Gravity: Motivation

- An initial theory describing the nature of the gravitational force by Newton is a product of the resolution of the Geocentric-Heliocentric debate (Brahe's data and Kepler's analysis)
- Gravity is a major force in the formation and dynamics of solar systems and galaxies. It plays a large role in structuring the matter and energy of the Universe
- Supportive reading Bennett Chapter 4

Gravity: Physics Fundamentals

Speed = distance/time elapsed

$$V = d/t$$

Gravity: Physics Fundamentals

A car traveling on a highway takes 3 seconds to travel between two poles that are separated by 100 m. What is the car's speed?

$$V = \frac{d}{t}$$

$$V = \frac{100m}{3s} = 33.3m/s$$

Gravity: Physics Fundamentals

Velocity is speed AND direction.

Thus velocity contains two pieces of information: a number representing the speed and a stated direction. Direction is important!

To represent the velocity (as opposed to the speed) we use the symbol $\vec{v}$ where the arrow over the v indicates that direction is important to the quantity.

Gravity: Physics Fundamentals

Consider the velocity of two cars.

Car A: $\vec{V}$ = 25 m/s East

Car B: $\vec{V}$ = 25 m/s North

These two cars have the same speed but different velocities because their directions are different.

Newton and Gravity

In Newton's 2nd Law of Motion we understand that a Force (push or pull) is required to change the velocity (motion, either speed or direction) of the object. [The change in the velocity of an object is also known as acceleration].

http://www.phys.virginia.edu/classes/109N/more_stuff/Applets/newt/newtmtn.html

Topics I'd Like to Give More Attention

- Artificial Satellite Orbit (in conjunciton with an improved more detailed, online tutorial, coverage of Kepler's Laws)
- Determining Earth-Sun Distance (Venus transit, is this the first time)
- Determing the Mass of the Sun
- Extra credit.

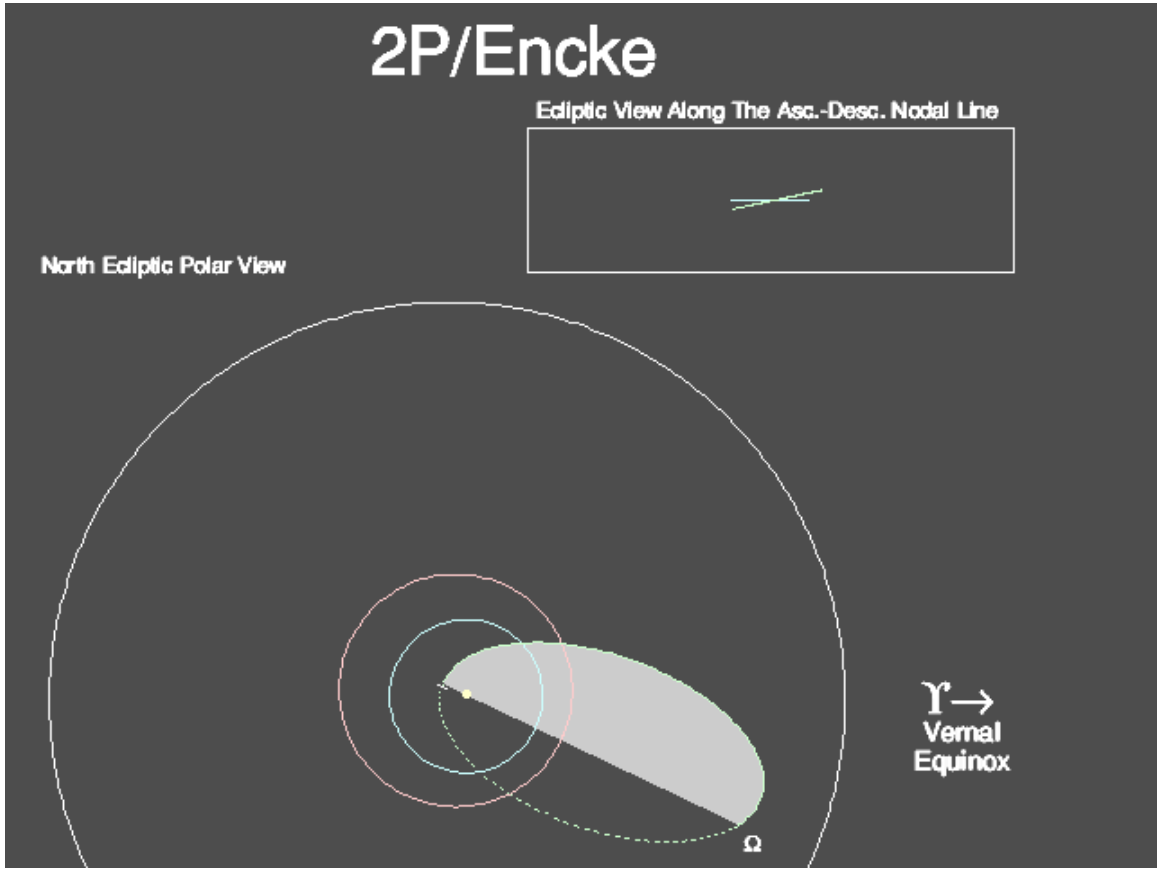
Gravity: Later Topics

- Mass and Weight
- Conservation of Angular Momentum
- Gravitational Tidal Force
- Energy forms and conservations ???

- Exam solutions will be available online by the end of the week
- Next homework will be assigned by next class, check your email
- Extra credit will be considered for the second half of the semester
- Read Chapter 4 and Chapter 7

Comet Neat at Perihelion

Recall that comets have highly elliptical orbits. Thus there is a large difference between their closest approach to the Sun (perihelion) and their furthest distance from the Sun (aphelion). (E.g. Comet Encke)



