Introduction to Astronomy
Lecture 2:
The Solar System

Presented by
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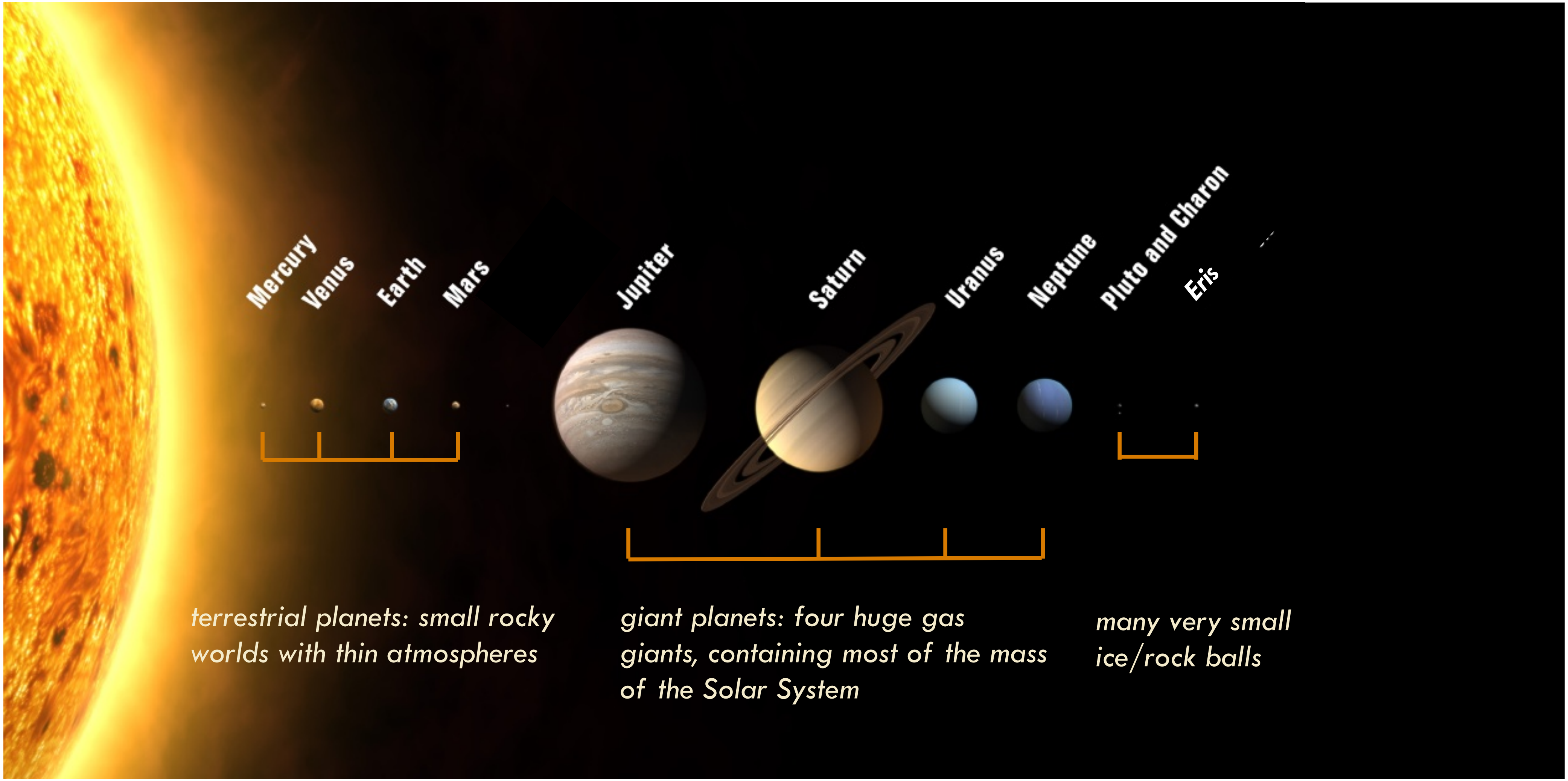
THE UNIVERSITY OF SYDNEY

In tonight's lecture

- Overview
  – *setting the scene of where we are*
- The Sun
- The terrestrial planets
- The giant planets
- Everything else

The Sun contains over 99.8% of the mass of the solar system. It has eight planets orbiting it, plus a multitude of smaller worlds.



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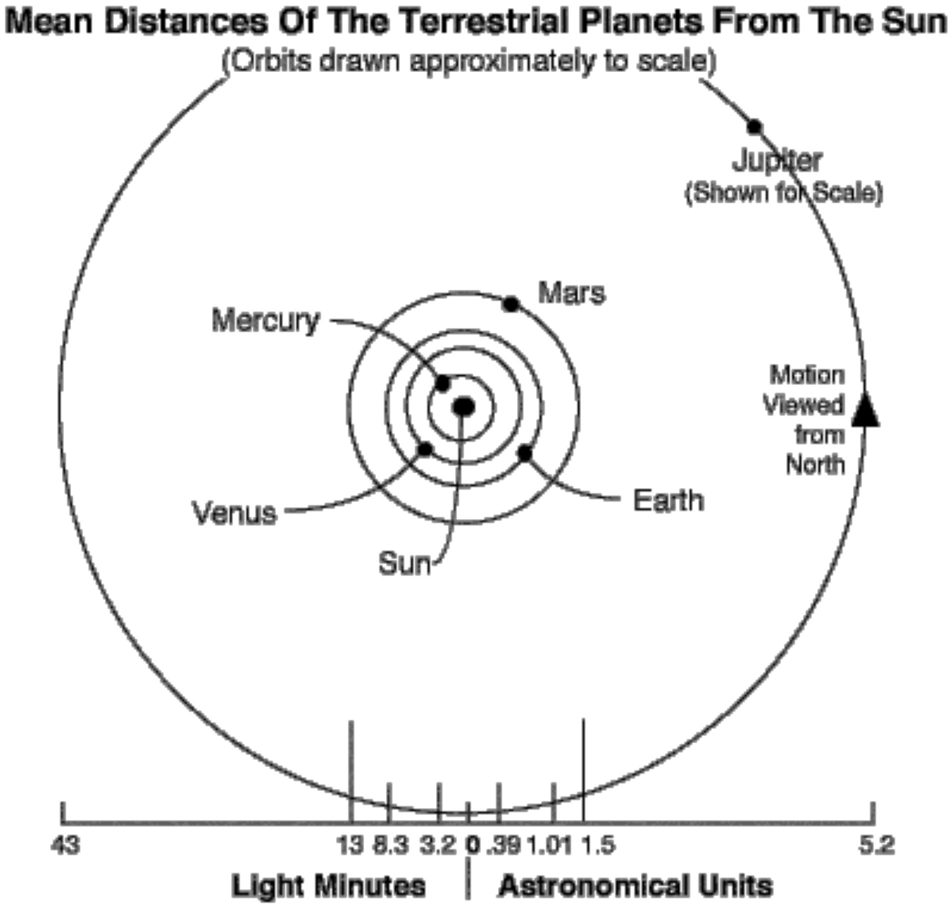
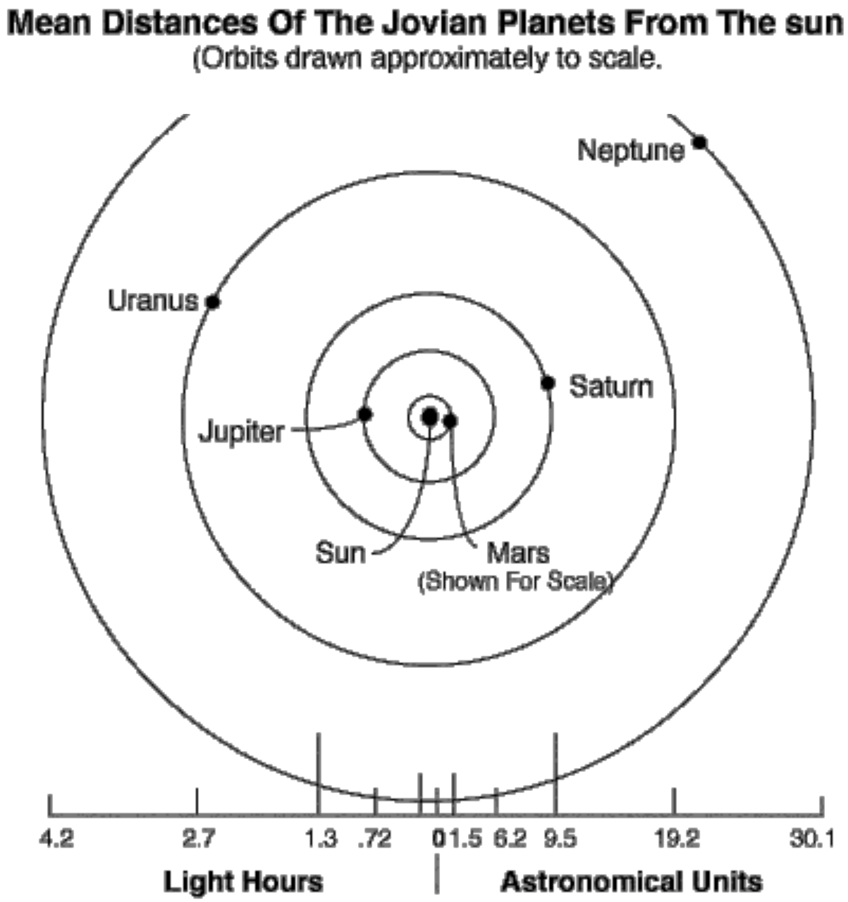
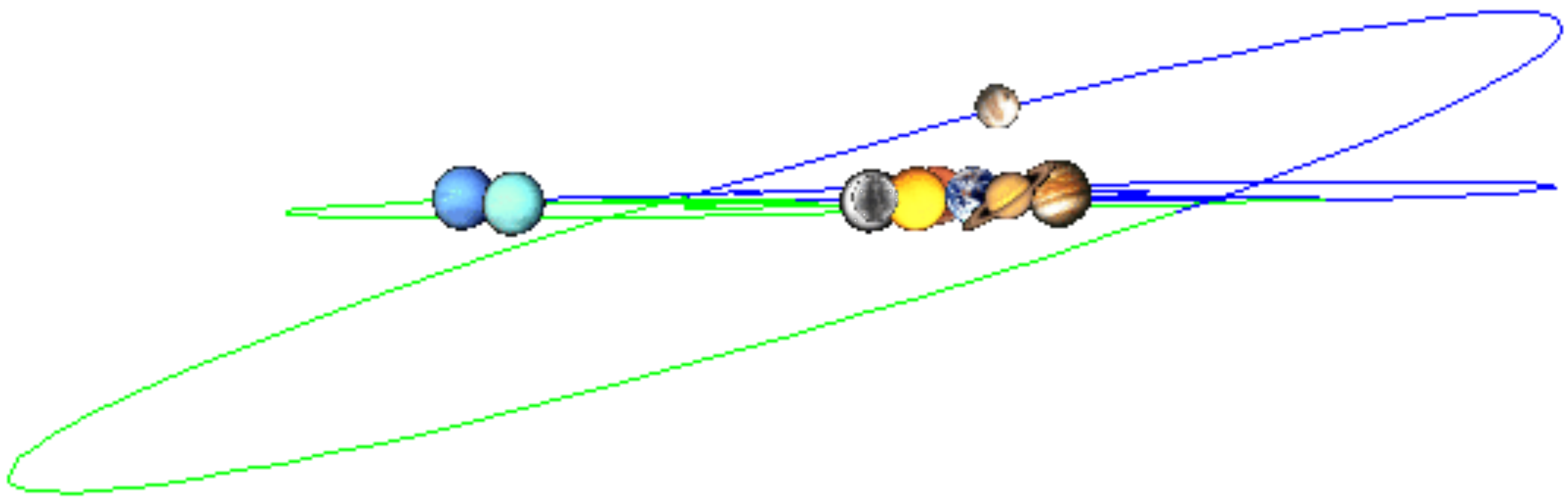
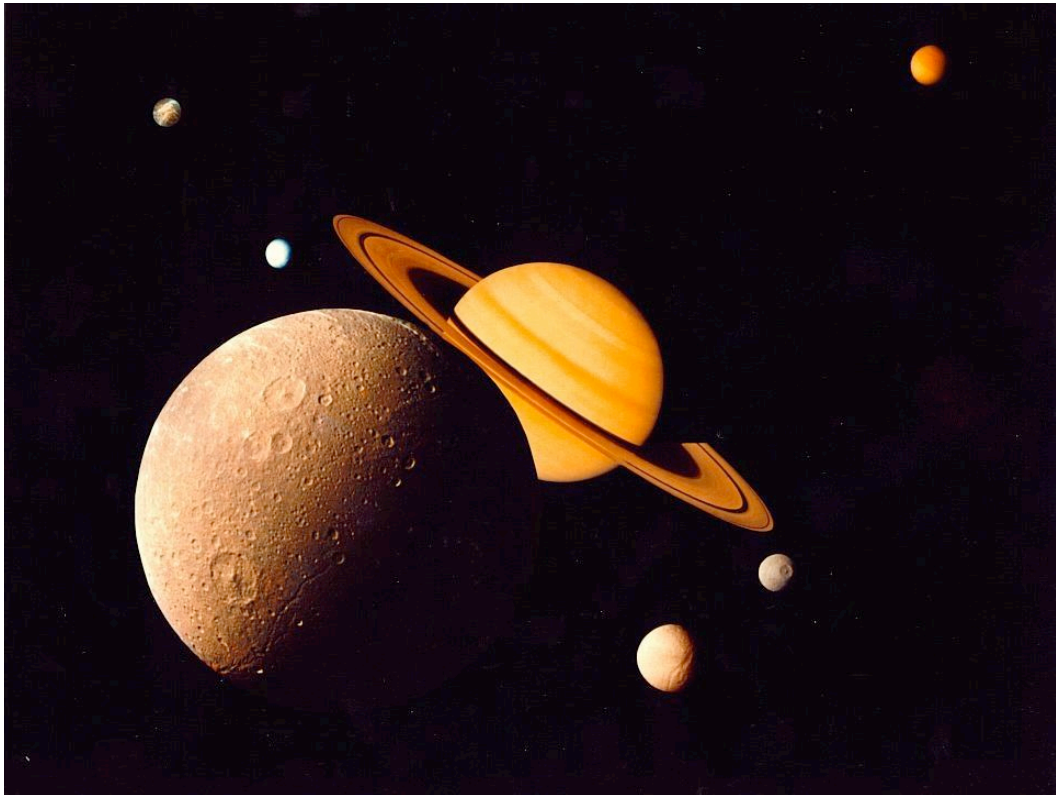
The orbits of the planets are very nearly circular and concentric.





All the planets (but not Pluto) orbit in the same direction and in the same plane: the *ecliptic* (to within 6o).



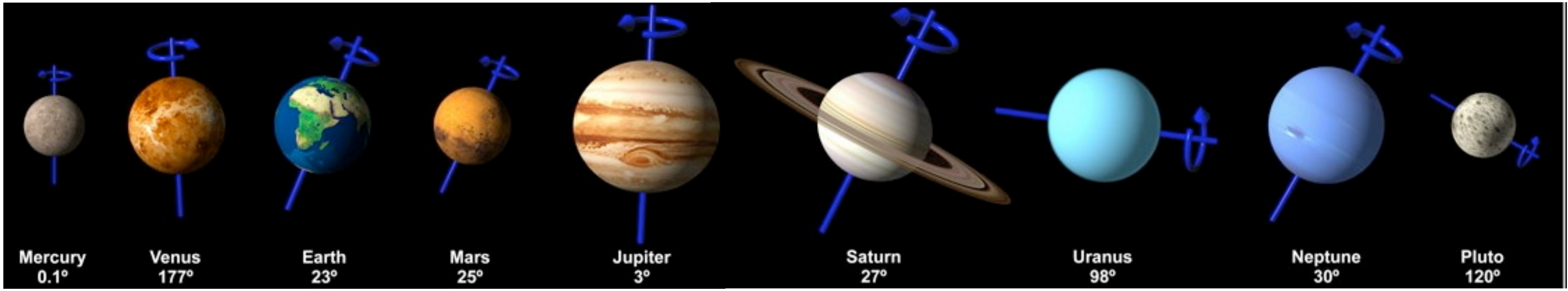


Most of the planets (all except Mercury and Venus) have moons in orbit around them. The giant planets all have large satellite systems, consisting of several large- and medium-size moons, as well as many smaller moons and rings.


Earth
Moon
Jupiter
Io
Europa
Ganymede
Callisto
Saturn
Mimas
Enceladus
Tethys
Dione
Rhea
Titan
Hyperion
Iapetus
Phoebe
Uranus
Miranda
Ariel
Umbriel
Titania
Oberon
Neptune
Proteus
Triton
Nereid

The largest of these satellites are larger than some of the planets.

All the planets go around the Sun in the same direction. Most moons go around their primaries in the same direction, and most (but not all) of the planets spin in the same direction as well.



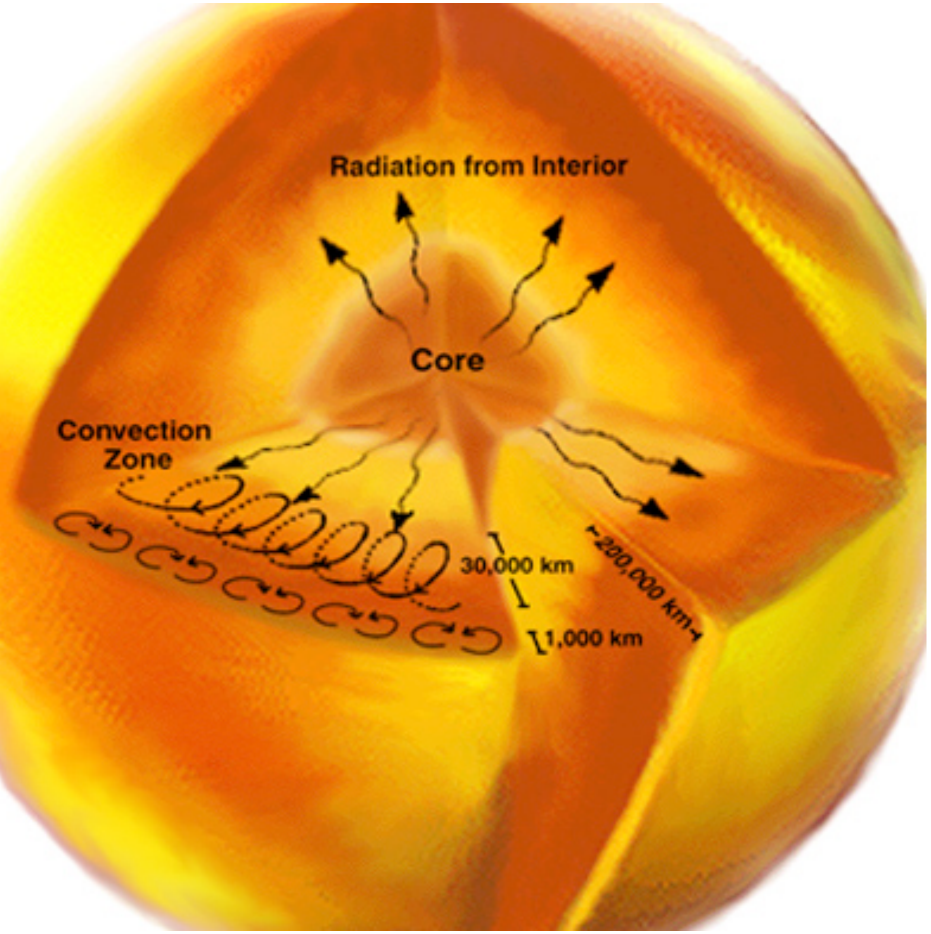

The Sun
– *the nearest star*

At the centre of the Solar System is the Sun. It is a fairly average G2-type star.

The Sun weighs about 300,000 times as much as the Earth and is 1.3 million times the volume.

The Sun shines because it is continually producing energy in its core through hydrogen fusion.

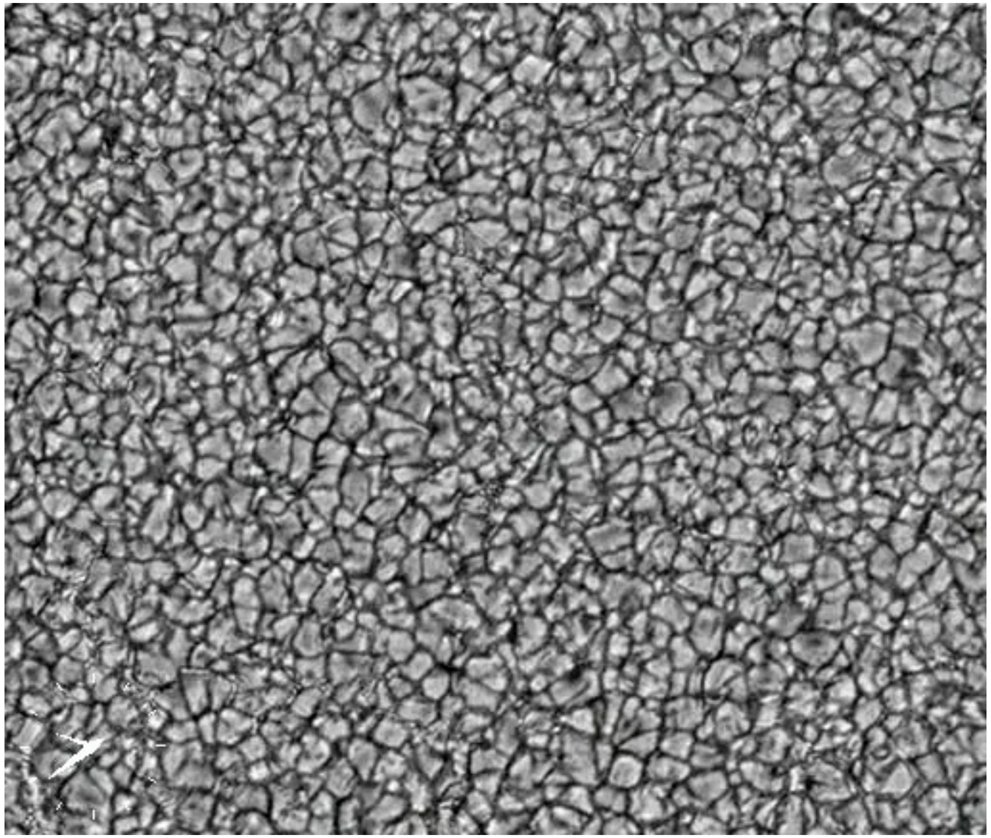
The temperature at the surface of the Sun is 5780 K. In the core, the temperature is about 15 million degrees.



The core extends from the Sun's centre to about one-quarter of its radius, or about 175 million km. It contains about 1.6% of the Sun's volume, but about one-half of its mass.

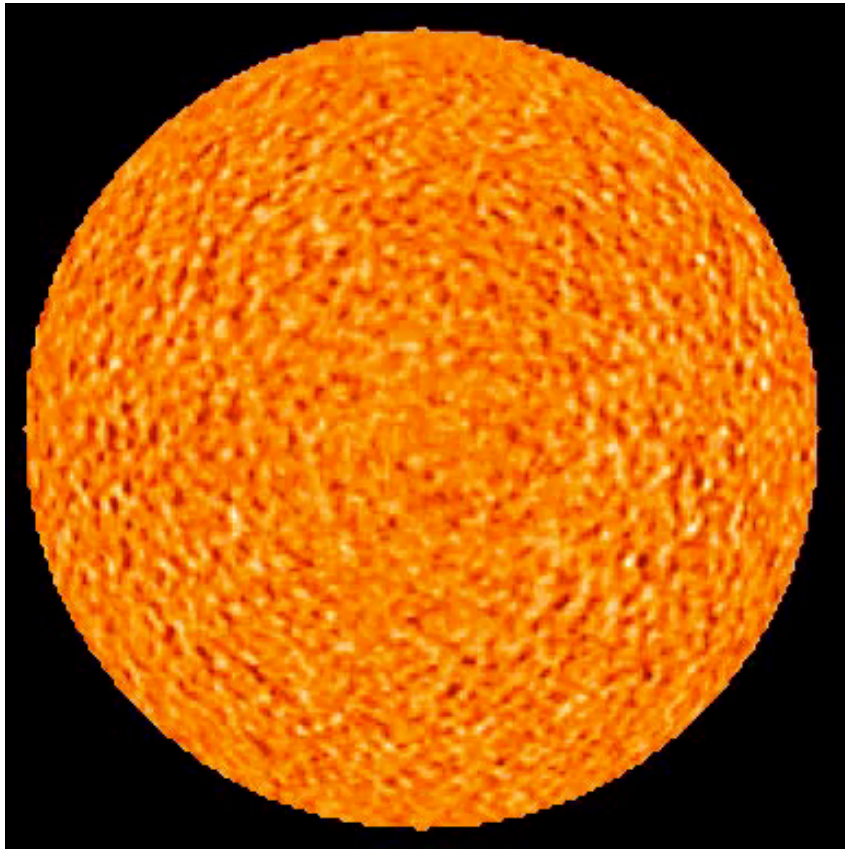
The convection zone takes up the outer 30% of the Sun's radius: the heat is transported by giant bubbles of gas circulating upwards, releasing their energy, then sinking down again.

These convection currents are visible on the surface as granules. Hot gas rises in the centres, radiates its heat, then sinks along the dark edges. Granules typically last 5–10 minutes, and are about 1300 km in size.



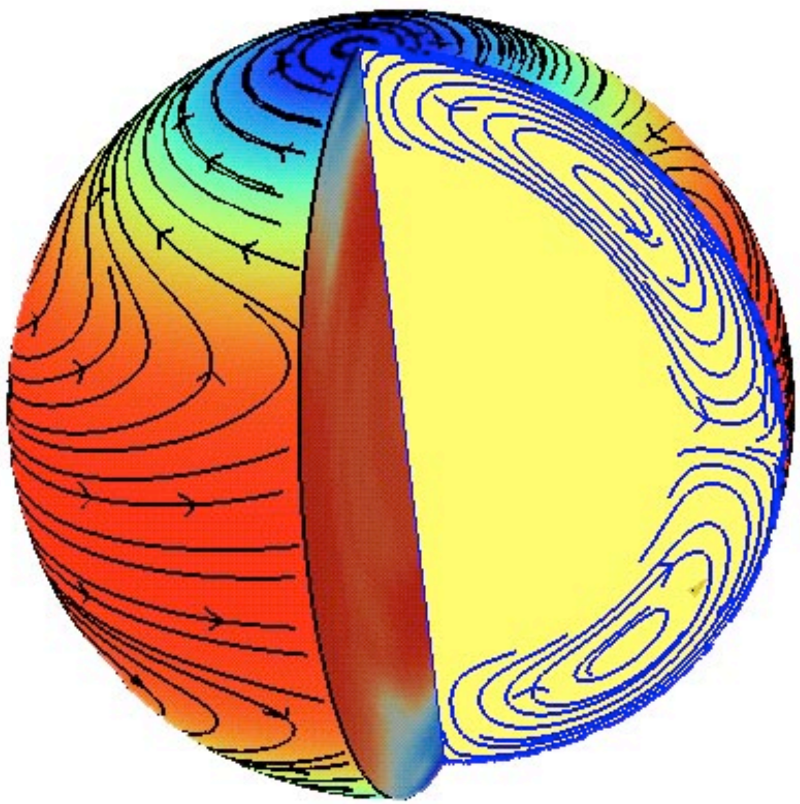
High-magnification images of the Sun, showing granules evolving.

We can't see below the outer surface of the Sun – the *photosphere* – but we can use *helioseismology*, the study of vibrations of the Sun, to understand the solar interior.



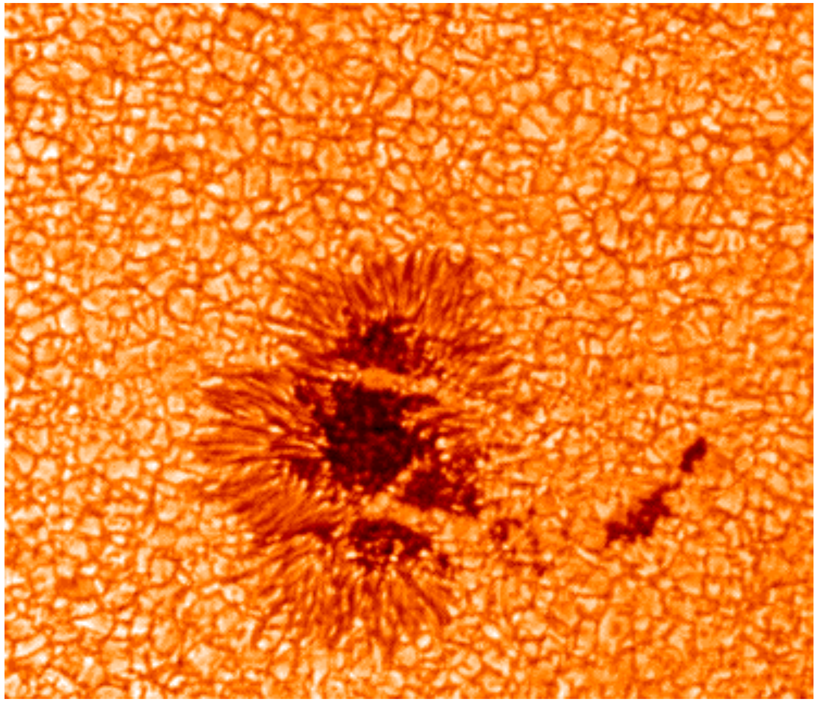
Five hours of solar oscillations.

These vibrations show that the Sun is completely gaseous, and rotates in bands, with the equator rotating faster than the poles. In addition, there is a polar "jet stream" below the surface, and a general flow from the equator to the poles.

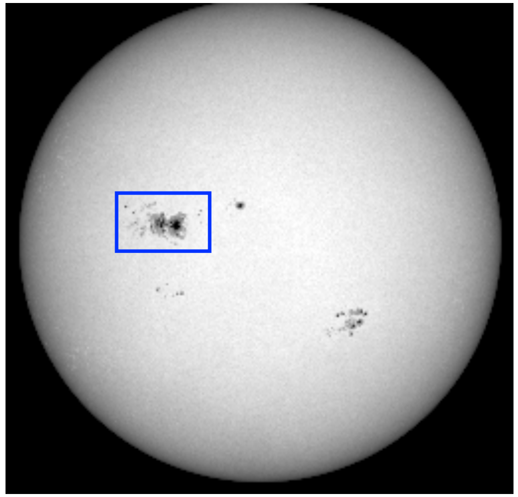


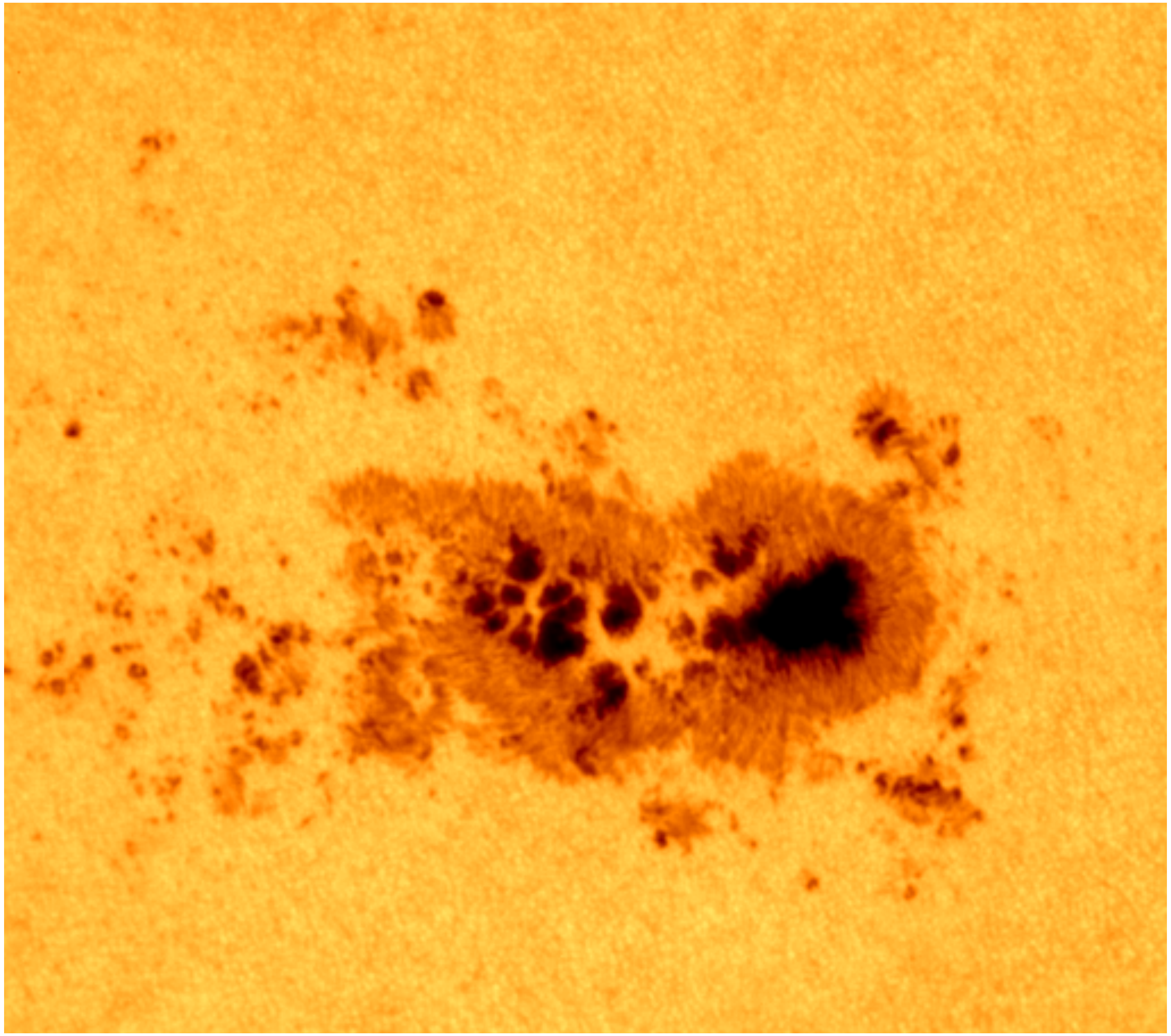
At the surface, we see the granules from the convection, but we also often see giant *sunspots*.

