cloud band stand out. The overall appearance is that of a clear, high-altitude sky with distinct cloud formations.

Weather on Neptune
= High Clouds



Pluto



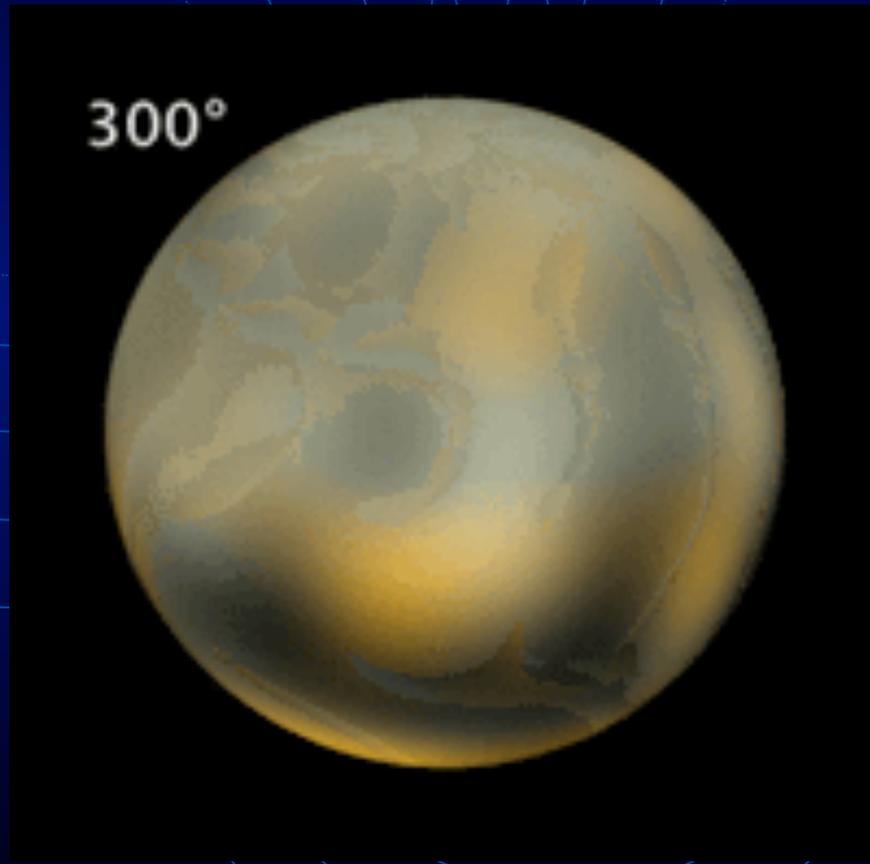
Artist Renditions



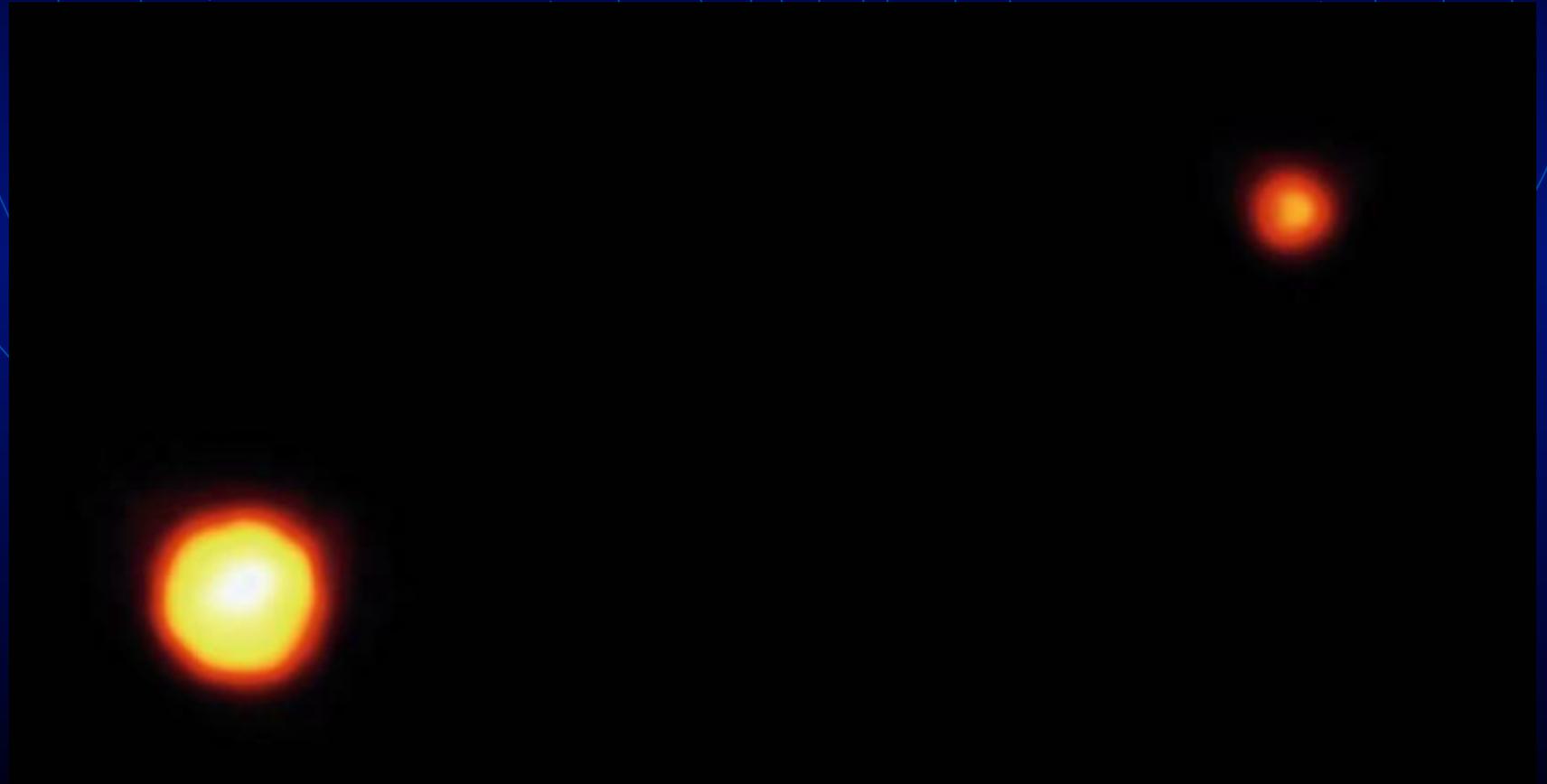
Pluto

- Discovered by prediction (wrong item right place)
- Usually the most distant planet (**Dwarf Planet**)
- Planet or Comet?
- No surface pictures really (Hubble = **picture above**)
- Closer than Neptune Jan 21, '79 – Mar 14, '99
- Most 'gasses' that could be atmosphere are frozen on the surface
- Moon discovered in 1978 (Charon) circles once every 6.387 days **next frame**
- 247 year, 'year' - not yet explored/visited
- **New Horizon's Mission en route : July 2015**

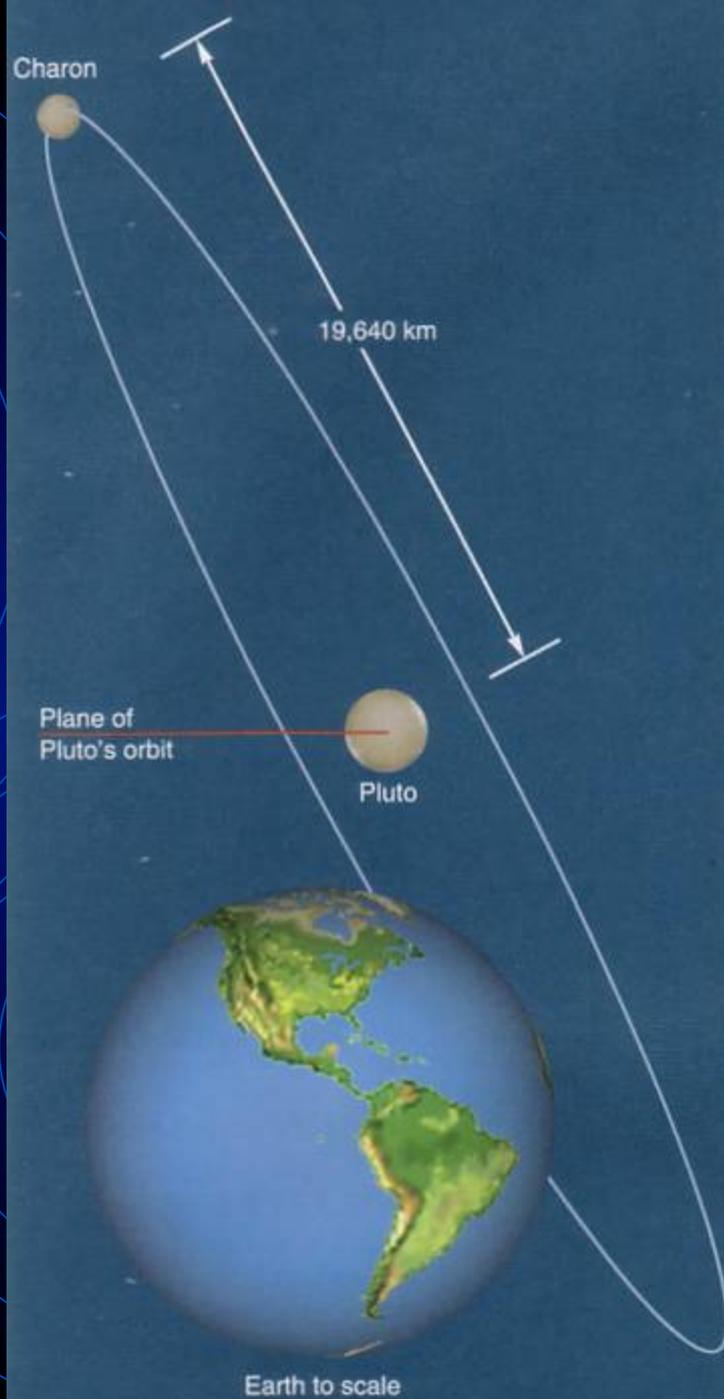
Albedo Map



Pluto and Charon via the Hubble Space Telescope



Charon



New Moons!