Comet Neat at Perihelion

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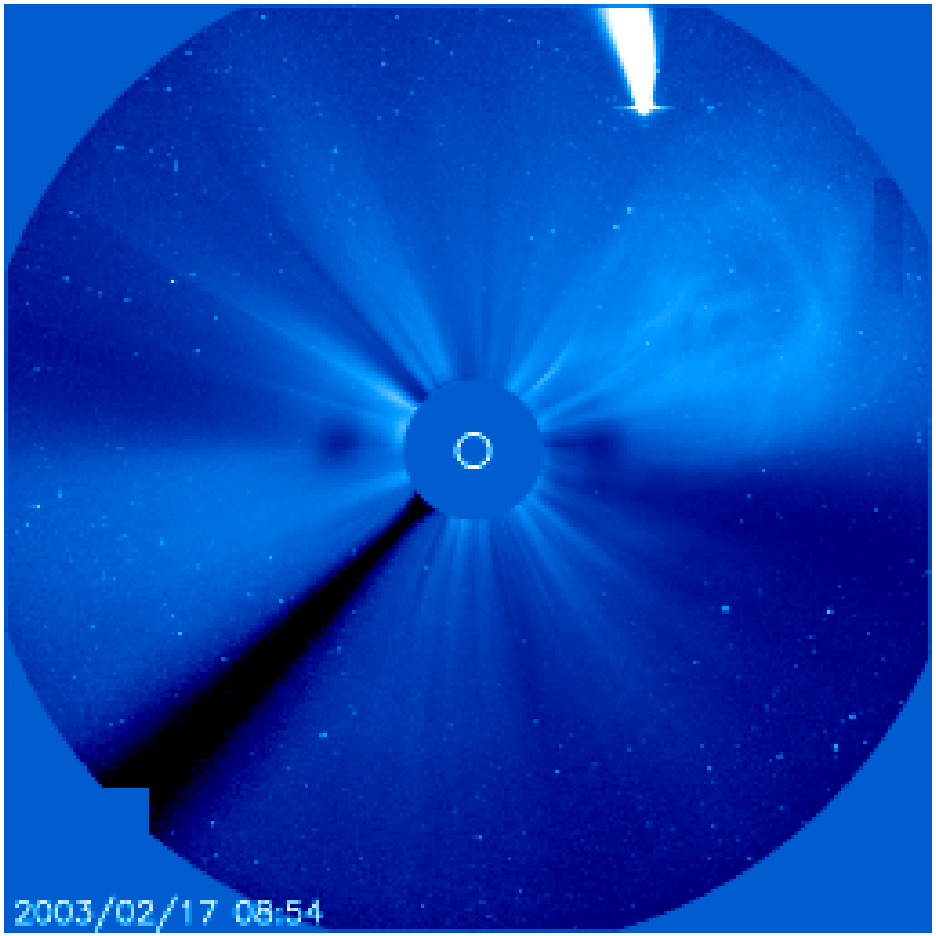
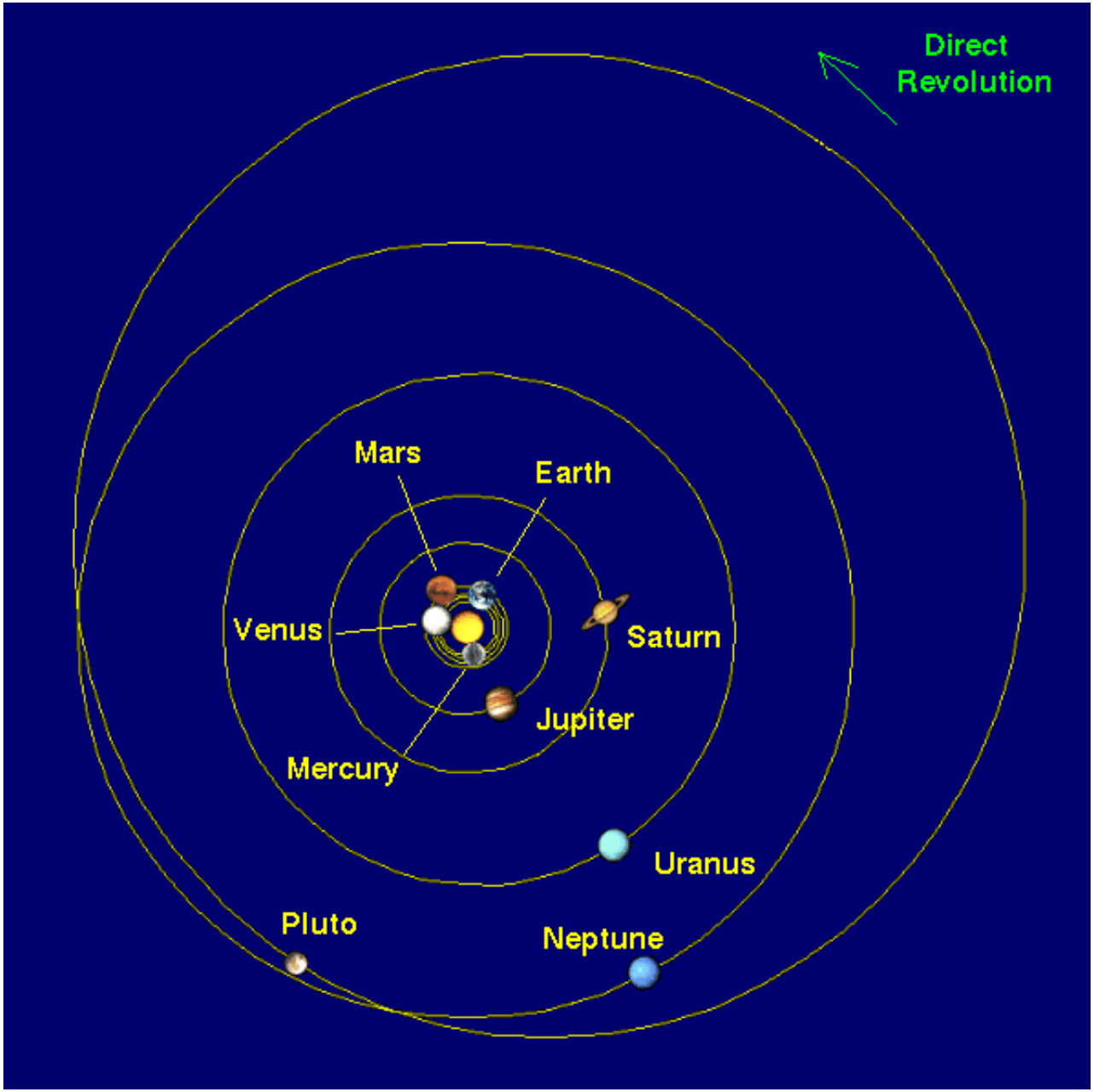
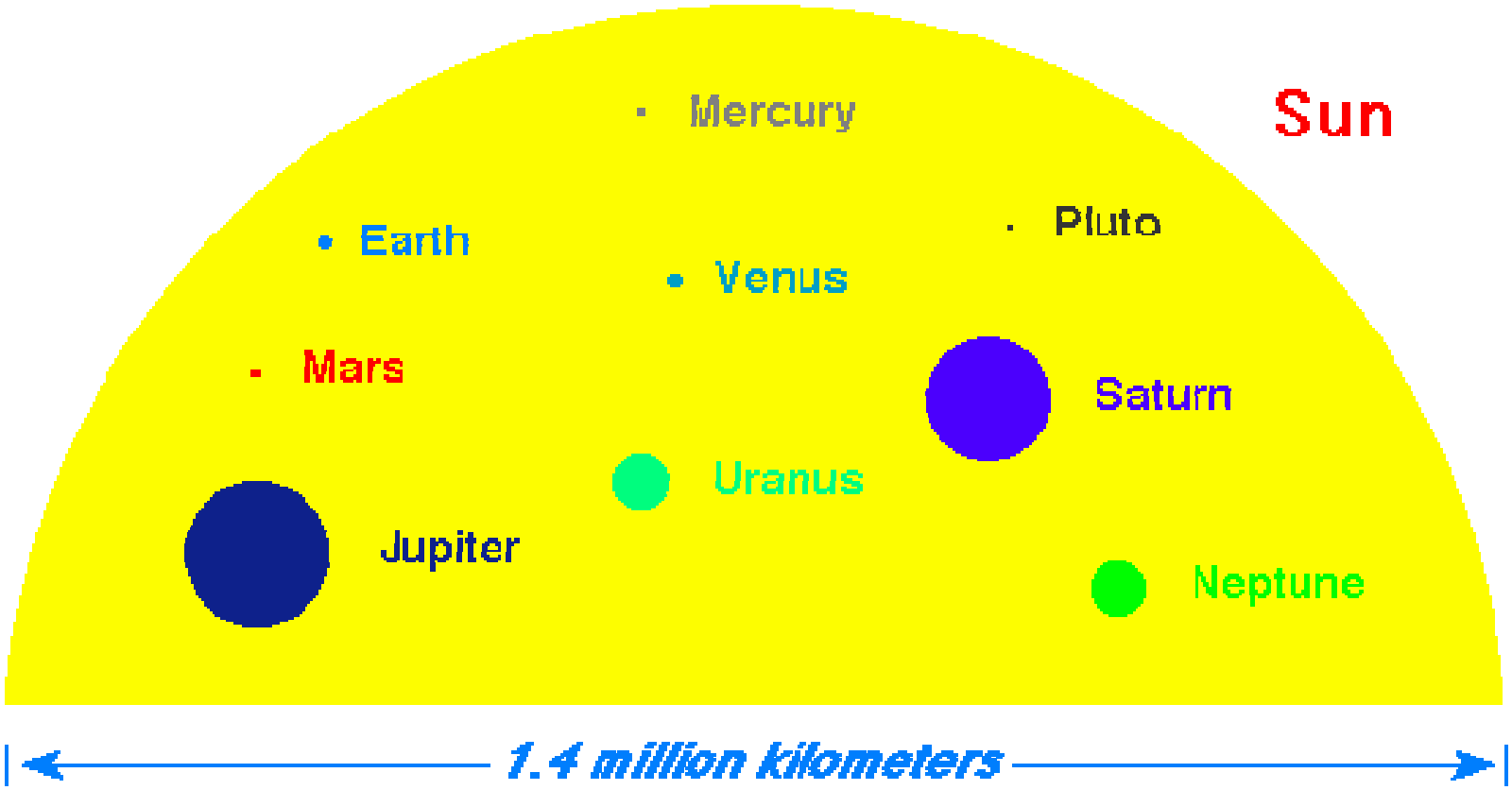


http://soho.nascom.nasa.gov/

Entire Solar System: Orbits to Scale



Size of Solar System Bodies to Scale



Solar System Overview

- **Our solar system consists of the sun and collection of bodies and debris that orbit it (Another definition may be based on the Sun's magnetic field)**
- **Terrestrial Planets: Rocky relatively large objects whose orbits are close to the Sun.**
- **Jovian Planets: Larger gaseous planets whose orbits are further from the Sun than the Terrestrial Planets.**
- **Dwarf Planets: Large enough that its own gravity has pulled it in to a spherical shape but not large enough to have cleared debris from its orbit.**