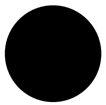
Sunspots can be many times larger than the Earth. They appear dark because they are cooler than their bright surroundings, about 2000 K cooler. Most sunspots remain visible for only a dew days; others can last for weeks or months.



A very large sunspot group, about 13 times the size of Earth

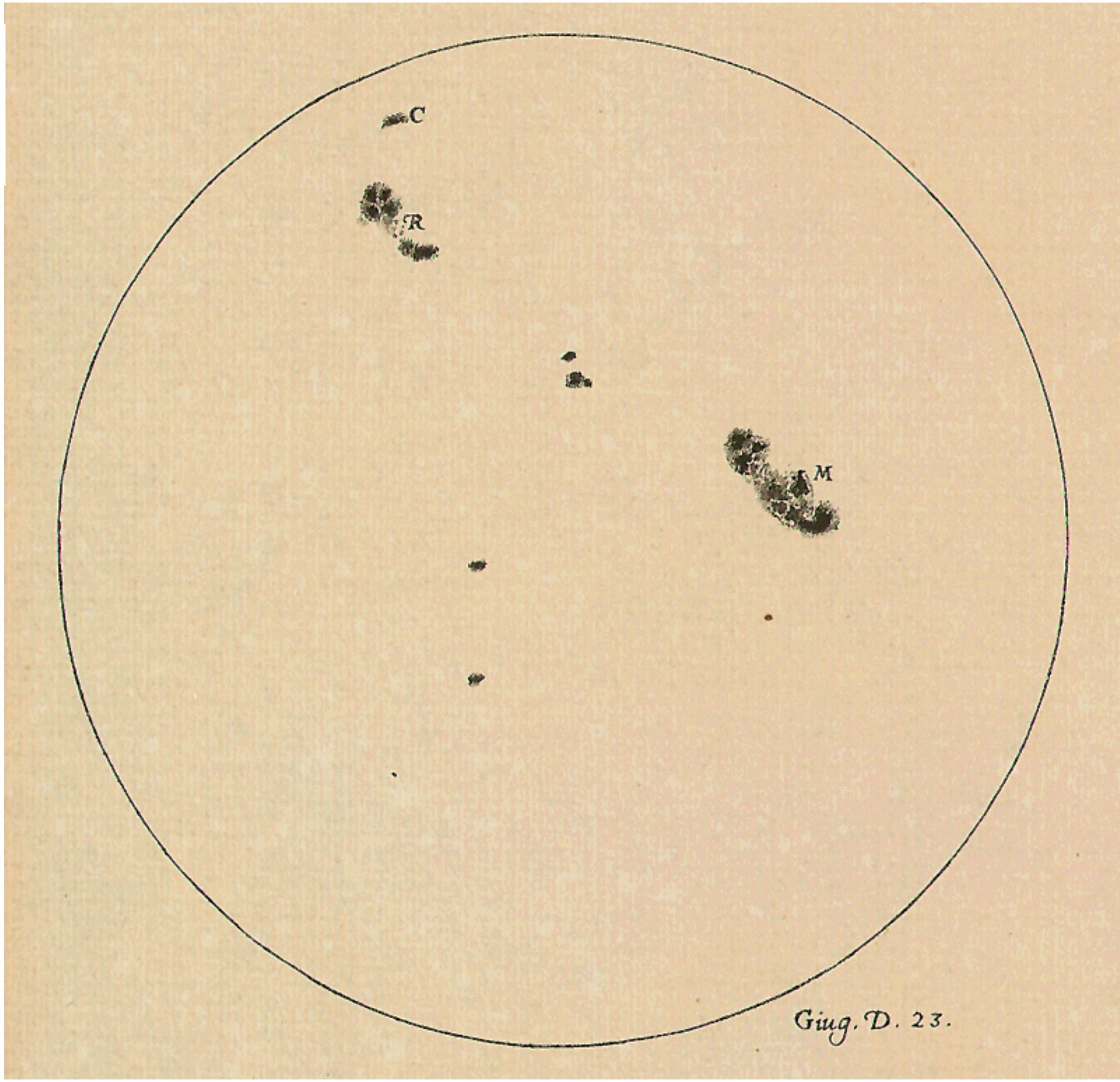




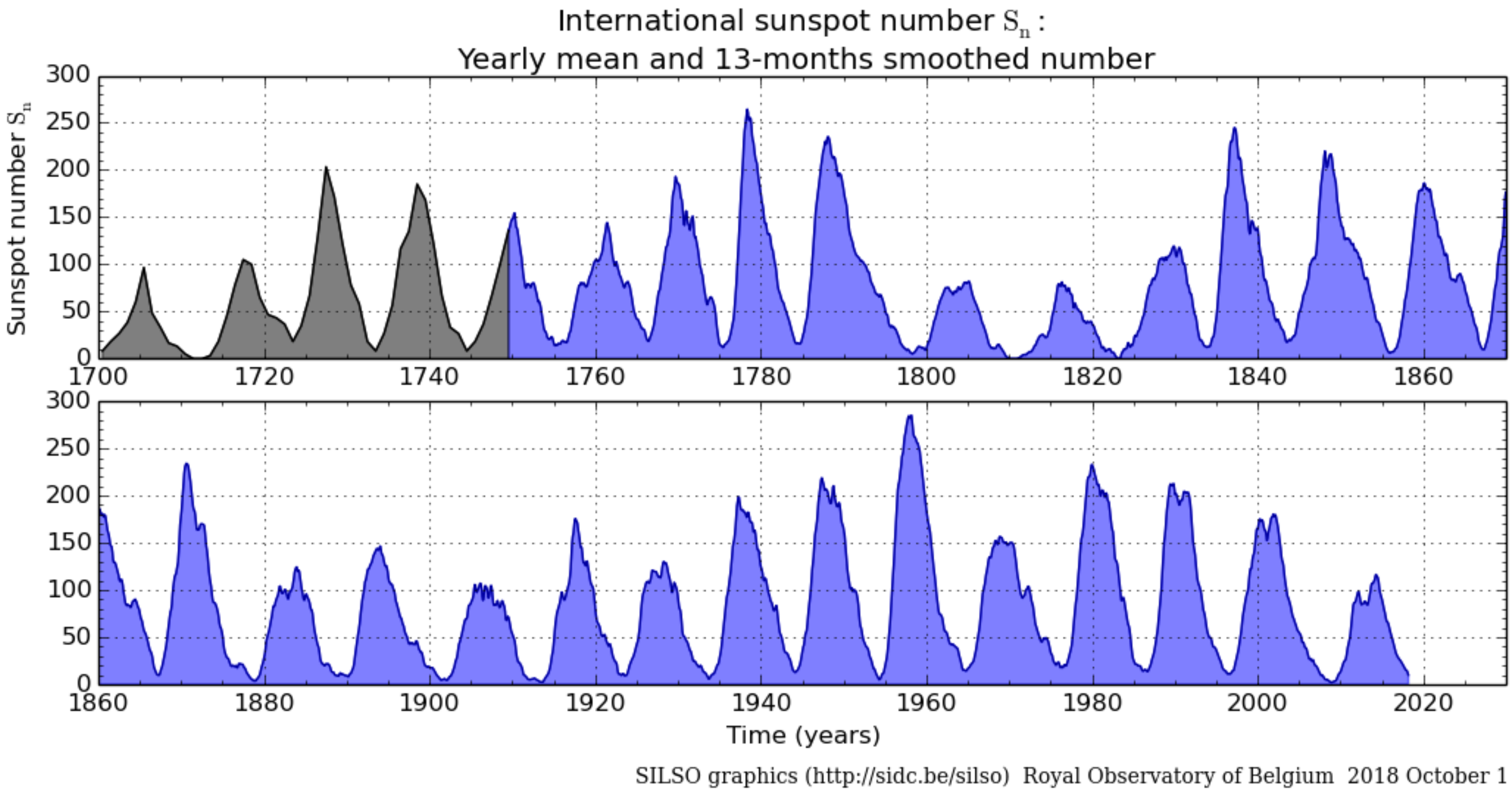


Size of Earth (approx)

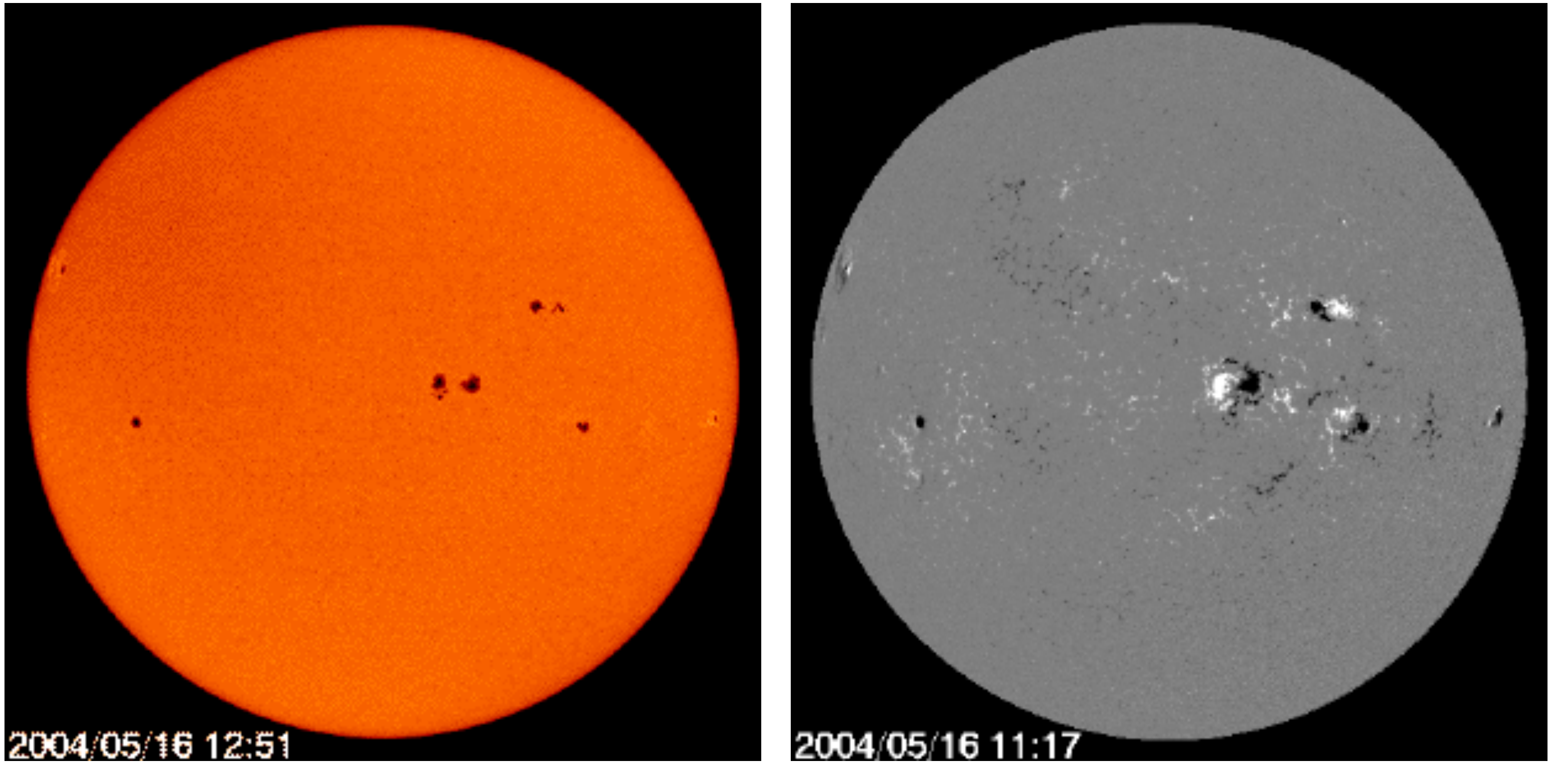
One of Galileo's drawings of sunspots, from 23 June 1613



The number of sunspots visible on the Sun waxes and wanes in an approximately 11-year cycle (although individual cycles vary from 8 to 14 years).

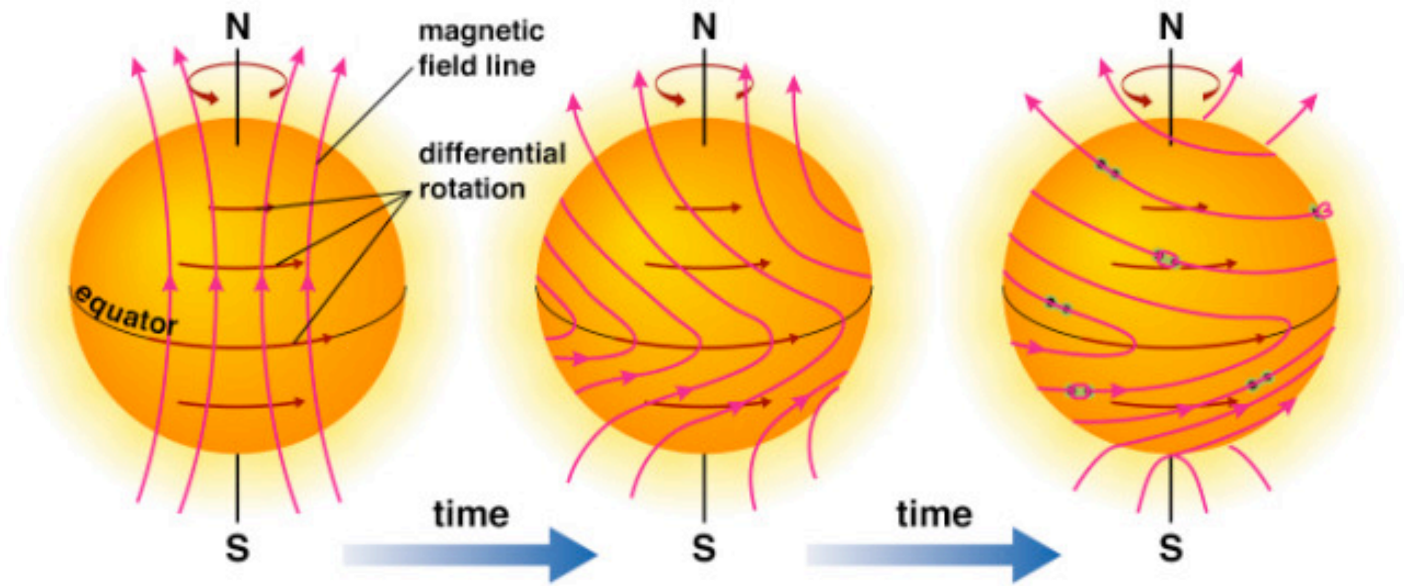


Sunspots are associated with strong magnetic fields. When sunspots come in pairs, they have opposite polarity (shown as black and white in the magnetogram).

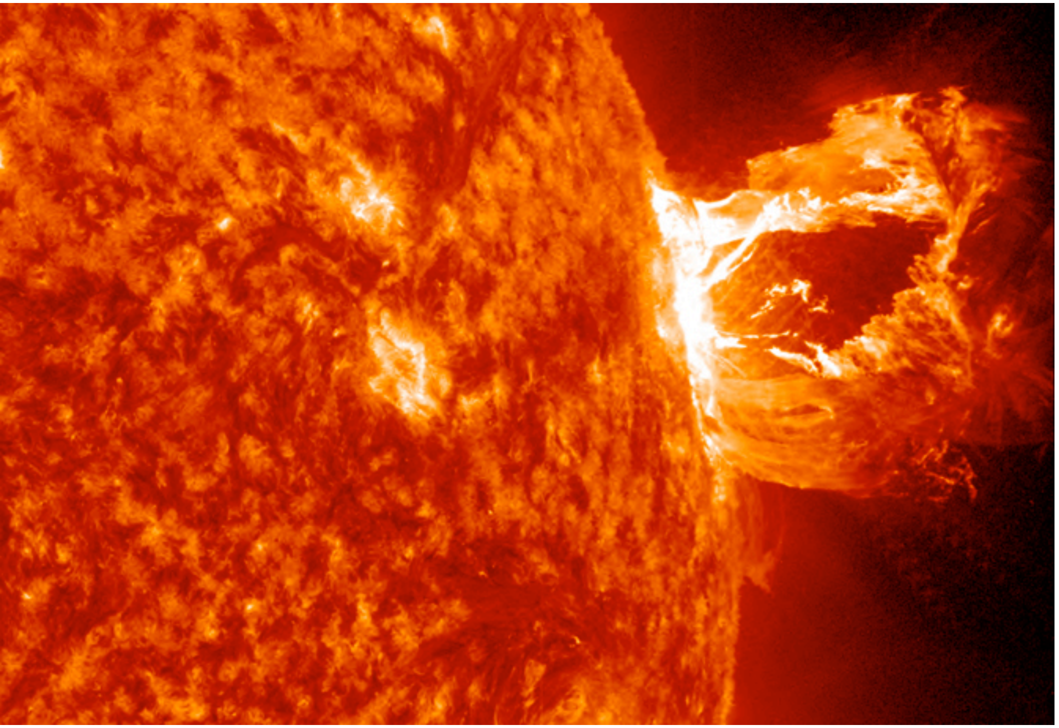


Continuum (left) and magnetogram (right) images from SOHO

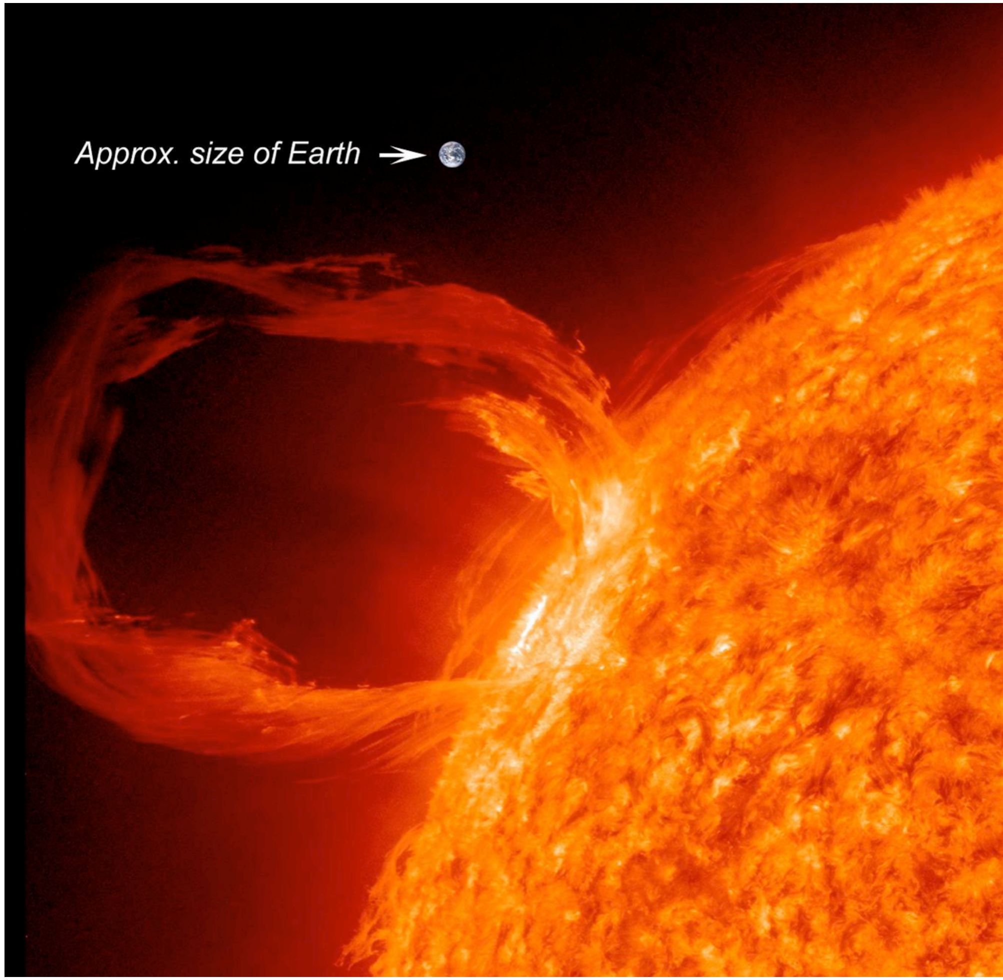
The Sun's magnetic field is confined to shallow layers near the surface. As the Sun rotates, since the equator rotates faster than the pole, the magnetic field lines get wound up. Occasionally a loop of magnetic field breaks free: we see the feet of the loop as a pair of sunspots.



When this loop seen off the edge of the Sun it is called a *prominence* in the lower atmosphere, or *chromosphere*.

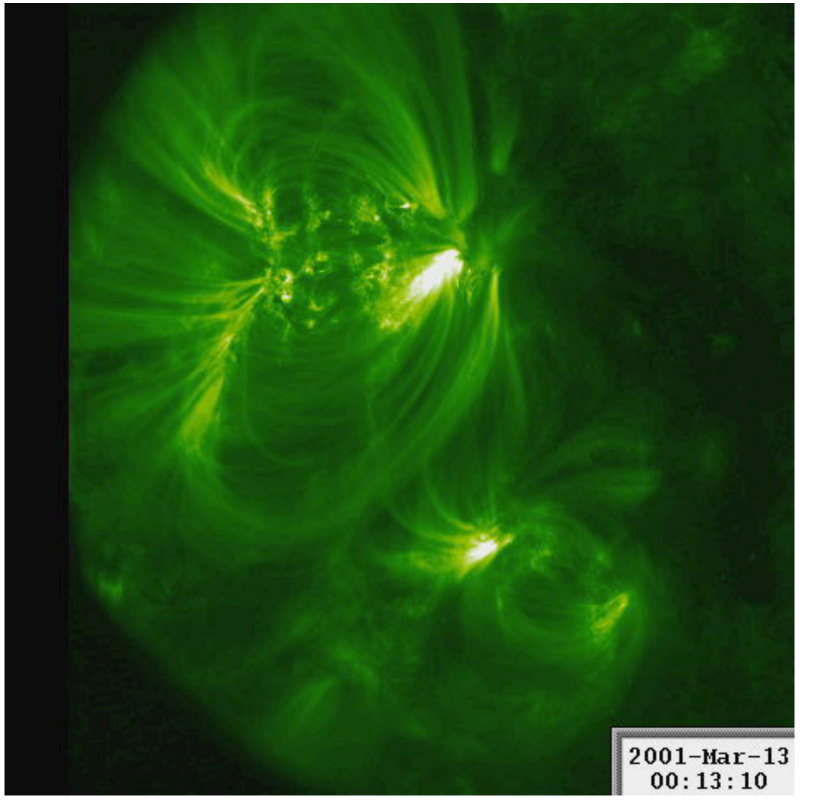


Some prominences erupt off the edge of the Sun in minutes or hours; these blobs of gas are truly enormous.



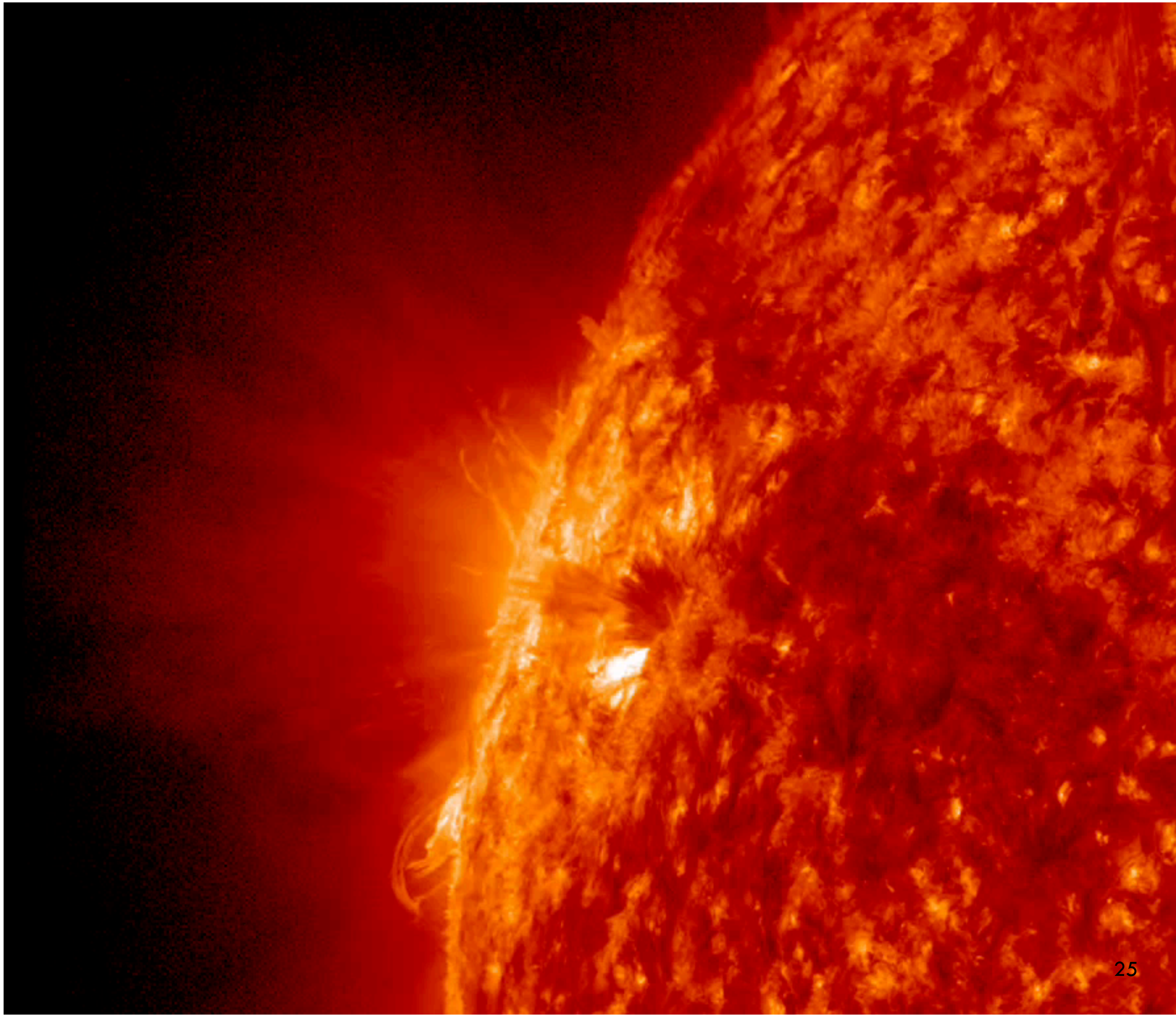
Above the chromosphere is the extended outer atmosphere called the corona. X-ray images of the Sun show that the corona is a violent, ever-changing place.

Coronal loops are found around sunspots. They are associated with the magnetic field lines connecting magnetic regions on the solar surface, and can last for days or weeks.



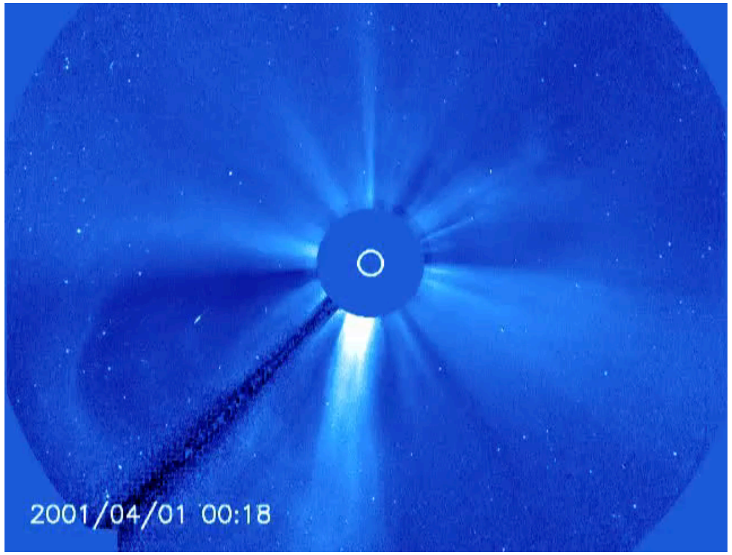
TRACE movie of coronal loops.

Solar flares are tremendous explosions on the surface of the Sun. They typically last a few minutes and release energy across the whole EM spectrum, from radio to X-rays, as well as energetic particles.



SDO observations of Active Region 1514, which popped off over a dozen flares over two days in June 2012.

Solar flares are often, but not always, associated with *coronal mass ejections*, where enormous quantities of material are ejected from the surface of the Sun. The two events now appear to be related but not identical.



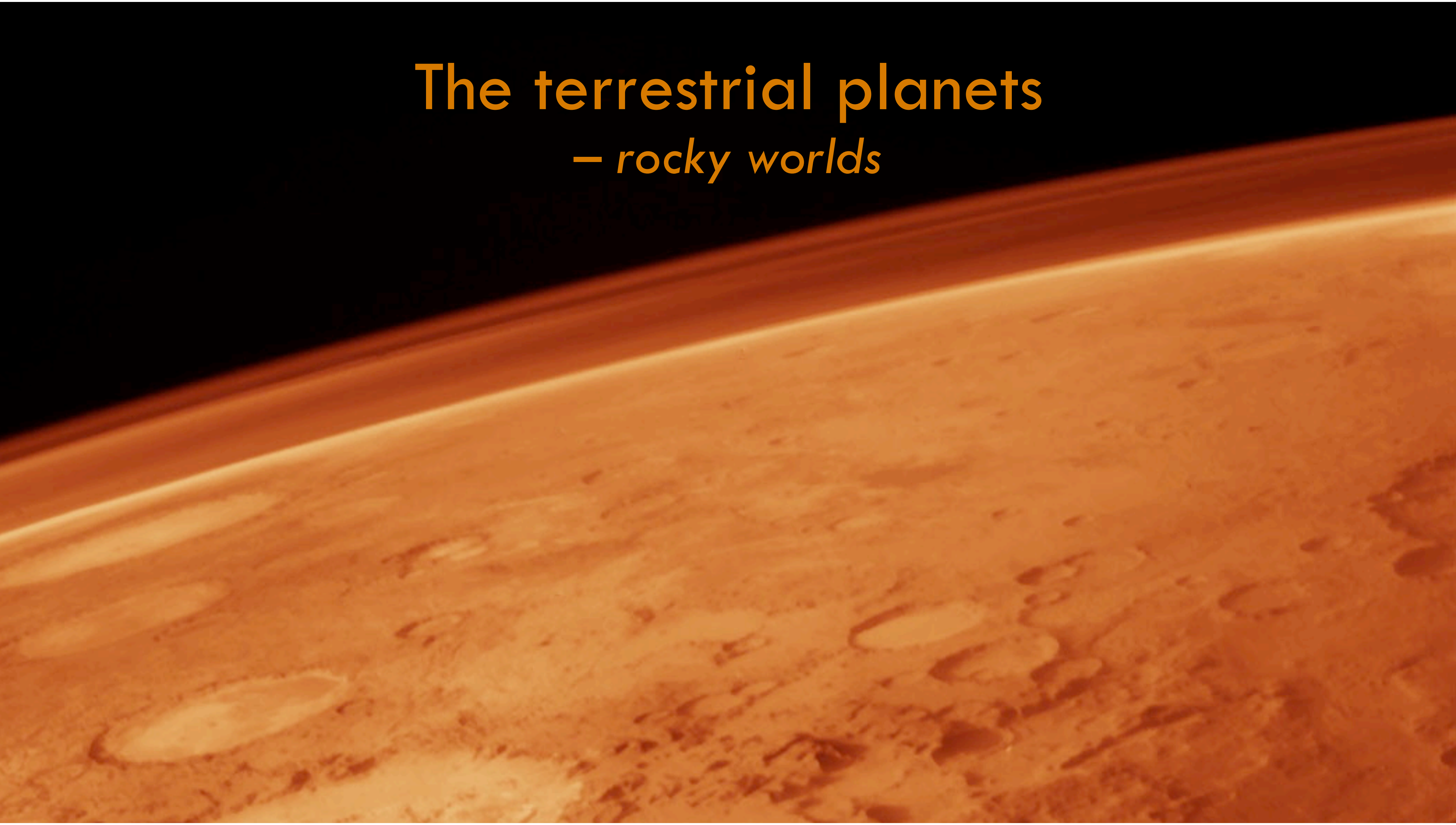
Movie showing several coronal mass ejections and associated proton showers.