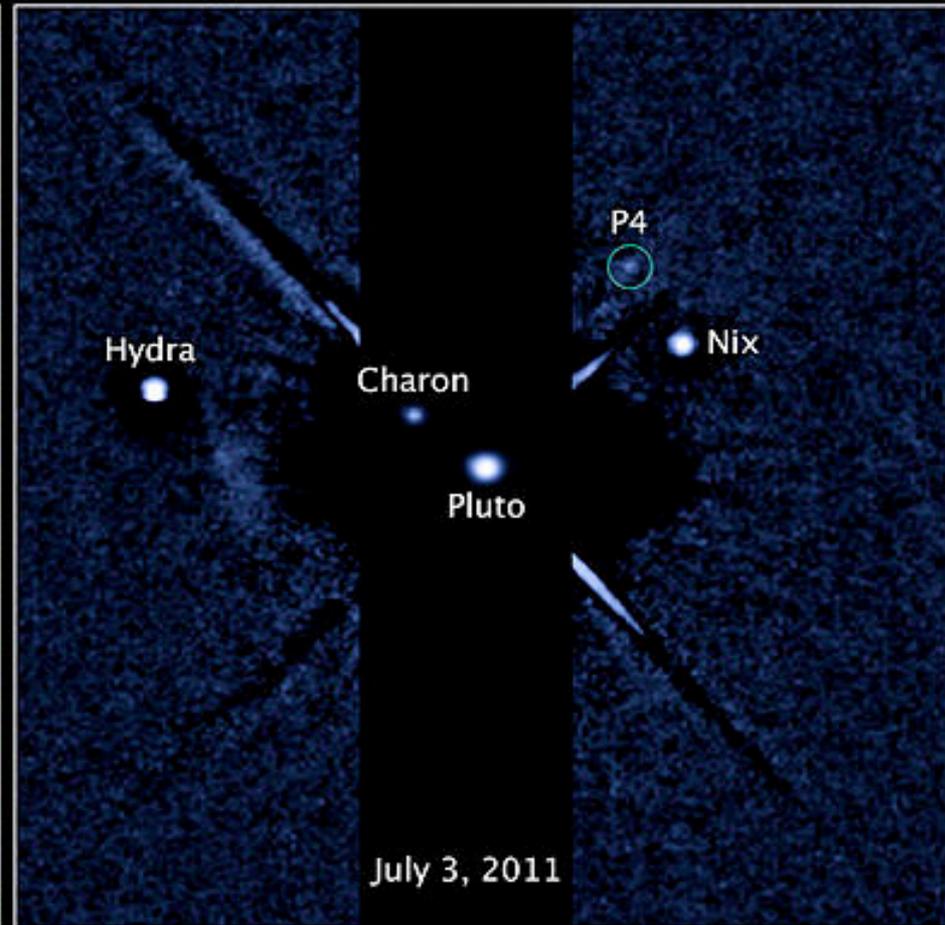
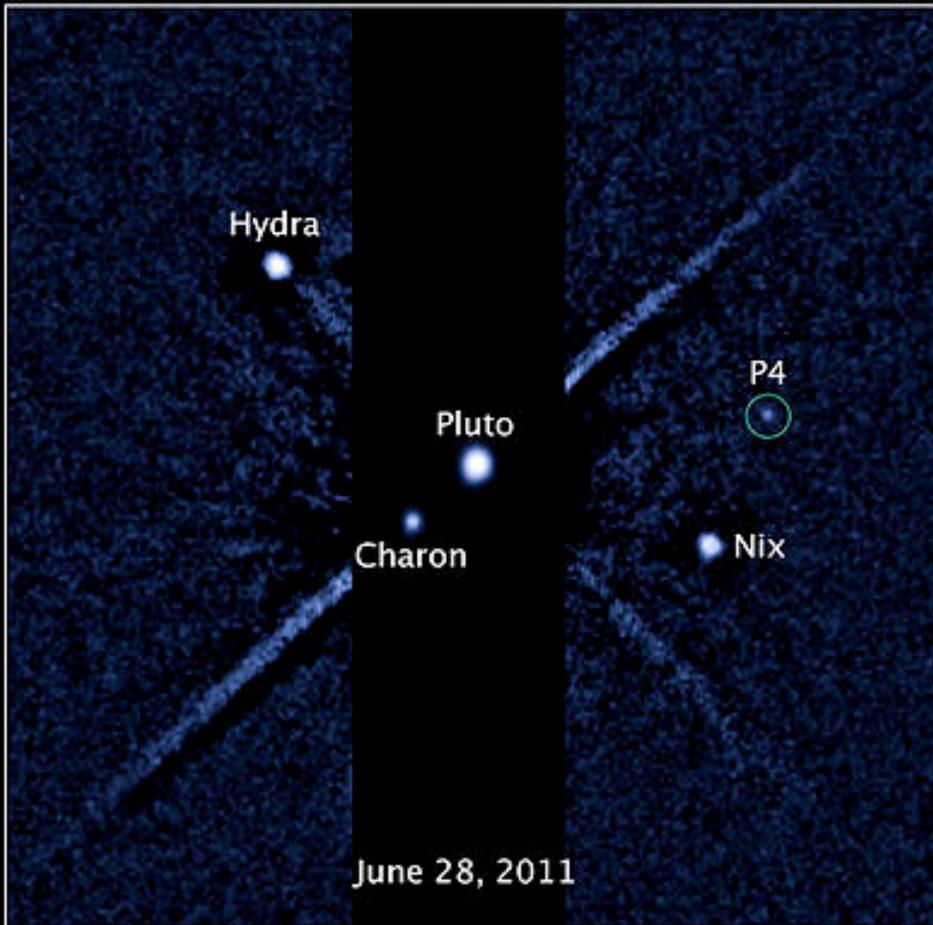
- Discovered Last year
- Might be created from impact that formed Charon
- Scientists now think the two moons are roughly 37 and 31 miles (60 and 50 kilometers) in diameter.
Charon has an estimated diameter of about 750 miles (1,200 kilometers).
- Now named:
Nix and Hydra



More New Moons July 7, 2012

- Up to 5 moons now – S/2011 and S/2012

Pluto System ■ Hubble Space Telescope ■ WFC3/UVIS



Two new (minor) planets too?! TNO: Trans-Neptunian Objects

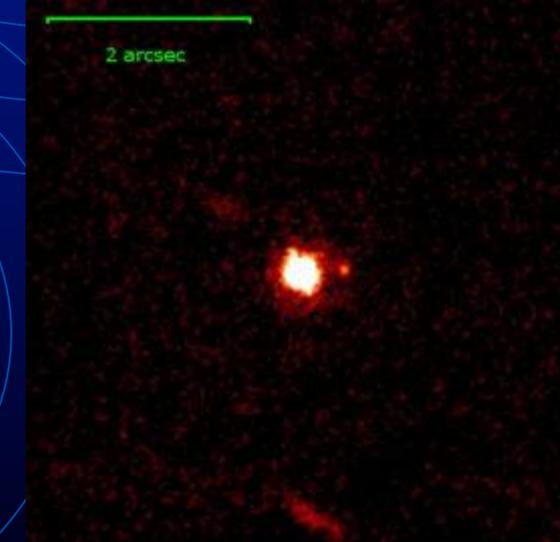
- Quaoar [pronounced *kwaɑ'·waar* or *kwow'·ər*].

- Discovered in 2002
- 43 to 42 AU
- 286 year “year”



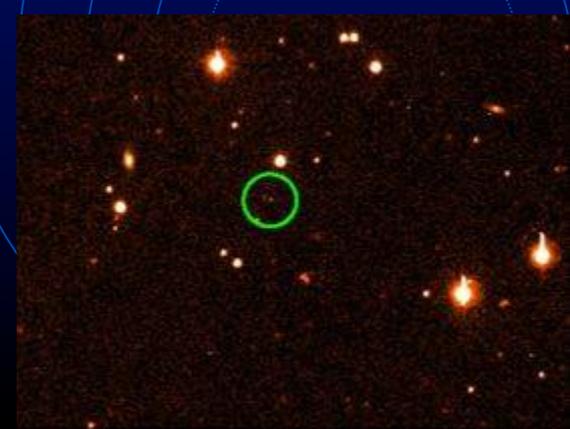
- ~~2003UB (Xena)~~ *Eris and moon Dysnomia:*

- Discovered in 2003
- 68 to 37 AU
- 557 year “year”



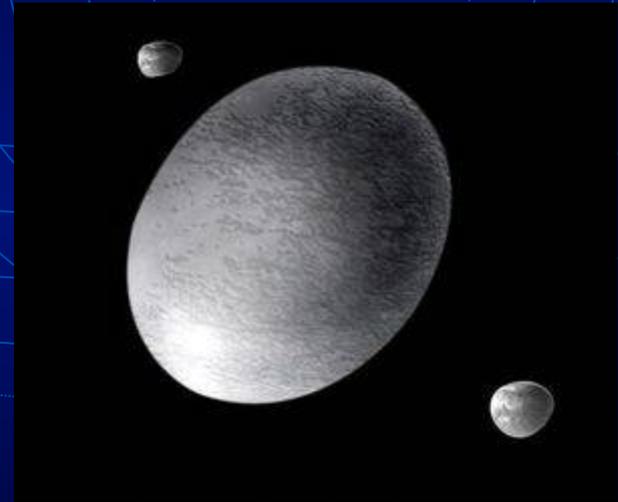
- Sedna:

- Discovered 2003
- 525au to 76 au
- 10,500 year “year”
- 12K



And another – EL61 (2003)