Solar System Overview

- **Dwarf Planets: Pluto and Eris (2005) in the Kuiper belt and Ceres the largest asteroid in the asteroid belt**

- **Asteroids: Small rocky bodies (largest are ~100's of km) mainly located between the orbits of Mars and Jupiter.**

- **Comets: Small icy objects (water ice, ammonia ice, methane ice) orbiting the Sun in the Kuiper belt ("regular" orbits outside of Neptunes orbit) and the Oort cloud (less systematic orbits further away)**

Solar System Overview

- **Annually, the Sun appeared to move against the background of stars along the Zodiac in a plane called the ecliptic.**

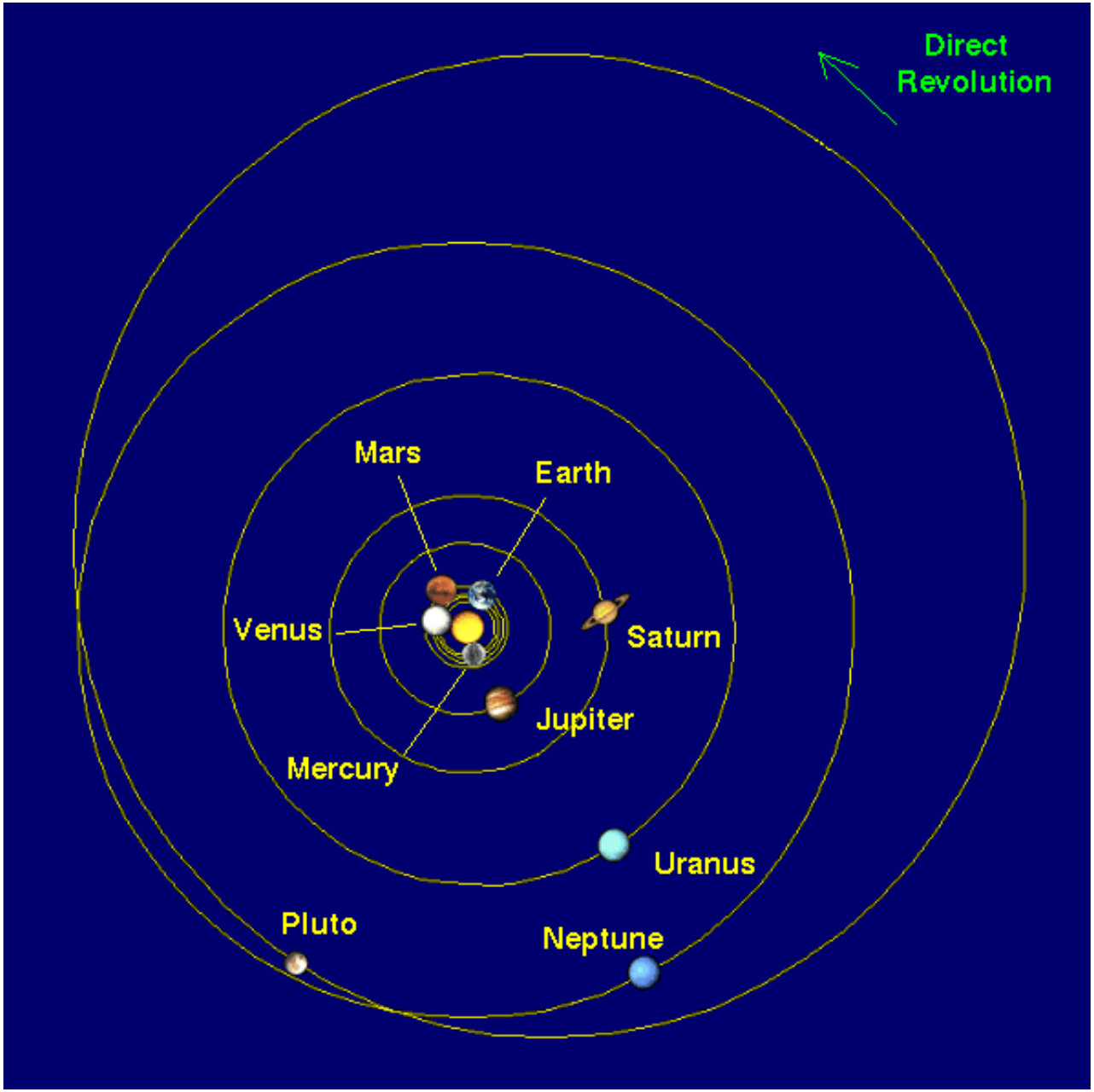
- **Due to the tilt of the Earth's rotational axis with respect to the ecliptic, the celestial equator (perpendicular to the rotational axis) and the ecliptic do not coincide. Thus latitude at which the Sun is overhead changes throughout the year.**

Solar System Overview

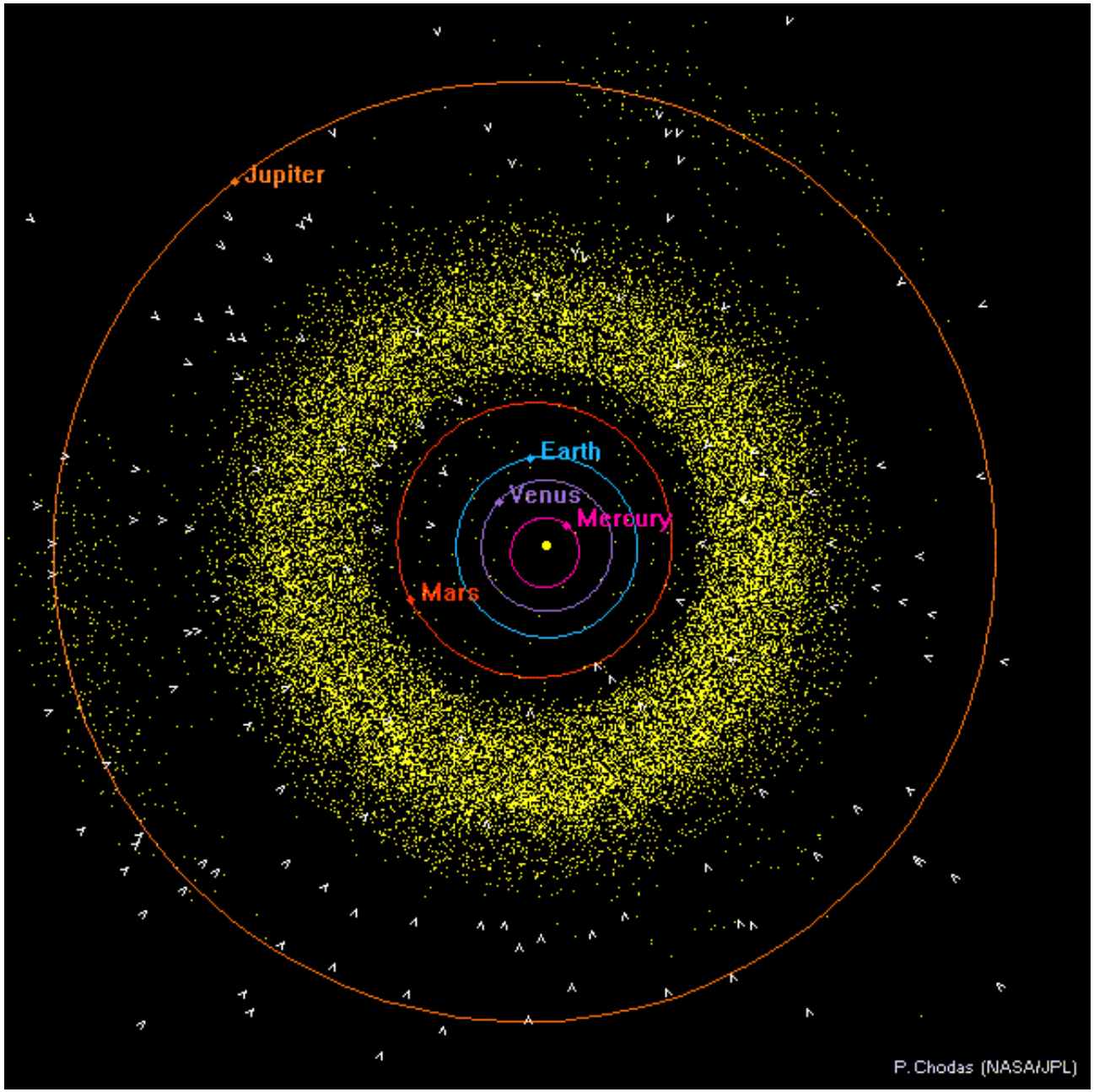
- **However, we know it is the Earth that moves around the Sun and thus it is the Earth that travels in the plane of the ecliptic.**