The Sun emits a high-speed *solar wind*, consisting primarily of electrons and protons, with a few heavier ions. It blows continuously at an average velocity of 400 km/s.

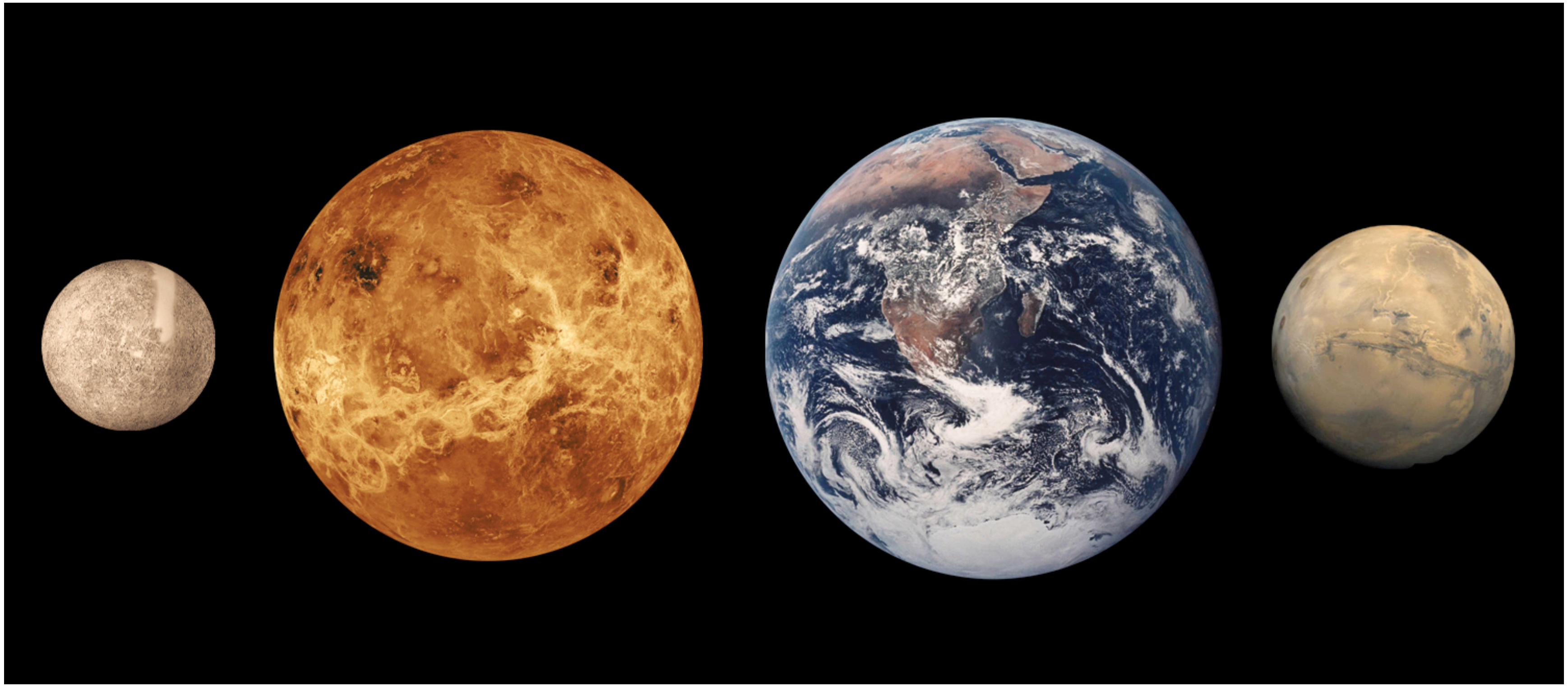
It escapes from the Sun primarily through coronal holes at the poles, and is responsible for auroras when particles from the solar wind are trapped in the Earth's magnetic field.

The terrestrial planets

– rocky worlds

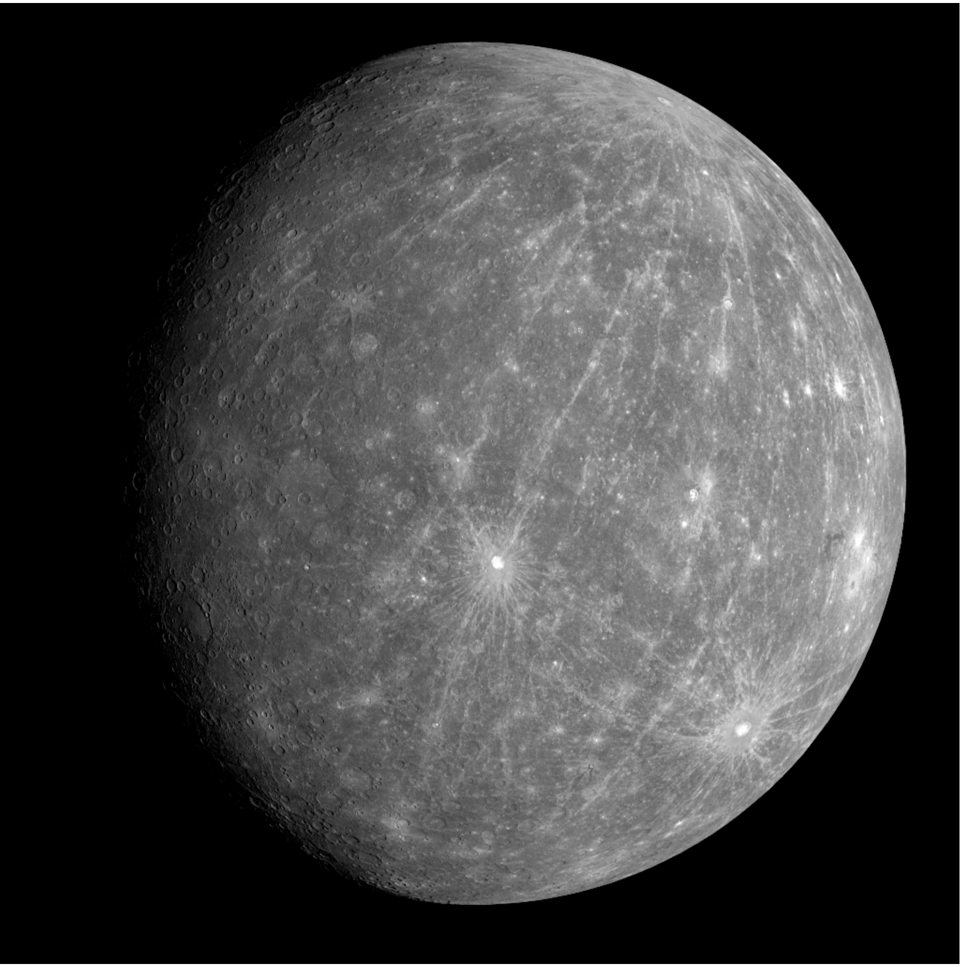


The innermost planets are the *terrestrial planets* – the (at least approximately) Earth-like planets. The terrestrial planets are small, dense, rocky worlds, with much less atmosphere than the outer planets. They all lie in the inner solar system.



Th *The four terrestrial planets: Mercury, Venus, Earth and Mars, showing the relative sizes.*

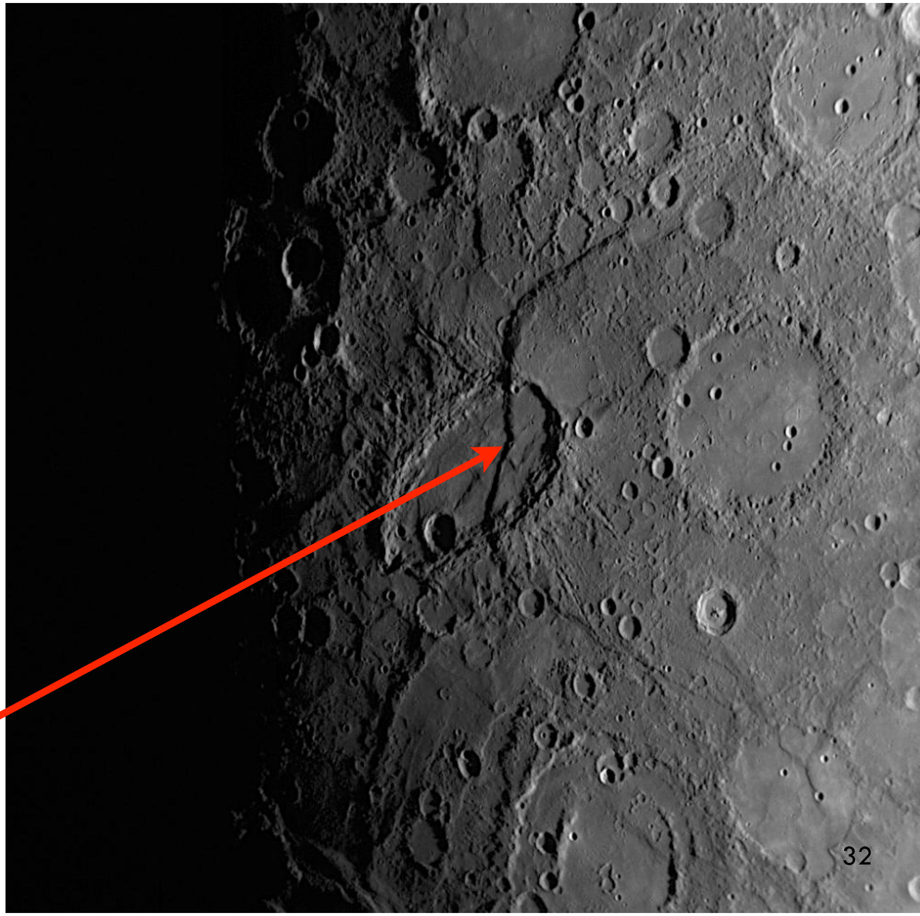
Mercury is the smallest planet in the Solar System, only slightly larger than the Moon. It is extremely dense, so must contain a very large core (~70% of its mass).



Mercury orbits the Sun every 88.0 days, and rotates on its axis once every 58.7 days. This combines to give Mercury a day of 176 (Earth) days long, twice the length of the year!

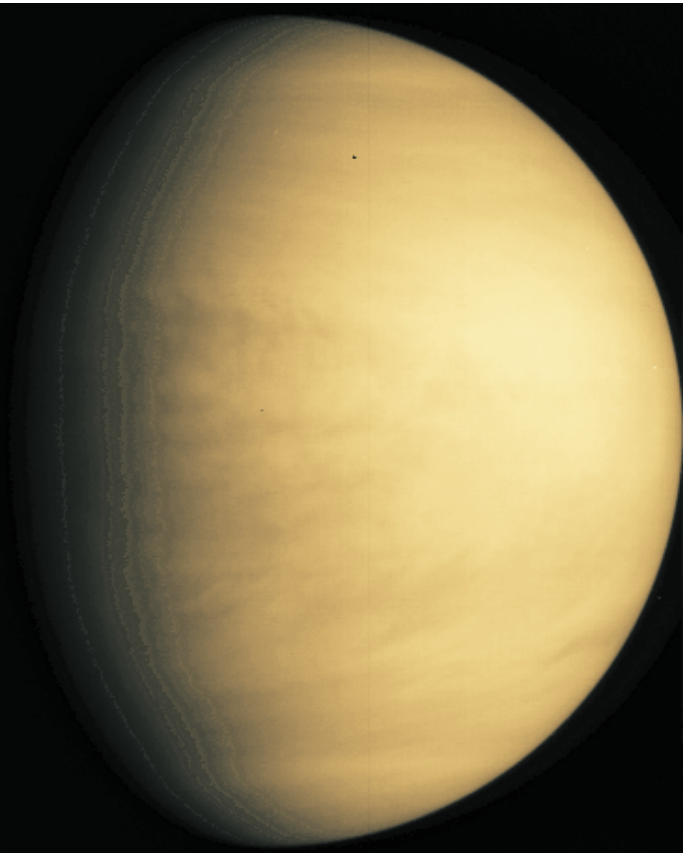
Mercury has almost no atmosphere.

Mercury's surface is dominated by impact craters and lava plains. It also has long linear features: *scarps* and *troughs*. The scarps are between 500–1000 m in height and can be several hundred km long. They are thought to have formed as the interior of Mercury cooled, causing the planet to contract slightly.



Beagle Rupes is more than 600 km long and bisects an unusual elliptical crater, Sveinsdóttir crater; the scarp is almost a kilometre high.

Venus is almost exactly the same size as Earth. It is completely covered by clouds. The atmosphere on Venus consists of 96% CO_2, 3% N_2, and trace amounts of other chemicals; the clouds are not water vapour, but sulphuric acid.

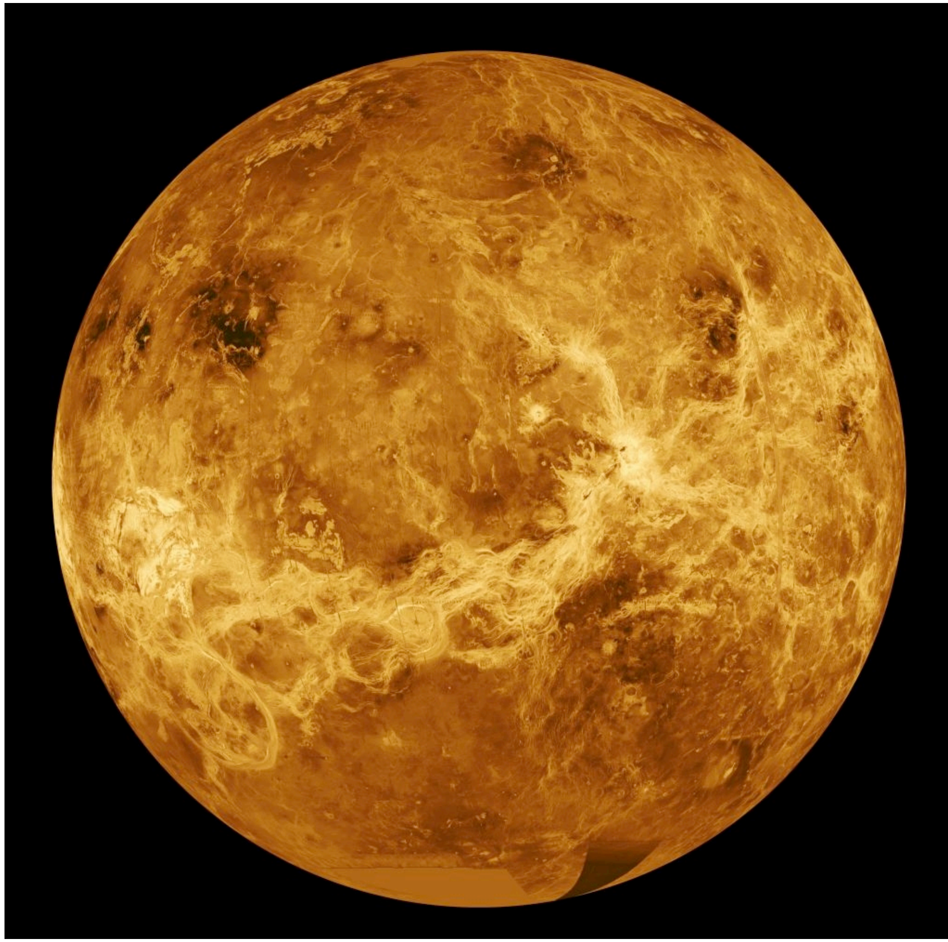


The pressure at the surface is 90 times the air pressure on Earth – the same pressure found at a depth of 1 km in Earth's oceans.

The temperature at the surface is 740 K (470° C), hot enough to melt lead.

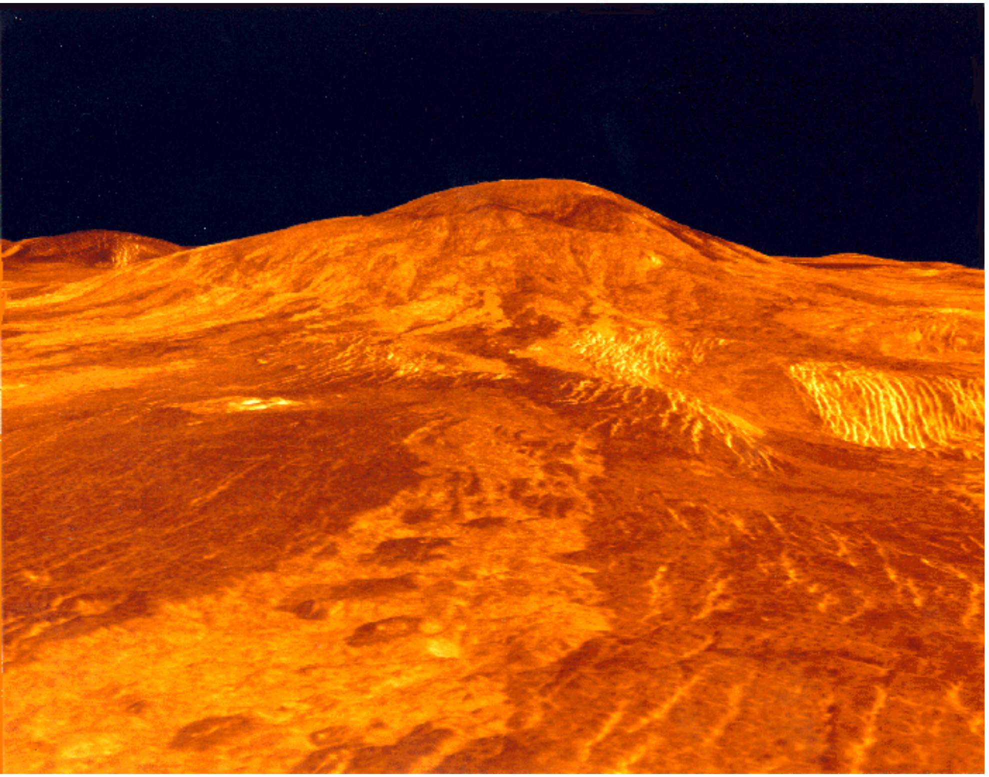
From the radar-mapping mission *Magellan* (1990–1994), we know that the surface of Venus is dominated by volcanoes: almost 90% of the surface is occupied by volcanic landforms.

More than 80% of the planet is covered by vast low-lying areas of relatively featureless flows of lava. There are also about 150 giant volcanoes, up to 700 km in diameter and up to 5.5 km in height.



Venus has hardly any impact craters; the surface density of craters indicates most of the surface is only 600 million years old; but craters do not appear to be eroding. Where are all the older craters?

Perhaps Venus undergoes periodic *catastrophic resurfacing*. The last such event would have taken place about 600 million years ago.



The volcano Sif Mons. is about 2 km high and nearly 300 km across. There appear to be recent lava flows at the front of the image: these flows are about 120 km long, which suggests that these lavas were also very fluid.

The surface of the *Earth* is concealed by the atmosphere, with its large cloud systems, by the large amounts of liquid water which cover 70% of the planet, and by vegetation; the latter two are unique in the Solar System.

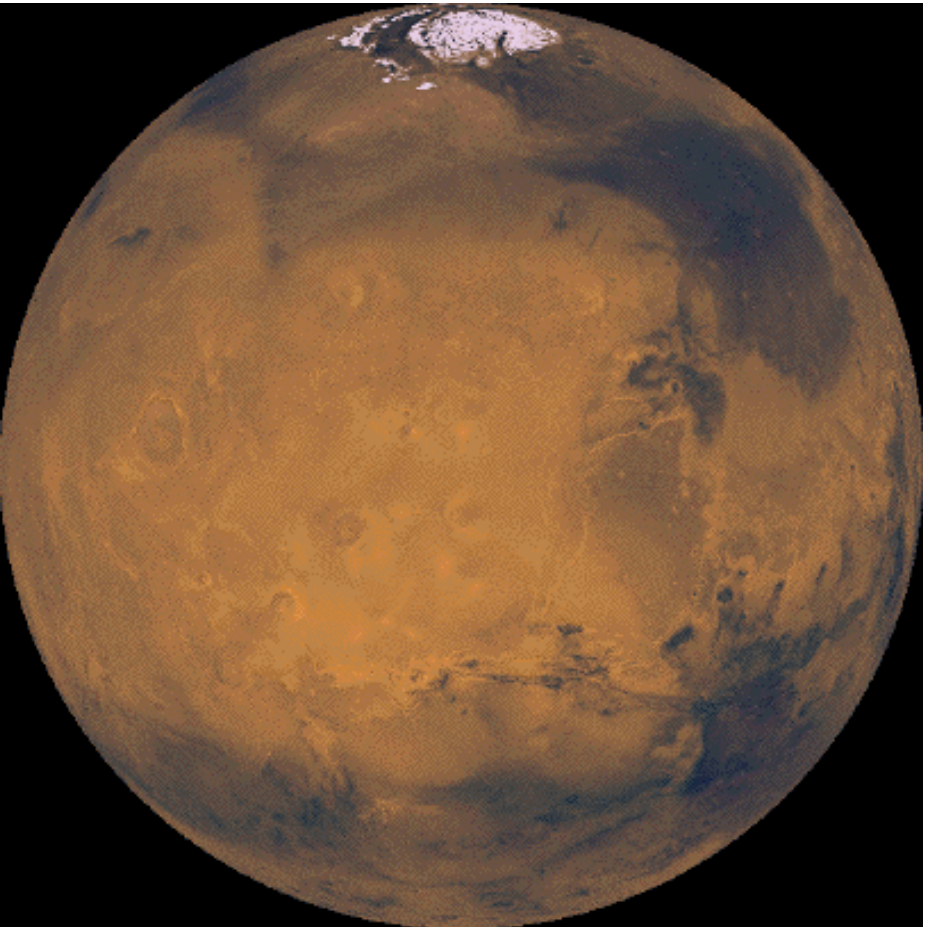
The Earth is the only planet which shows evidence of large-scale plate tectonics.

Earth's atmosphere is composed primarily of oxygen and nitrogen. This composition has changed significantly the Earth's history, principally because of the development of photosynthesis.

The Earth's moon is the largest in relation to the planet of any object in the Solar System except Pluto/Charon: the Moon is 1/4 the radius of the Earth, and 1/80 the mass.

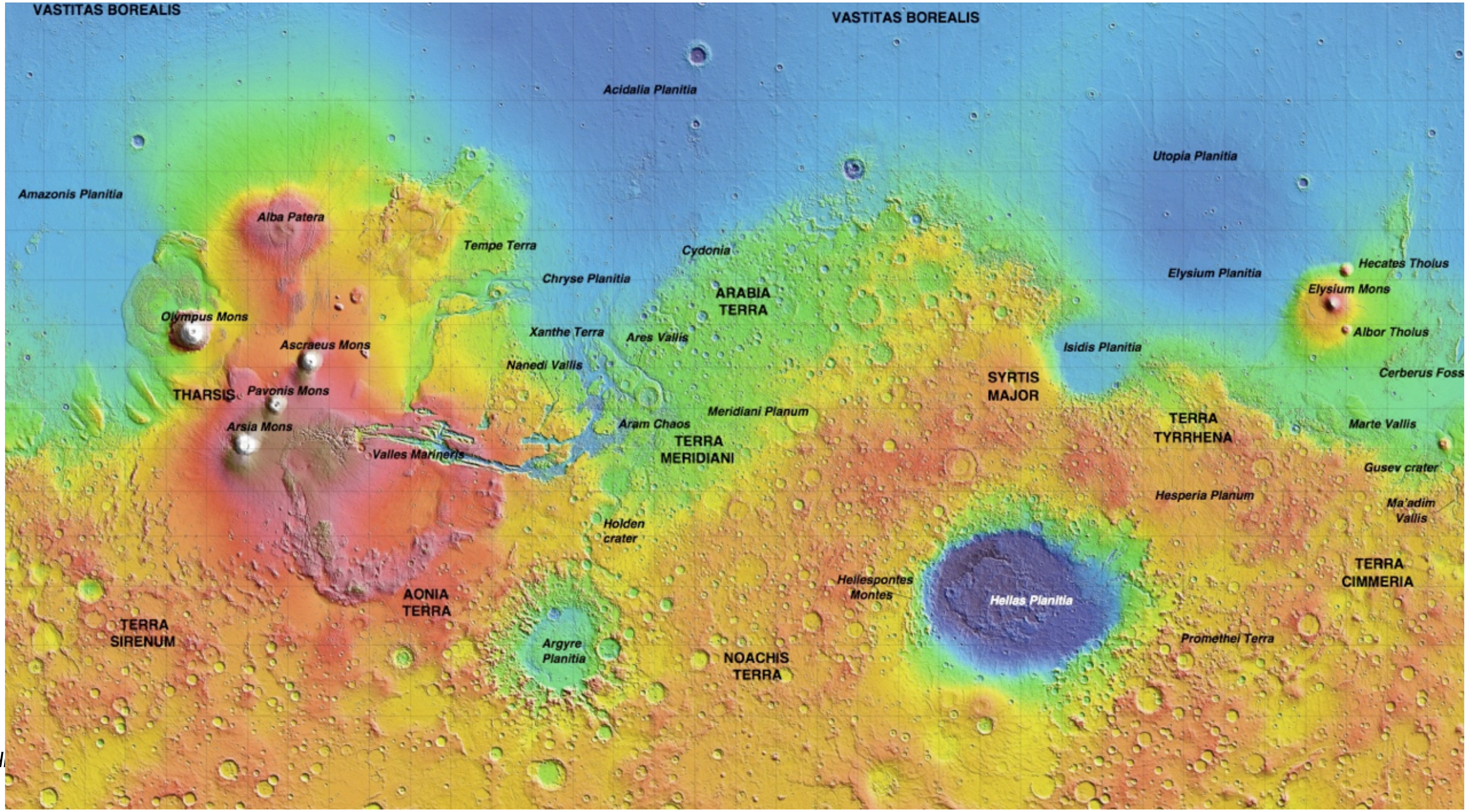
Image of the Earth and Moon taken by the Deep Space Climate Observatory (DSCOVR) satellite.

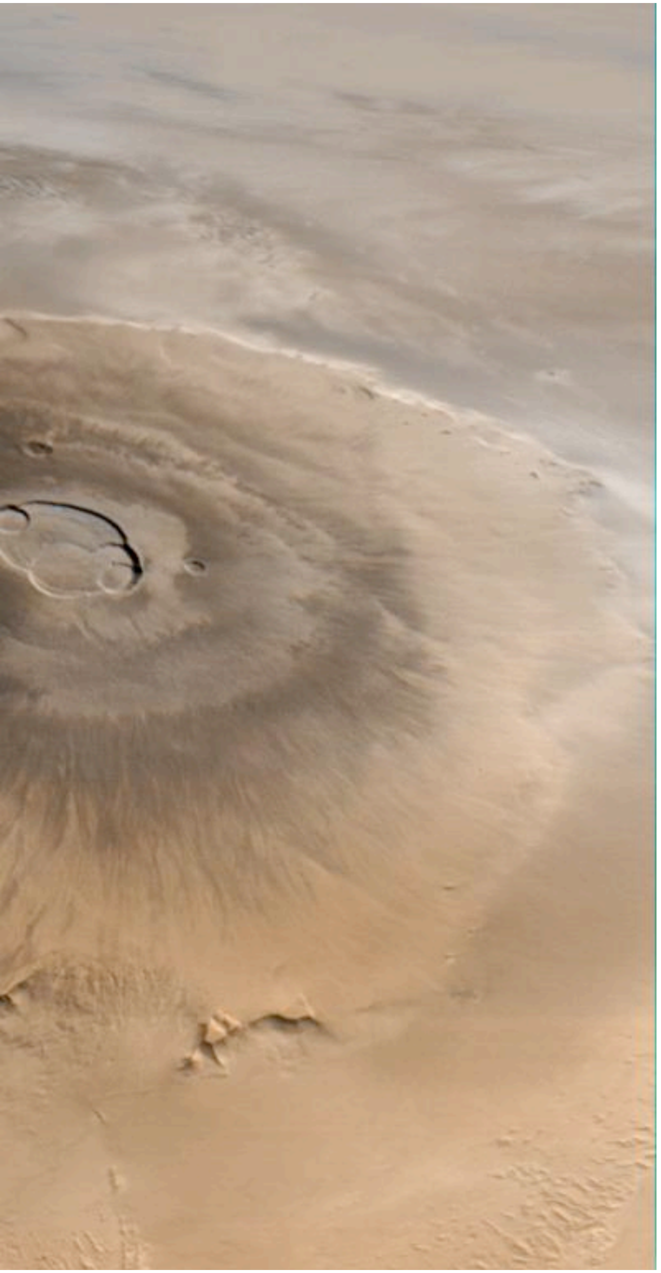
Mars is half the radius of the Earth and about 10% of the mass. It take nearly twice as long to orbit the Sun, but the length of its day and its axial tilt are very close to Earth's.



Mars has a thin atmosphere – 1/150th the pressure of Earth's – which is primarily CO_2, with small amounts of nitrogen and argon.

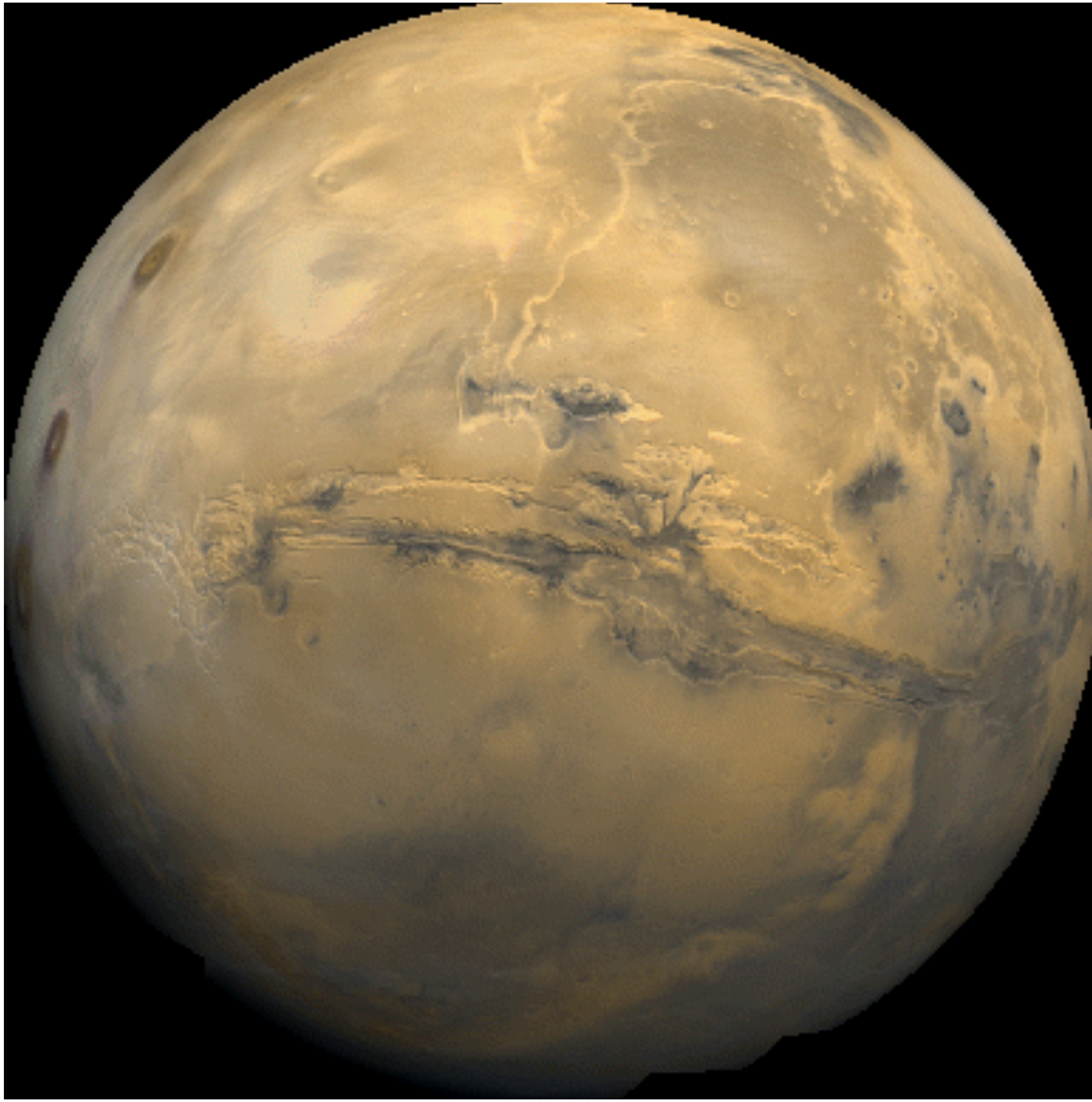
The southern hemisphere of Mars is several kilometres higher than the northern. Half the planet is heavily cratered and raised 1–4 km, the other is relatively smooth. This is known as the *crustal dichotomy*.