- Oblong
- Nicknamed Santa
- 2 (unnamed) moons

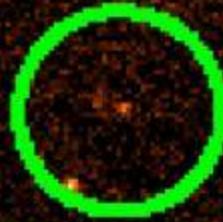


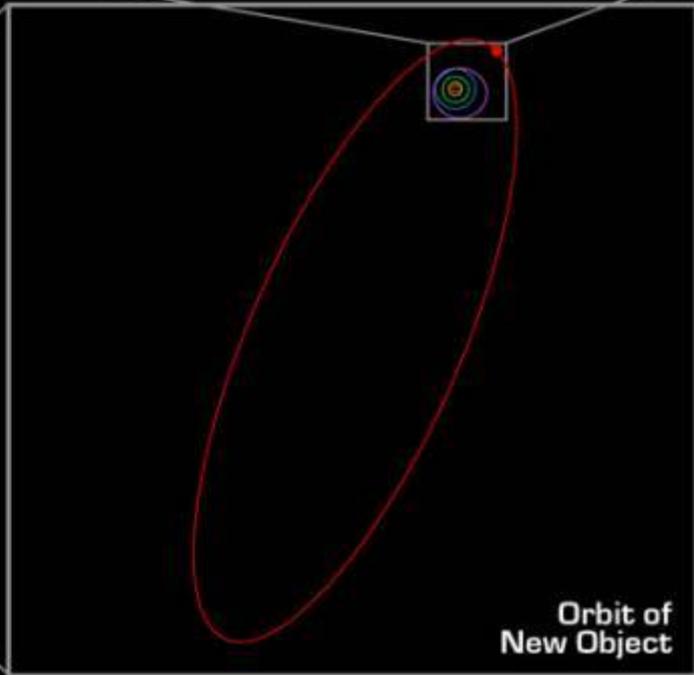
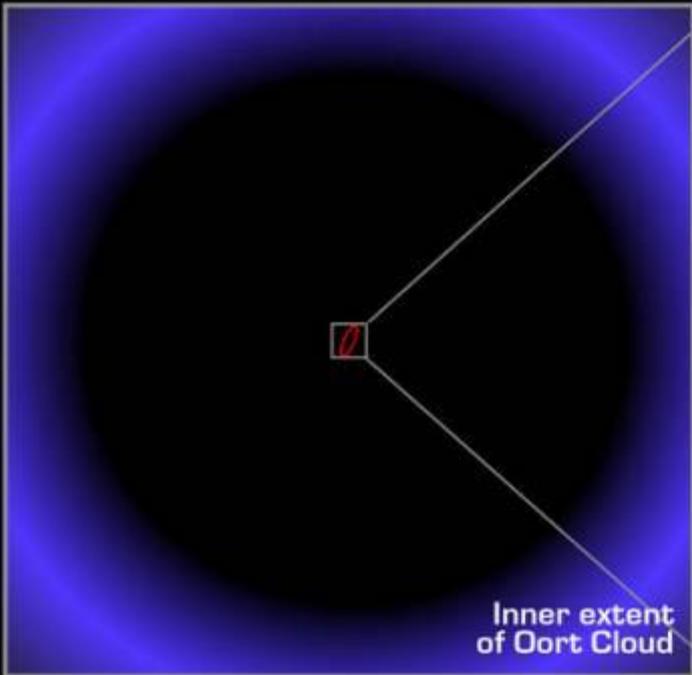
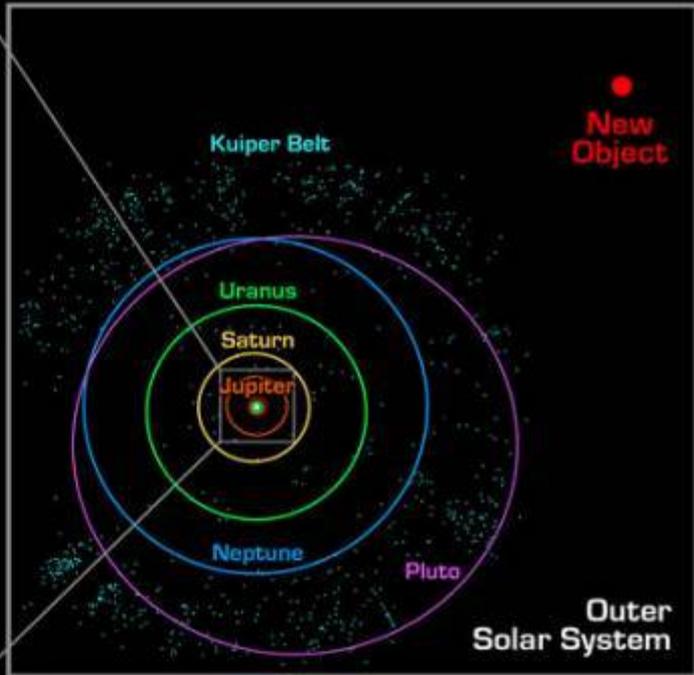
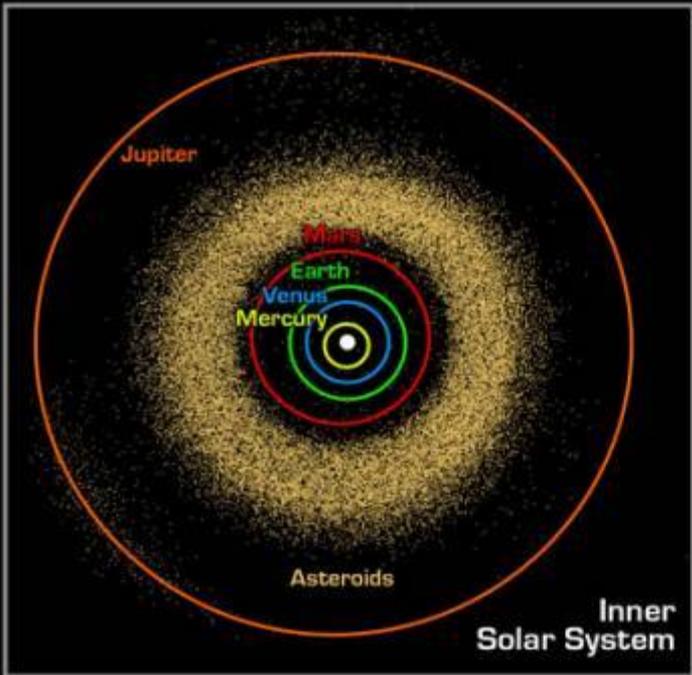
Quaoar



Artist's View

Sedna's Discovery





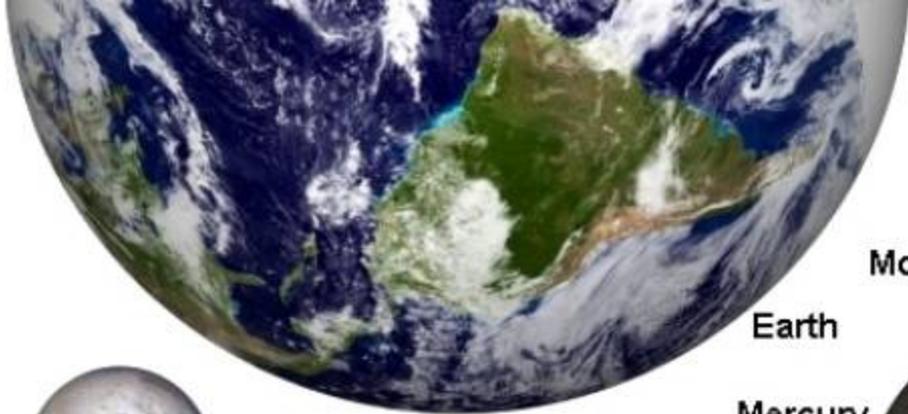
Sedna

Artist's View of 2003 VB12 "Sedna"



Comparisons (this slide already wrong...)





Earth



Moon



Mercury



Triton

(4) Vesta (1) Ceres (2) Pallas



TEXAS

Pluto



Charon

Nix • • Hydra

(28978) Ixion

(90482) Orcus

2003 AZ84



(136108)
2003 EL61

2002 MS4

(24835) 1995 SM55

(47171) 1999 TC36

(90568) 2004 GV9

(55637) 2002 UX25

(20000) Varuna

(19308) 1996 TO66



(136472)
2005 FY9

(50000) Quaoar

(55636) 2002 TX300

(19521) Chaos

(120178) 2003 OP32

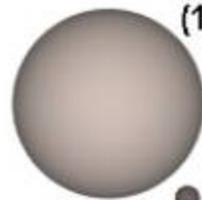
(42301) 2003 TC302

2003 MW12

(136199) Eris

(84522) 2002 TC302

(55565) 2002 AW197



Dysnomia

(90377) Sedna

Haumea



Eris



Sedna



Orcus



Quaoar



Makemake



Varuna



Ixion



Ceres



Vesta



Pallas



Hygiea



Odd Balls – Meteors/Asteroids/ Comets

- Meteorites
- Left over debris from the solar system's formation
 - Particles, grains of sand- usually very small (pinky fingernail in size)
 - Moving about 10 to 40 km/sec
 - Terminology
 - Meteoroid = rock in space
 - Meteor = streak of light
 - Meteorite = rock on ground (weird huh!?)

Odd Balls – Meteors/Asteroids/ Comets

- Types of meteors
 - Iron/nickel type
 - Chondrites = stony meteorites (white and not heated much)
 - Achondrites = stony but heated (looks like lava rock)
- Iron meteorites have Widmanstätten patterns (long/large iron crystals) They need a cooling rate no faster than a few degrees per million years! **Next page**

Meteors: Stony and Iron



Meteors Continued

- Meteor Showers = meteors that seem to come from a point in space (parallel in reality but seem to come from a point like railroad tracks **next page**) – more enter the atmosphere than the normal rate of a few an hour from random directions

- Remains of comets that have littered their orbits and the Earth passes through their orbit once a year
- Famous showers include the Perseids and Leonids **page after next**