- **Most of the planets in the solar system orbit the Sun in (or near) the ecliptic (equatorial plane of the Sun. That is their orbits are only slightly inclined to the ecliptic plane.**

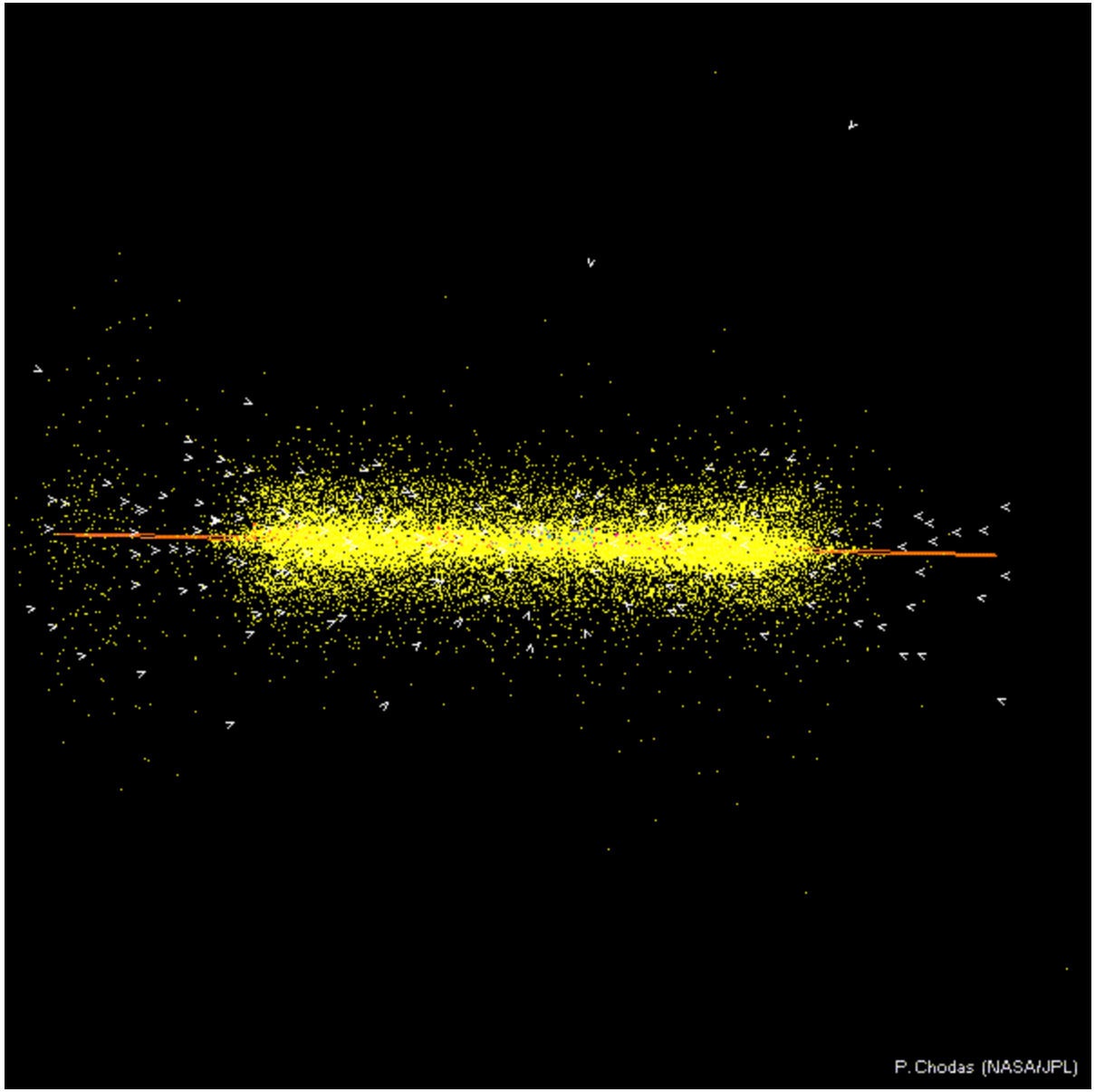
Entire Solar System: Orbits to Scale



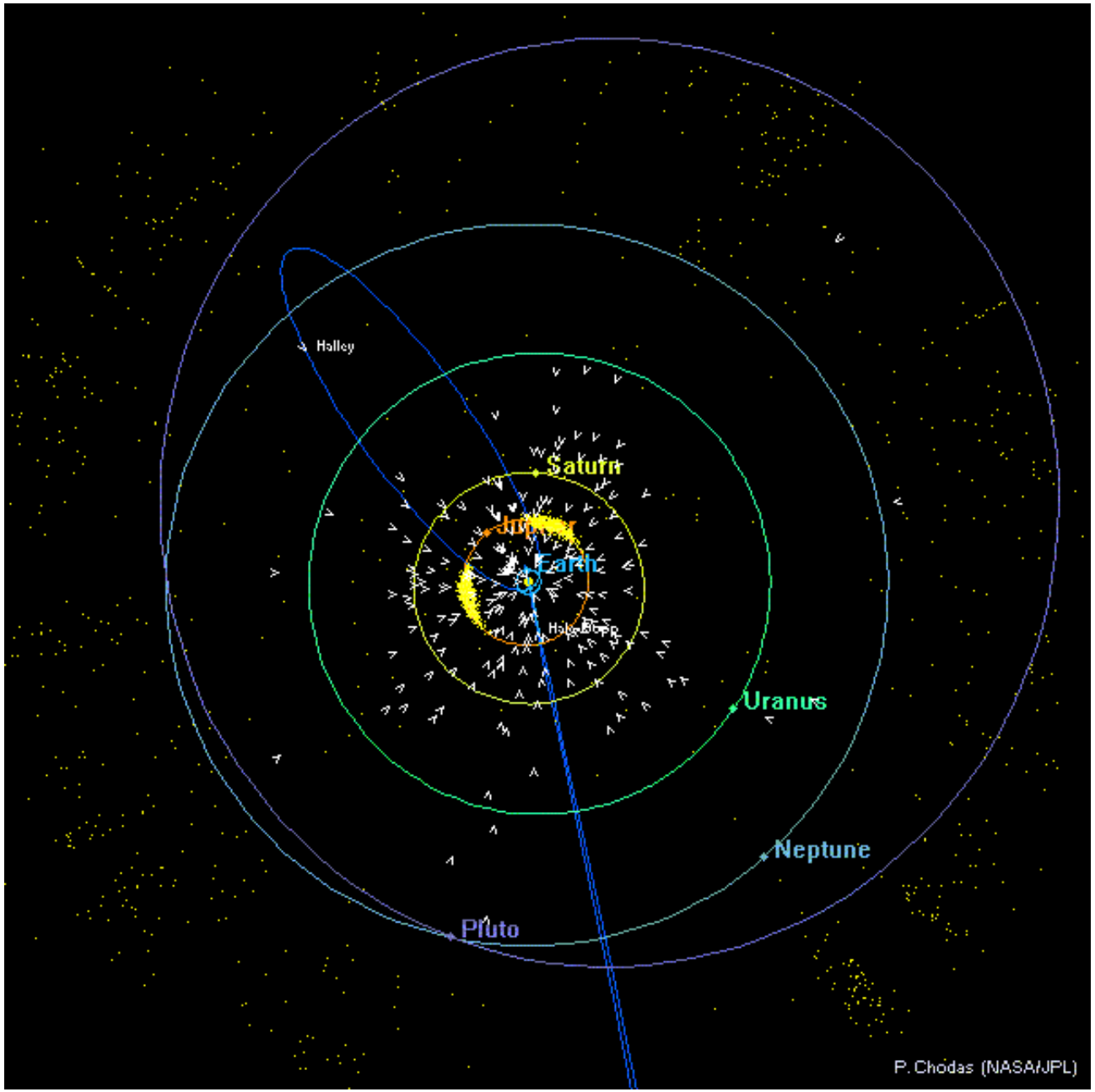
Inner Solar System: Looking Down on the Ecliptic