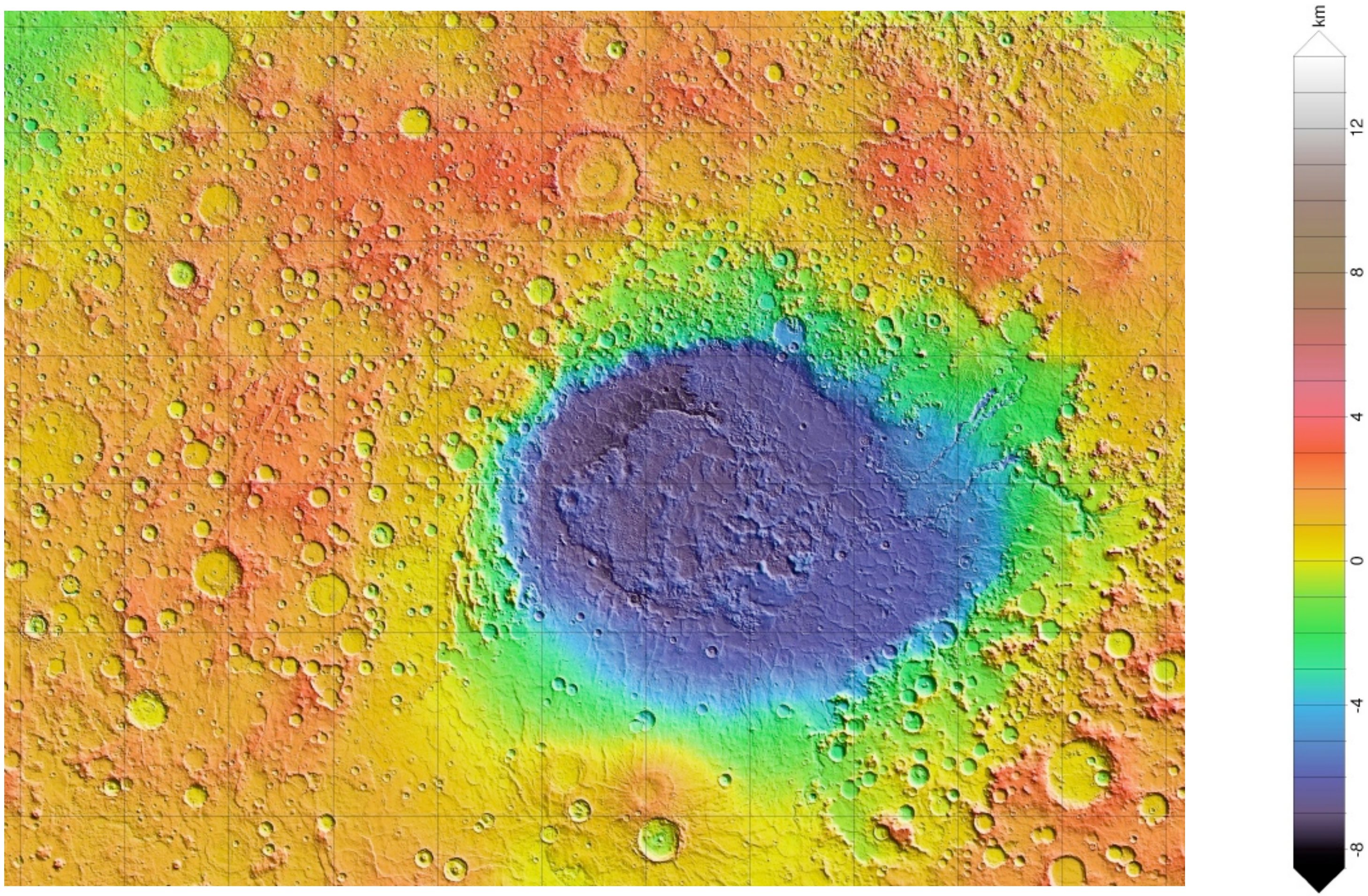


Mars is a planet of extremes. It has the tallest mountain in the Solar System: *Olympus Mons*, 27 km high;

the biggest canyon in the Solar System: *Valles Marineris*, over 4000 km long

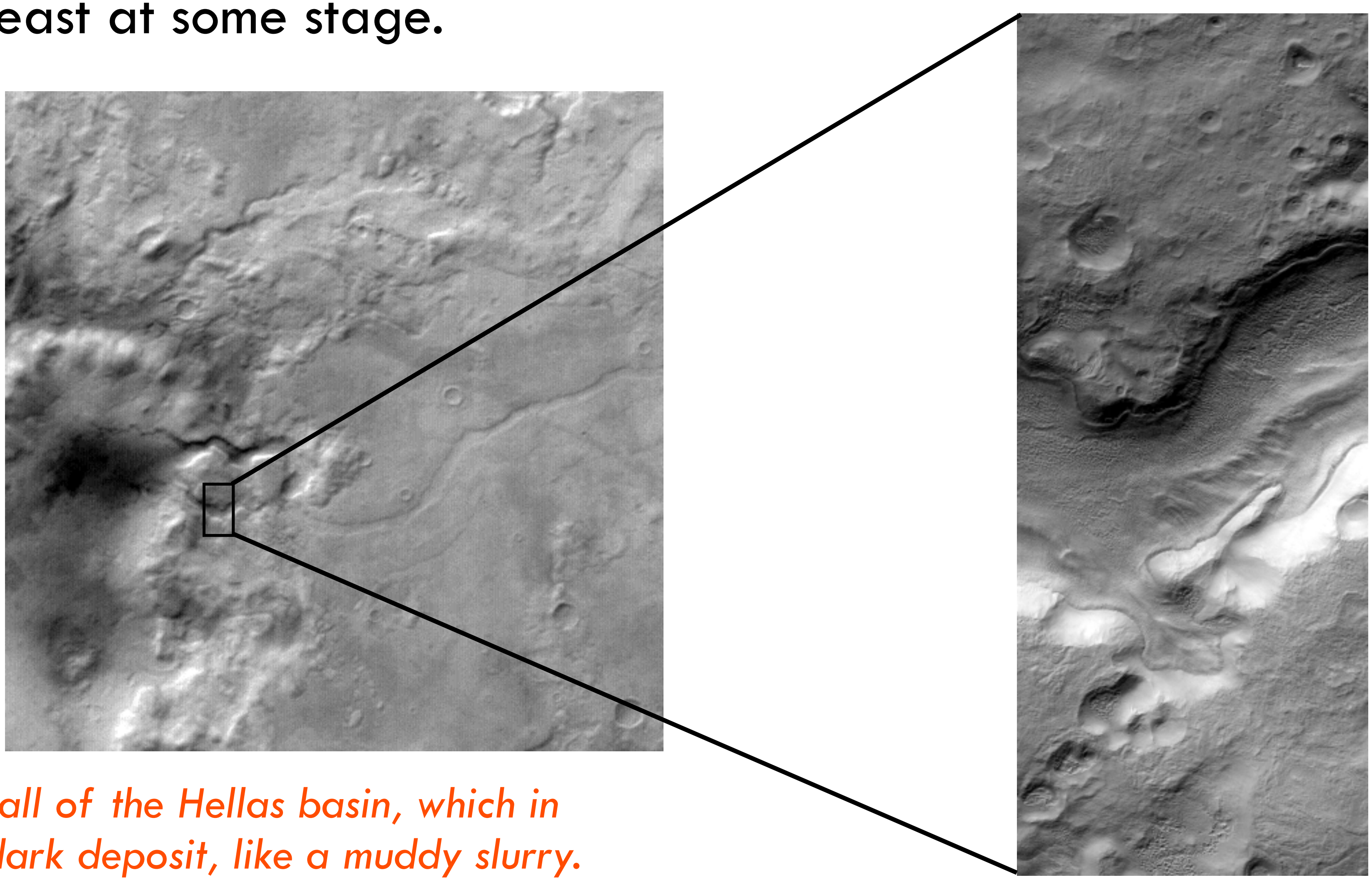


The Valles Marineris hemisphere of Mars, from mosaic of Viking images.

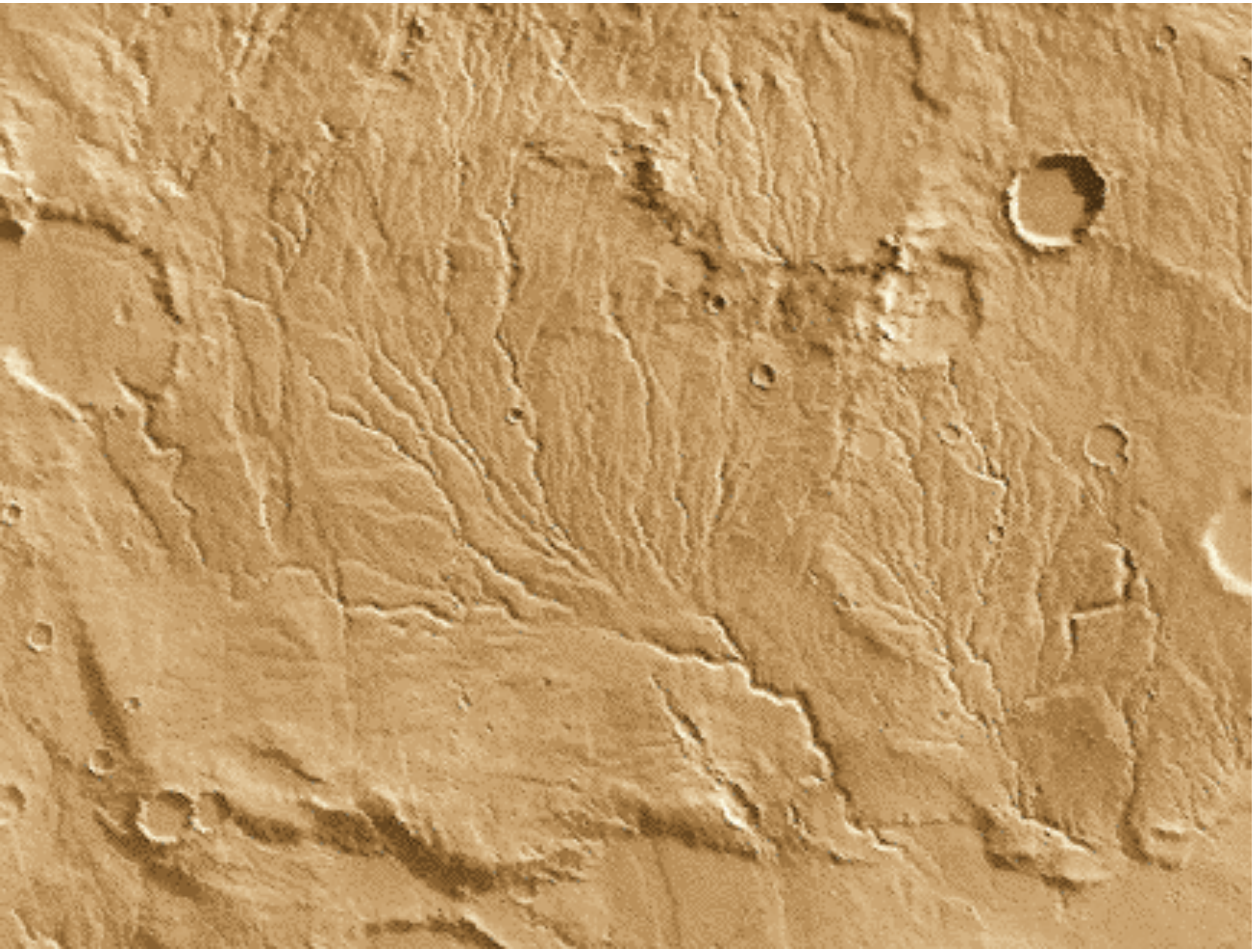


the deepest hole in the Solar System: *Hellas Basin*, a giant impact basin 8.2 km below the surrounding uplands.

There are many features showing that liquid (water?) was active on Mars at least at some stage.

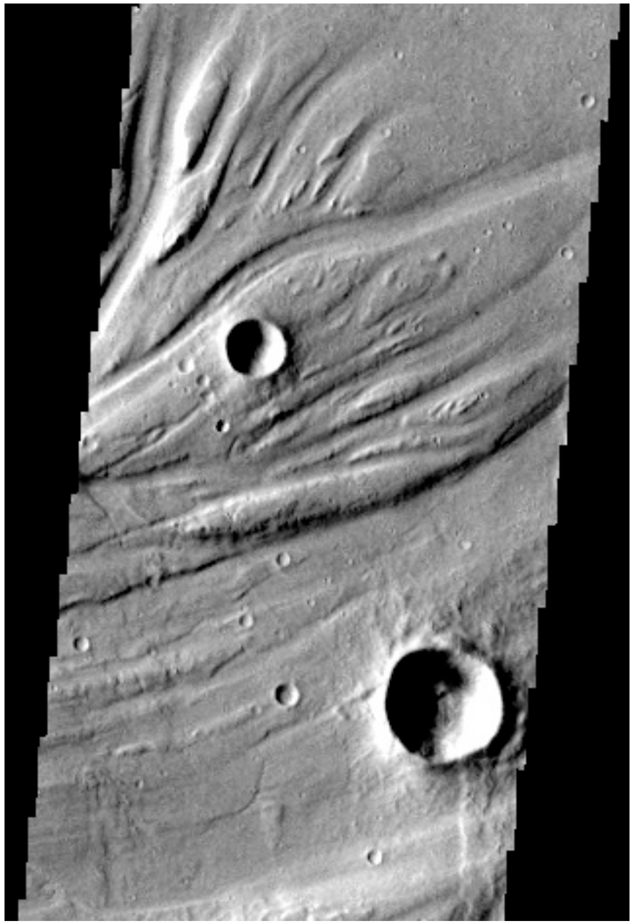


Channels in the wall of the Hellas basin, which in close-up show a dark deposit, like a muddy slurry.



Network of drainage channels, suggesting sustained flows of water.

Outflow in Chryse Planitia, about 20 km across. The crater at the top pre-dates the flow, while the bottom craters post-date it.



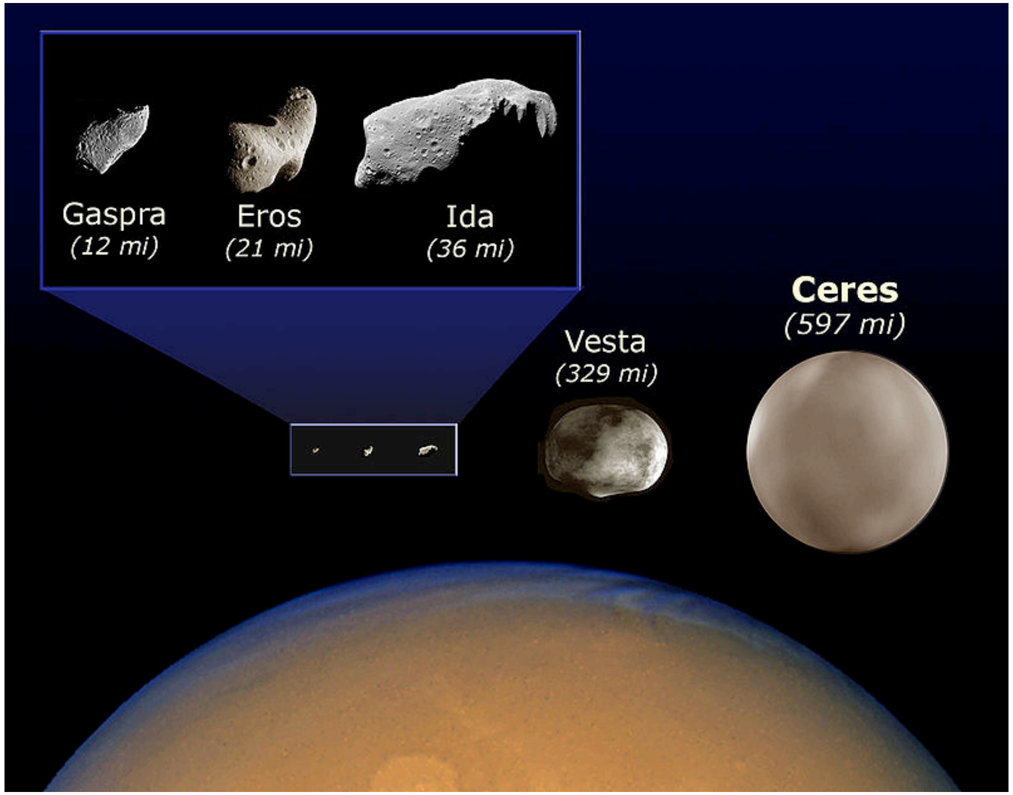
It seems clear that Mars had flowing liquid on its surface at least at some stage during its history. Was there ever free water on Mars – a giant ocean in the north?

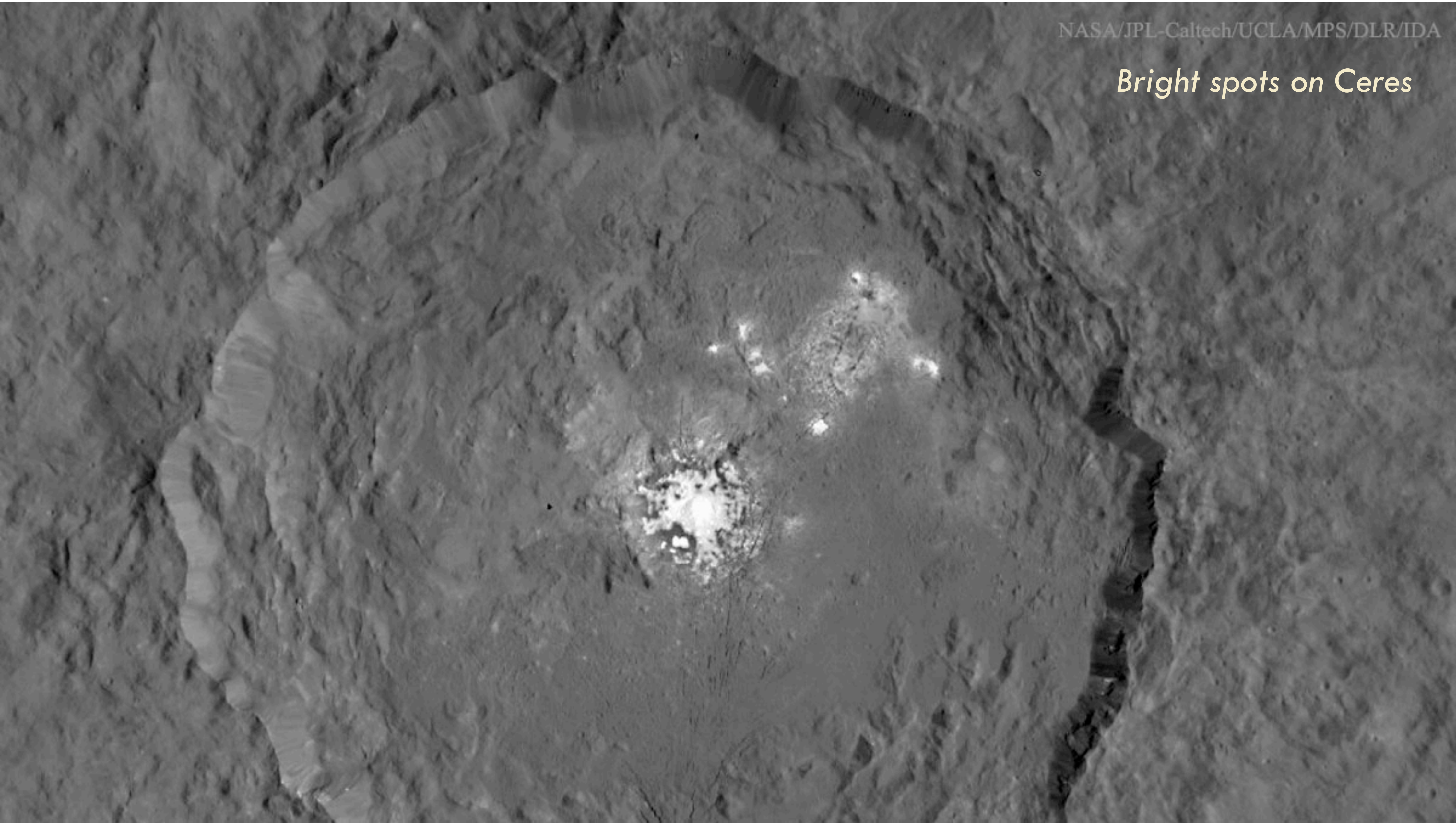
Liquid water cannot exist on Mars at its current temperature and pressure. For Mars to have had surface water, its atmosphere must have been significantly thicker.

Did Mars lose much of its atmosphere early in its history? Or perhaps changes in Mars' orbit could result in large climate changes?

Between Mars and Jupiter is the *asteroid belt*, which contains probably 1–2 million objects.

The largest are Ceres, Pallas, Vesta and Hygiea. Only 16 asteroids are larger than 240 km in size. Altogether, the total mass of asteroids would make an object only about a twentieth the size of the Moon.



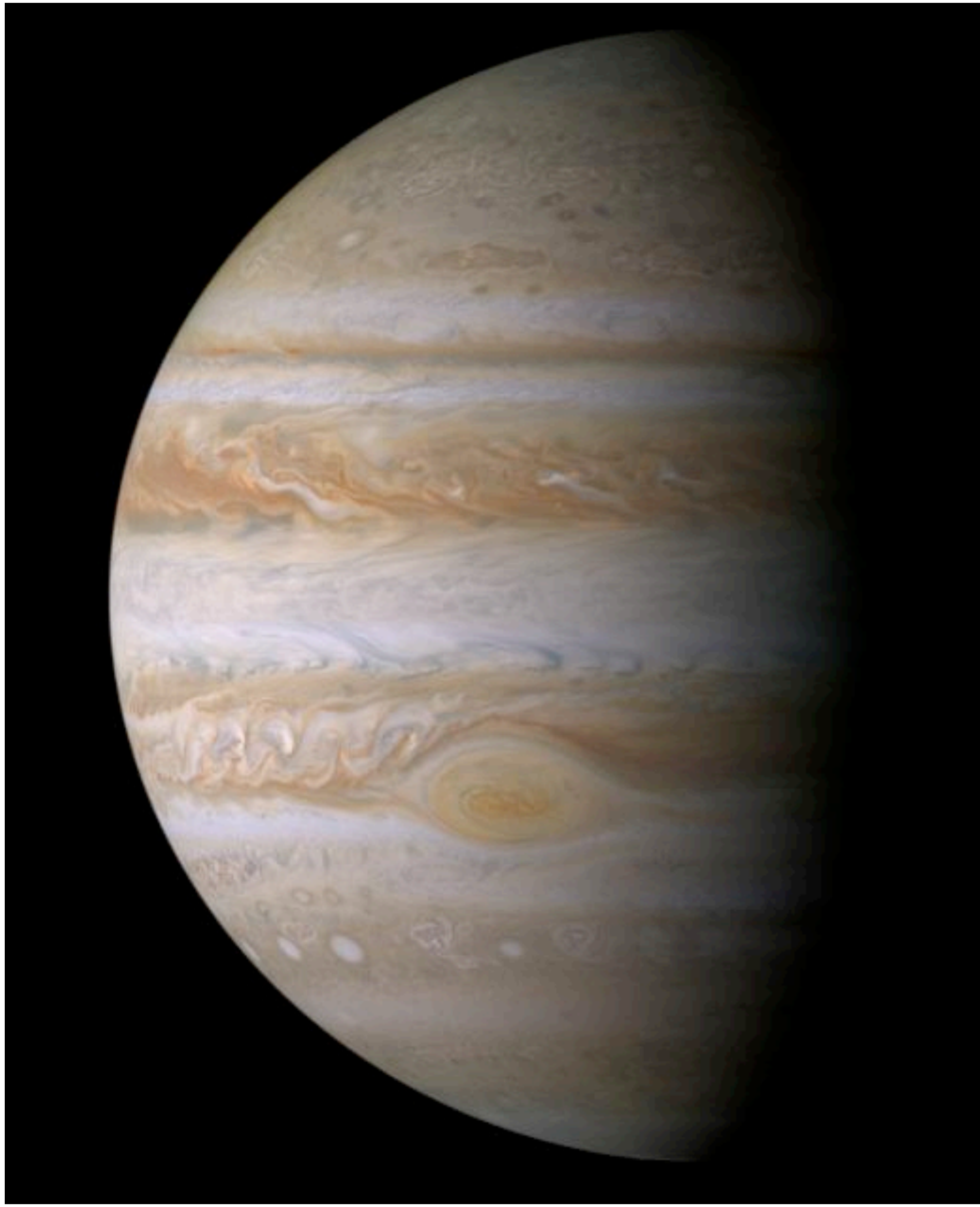

NASA/JPL-Caltech/UCLA/MPS/DLR/IDA
Bright spots on Ceres

The giant planets

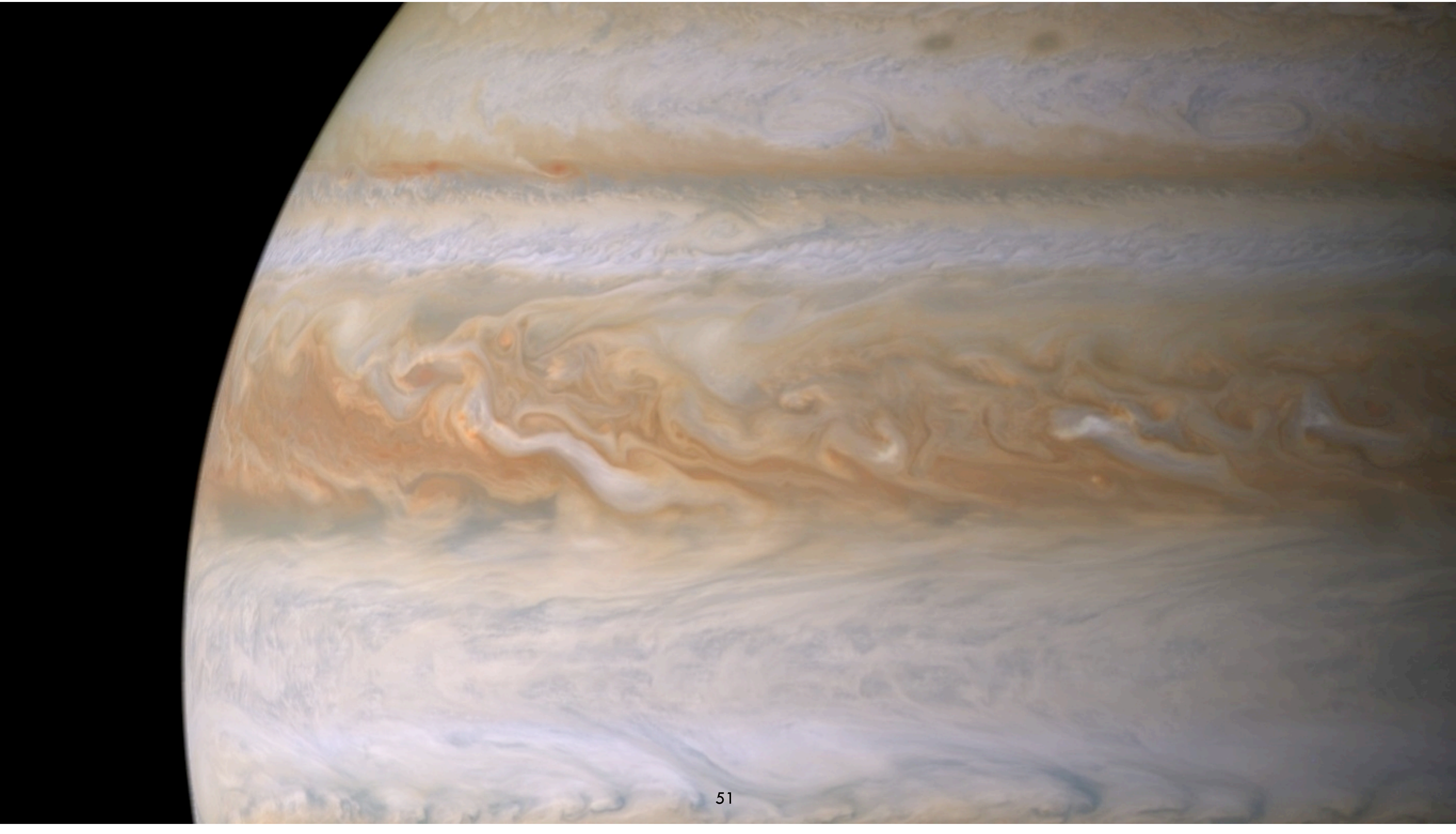
– gas and ice worlds

Jupiter is the most massive of the planets, 2.5 times the mass of the other planets combined.

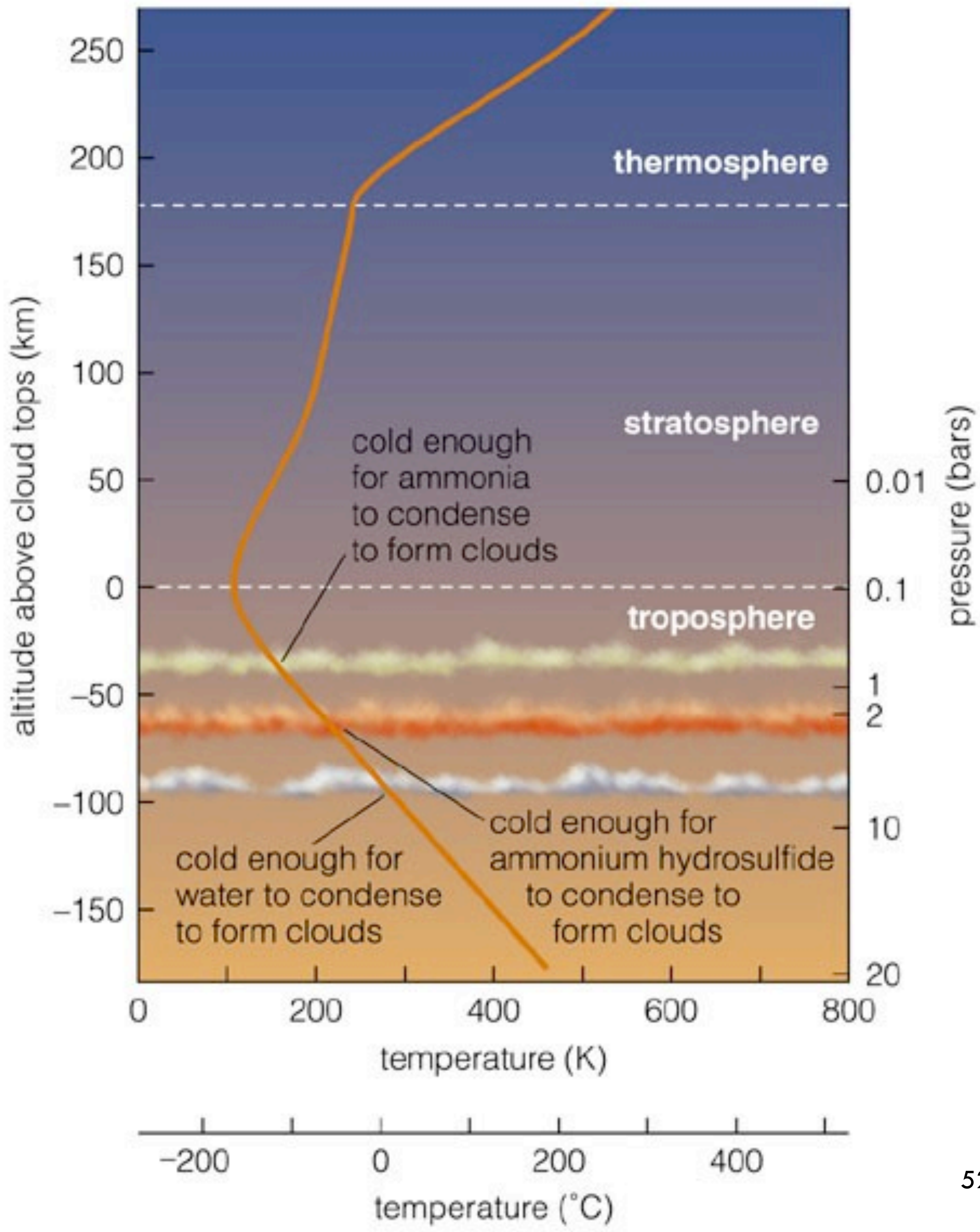
Jupiter's visible surface is not solid: it is a gas giant. Everything visible on the planet is a cloud.