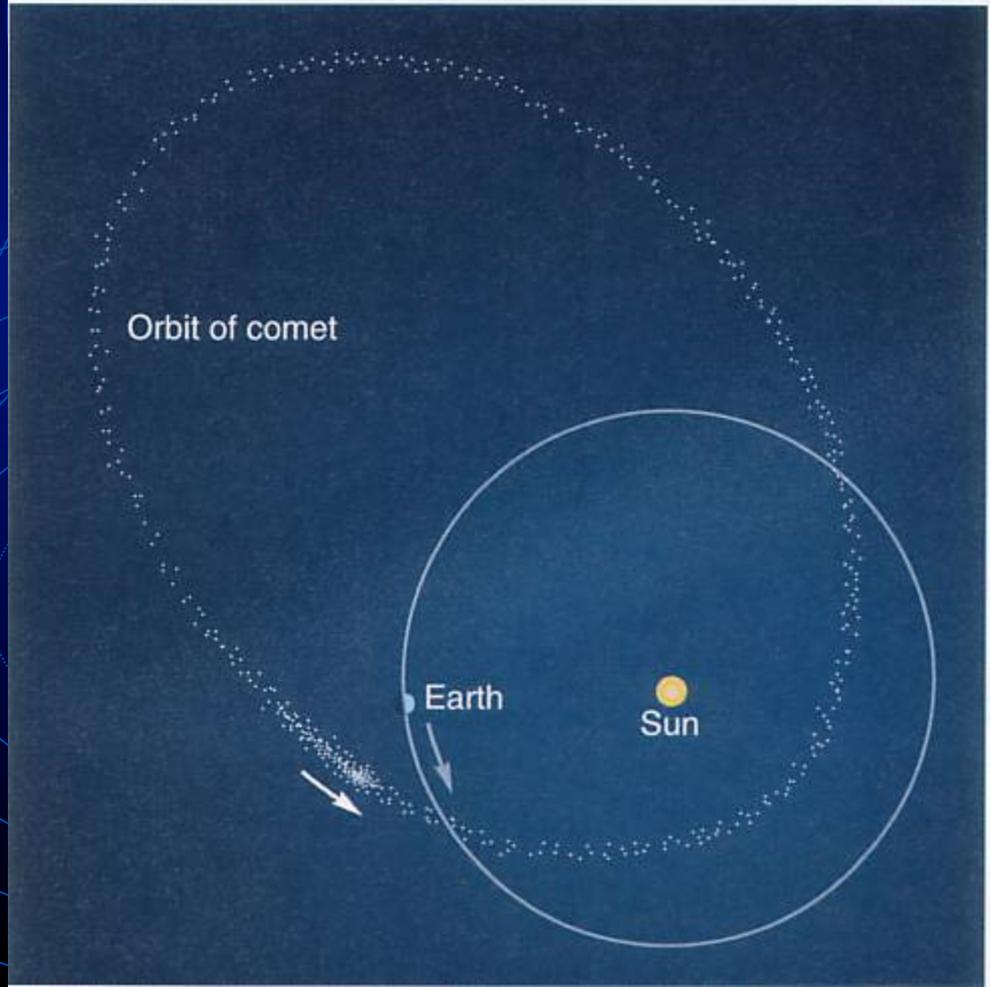
Meteor Showers



a



b





Copyright Frank S. Andreassen / www.nettfoto.no



-13 Fireball taken from St. Croix, Nova Scotia
28mm lens at f/2.8
copyright 2001 Darren Talbot

Regularly Scheduled Showers

pg344

Table 19-1 Meteor Showers

Shower	Dates	Hourly Rate	Radiant*		Associated Comet
			R.A.	Dec.	
Quadrantids	Jan. 2–4	30	15 ^h 24 ^m	50°	
Lyrids	April 20–22	8	18 ^h 4 ^m	33°	1861 I
η Aquarids	May 2–7	10	22 ^h 24 ^m	0°	Halley?
δ Aquarids	July 26–31	15	22 ^h 36 ^m	–10°	
Perseids	Aug. 10–14	40	3 ^h 4 ^m	58°	1982 III
Orionids	Oct. 18–23	15	6 ^h 20 ^m	15°	Halley?
Taurids	Nov. 1–7	8	3 ^h 40 ^m	17°	Encke
Leonids	Nov. 14–19	6	10 ^h 12 ^m	22°	1866 I Temp
Geminids	Dec. 10–13	50	7 ^h 28 ^m	32°	

Asteroids

- Asteroids = possible smashed up planetesimal
- Many located in region between Mars and Jupiter (but Apollo asteroids get closer to the sun than the Earth and some cross our orbit! – dangerous! Maybe 2000 >1km)
- Largest = Ceres
- Spacecraft just went into orbit of Eros (on Valentines Day- when else...?)
- Low density (1.3 g/cm^3)
- Some orbit each other
- Proximity to Jupiter may have kept a larger planet from forming – and herd the asteroids like shepherd moons work on rings (a ring around the sun)

Comets

- Famous Comets
 - Halley (earlier), 1910, 1986, etc...
 - Kohoutek 1973
 - West 1976
 - Hale-Bopp 1996/7
- Mostly icy bodies from the outer solar system (frozen gasses) – outer layers vaporize when they get close to the sun (very elliptical orbit – some times a parabola = no return)
- Slow moving- usually dim- often with a tail
- FEATURES
 - A coma (or head) – gas = H_2O , CO_2 , CO , H , OH , O , S , C etc. and soot like particles = dirty snowball
 - Tail can extend 10^7 to 10^8 km (1 AU = 1.5×10^8 km)
 - Can cross much of the sky (30-100 degrees)
 - Two tails= dust tail (along orbit) and gas tail (away from sun)

Comets



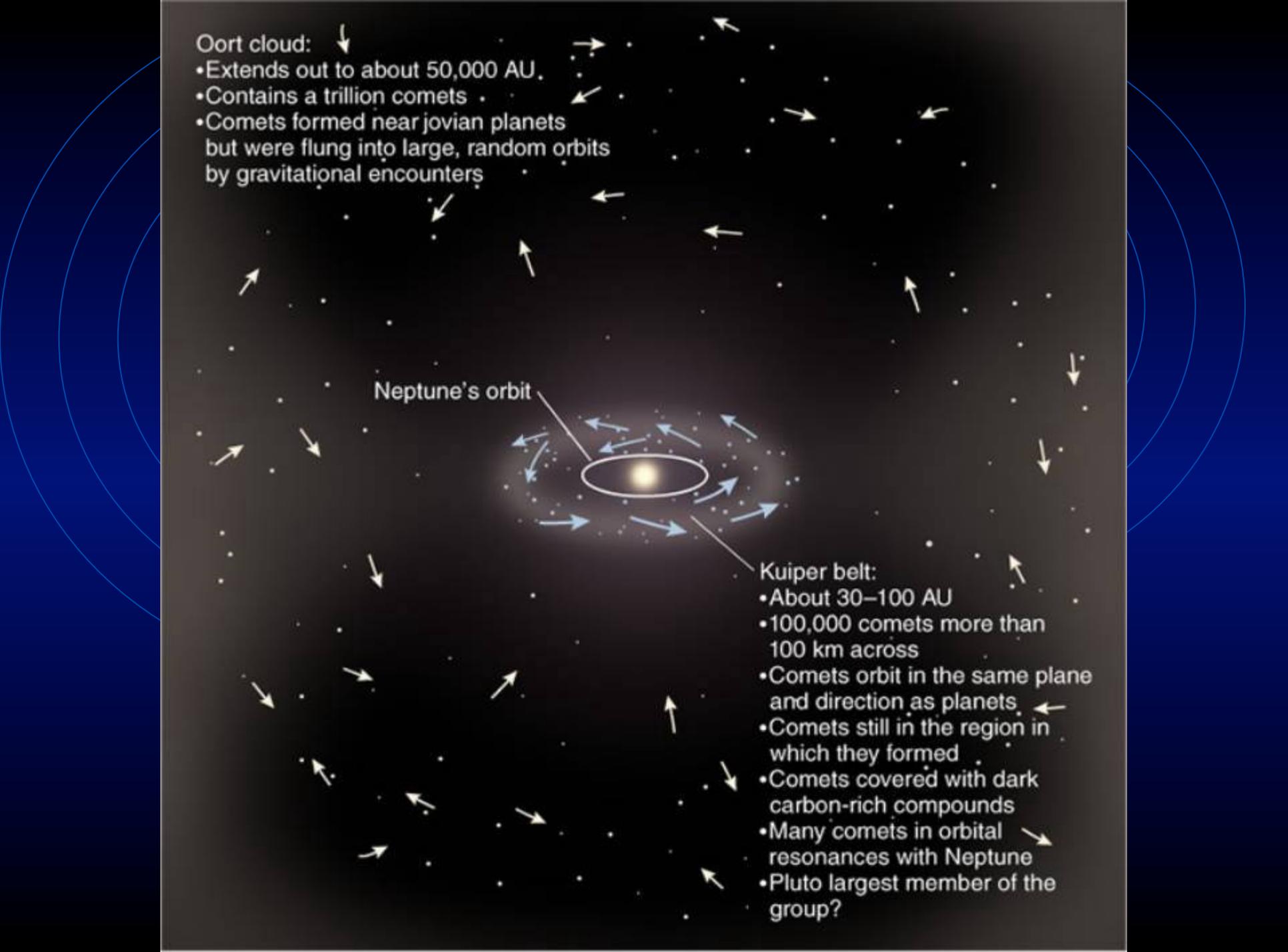
Oort cloud:

- Extends out to about 50,000 AU.
- Contains a trillion comets
- Comets formed near jovian planets but were flung into large, random orbits by gravitational encounters

Neptune's orbit

Kuiper belt:

- About 30–100 AU
- 100,000 comets more than 100 km across
- Comets orbit in the same plane and direction as planets
- Comets still in the region in which they formed
- Comets covered with dark carbon-rich compounds
- Many comets in orbital resonances with Neptune
- Pluto largest member of the group?



Comets continued

- Very dark surface (easy to heat!)
- 'hot' spots release gas in jets
- Low mass .1-.25 gm/cm³
- Halley = 16x8x7km, Hale-Bopp = 30 to 40km
- Eventually they run out of frozen gasses and become fluffy dark collections of dust and rock
- Origins
 - Long (>200 year returns) and short (<200 year returns) period comets are classified as distinct
 - Comets probably last only 100-1000 passes by the sun (must be young!)
 - Oort Cloud = 10,000 to 100,000 AU from sun source of comets (spherical = comets coming from any direction)
 - Kuiper Belt = short period comets = in the plane of the solar system – beyond the Gas Giants = 30-100 AU

Recent Visitor : Mc Naught

- Approached the inner solar system later 2006, put on a great show January 2007 (first in the northern hemisphere, then the southern)
- Visible in the daytime
- 3rd brightest comet of all time = a Great Comet.
- More at: http://spaceweather.com/comets/gallery_mcnaught.php



©Kevin Crause

Comet 17P/Holmes - Oct '07 to present?





Impacts and Climate

- Impacts do happen and still fairly often in the solar system (comets and asteroids)
- Sediment and gravitational observations show an impact 65 million years ago in the Gulf of Mexico (Chicxulub Crater) (probably .25 miles in diameter)





Each blue dot below represents a cenote such as the one to the left.