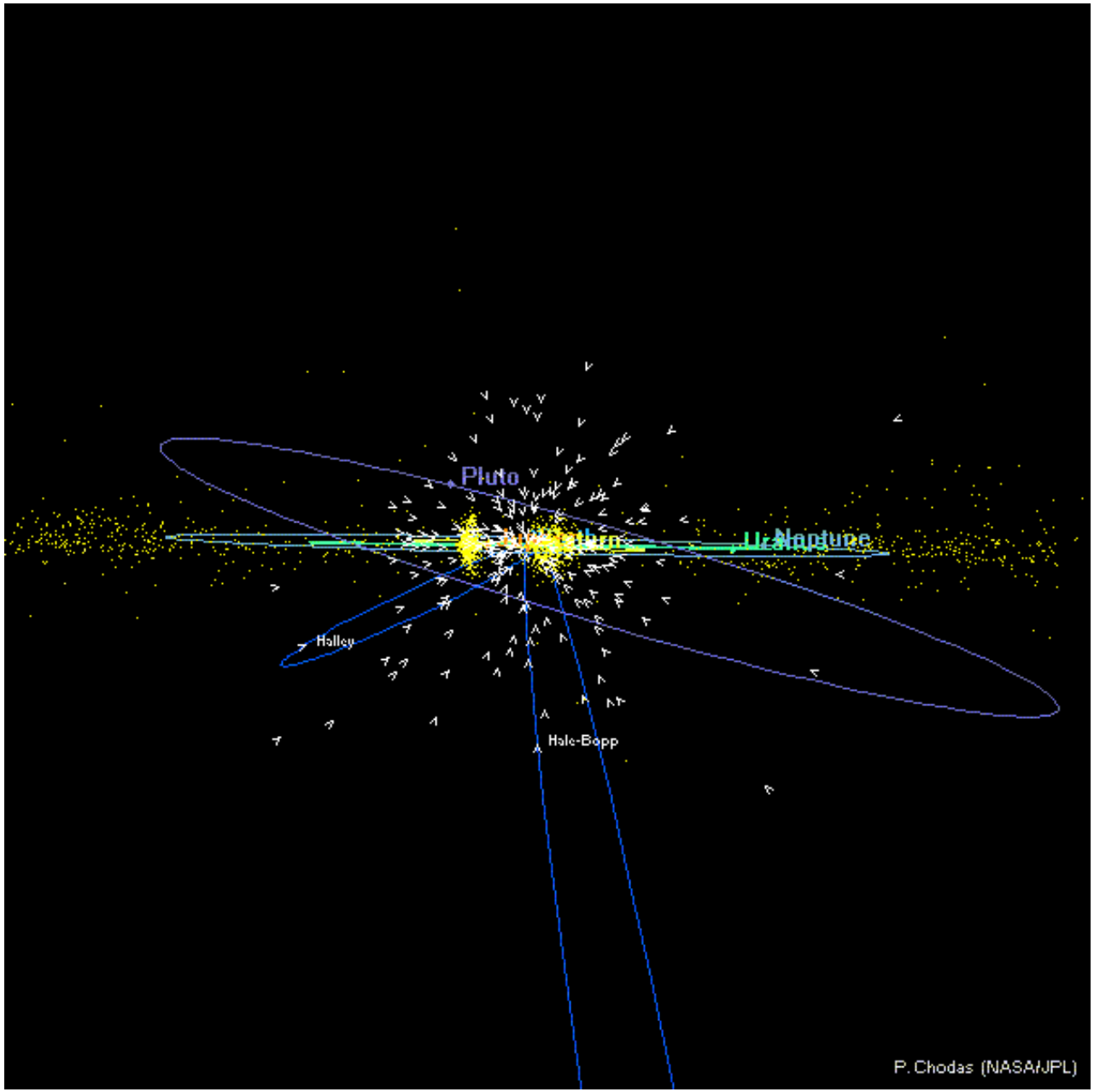
Inner Solar System: Looking at the Ecliptic Edge On



Outer Solar System: Looking Down on the Ecliptic



Outer Solar System: Looking at the Ecliptic Edge On

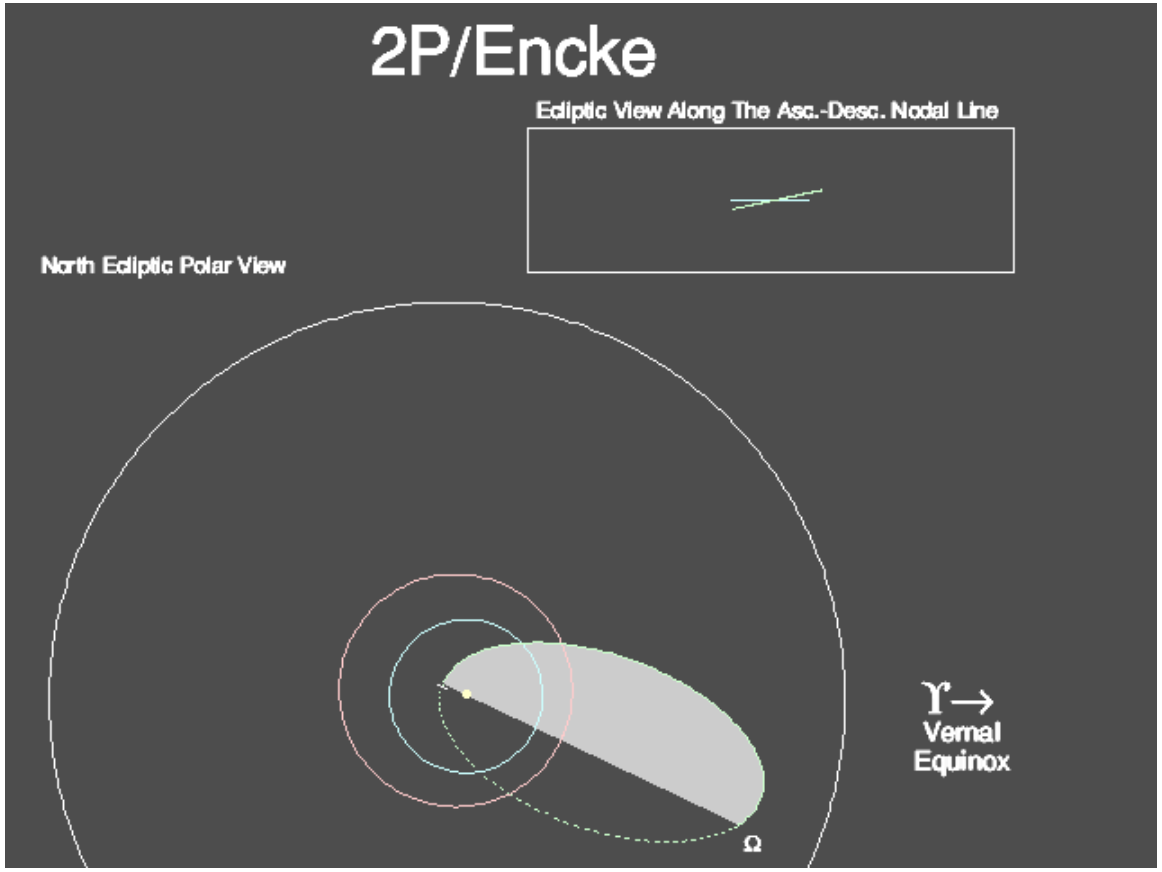


Solar System Overview

- **Note that the planet's orbits are confined to the plane of the ecliptic (small inclination)**
- **Note that the orbits of the planets are roughly circular (eccentricity of zero)**
- **Note that the orbits of Pluto and some comets are highly inclined and highly eccentric**

Comet Neat at Perihelion

Recall that comets have highly elliptical orbits. Thus there is a large difference between their closest approach to the Sun (perihelion) and their furthest distance from the Sun (aphelion). (E.g. Comet Encke)