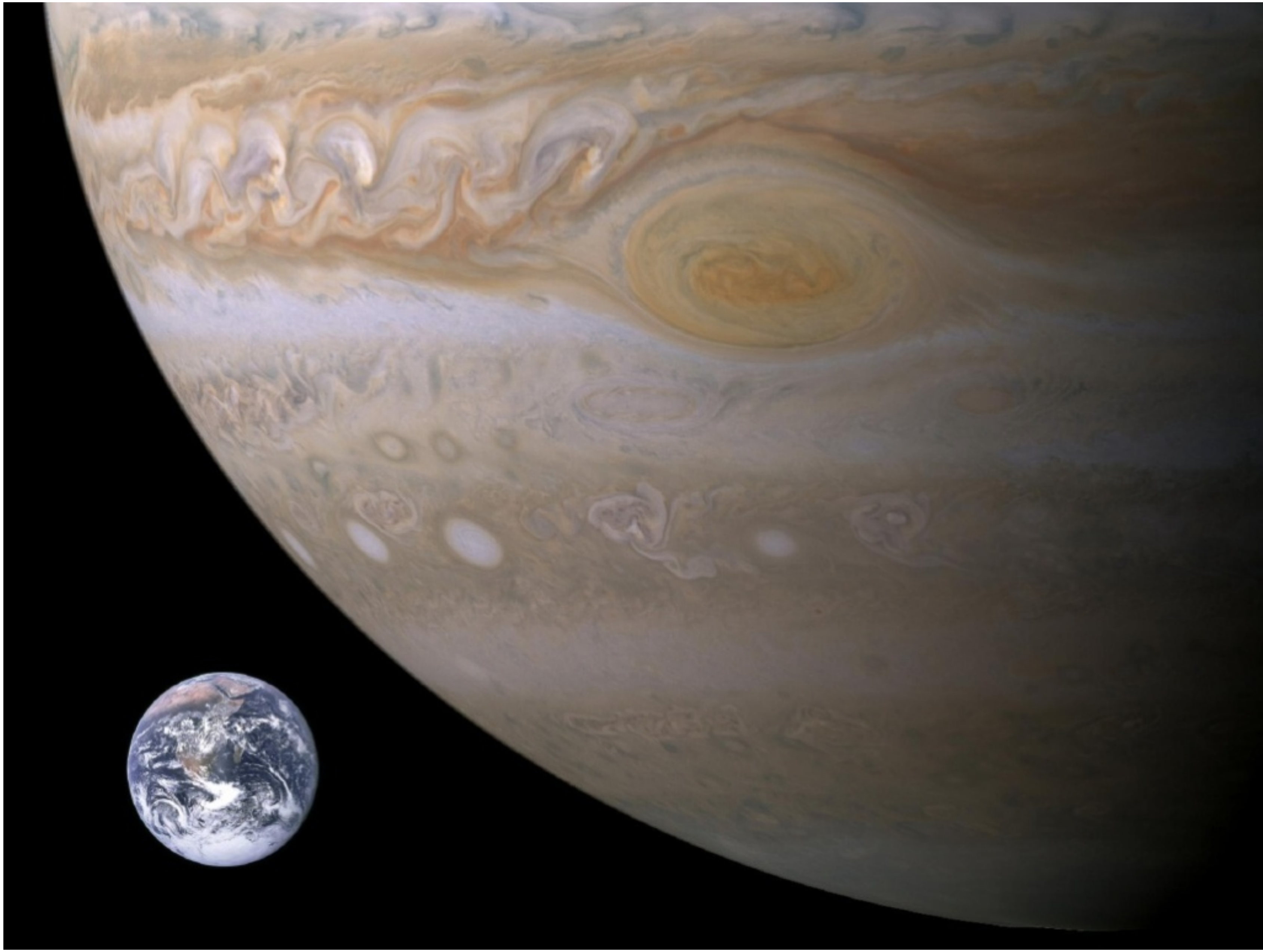
True colour picture of Jupiter, taken by Cassini on its way to Saturn during closest approach. The smallest features visible are only 60 km across.



The different colours of the clouds represent different chemicals: ammonia, ammonium hydrosulfide, and water. The reddish regions are the coolest: they sit highest up in the atmosphere.



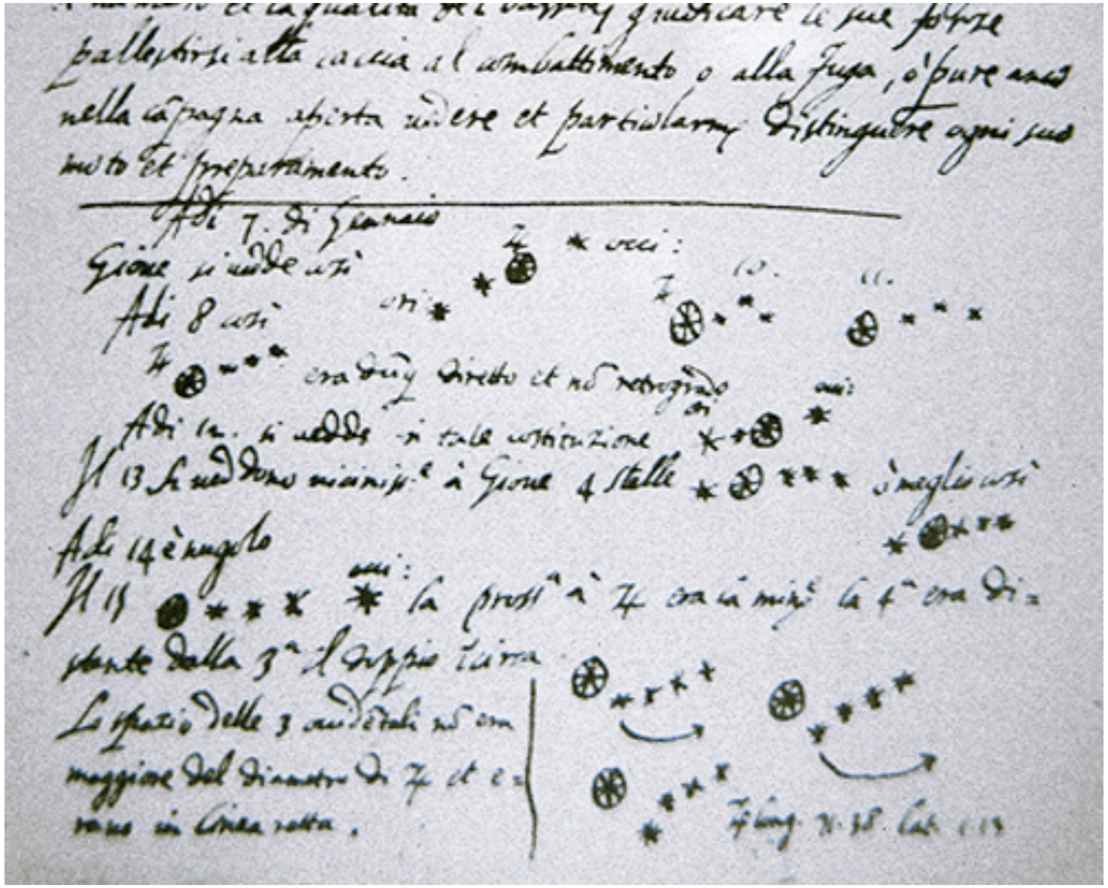
The *Great Red Spot* is a giant storm that has been raging for at least 350 years, since its discovery by Robert Hooke in 1664.



Comparison between the size of Earth and the Great Red Spot

Jupiter has (at least) 63 moons, the four largest of which are known as the *Galilean satellites*.

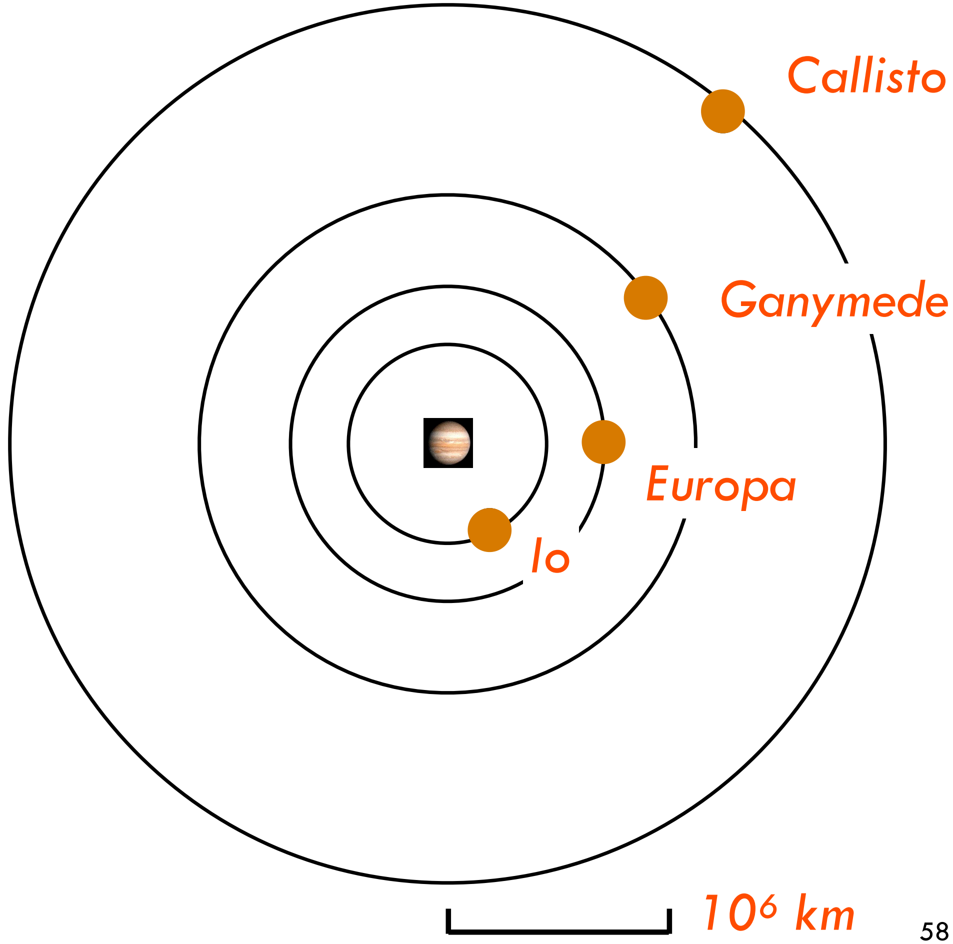
(from left): Io, Europa, Ganymede and Callisto



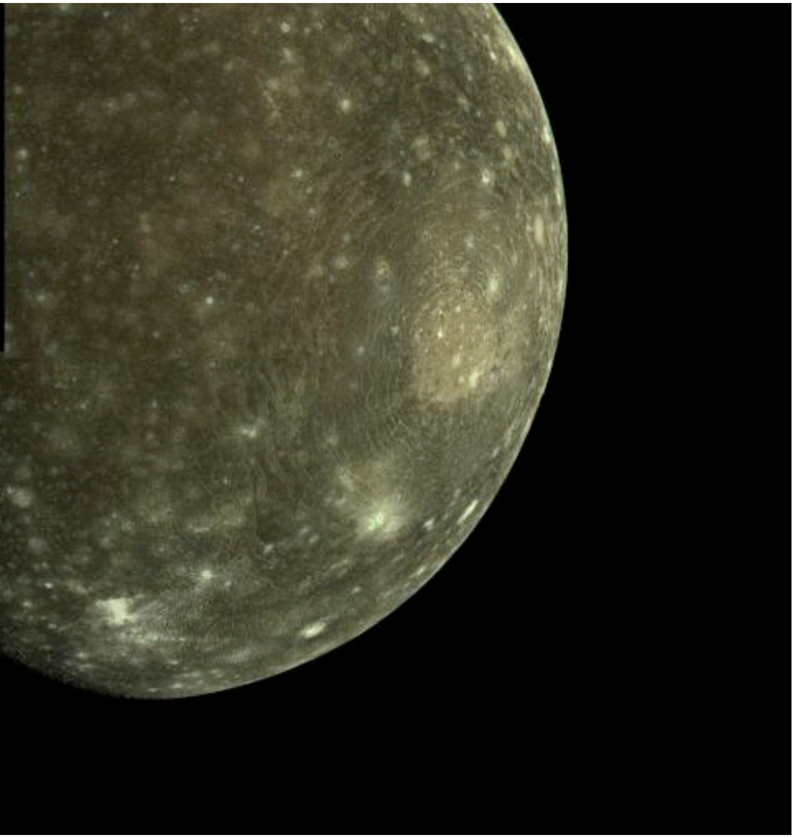
Part of Galileo's journal from1610, with sketches of the four "stars" near Jupiter which he later recognized to be moons.

Three of these moons are bigger than Earth's moon, and Ganymede is larger than Mercury.

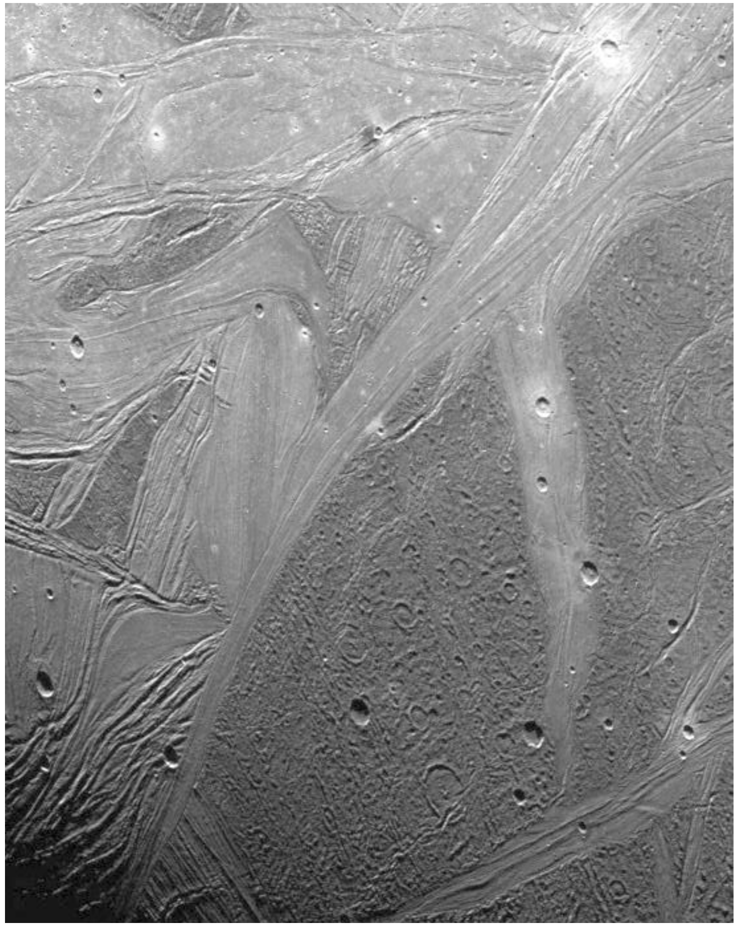
Io takes only 1.8 days to orbit Jupiter; Europa, Ganymede and Callisto take 2x, 4x and 9.3x as long to go around.



The relative sizes of the orbits of the Galilean satellites. The moons are not to scale.

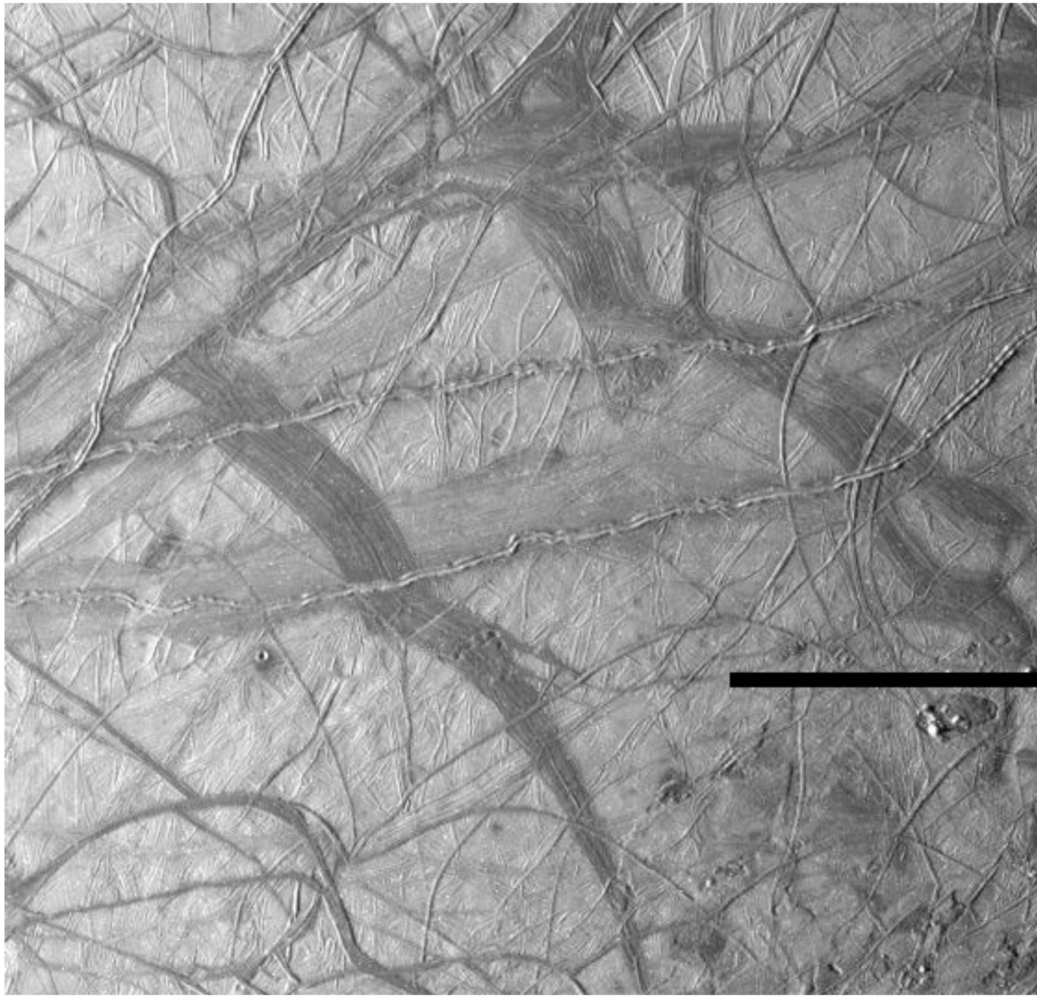


All four moons are worlds in their own right, and quite different from each other. *Callisto* is covered in icy craters;

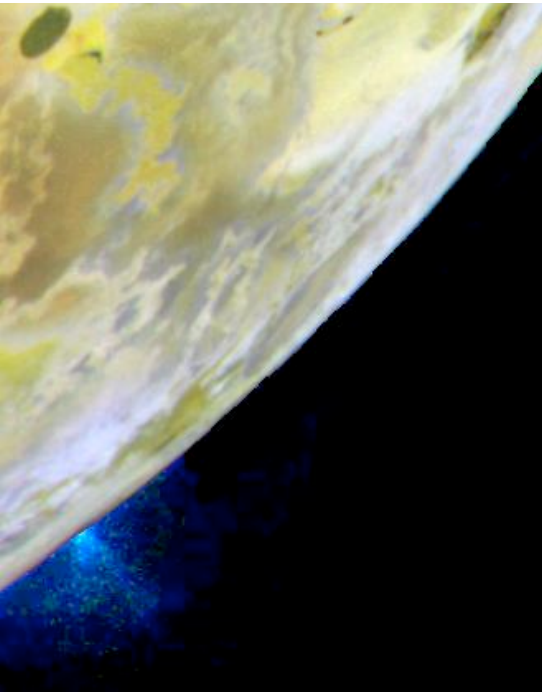


while the surface of *Ganymede* shows both craters and ice-flow features.

Europa is completely covered with ice – the smoothest object in the Solar System.

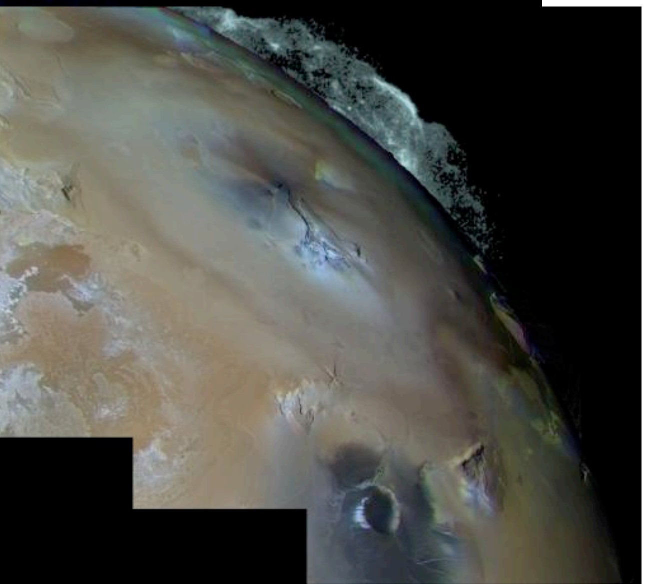


Intricate patterns on Europa's surface caused by the ice flowing and fracturing under tidal stress from Jupiter.



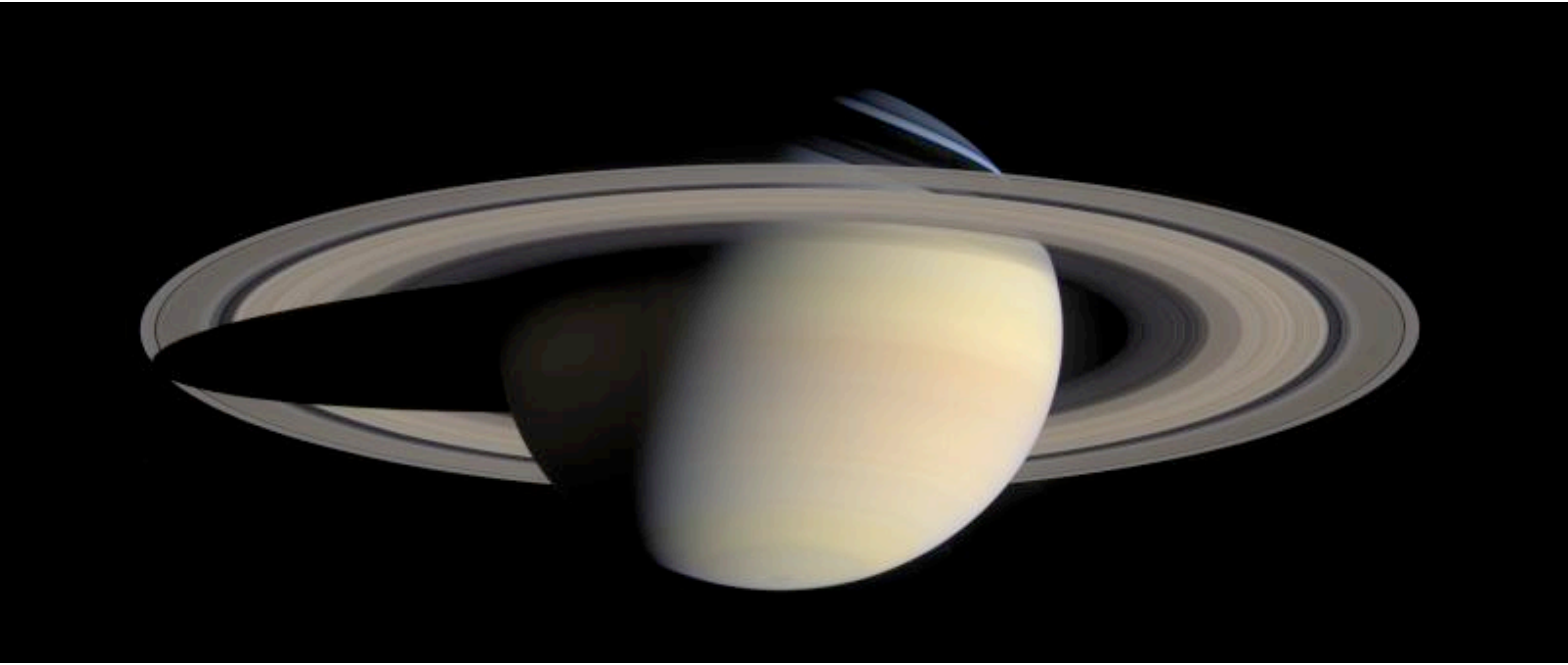
Io is covered with volcanos: the most volcanically active world in the Solar System.

Tidal stress keeps the interior of Io molten; Io's red-orange colour is from sulphur and its compounds.



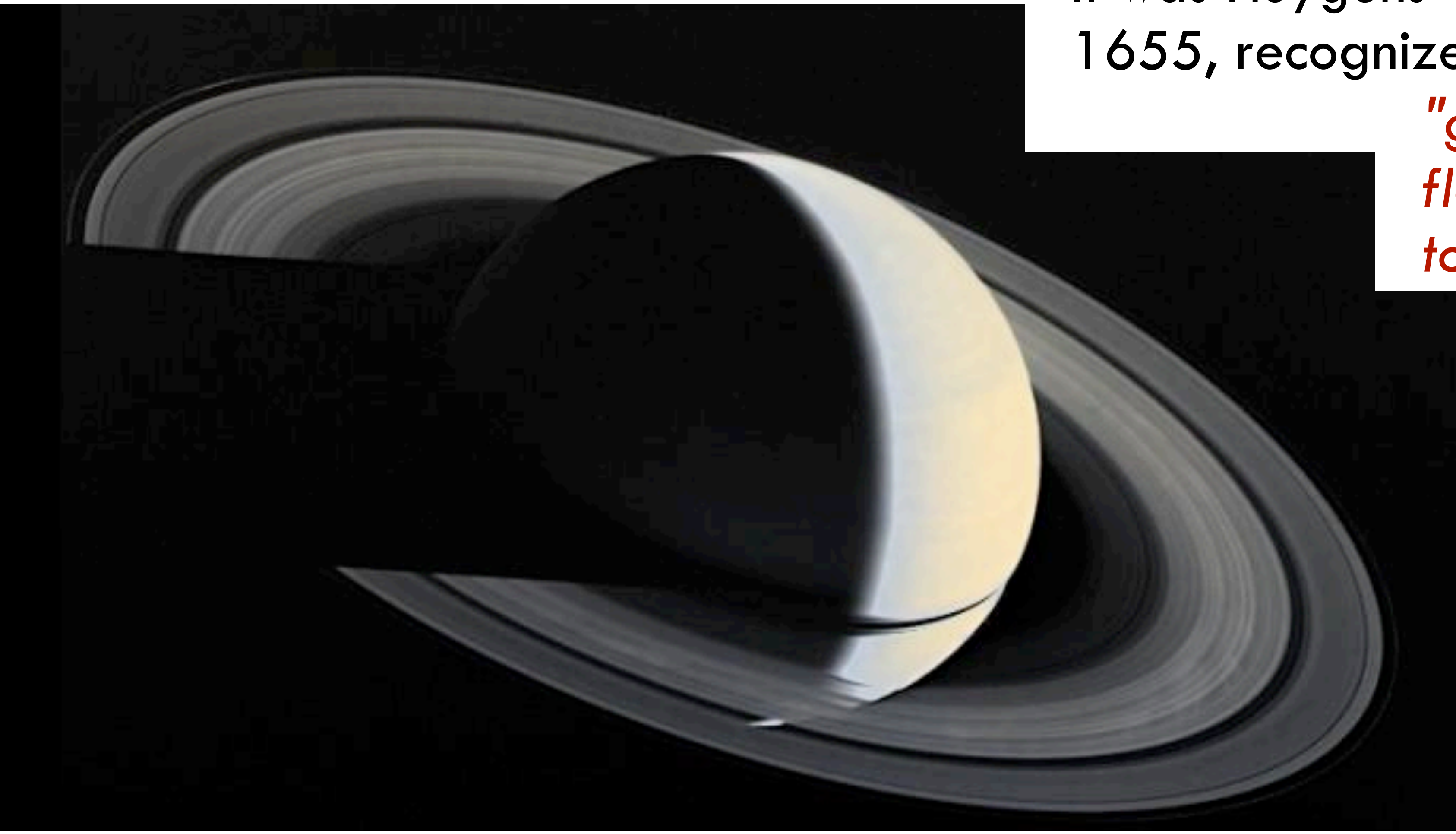
Eruptions over Io. Clockwise from top left: Masubi (Galileo), Loki (Voyager 1), and Pillan Patera and Prometheus (Galileo).

Saturn is almost as large as Jupiter (85% of the diameter), but has only 30% of Jupiter's mass. Like Jupiter, it is a gas giant.



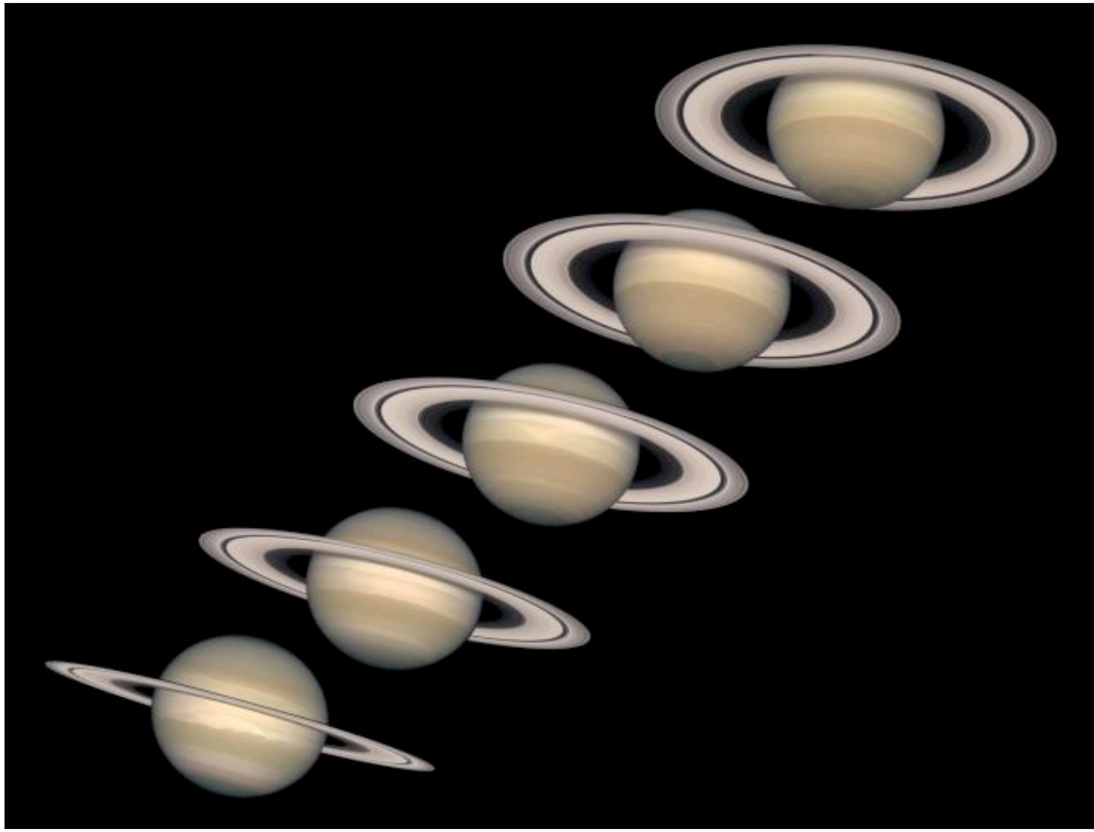
The most obvious feature of Saturn are the immense rings. The ring system is remarkably complex, and is still poorly understood.