Chicxulub Crater

- Tidal wave to Waco (boulders still visible in arc across Texas)
- Fire storm across N. America all the way to Arctic Circle
- Began process of mass extinction on earth (dinosaurs); Global Climate Change
- Barringer Meteor Crater near Flagstaff AZ = 50,000 years ago – the size of a mobile home = 1 mile wide crater

More Meteors

- Tunguska, Siberia 1908 pg 348

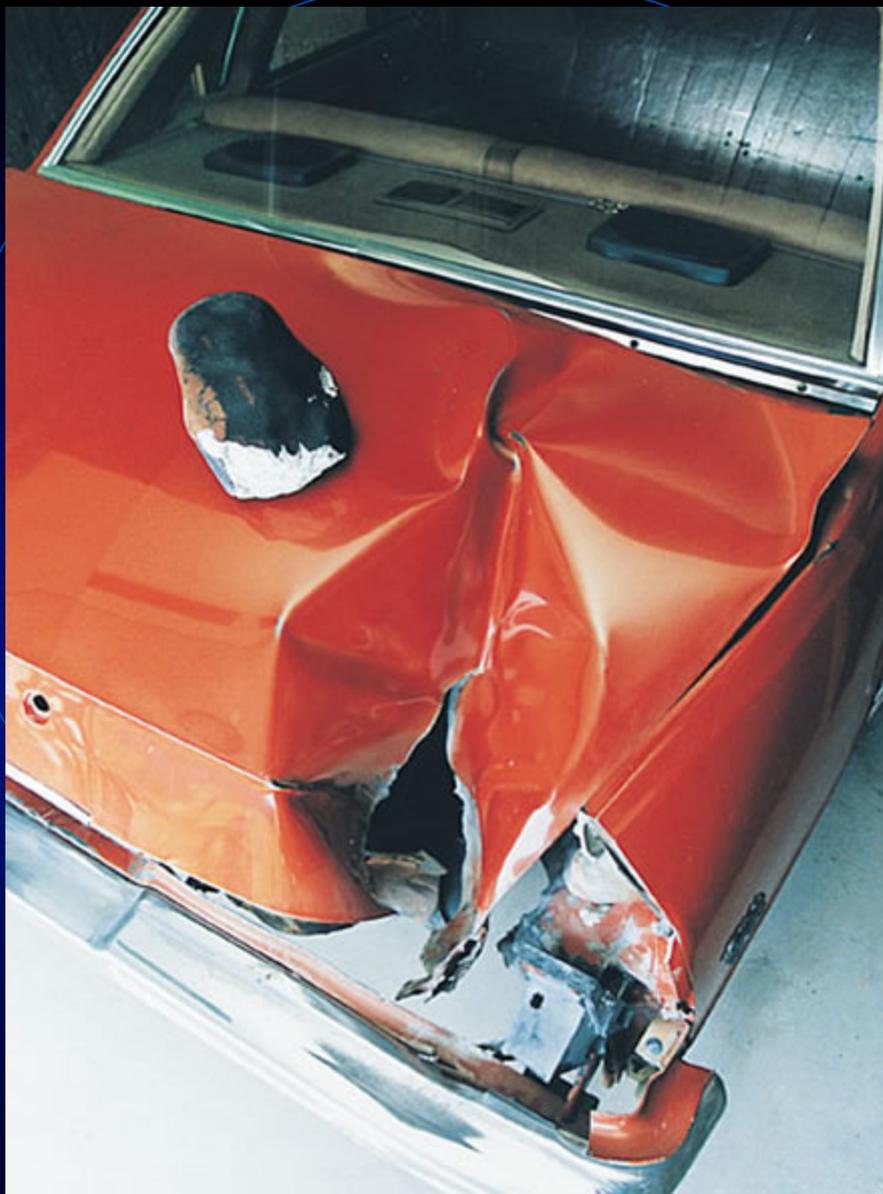


Other Impacts

- 150 impacts known around the world including under the Chesapeake Bay and in Iowa.
- Jupiter hit in 1994

<http://www.solarviews.com/eng/tercrate.htm>





Annie Hodges, Sylacauga,
Alabama 1954

Oct 9th, 1992

<http://www.oberlin.edu/faculty/bsimonso/group9.htm>

Impact near Lake Titicaca in southern Peru – Sept. 15, 2007



Lorton, VA Doctor's office Jan 4th, 2010



(I couldn't find a picture of the building damage except it might be on a site Google thinks is very dangerous.)

Earth and Impacts



Earth Impacts — Wolf Creek, Australia



Earth Impacts — Manicouagan, Quebec, Canada



Apophis Near Earth Asteroid

- “May” hit earth in April 13, 2036
- 2 ½ football fields in size
- Odds now 1 in 45,000 to 1 in 1,000,000
- Even less likely in 2029 and 2068
- (Initially 2.9% chance in 2029!!)

Asteroid Watch

<http://www.jpl.nasa.gov/asteroidwatch/download.cfm>

What about planets out in the universe?

- Exoplanets (important for the search for extraterrestrial life – Week 5)

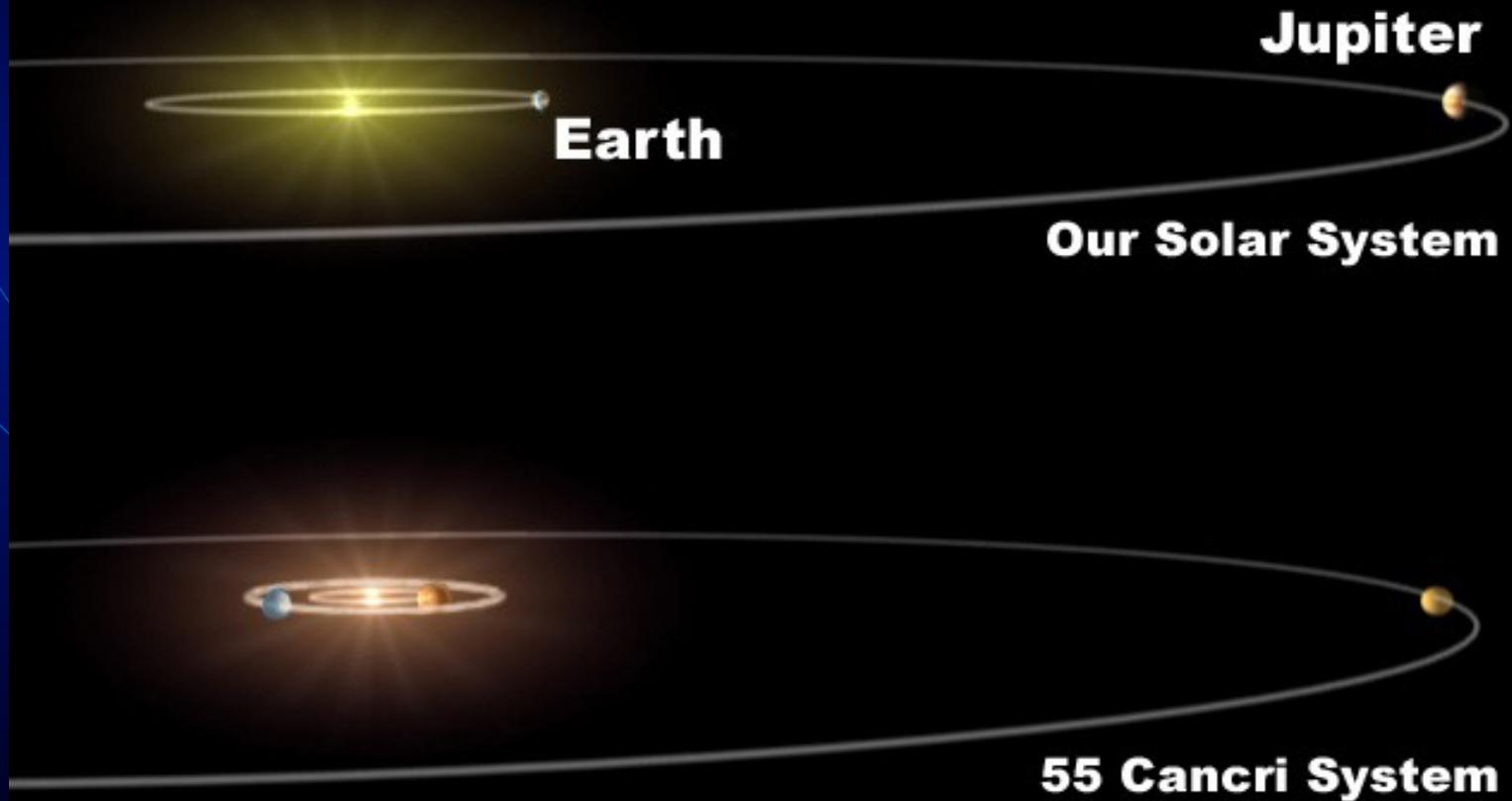
Telescopes searching for Exoplanets from the ground

- The Keck Observatory
- The Lick Observatory
- The Anglo-Australian Telescope
- Magellan Telescope

Other Planets?