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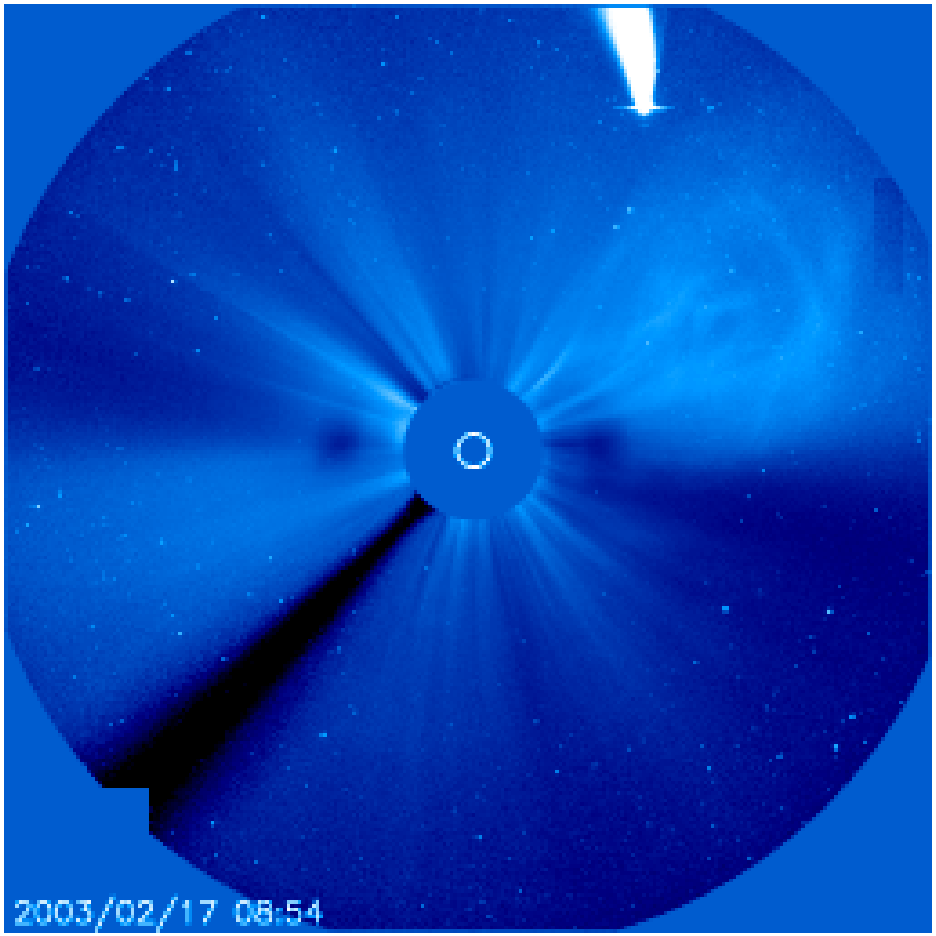

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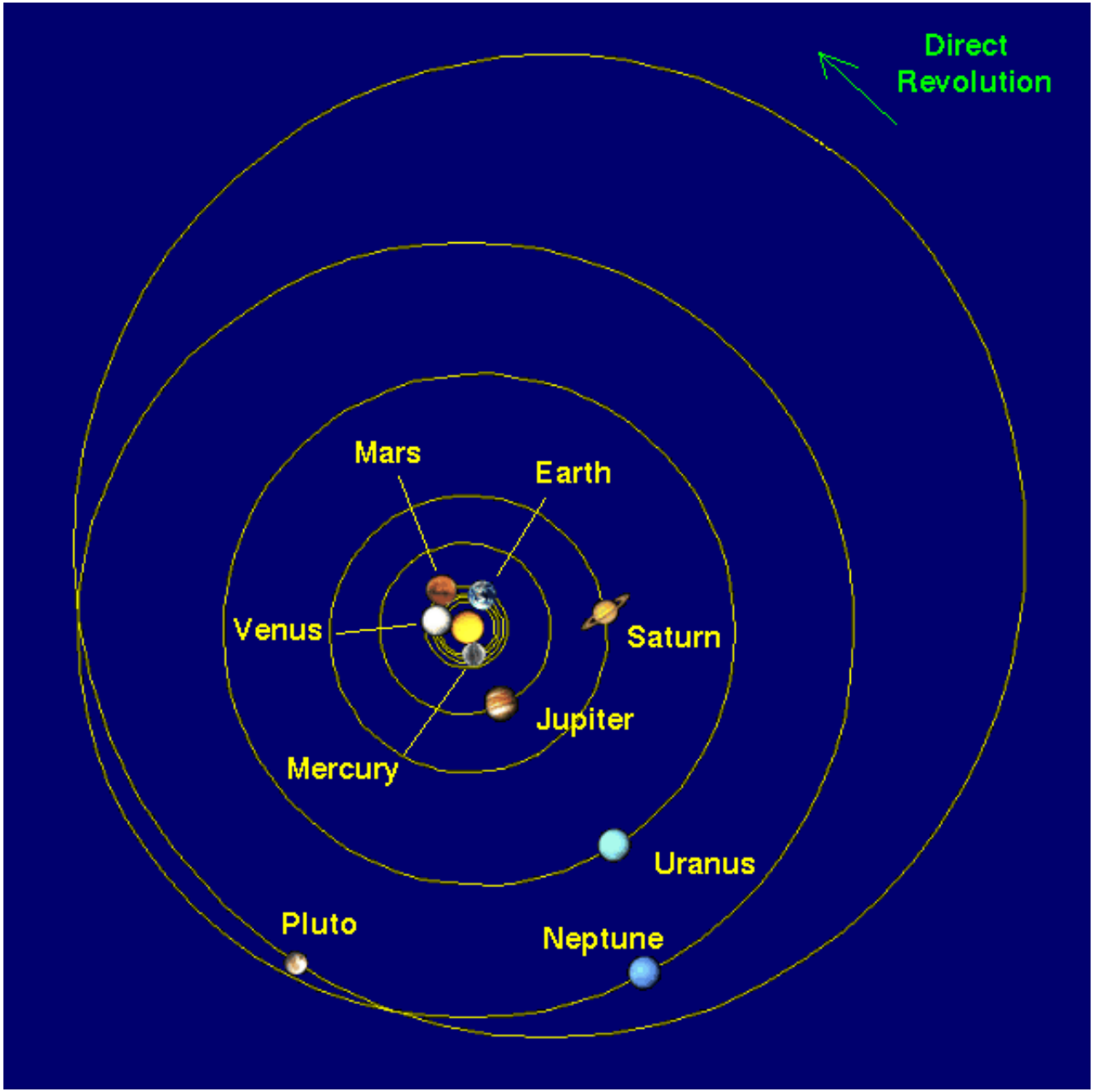
Entire Solar System: Orbits to Scale



Solar System Overview

- **Note that all of the planets revolve around the Sun in the same direction**
- **Note that most planets rotate in the same direction as their revolution (Venus rotates in the opposite direction)**
- **Note that most of the planet's axes of rotation are roughly perpendicular to the ecliptic (Uranus axis of rotation is almost parallel to the ecliptic)**
- **Note that most of the satellites of the planets have orbital characteristics similar to those of the planets**

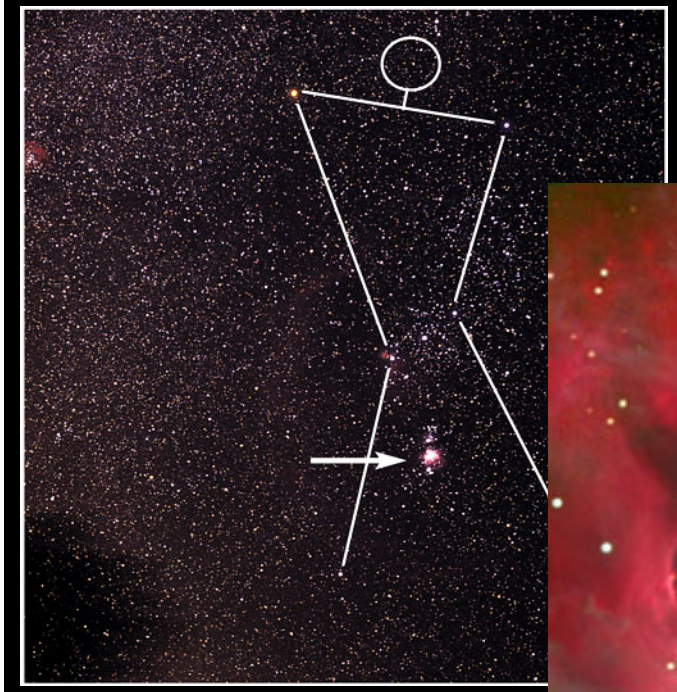
Solar System Formation Clues

- The orbital planes of the planets are nearly the same and lie almost in the equatorial plane of the Sun.
- The planets revolve around the Sun in the same direction in nearly circular orbits.
- Most planets rotate in the same direction that they revolve and their axis of rotation is approximately perpendicular to the equatorial plane of the Sun.
- The characteristic above dominate but there are anomilies (e.g. Venus and Uranus) that need to be addressed.