It was Huygens who, around 1655, recognized that Saturn was *"girdled by a thin, flat ring, nowhere touching it."*



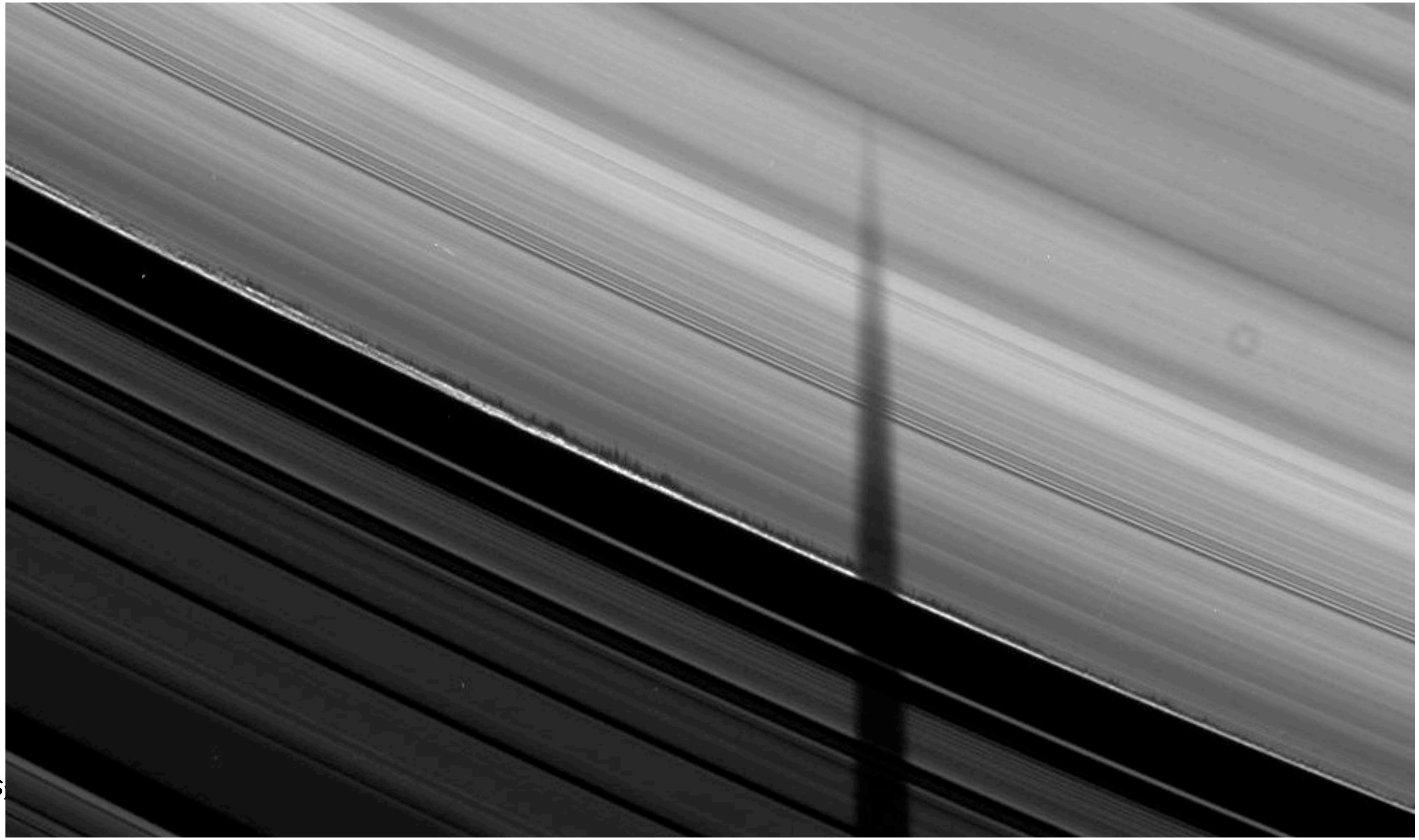
Saturn's equator is tilted relative to its orbit by 27°. As Saturn moves along its orbit, first one hemisphere, then the other is tilted towards the Sun.

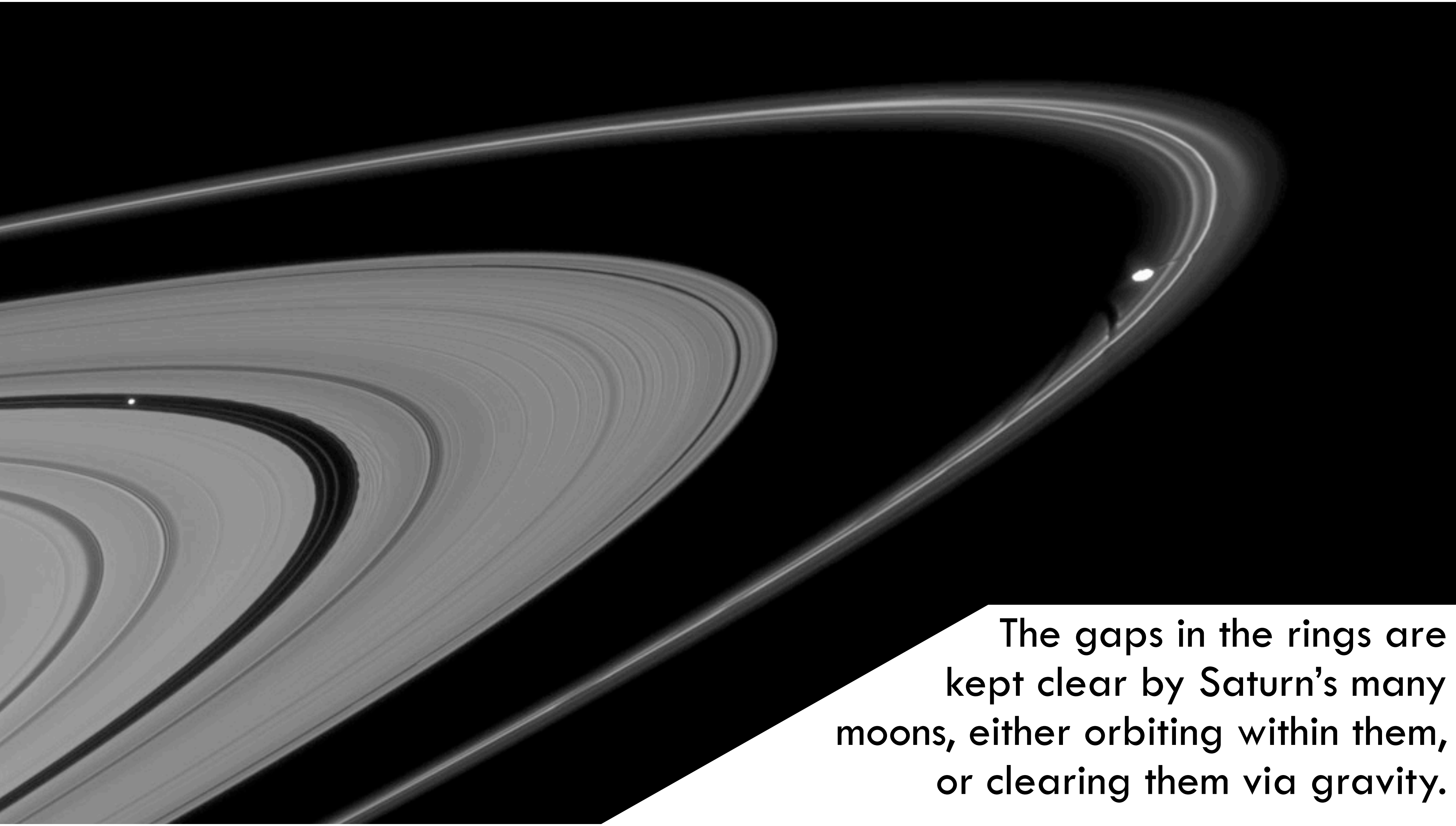
From the Earth, we can see Saturn's rings open up from edge-on to nearly fully open, then close again to a thin line as Saturn moves along its 29 year orbit.



Sequence of Hubble pictures taken between 1996 and 2000.

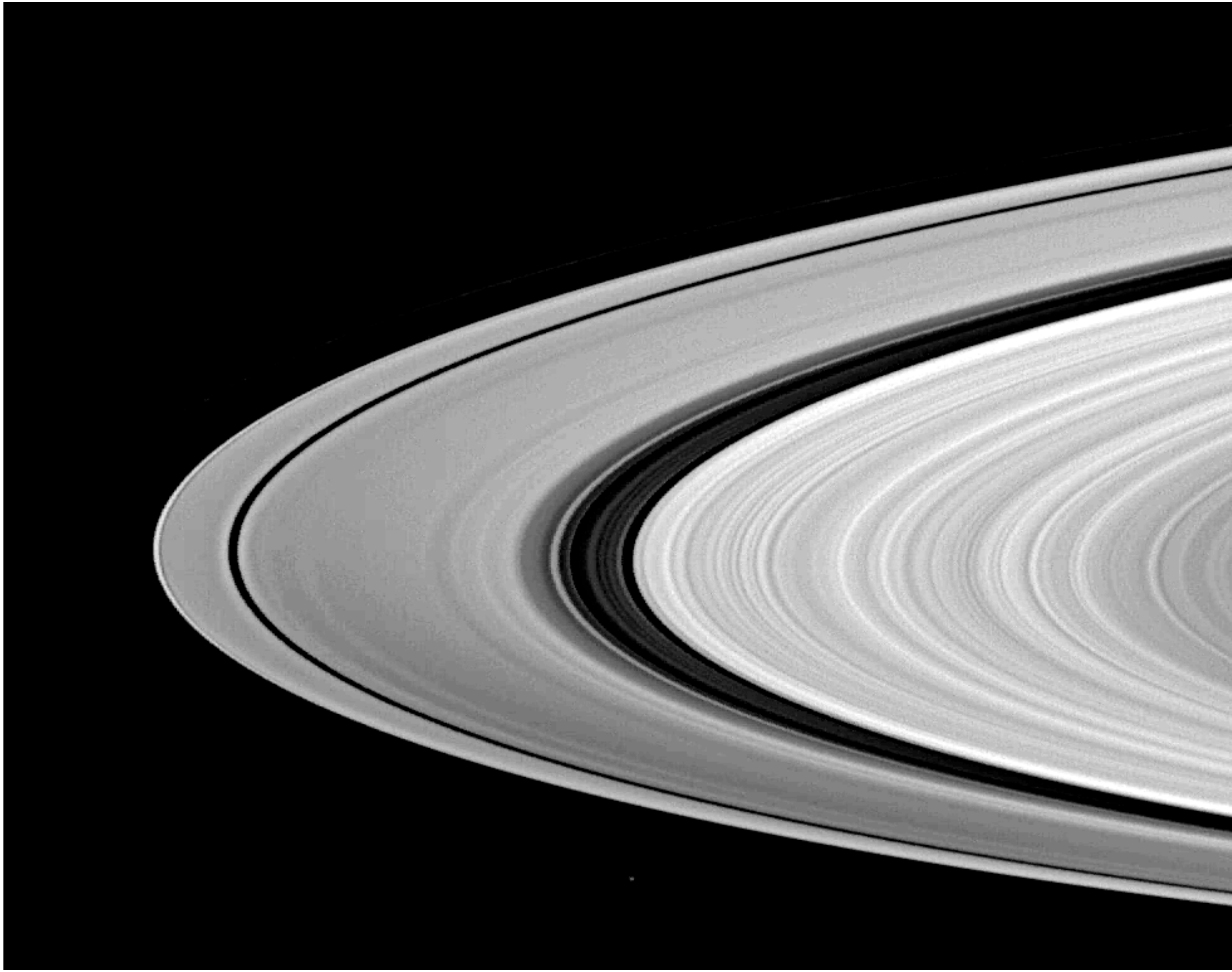
The rings are extremely thin – possibly only 10 m thick – and composed almost entirely of chunks of water ice.





The gaps in the rings are kept clear by Saturn's many moons, either orbiting within them, or clearing them via gravity.

The Cassini satellite took this sequence of images which shows how thin the rings are.

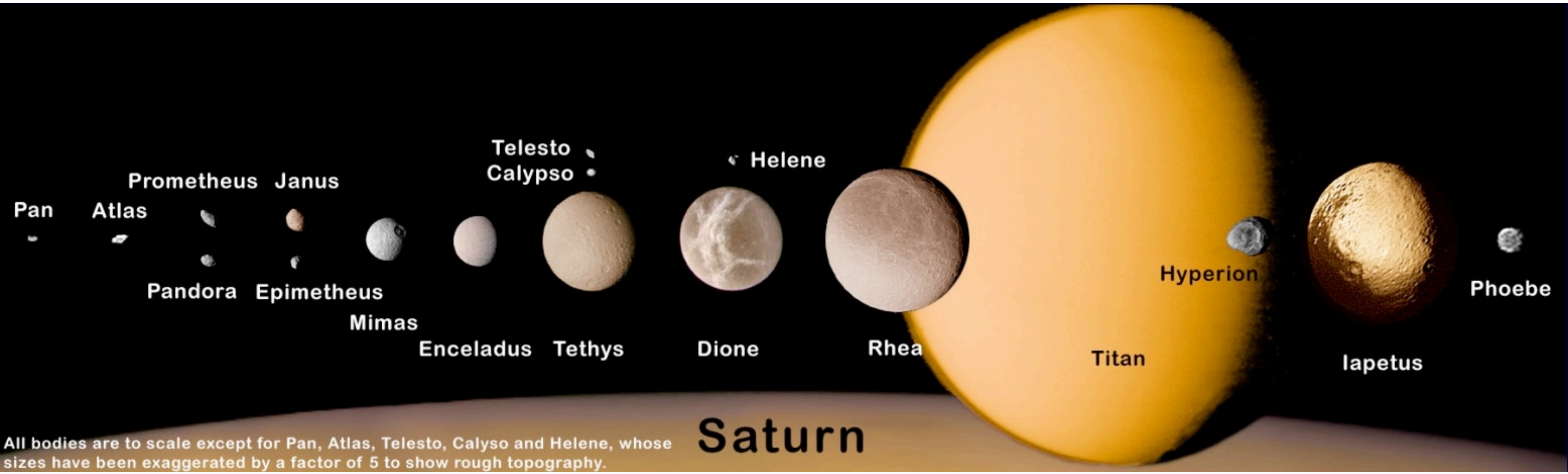


Movie made from 34 images taken during a ring-plane crossing from the sunlit side, in January 2007. The first large moon seen is Enceladus, showing its inclined orbit.

Like Jupiter, Saturn has a large family of moons.

Titan is the largest (larger than Mercury, and second only to Ganymede); then there are six large icy moons, and a whole host of small ones.

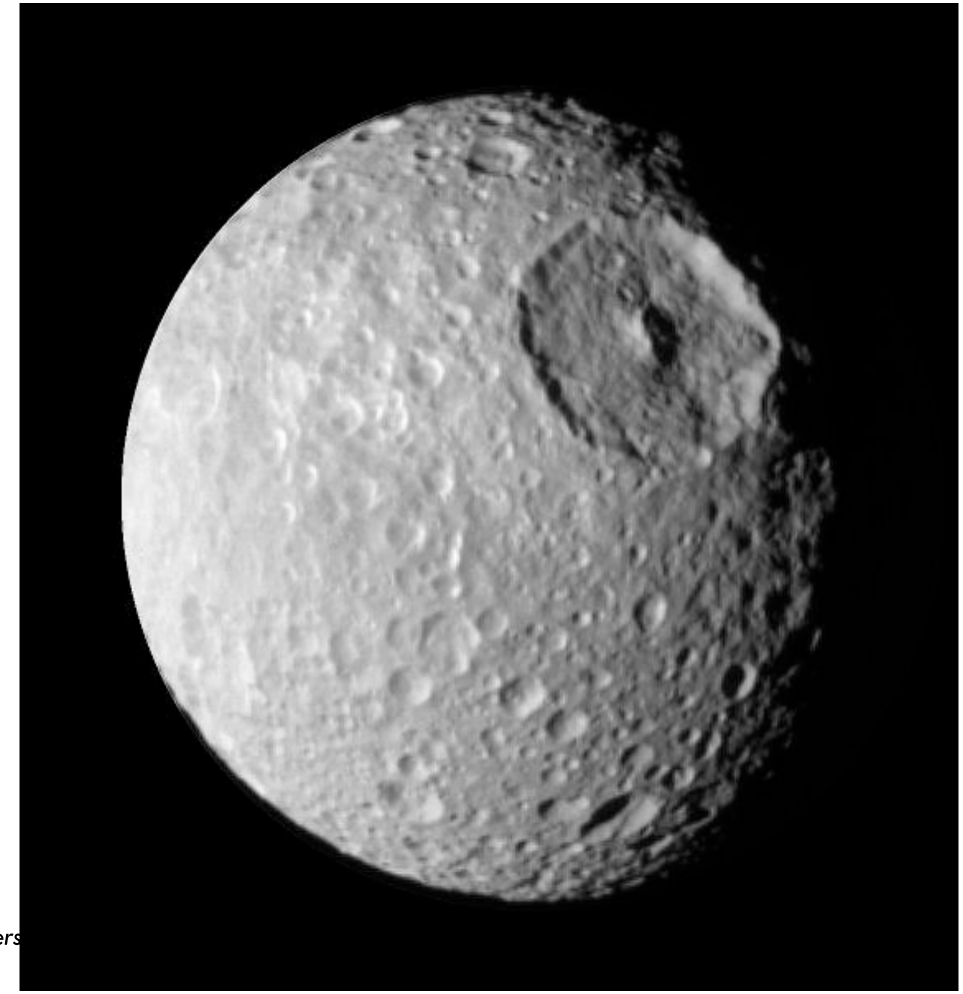
Sixteen satellites orbit within the main rings themselves.



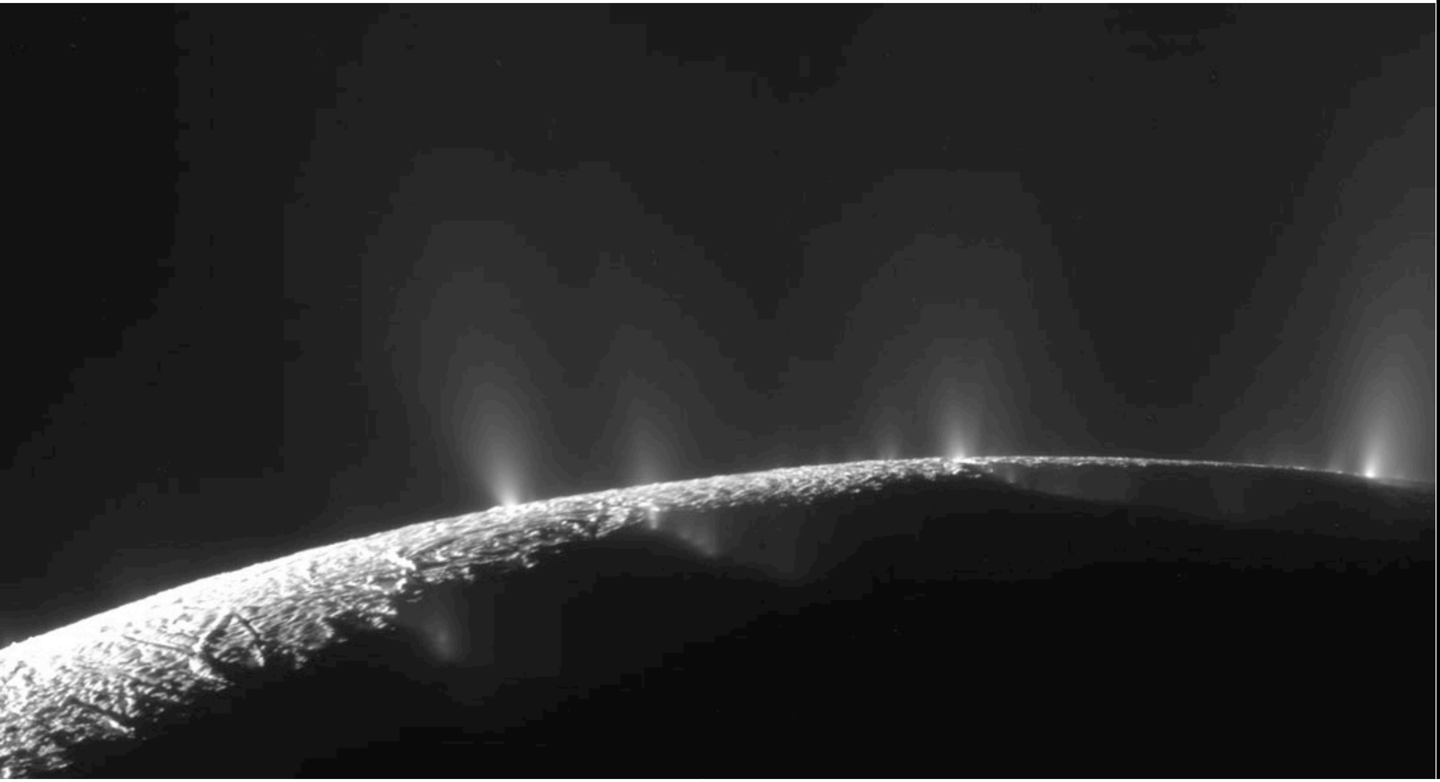
The six medium-sized icy worlds are tidally locked, keeping the same face towards the planet as they orbit. Unlike the relatively orderly Galilean satellites of Jupiter, Saturn's system of satellites shows few regularities.

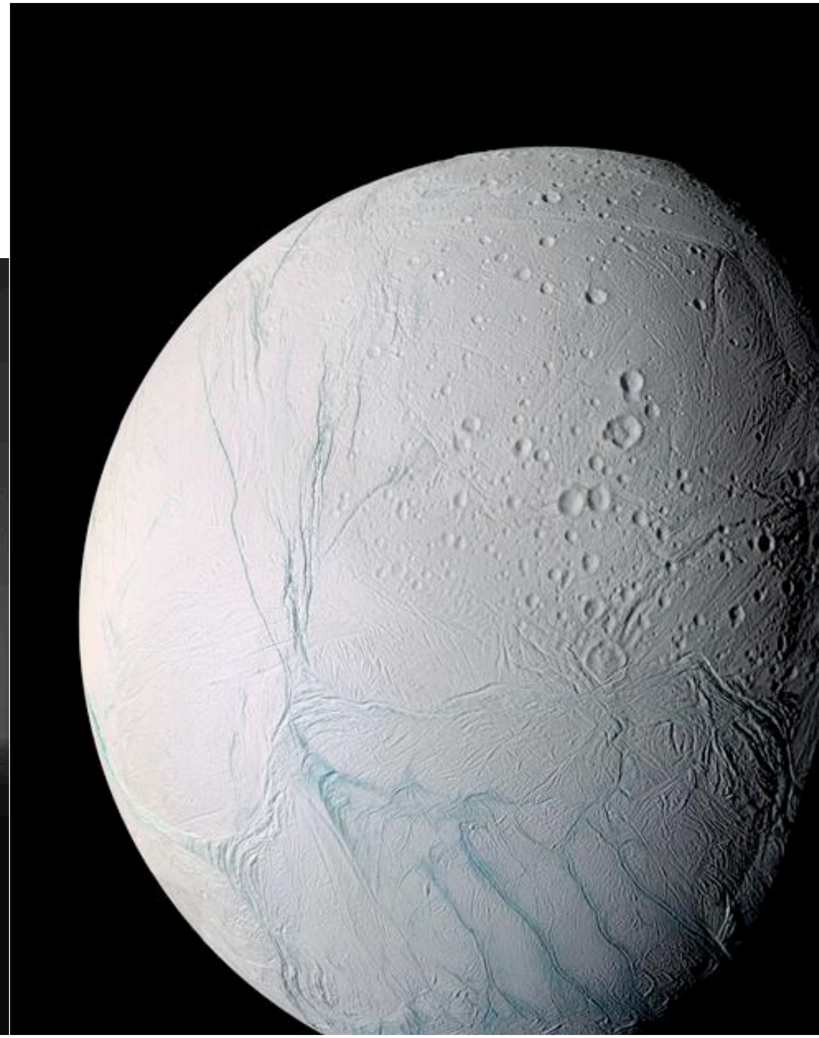
The medium sized Saturnian moons, with the Earth's moon for comparison.

Mimas is dominated by a single large crater – Herschel crater (130 km across with walls 5 km high).

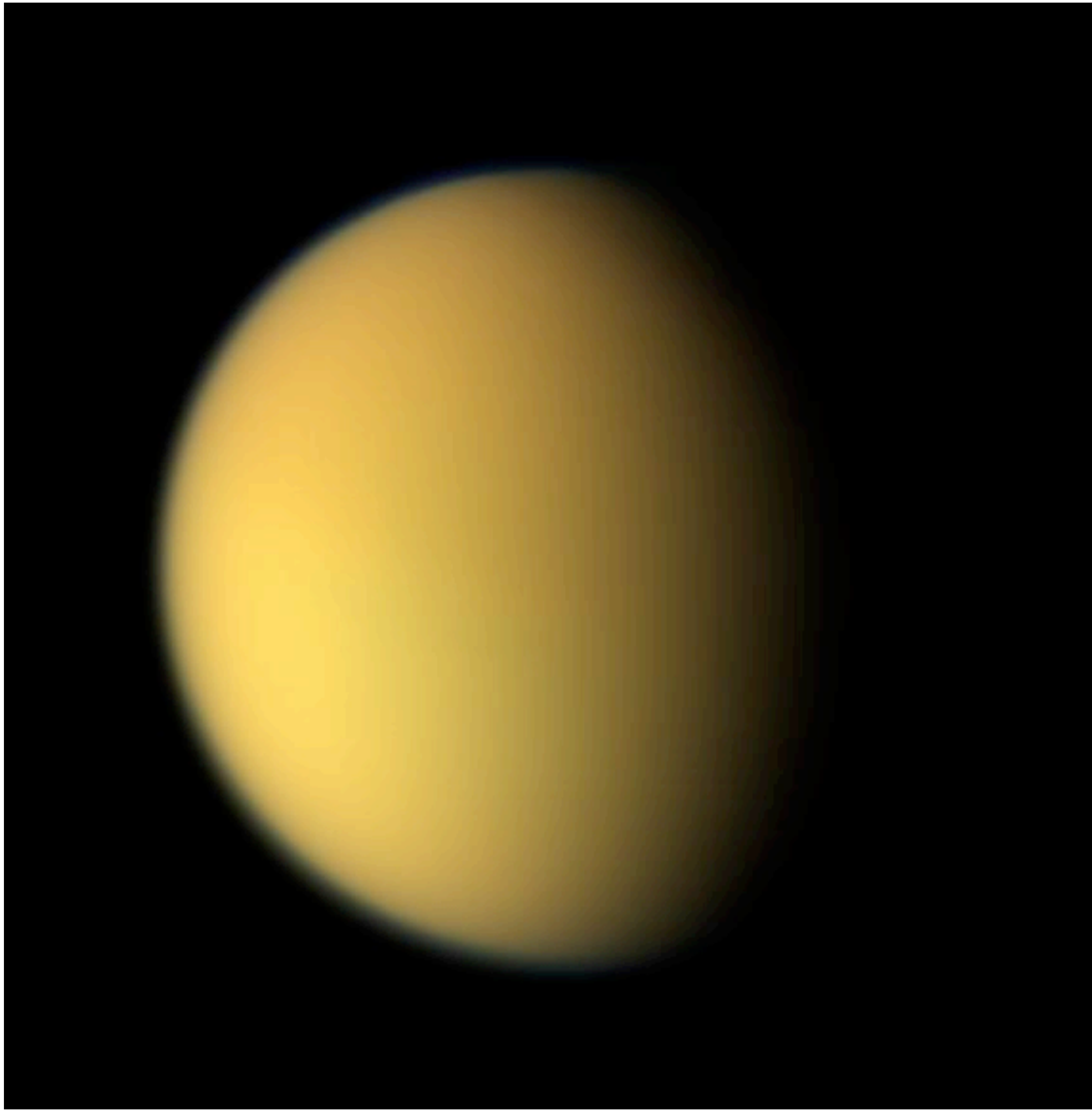


Enceladus has a surface dominated by fresh, clean ice. It has icy geysers erupting from its southern regions, which probably come from a sub-surface ocean.

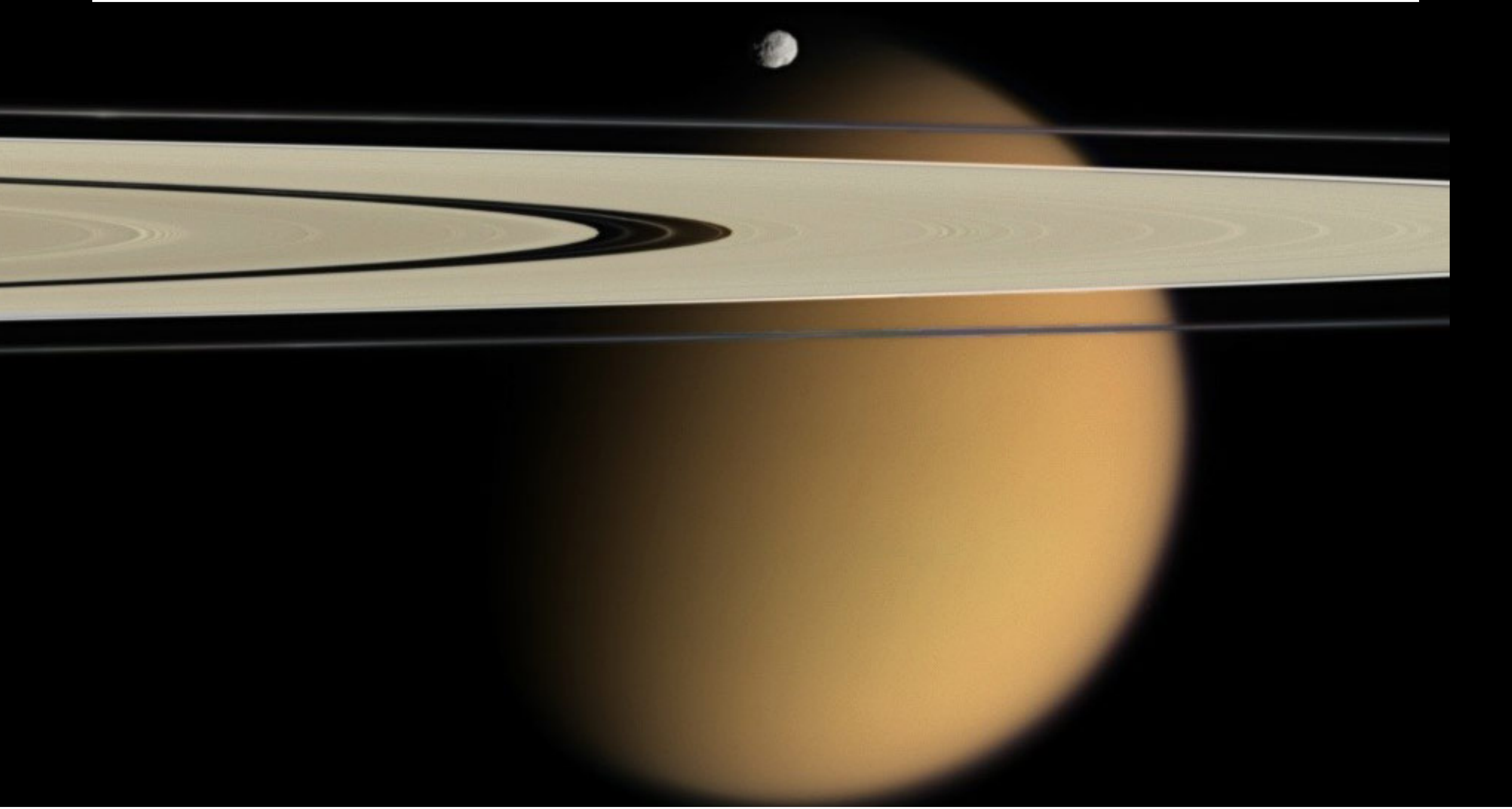




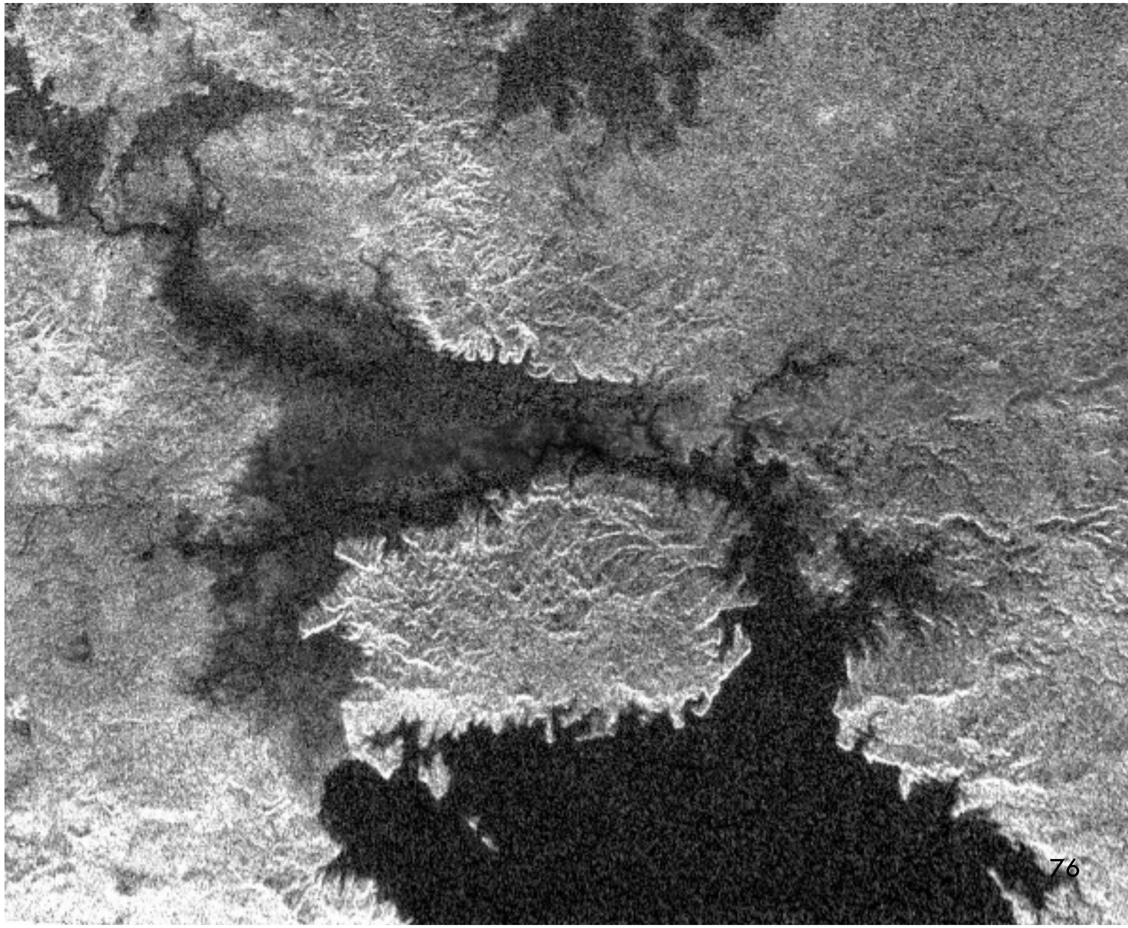
Saturn's largest moon, *Titan*, is the only satellite in the Solar System with an atmosphere.