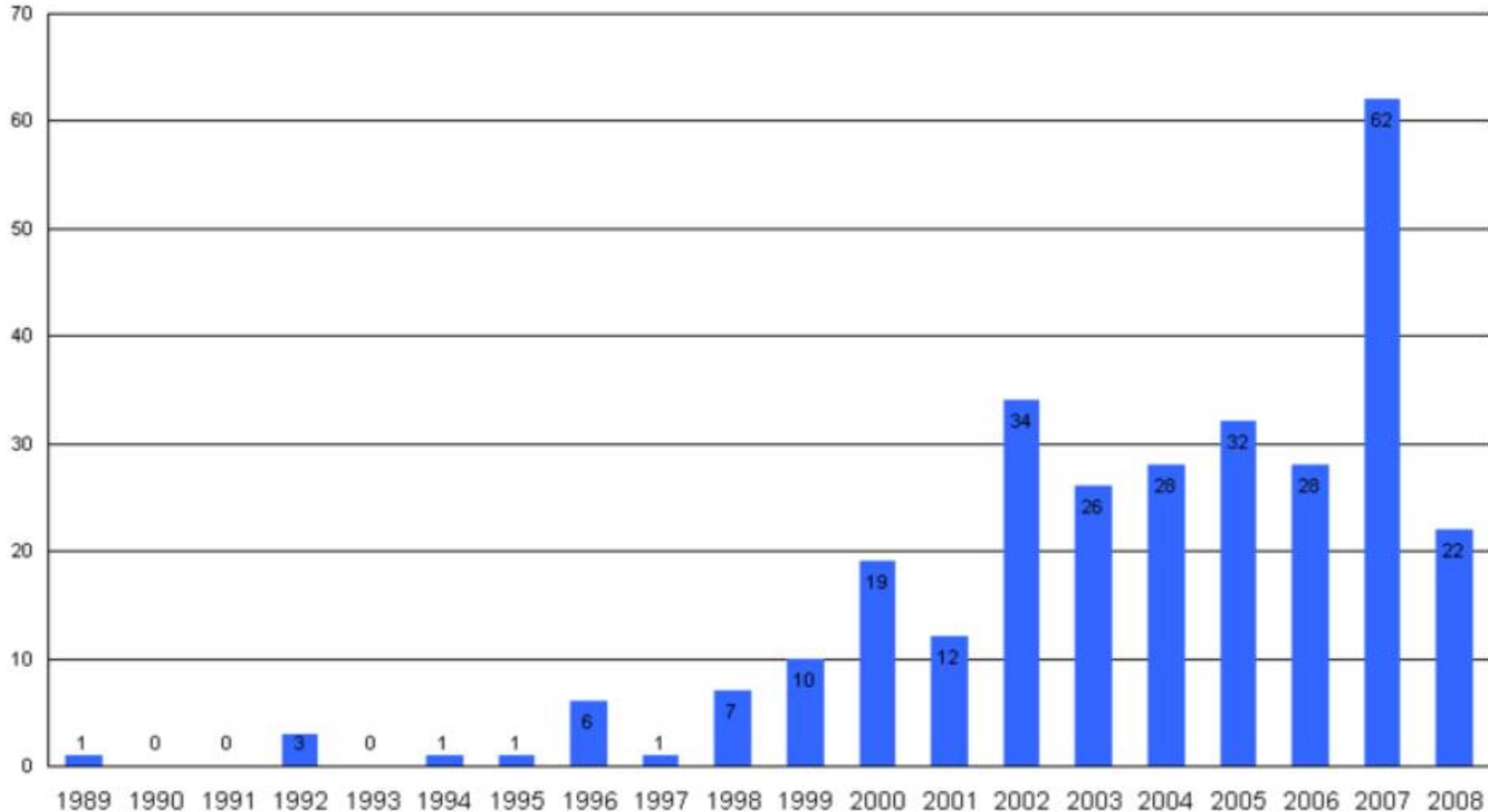
- Called: Extra Solar Planets (Exoplanets)
- As of May 2008 – 293 discovered
- As of July 2012 – 783 discovered
- Kepler mission candidates – 2321
- First confirmed = PSR B1257+12B,C in 1992 (strongly suspected in 1988).
- Most are massive gas giants (we can detect them) – for example →

55 Cancri System (5 planets)

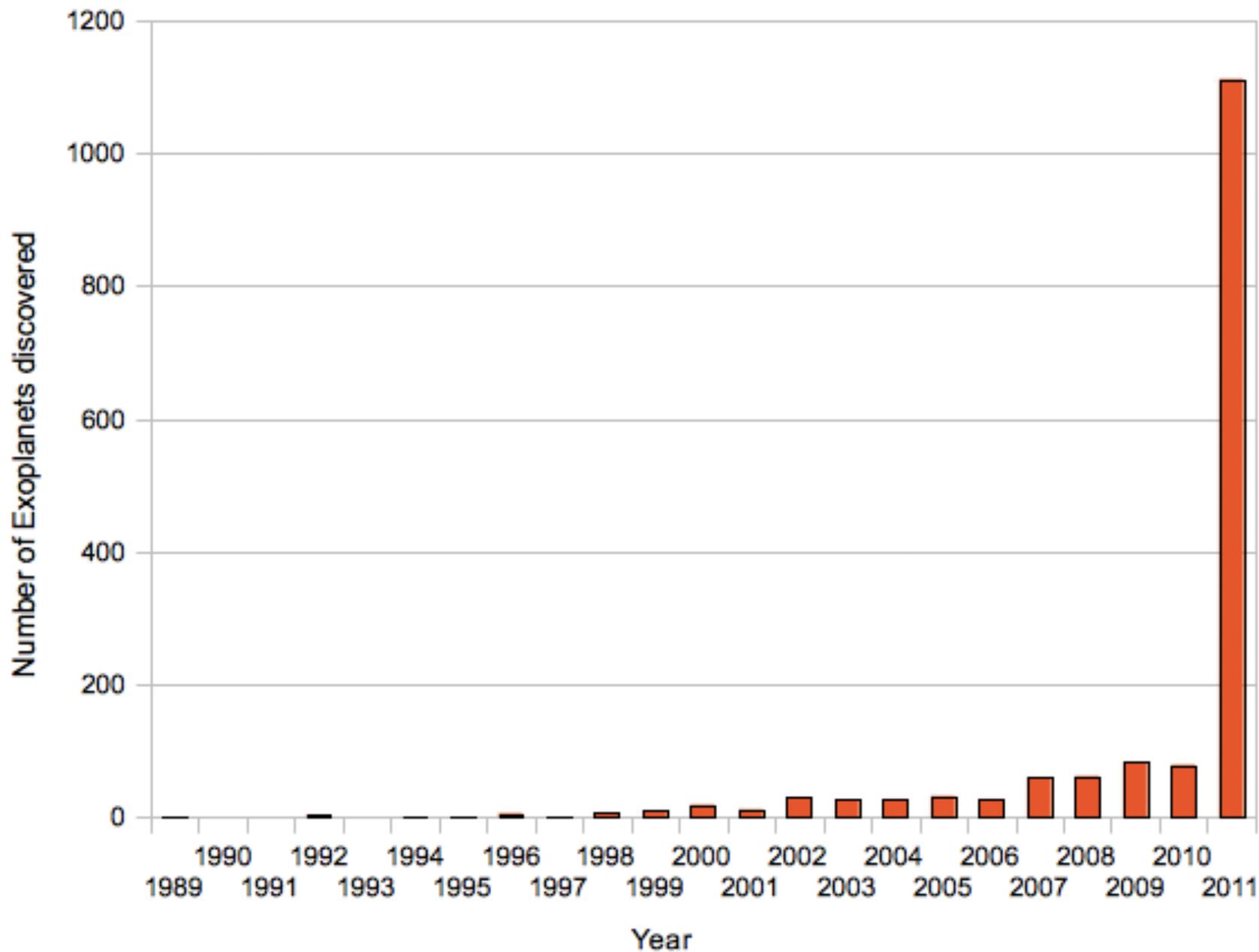


Better equipment = more!

Extrasolar Planet Discoveries

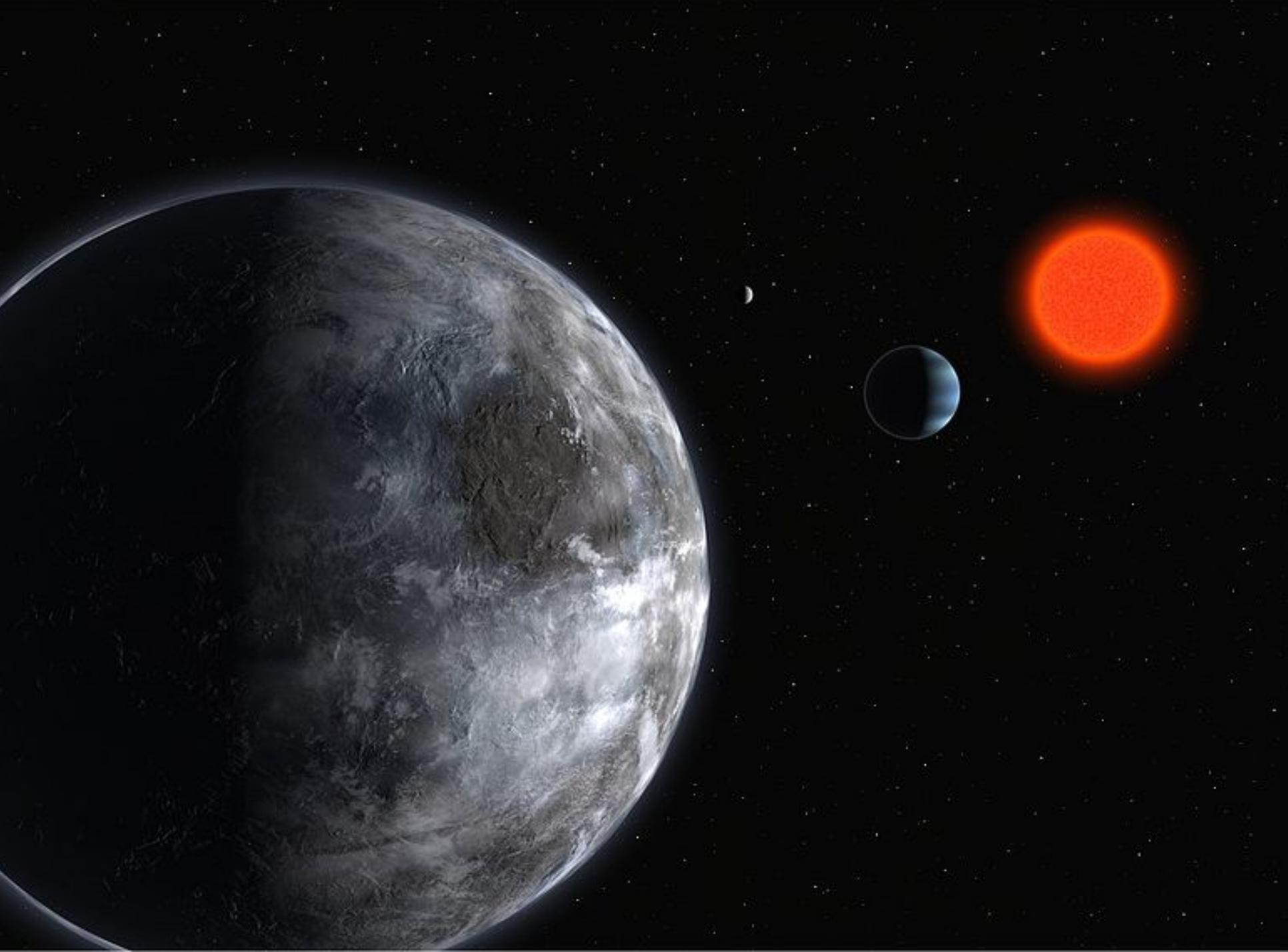


Extrasolar Planet Discoveries, by year



GLIESE 581c (also Wolf 562)

- 20.4 light years from Earth!
- It is the extra solar planet discovered so far that is closest in size to the Earth and in its system's habitable zone (as of April 2007)
- In constellation of Libra around an M2 star
- Radius is 50% larger than earth
- Gravity about 2.24X stronger



GLIESE 581c (also Wolf 562)

- If it is an icy/water planet, it is smaller and it's gravity would be only 1.25X
- It's year is 13 earth days long!!
- One face always toward sun
(14x larger in sky) like our Moon to us and Charon to Pluto.