Solar System Formation Clues (cont.)

- The satellite systems of the outer planets have similar characteristics to those described above.
- There are two major categories of planets: rocky terrestrial planets near the Sun and large hydrogen rich planets (Jovian) further out.
- There are a huge number of asteroids and comets that seem to reside primarily in regions known as the asteroid belt, Kuiper belt and Oort cloud.

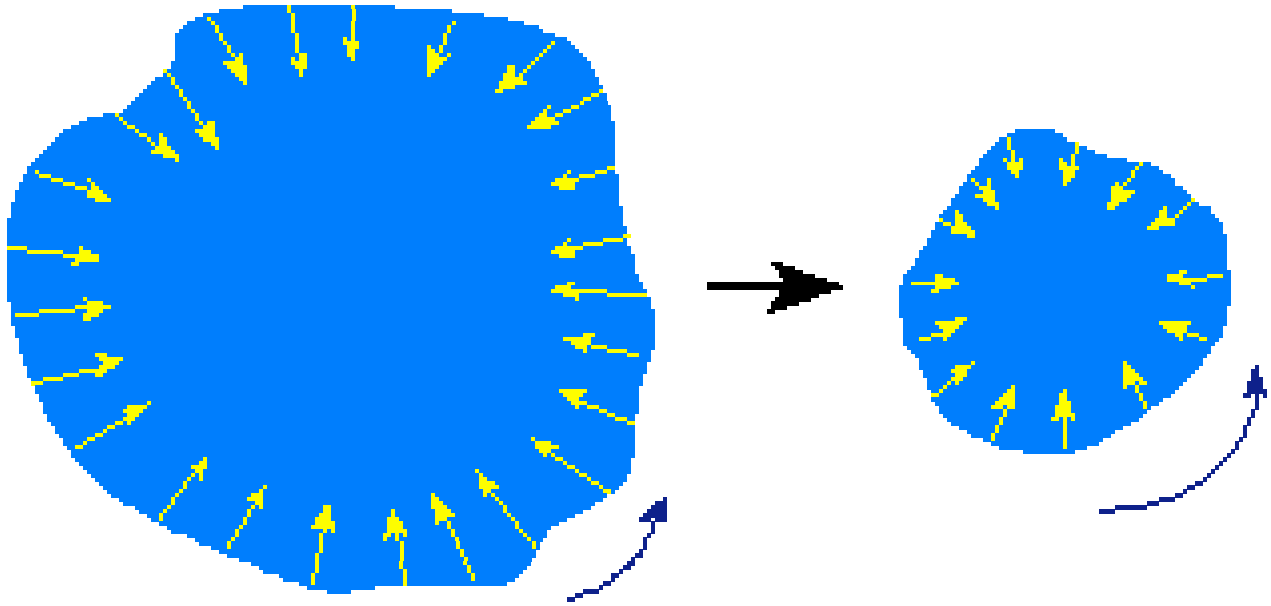
Nebula Hypothesis



Nebula Hypothesis

- The solar system will form from a relatively uniform cloud of gas, the solar nebula.
- This was likely composed of 98% hydrogen and helium and 2% heavier elements forged in stars the died long ago.
- On average the cloud likely had a very small rotation
- The cloud was likely stable until a “disturbance” propagated through it and started the “clumping” of nebula material

Collapse of Solar Nebula



Solar Nebula starts to contract under the mutual gravitational force of its constituents. As the radius of the cloud decreases it must rotate faster to conserve angular momentum.

Angular Momentum (see chapter 4)

Angular Momentum = Moment of Inertia x Angular Velocity

$$L = I \omega$$

L is the angular momentum

I is the moment of inertia. Tells how resistive an object is to changing its angular velocity. Depends on mass and the distance the mass is from the axis of rotation.

ω is the angular speed. Tells how fast the object is rotating.

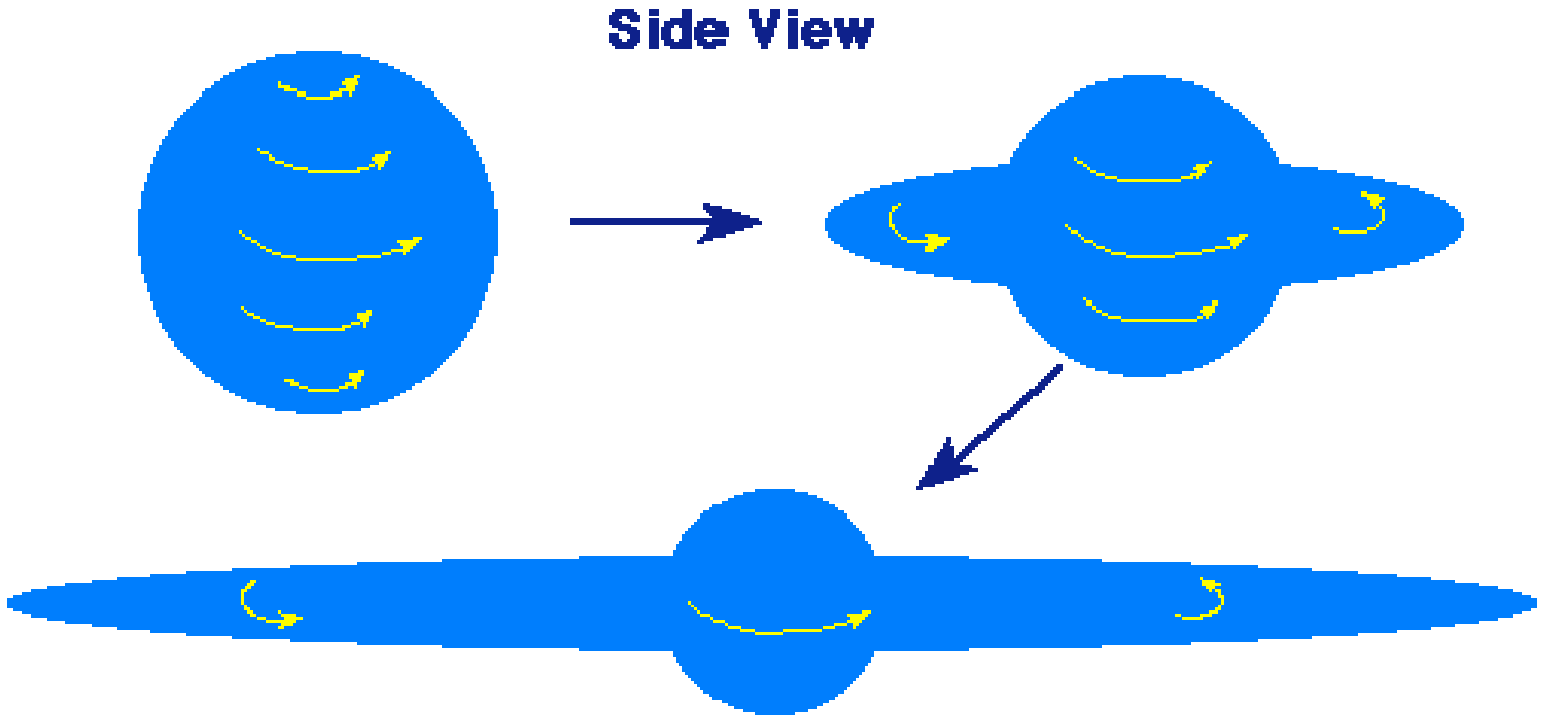
Angular Momentum Conservation

As long as there is no torque (force applied perpendicular, but not through, the axis of rotation) applied to a system its angular momentum will remain constant.