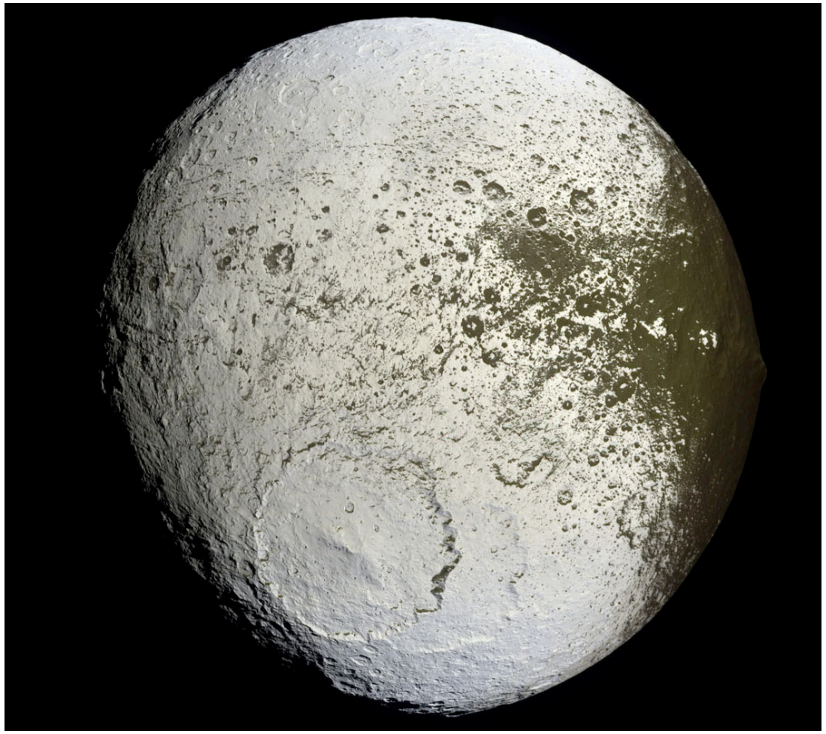
Small, battered Epimetheus before Saturn's A and F rings and smog-enshrouded Titan

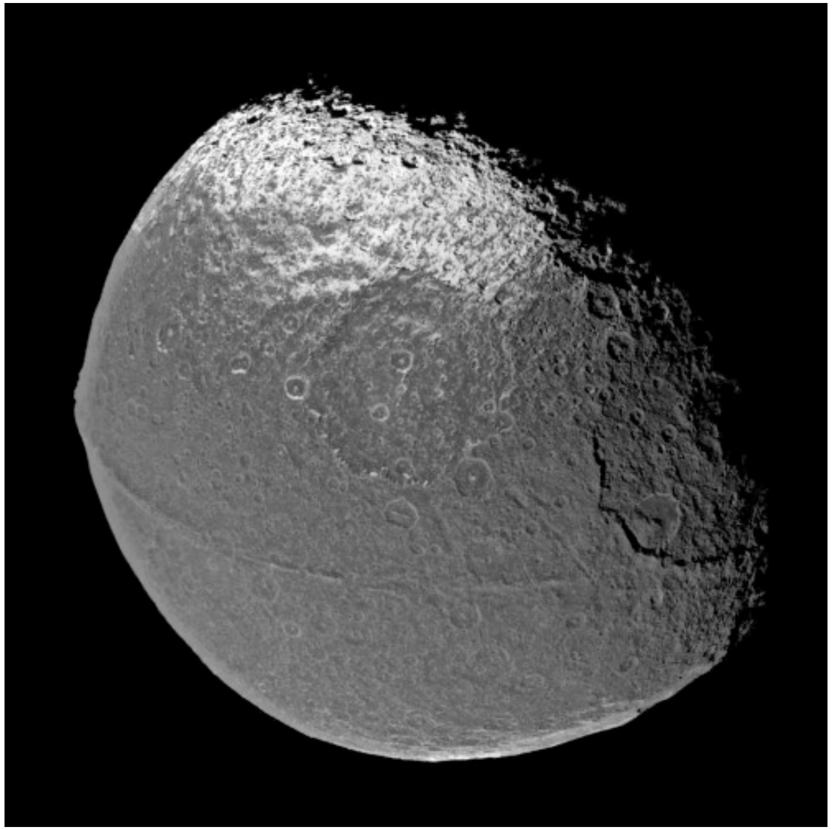


Titan’s surface air pressure is 50% higher than Earth’s. The atmosphere is made up mostly of nitrogen and hydrocarbons. Radar images show lakes and rivers, made of liquid methane and ethane.



Iapetus is shaped like a walnut, with a 20km high ridge at the equator. Its two hemispheres have completely different colours: the dark side appears to result from some dark material deposited on the icy surface.





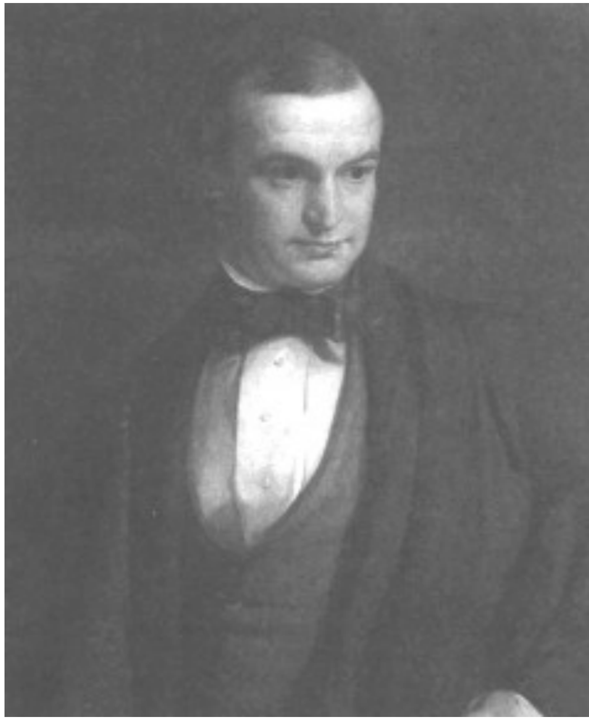
The extreme brightness dichotomy of Iapetus.

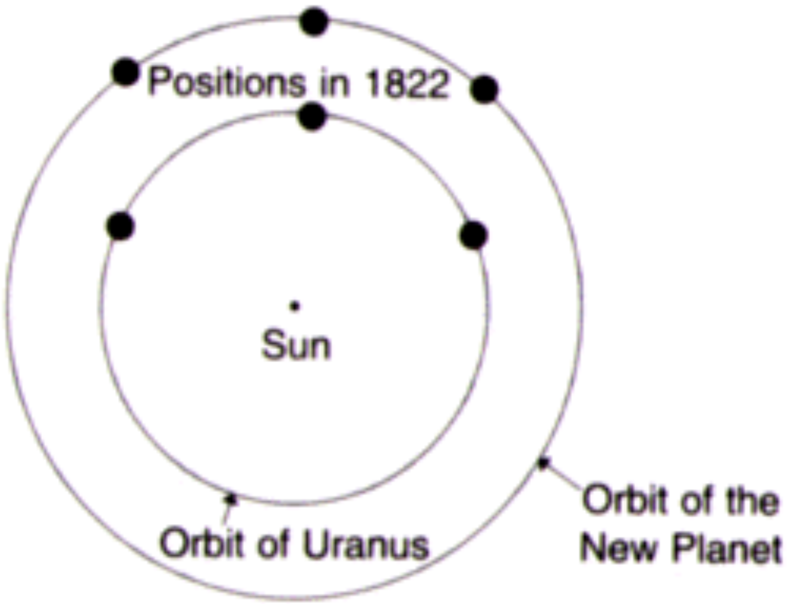
Beyond Saturn are the two ice giants: *Uranus* and *Neptune*. They are very similar in size, though Neptune is slightly more massive. Methane gives the planets their blue-green or blue appearance.

Neptune is slightly more massive. Methane gives the planets their blue-green or blue appearance.

Uranus was discovered in 1781 by William Herschel, musician and amateur astronomer. Herschel became the first person in recorded history to discover a new planet, at a stroke doubling the size of the known Solar System. In fact, Uranus had been detected, mistaken for a star, on 22 occasions during the preceding century.

After Herschel's discovery, Uranus was not moving as predicted. Until 1822, it seemed to accelerate in its orbit, and to slow after that. Two young mathematicians independently suggested it must be being pulled off course by a new planet.





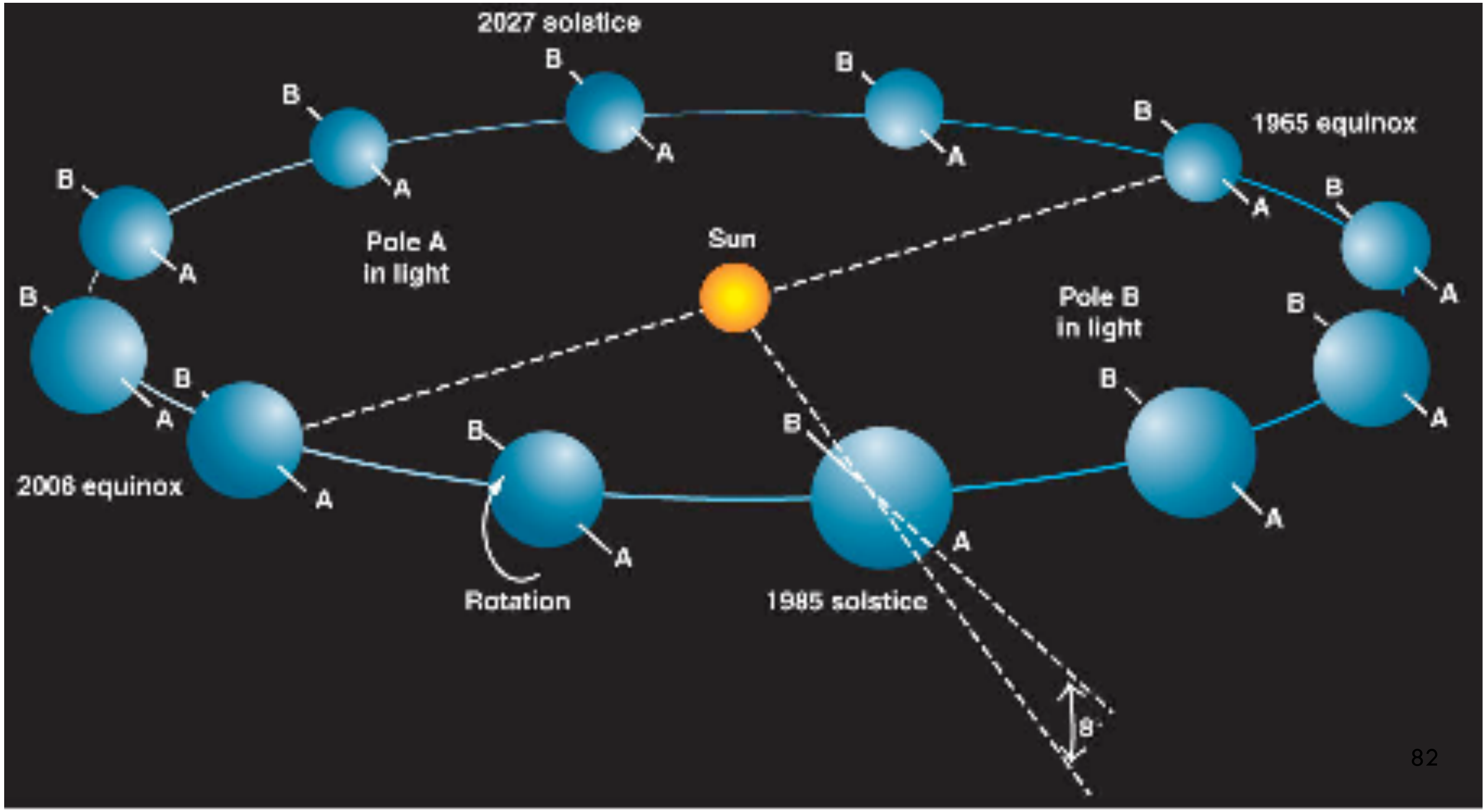
John Couch Adams predicted the position of the planet, as did Urbain Leverrier, whose solution led to the discovery of the planet by Johann Galle at the Berlin Observatory in 1846.

Neptune was discovered by Johann Galle in 1846, leading to an international dispute over priority.

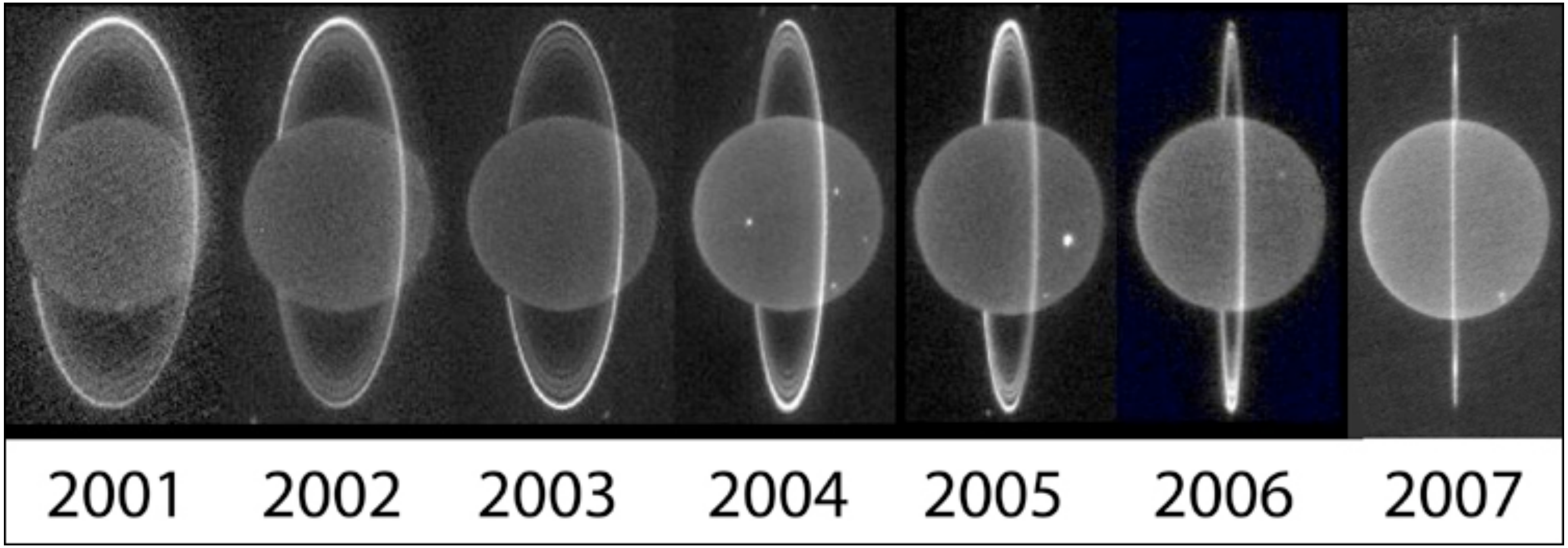
On 12 July 2011, Neptune completed its first orbit since its discovery.

Comparison between Adams' and Leverrier's predicted positions for Neptune, and where it was found.

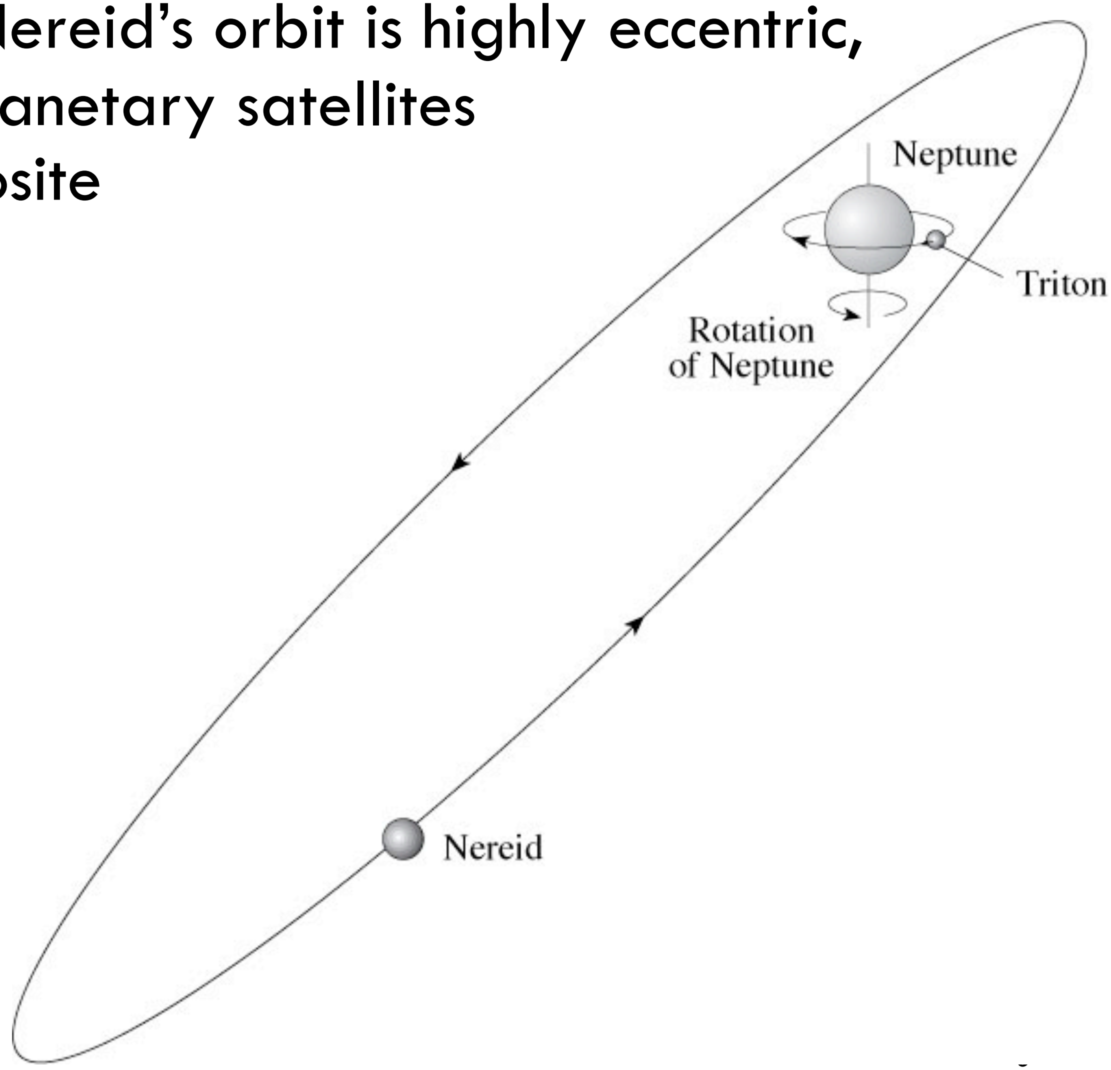
Unlike the other planets, Uranus' axis of rotation is tilted to lie almost in the plane of its orbit. This means it has very bizarre seasons, with each pole being sunlit for 42 (Earth) years. During this time, the pole receives more light than the equator, before being plunged into darkness for the next 42 years.

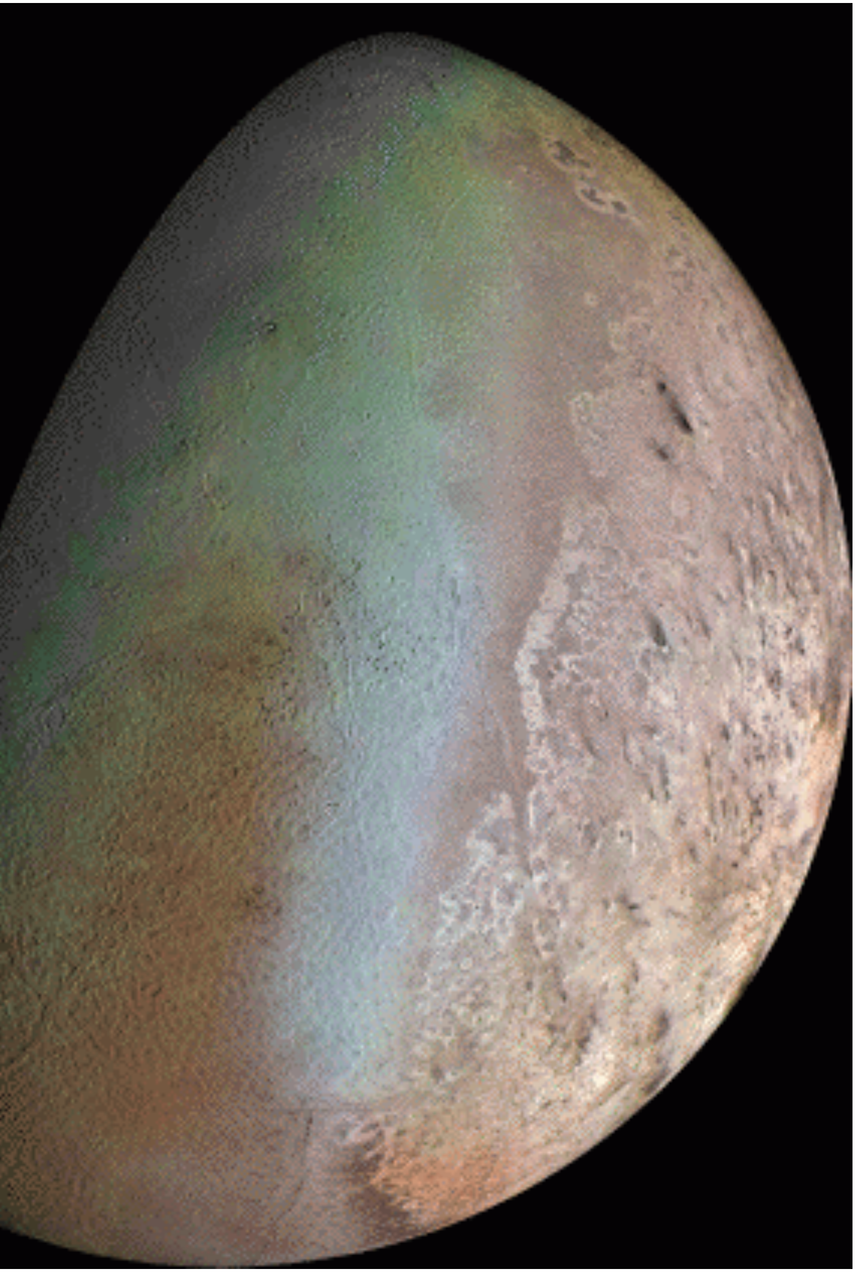


Uranus has faint rings (which were easiest to see during Uranus' equinox, in December 2007), plus at least 27 moons. Only five are of significant size – Miranda, Ariel, Umbriel, Titania and Oberon – and all are much smaller than the Earth's Moon.



Neptune has thirteen moons, only two visible from Earth – Triton and Nereid. Both have peculiar orbits: Nereid's orbit is highly eccentric, and Triton is unique among large planetary satellites because it orbits backwards – opposite to the sense of the planet's rotation.

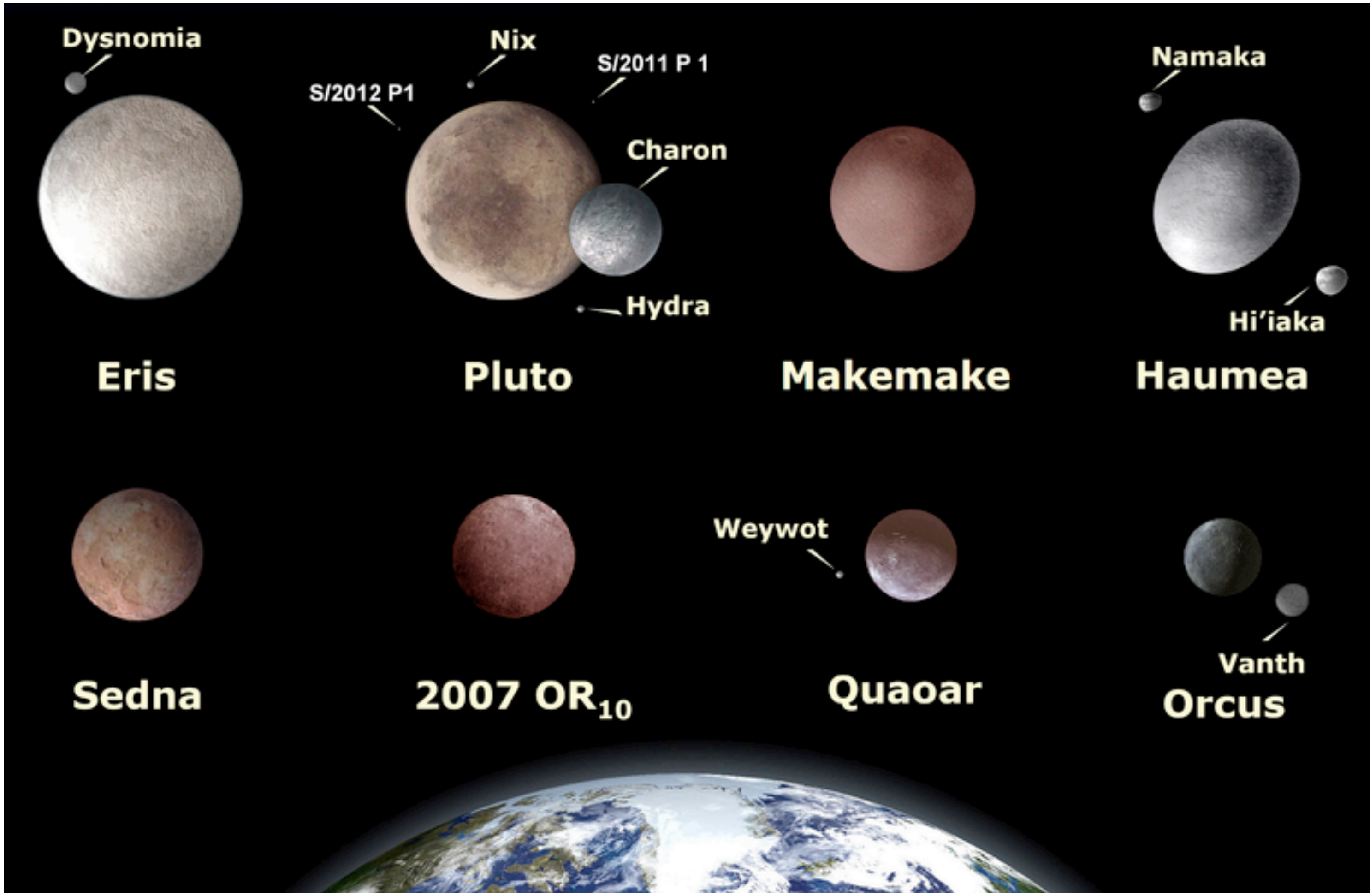




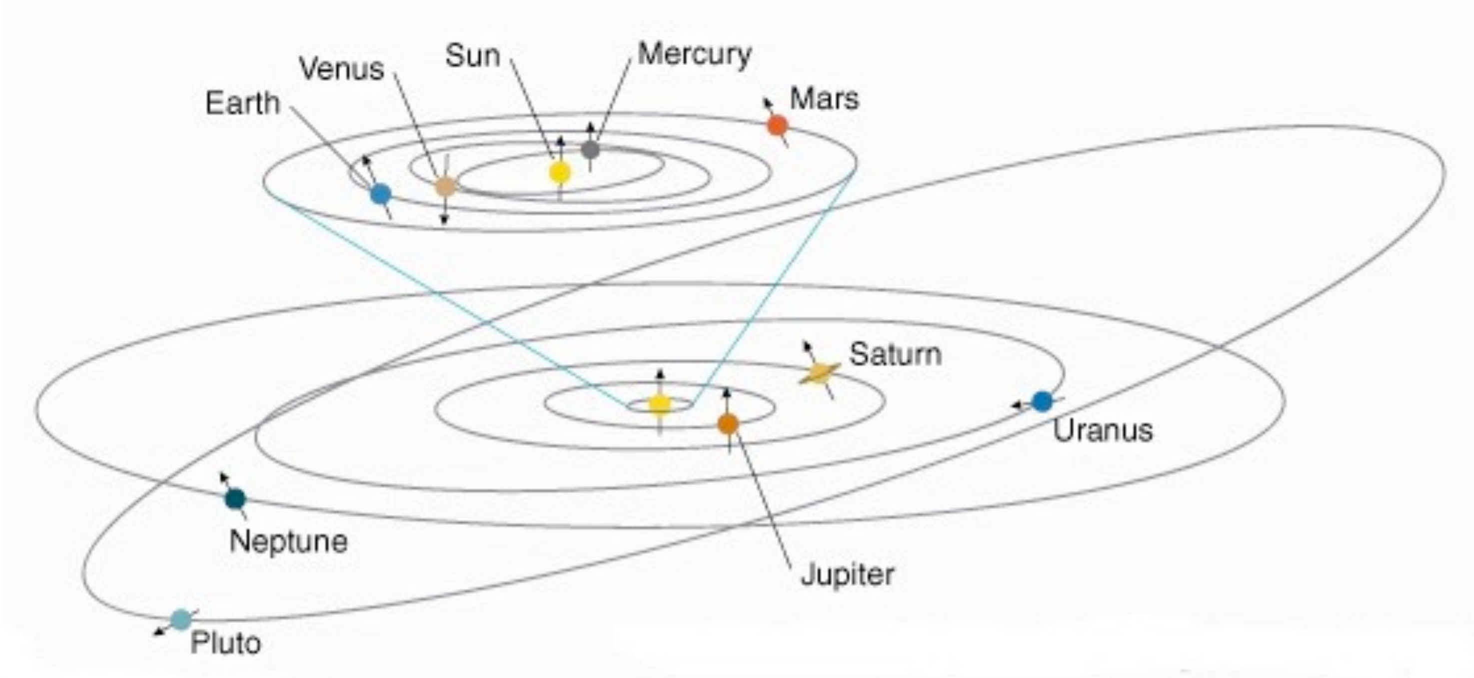
Triton is almost as large as Earth's moon. The surface temperature is –235° C, the coldest temperature yet measured in the Solar System.


Everything else
– tiny worlds beyond

Beyond Neptune, there is a large number of small icy worlds, collectively called the *trans-Neptunian objects* (TNOs). As of 2015, there were nearly 1800 objects known beyond the orbit of Neptune, the largest of which are *Eris* and *Pluto*.



Like many other TNOs, Pluto’s orbit is highly elliptical, and not in the same plane as the major planets. Pluto’s orbit takes it from 29.7 AU (within the orbit of Neptune) to 49.3 AU. It crossed back outside Neptune’s orbit in March 1999. Pluto is locked in a 3:2 resonance with Neptune, so its orbital period is exactly 1.5 times longer than Neptune's.