GLIESE 581c

EARTH



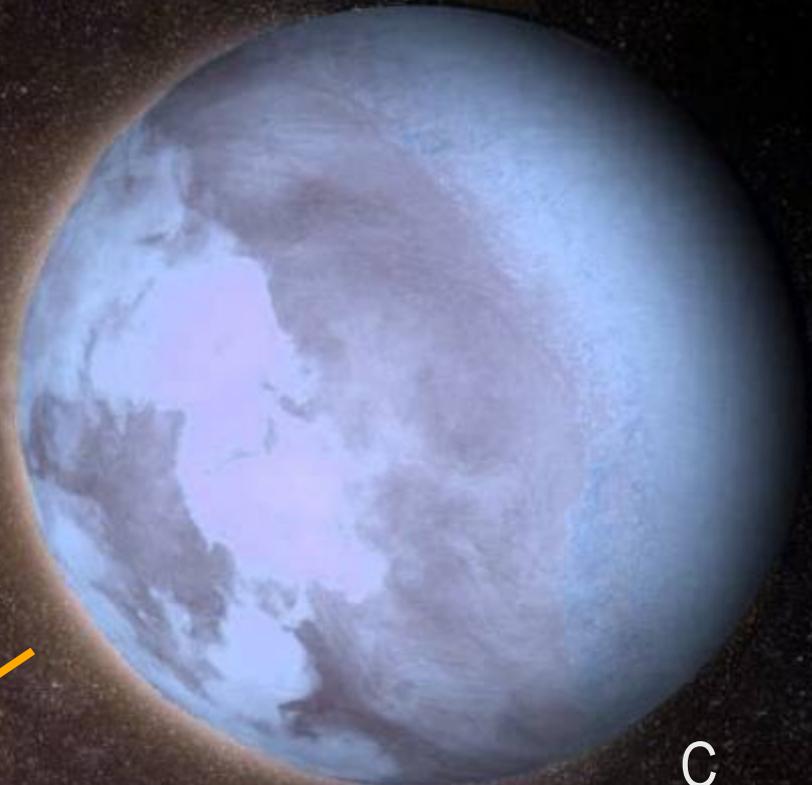
GLIESE 581 C

5000 km
(3107 mi)

GLIESE 581c

- All ice on one side

To GLIESE
581



C

OGLE-2005-BLG-390Lb

- Another near-Earth sized planet
- With some problems...
- Artist Conception:

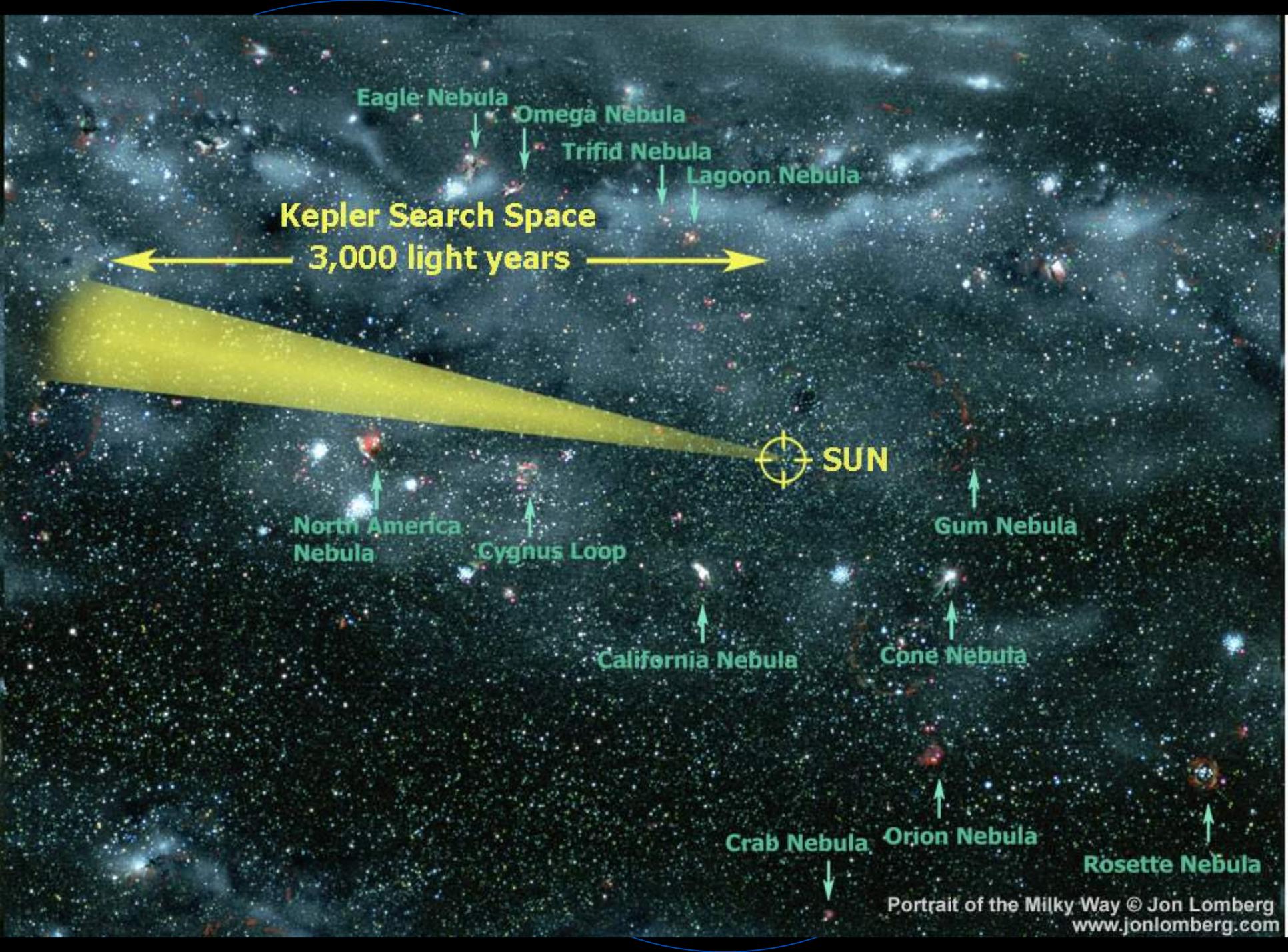


OGLE-2005-BLG-390Lb

- About 21,500ly from Earth
- 2 to 4 AU from its sun, an M class star
- In constellation Scorpius
- 5X Earth's Mass
- 10 Earth year 'year'
- Very cold – 50K (-370 degrees F)

The Kepler Mission





Eagle Nebula

Omega Nebula

Trifid Nebula

Lagoon Nebula

Kepler Search Space

3,000 light years

SUN

North America Nebula

Cygnus Loop

California Nebula

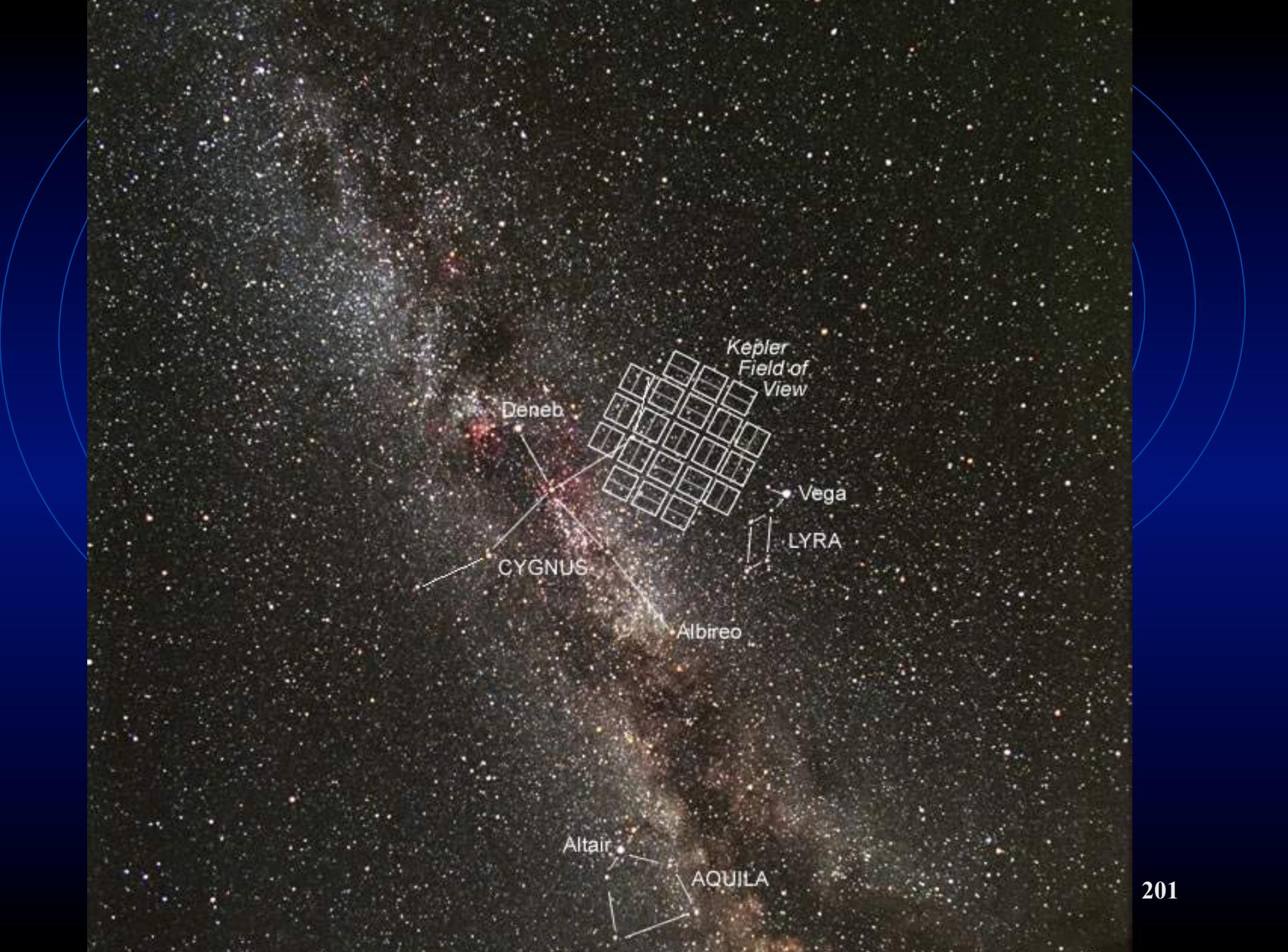
Gum Nebula

Cone Nebula

Crab Nebula

Orion Nebula

Rosette Nebula



Kepler
Field of
View

Deneb

Vega

LYRA

CYGNUS

Albireo

Altair

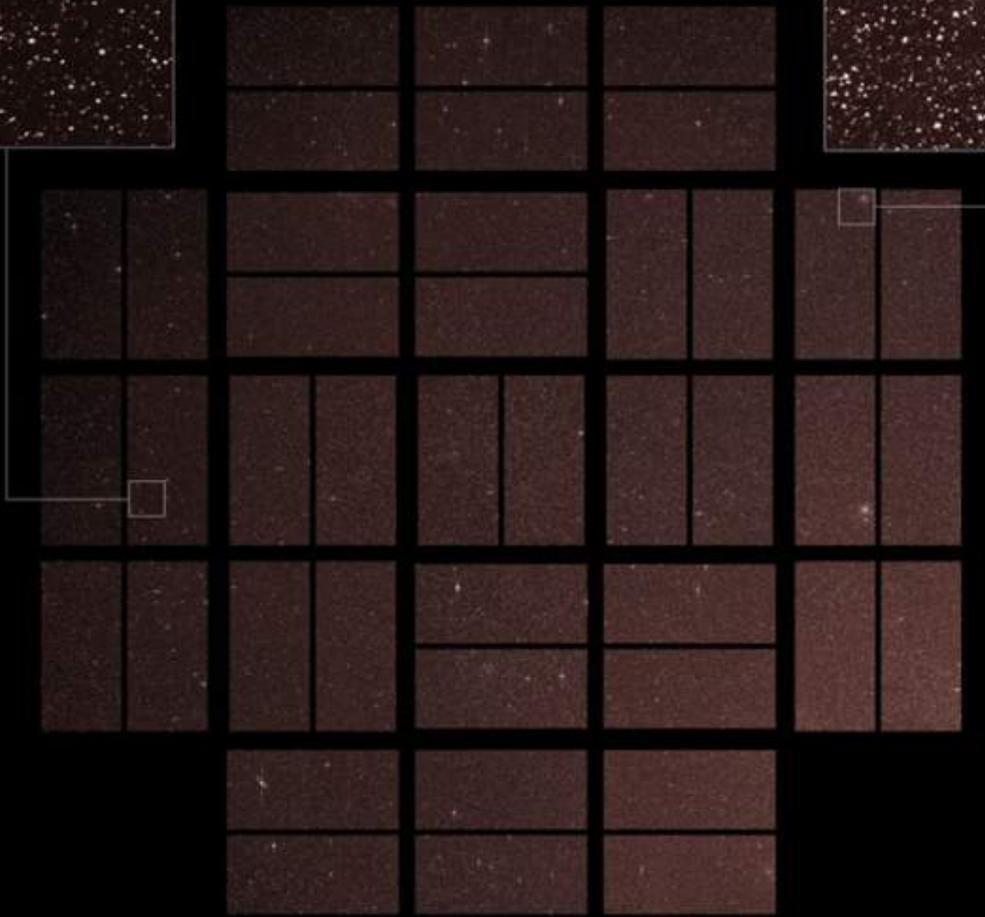
AQUILA



TrES-2

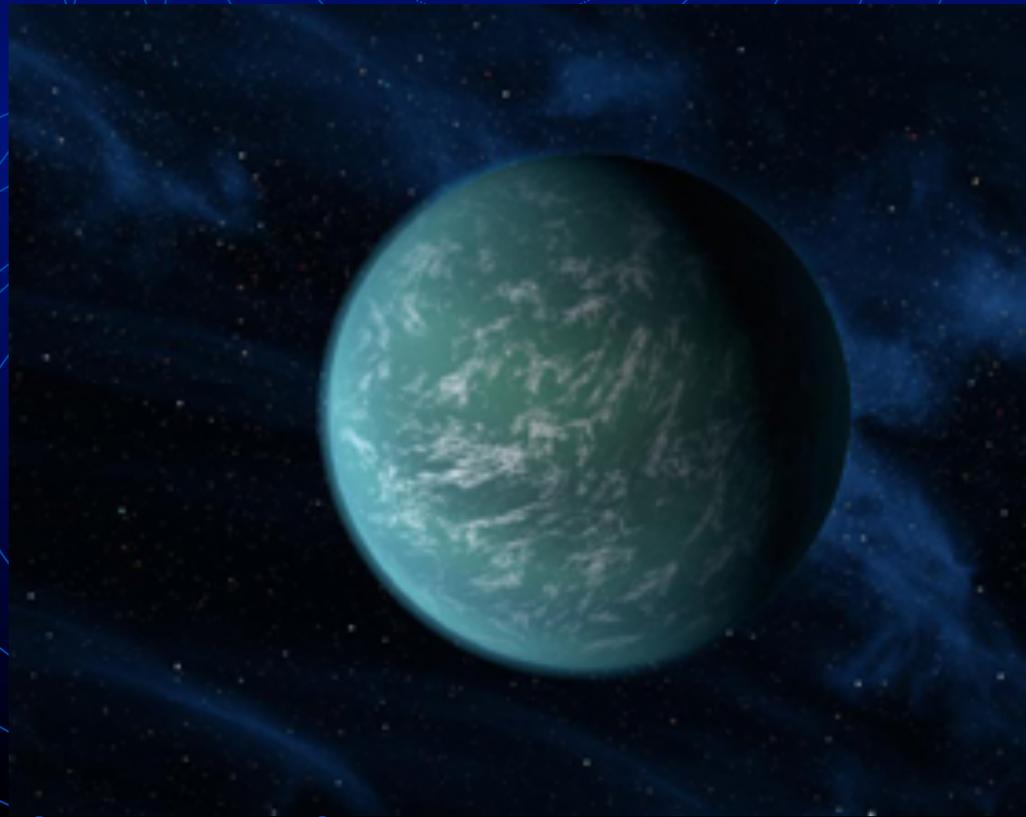


NGC 6791



NEW! Kepler 22b

- In the habitable zone (liquid water)
- 2.4x diameter of earth
- Is one of 29 confirmed, 2,326 candidates
- Year 289.9 earth days
- Similar star



Kepler-22 System

Solar System

Habitable Zone



Kepler-22b

Mercury



Venus

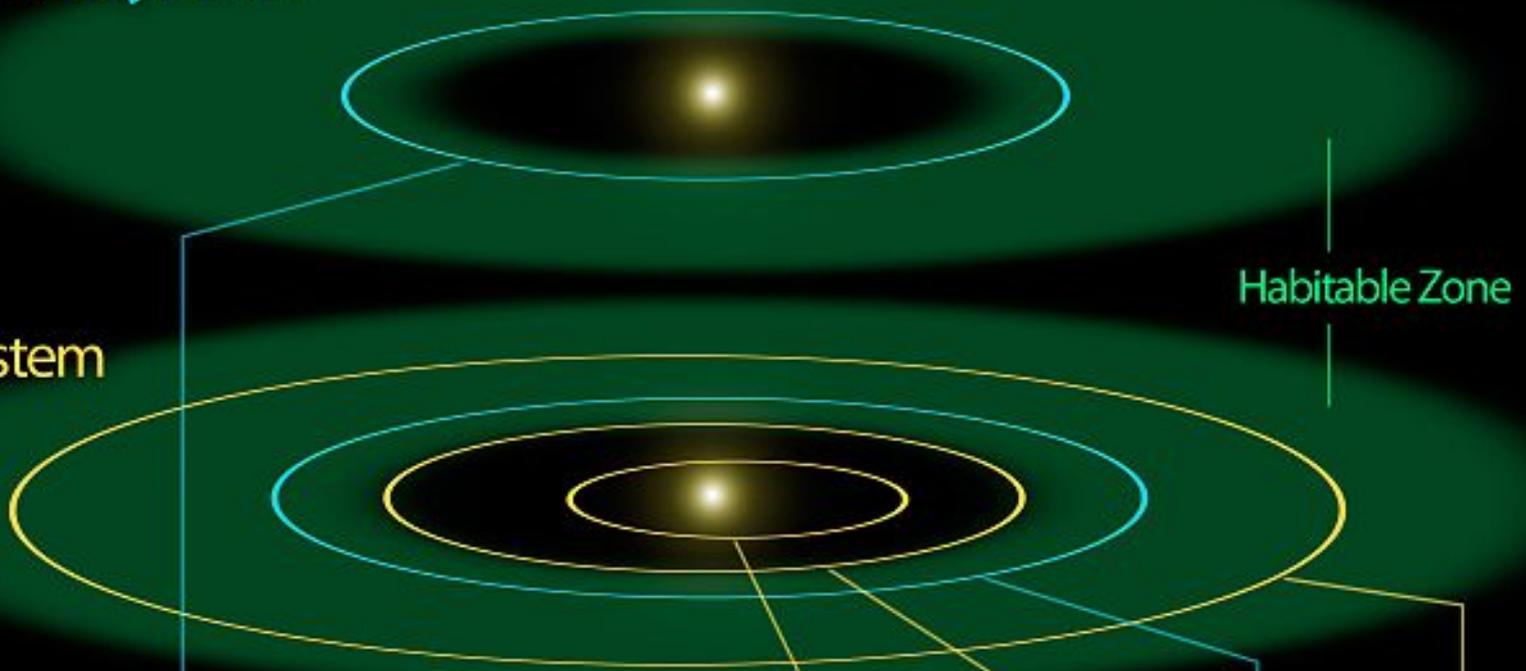


Earth



Mars

Planets and orbits to scale



Are We Alone then?

- We' ll find out Week 5...