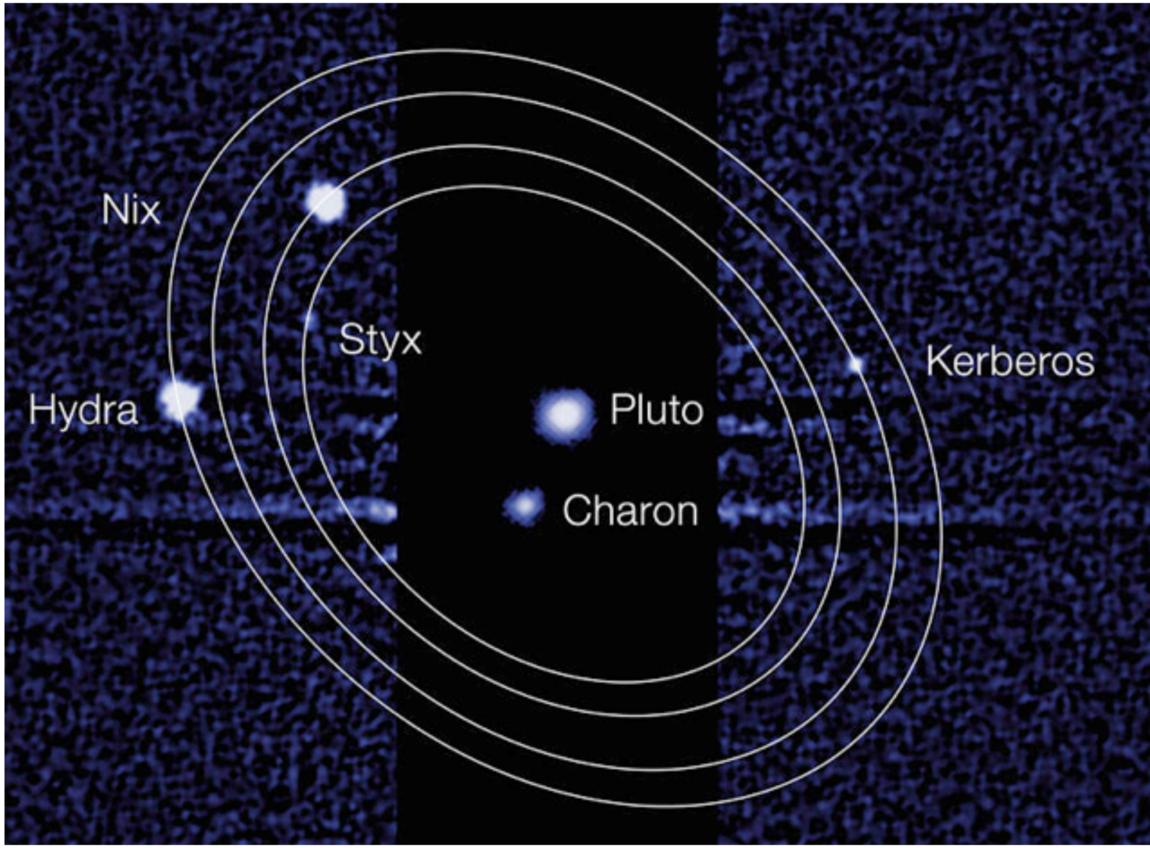


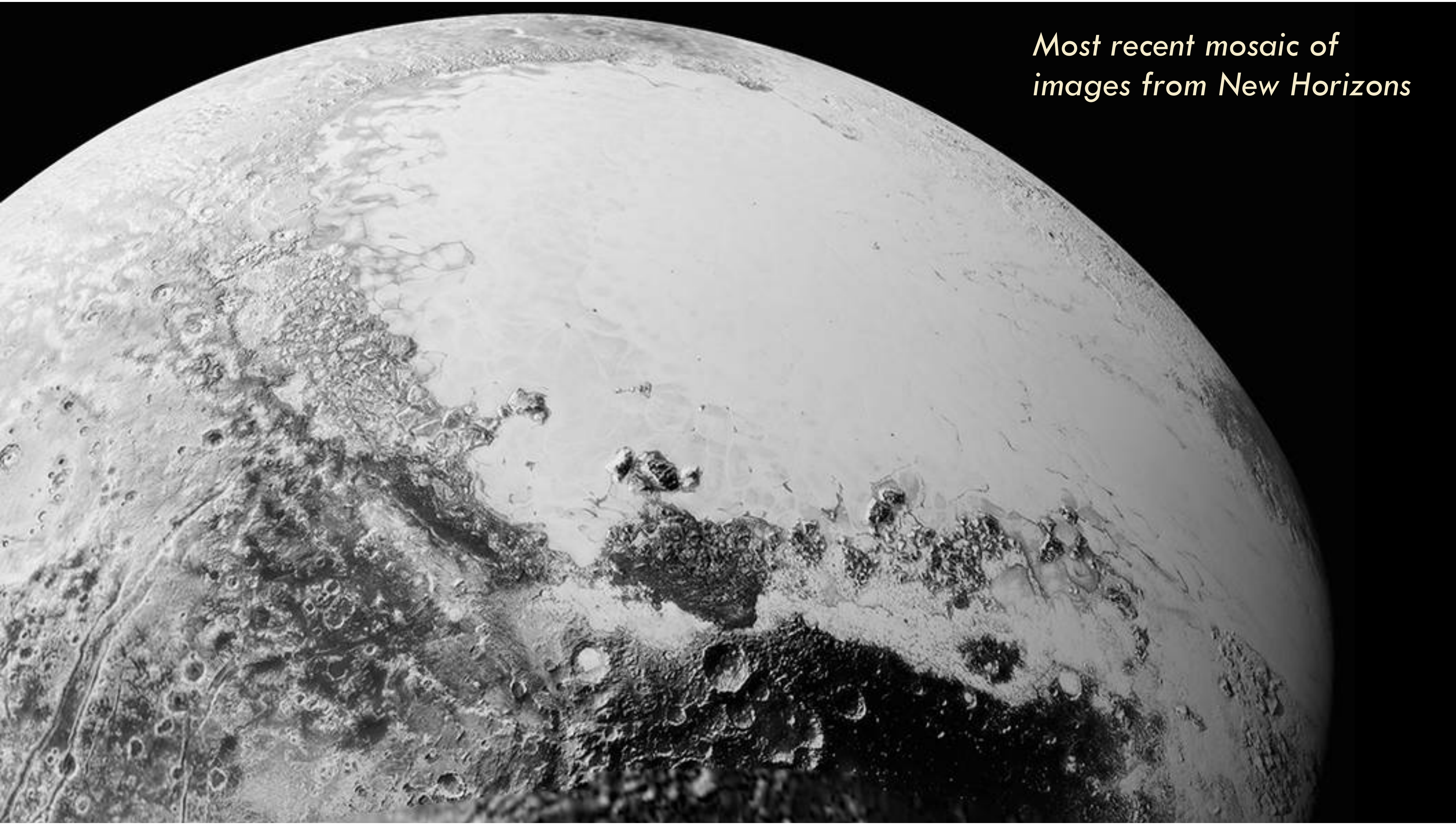
Pluto has one large moon, Charon, orbiting every 6.4 days.

Pluto and Charon are both tidally locked, so they always present the same face to each other. From one side of Pluto, Charon would stay in the same place in the sky as the stars rotated past, while from the far side you would never see Charon at all.

Pluto and Charon seen by New Horizons on closest approach

In recent years, four more tiny (~ a few km) moons have been discovered around Pluto; *Nix*, *Hydra*, *Kerberos* and *Styx,* the smallest of which is only about 20 km in diameter.

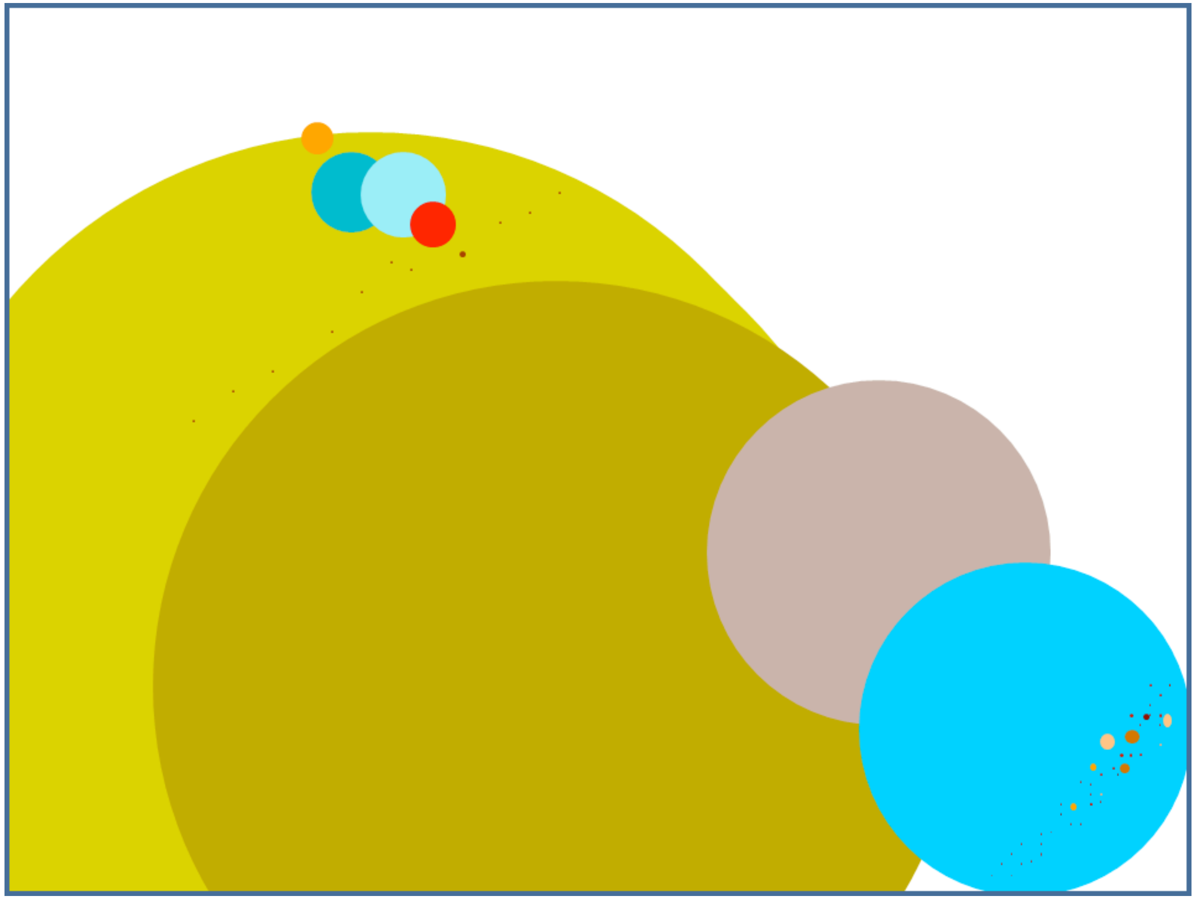



Most recent mosaic of
images from New Horizons

The first TNO other than Pluto/Charon was discovered in 1992. In 2003 a new object was discovered, which turned out to be larger than Pluto. It was given the temporary designation 2003 UB313, and later called Eris.

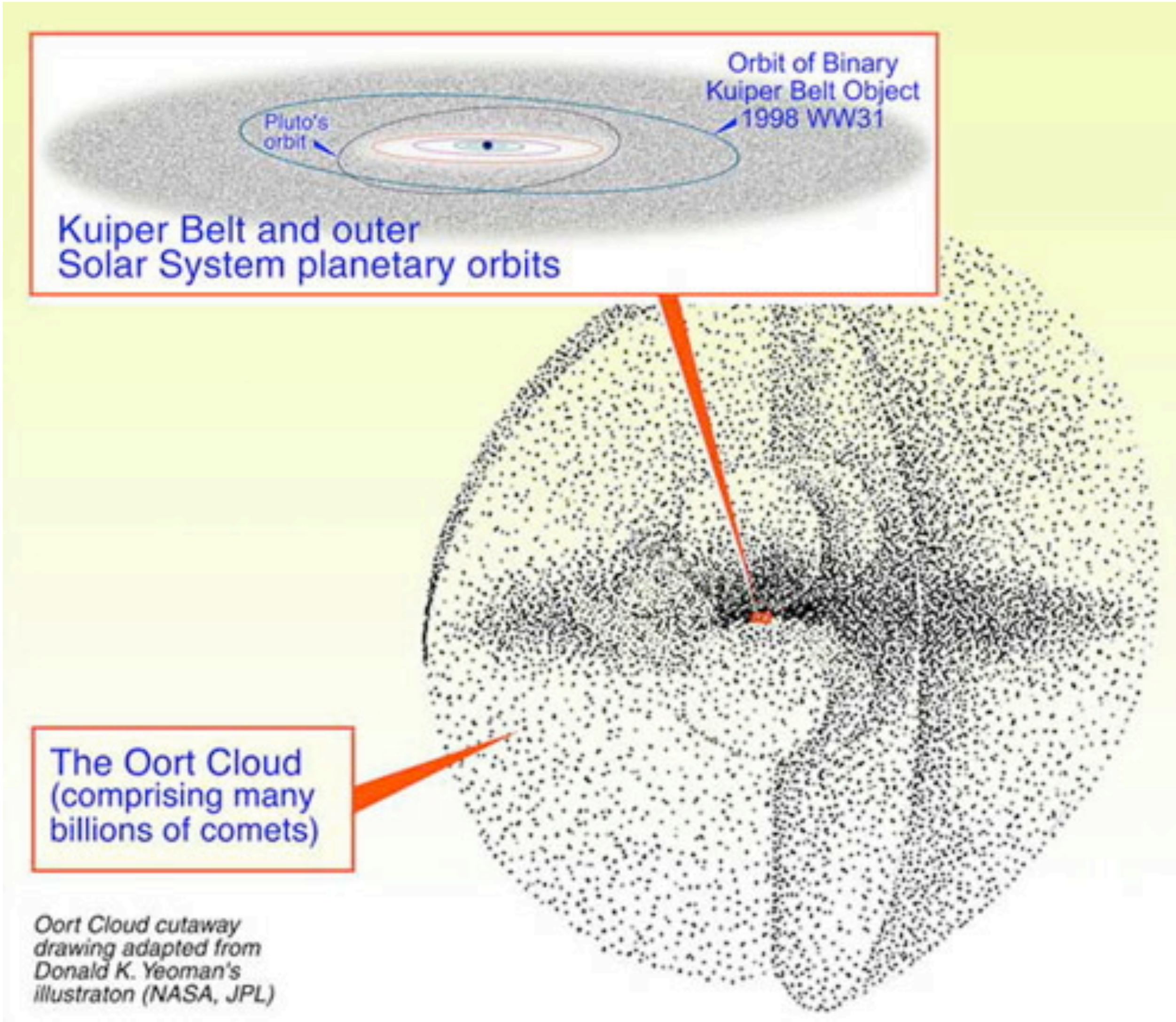
This precipitated the decision of the International Astronomical Union to re-classify Pluto as a dwarf planet, one of several other large bodies beyond Neptune.

Mike Brown (discoverer of Eris) has made an image showing the relative sizes of the planets, in a way which makes it clear why the demotion of Pluto was correct.



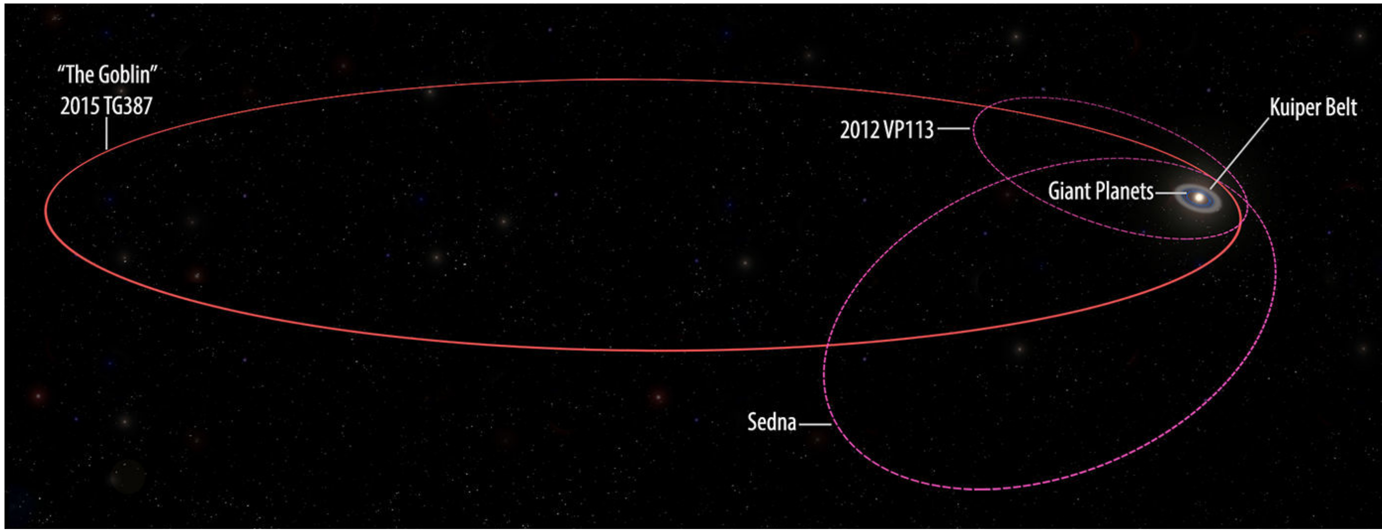
Most TNOs live in the Kuiper Belt, a disk-shaped region beyond the orbit of Neptune.

Far beyond that is thought to lie the Oort Cloud, a spherical region surrounding the Solar System where long-period comets originate.

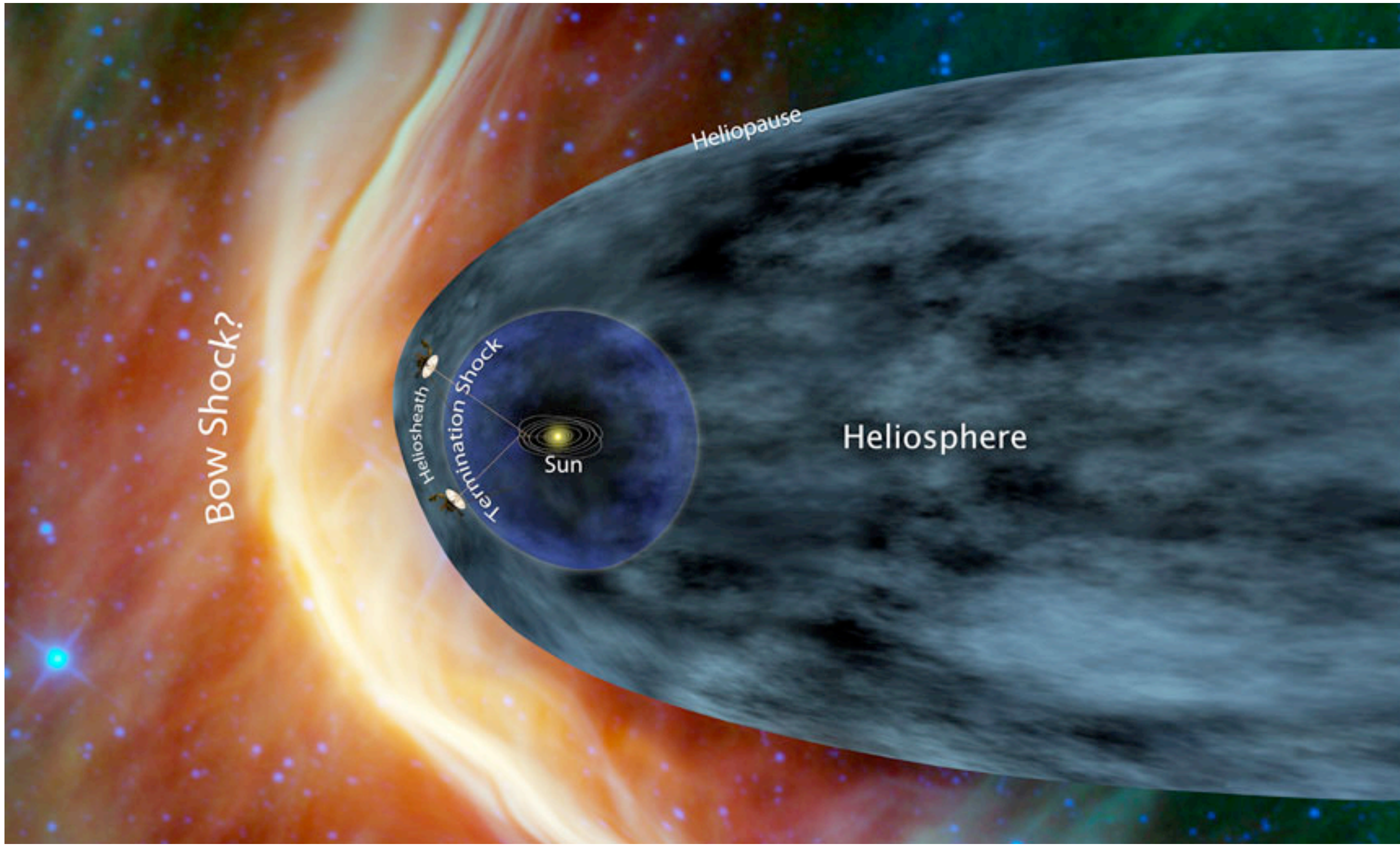


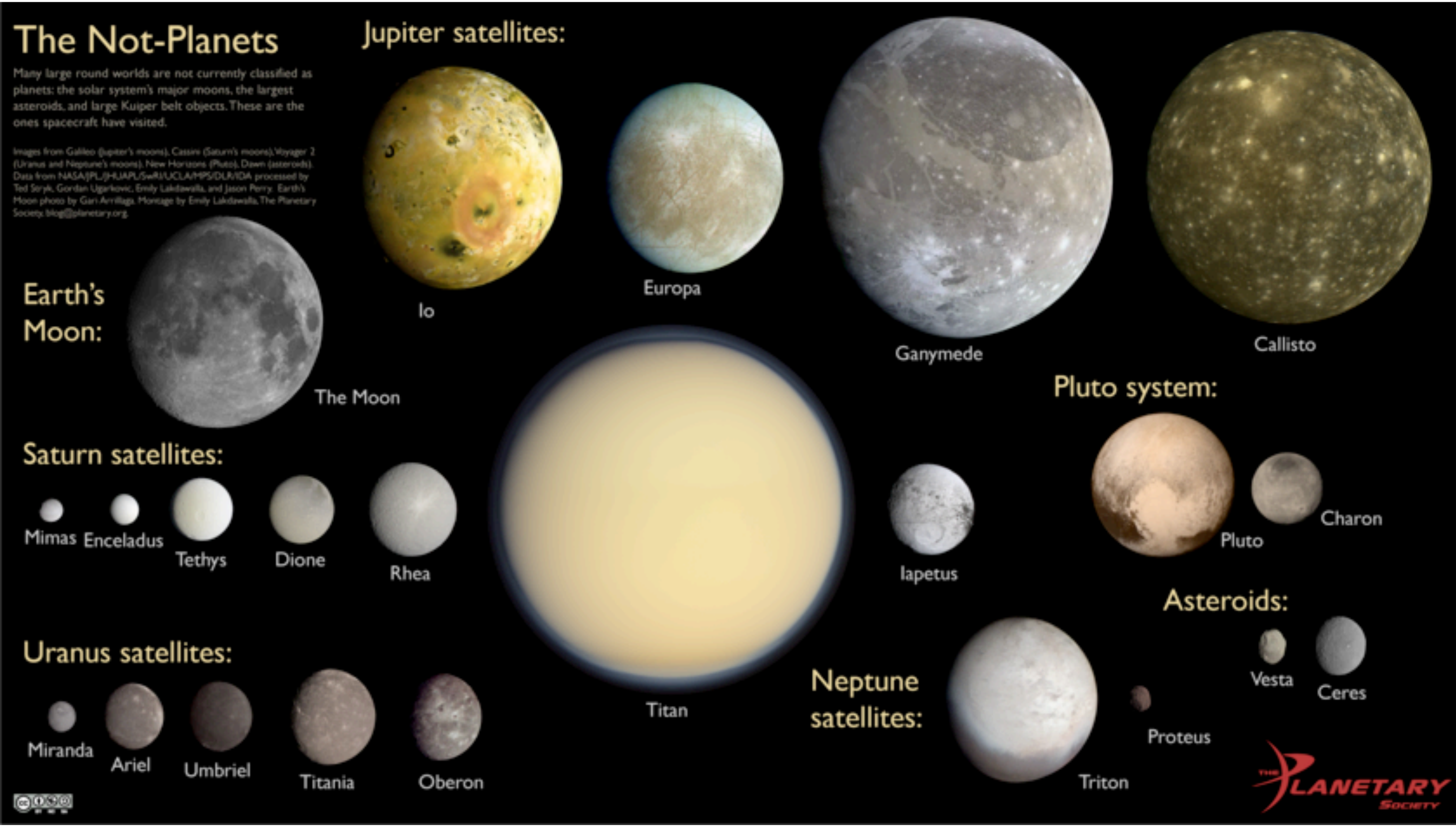
Just last week, the discovery of a new, extremely distant object, was announced: 2015 TG387 (nicknamed “The Goblin”). Its orbit is extremely elliptical, and its distance from the Sun varies from 65 AU to 2300 AU – almost 60 times further out than Pluto, and taking 40,000 years to loop once around the sun.

The alignment of the three objects so far discovered in the outer solar system might point to the existence of “Planet Nine”, a super-Earth sized planet out past the Kuiper Belt.



Currently, the most distant spacecraft are the two *Voyager* craft, both of which are currently leaving the Solar System. *Voyager 1* is currently 132 AU (20 billion km) from the Sun, 38 years after launch. It is thought Voyager 1 crossed the heliopause sometime around 2014.





The Not-Planets
Many large round worlds are not currently classified as planets: the solar system's major moons, the largest asteroids, and large Kuiper belt objects. These are the ones spacecraft have visited.
Images from Galileo (Jupiter's moons), Cassini (Saturn's moons), Voyager 2 (Uranus and Neptune's moons), New Horizons (Pluto), Dawn (asteroids). Data from NASA/JPL/JHUAPL/SwRI/UCLA/MPS/DLR/IDA processed by Ted Stryk, Gordan Ugarkovic, Emily Lakdawalla, and Jason Perry. Earth's Moon photo by Gari Arrillaga. Montage by Emily Lakdawalla, The Planetary Society. blog@planetary.org.
Jupiter satellites:
Io
Europa
Ganymede
Callisto
Earth's Moon:
The Moon
Saturn satellites:
Mimas
Enceladus
Tethys
Dione
Rhea
Titan
Iapetus
Pluto system:
Pluto
Charon
Asteroids:
Vesta
Ceres
Uranus satellites:
Miranda
Ariel
Umbriel
Titania
Oberon
Neptune satellites:
Triton
Proteus
The Planetary Society

Next week

... we'll look at how stars (and planets) are born.

Further reading

- The website for the Solar Dynamics Observatory, the latest and greatest solar satellite from NASA, is at http://sdo.gsfc.nasa.gov/.
- There's a truly wonderful book written recently, about the discovery of the solar cycle and space weather: "**The Sun Kings**" by Stuart Clark, subtitled: "The unexpected tragedy of Richard Carrington and the tale of how modern astronomy began" (Princeton UP, 2007). It starts with the 1859 "superstorm" and has lots of fascinating information about what we've learned about solar activity. A ripping good read.
- Check out Galileo's drawings of sunspots at "**The Galileo Project**", http://galileo.rice.edu/index.html; look in Science > Sunspots > Galileo's Sunspot Drawings
- NASA has a site with all the publicly released images from its Solar System program at the **Planetary Photojournal**, http://photojournal.jpl.nasa.gov/index.html
- "**The Cambridge Photographic Guide to the Planets**" by F.W. Taylor (Cambridge UP, 2001) is a lovely book , which contains very good descriptions of what is known about each planet, together with spectacular pictures
- The BBC documentary "**The Planets**", available on video or DVD. An excellent introduction to the solar system and its formation, including some wonderful interviews with many of the project scientists for Voyager and other missions.

- "**Space Odyssey: Voyage to the Planets**" is a two-part BBC series by the same people who made "Walking with Dinosaurs", describing a fictional five-person mission to the planets, in the style of a documentary. It's fun, and certainly gives a good feeling what visiting these worlds would be like.
- There is an absolutely gorgeous book called "**Beyond: Visions of the Interplanetary Probes**" by Michael Benson (Harry N. Abrams, 2003). The author has compiled and digitally processed the best images sent back by the space probes into one of the most beautiful collections you'll ever see.
- Govert Schilling tells the story of the discovery of the outer solar system, going all the way back to the discovery of Uranus and the asteroids, in "**The Hunt for Planet X: New worlds and the fate of Pluto**". (Springer, 2009) The book was being written during the hoopla about Pluto, and he ties the stories together very nicely. A good read.
- Mike Brown, the discoverer of Eris, has written a very entertaining book called "**How I Killed Pluto: And why it had it coming**" (Random House, 2012). Which kind of says it all.
- Alan Taylor has put together a beautiful image of "**All (known) Bodies in the Solar System Larger than 200 Miles in Diameter**" (now including a new metric version with everything larger than 320 km in diameter) at http://www.kokogiak.com/gedankengang/2007/03/all-known-bodies-in-solar-system.html. Because this was made in 2007, some of the dwarf planets, like Haumea and Makemake, still have their provisional designations.

- One of my favourite space-related blogs is Emily Lakdawalla's **"Snapshots from Space"** http://www.planetary.org/blogs/emily-lakdawalla/. She concentrates on results from planetary missions, and is one of the best ways of staying up-to-date with what's going on.
- For the discovery of 2015 TG387: see https://www.theguardian.com/science/2018/oct/02/dwarf-planet-the-goblin-discovery-planet-nine-oort-cloud and https://www.syfy.com/syfywire/a-newly-discovered-extremely-distant-icy-world-points-to-planet-9

Sources for images used:

- Solar system; from Chandra Photo Journal http://chandra.harvard.edu/photo/2005/orion/najita.html
- Sun: SOHO image of the Sun, taken in ultraviolet light. http://sohowww.nascom.nasa.gov
- Sizes of orbits: from http://www.solarviews.com/eng/solarsys.htm
- Jupiter and Saturn families of moons: from NSSDC Photo Gallery, http://nssdc.gsfc.nasa.gov/photo_gallery/
- Moons: from Paul Schenk, "Satellites of the Outer Planets" http://www.lpi.usra.edu/research/outerp/moons.html
- Moons by size: http://www.solarviews.com/eng/solarsys.htm
- Co-planar and circular orbits: generated using "Solar System Live" http://www.fourmilab.ch/solar/solar.html. These particular positions are for 1 March 2005, viewed from heliocentric latitude 0°, longitude 180° and latitude 90°, longitude 0°.
- Title image of the Sun: from http://www.celestiamotherlode.net/catalog/sol.php, image by Runar Thorvaldsen
- Structure of the Sun: from CPEP: Online Fusion Course: "From Core to Corona", http://fusedweb.pppl.gov/CPEP/Chart_pages/5.Plasmas/SunLayers.html
- Images of core of Sun: from Windows to the Universe, http://www.windows.ucar.edu/tour/link=/sun/solar_interior_new.html
- Solar granulation movie: from Windows to the Universe, http://www.windows.ucar.edu/tour/link=/sun/Solar_interior/Sun_layers/Convection_zone/convection_zone.html&edu=high
- Vibrating Sun: from The Singing Sun, http://solar-center.stanford.edu/singing/singing.html
- Results from MDI/SOHO: from Scientists Discover Massive Jet Streams Flowing Inside the Sun, http://soi.stanford.edu/press/ssu8-97/ssu.html
- Sunspot: from Some images of a medium size sunspot by Peter Brandt, http://www.kis.uni-freiburg.de/~pnb/spottext1.html
- Sunspot numbers: from SILSO data/image, Royal Observatory of Belgium, Brussels http://www.sidc.be/silso/yearlyssnplot
- SOHO continuum and magnetogram images: from SOHO Latest Images,
- Solar magnetic fields: from The Sun Today, http://www.thesuntoday.org/solar-facts/suns-magnetic-poles-flipped-solar-max-is-here/
- Animation of sunspot formation and flare: from SOHO Gallery: Movies http://sohowww.nascom.nasa.gov/gallery/Movies/animations.html
- Prominences: from NASA, "An eruptive solar prominence", http://www.nasa.gov/mission_pages/sunearth/science/solar-prominence.html
- Earth compared to prominence: from SDAC, http://umbra.nascom.nasa.gov/sdac.html
- Coronal loops movie: from Solar Physics: Coronal features, http://science.nasa.gov/ssl/PAD/SOLAR/feature3.htm
- Flaring region: from http://sdo.gsfc.nasa.gov/gallery/potw.php?v=item&id=102
- Coronal mass ejection flare 31 August 2012: from http://sdo.gsfc.nasa.gov/gallery/main.php?v=item&id=158
- LASCO movie of coronal mass ejection event: from Best of SOHO Movies, http://sohowww.nascom.nasa.gov/
- Aurora over Alaska, image by Bud Kuenzli, from APOD 2007 Oct 9, http://antwrp.gsfc.nasa.gov/apod/ap071009.html
- Terrestrial planets: from NASA http://solarsystem.nasa.gov/multimedia/gallery/terr_sizes.jpg
- MESSENGER Flyby 2 mosaic: from http://messenger.jhuapl.edu/gallery/sciencePhotos/image.php?gallery_id=2&image_id=214
- Mercury scarp: PIA10939 http://photojournal.jpl.nasa.gov/catalog/PIA10939
- Image of Venus' clouds from Galileo: Astronomy Picture of the Day, 2004 May 16, http://antwrp.gsfc.nasa.gov/apod/ap040516.html

- Venus surface: computer generated picture of Magellan radar data, from Astronomy Picture of the Day 2002 March 30, http://antwrp.gsfc.nasa.gov/apod/ap020330.html
- Volcano Sif Mons: PIA00108 http://photojournal.jpl.nasa.gov/catalog/PIA00108
- Earth: view from Apollo 17, Astronaut Photography of the Earth, http://eol.jsc.nasa.gov/scripts/sseop/photo.pl?mission=AS17&roll=148&frame=22727
- DISCOVR image of the Earth and Moon: from NASA Planetary Photojournal http://photojournal.jpl.nasa.gov/catalog/PIA00342
- Global view of Mars from Viking: from NASA Planetary Photojournal http://photojournal.jpl.nasa.gov/catalog/PIA00407
- Topographic image of Mars: taken by the Mars Global Surveyor. From the NASA Planetary Photojournal http://photojournal.jpl.nasa.gov/catalog/PIA02031
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- Valles Marineris hemisphere: mosaic of Viking images, from http://nineplanets.org/mars.html
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