Thus if L is constant and the moment of inertia decreases the angular velocity must increase

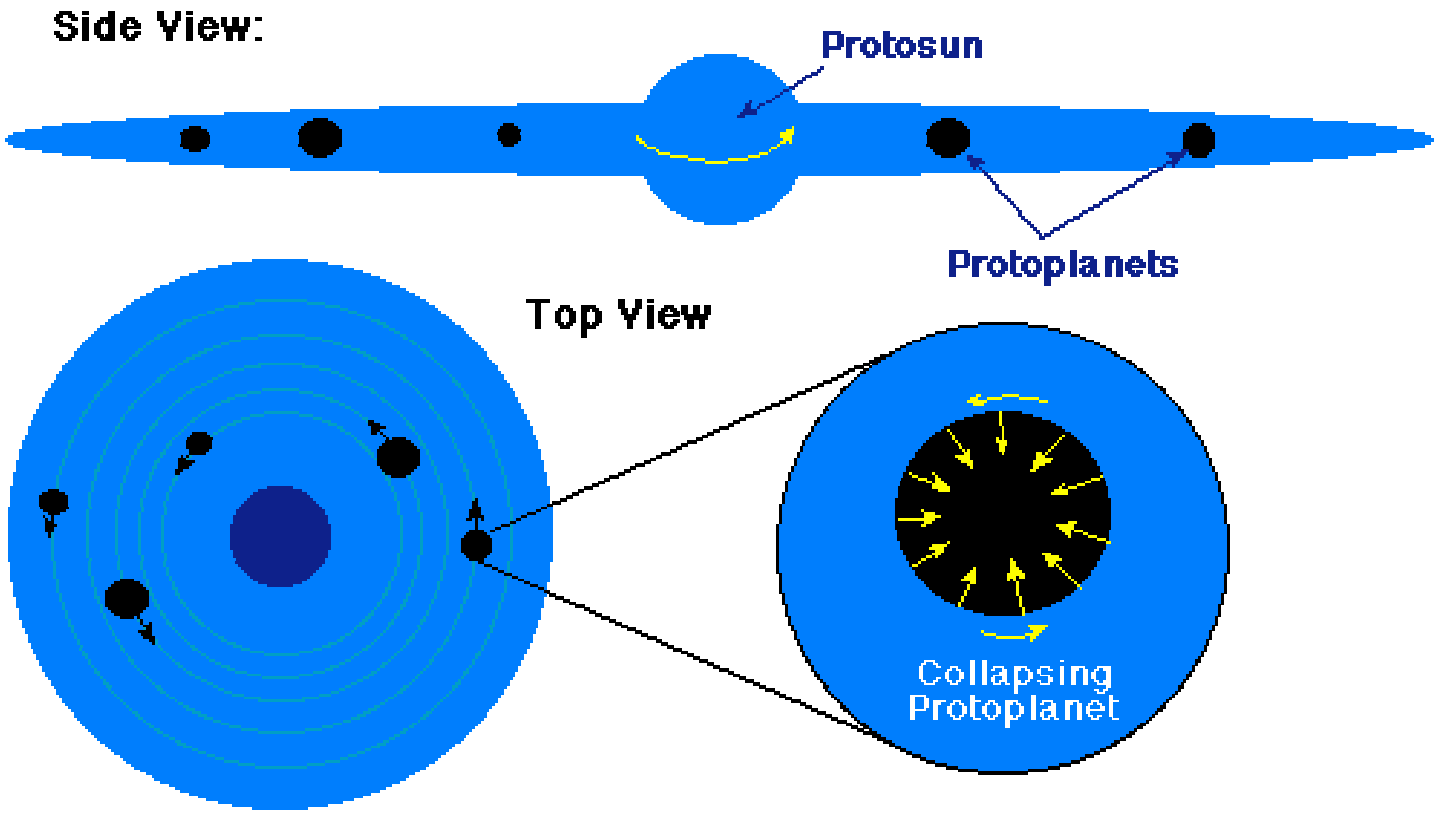
$$L = I \omega$$

Flattening of Solar Nebula



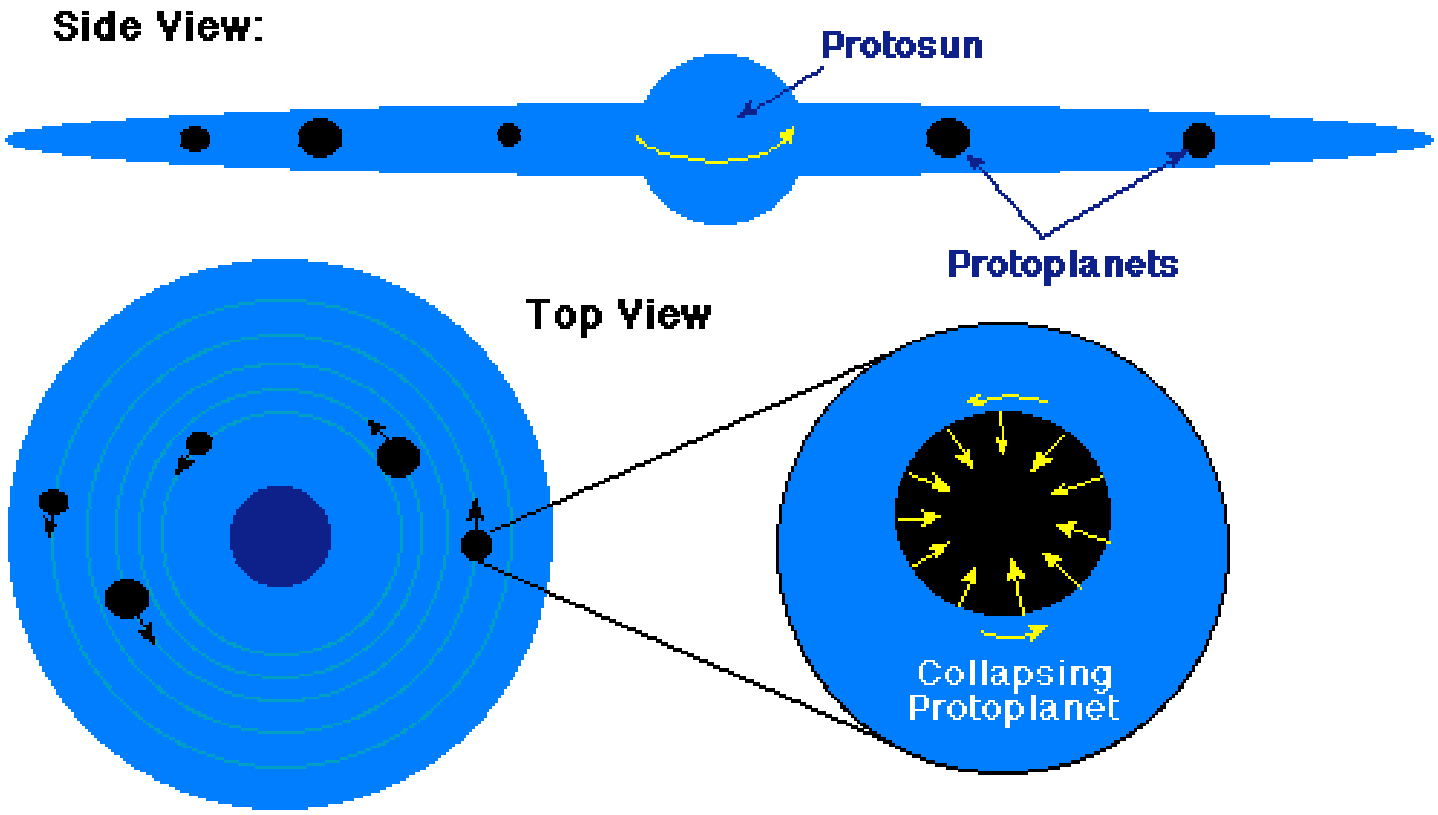
As the cloud spins about a vertical axis, the increased centripetal acceleration (due to increased speed of rotation) takes up (balances) the gravitational force so that the horizontal contraction slows. The vertical contraction continues and the cloud flattens.

Solar Nebula: Protoplanets



Protoplanets form from the condensation, electrostatic attraction, collision and subsequent gravitational attraction of Nebula material.

Solar Nebula: Protoplanets



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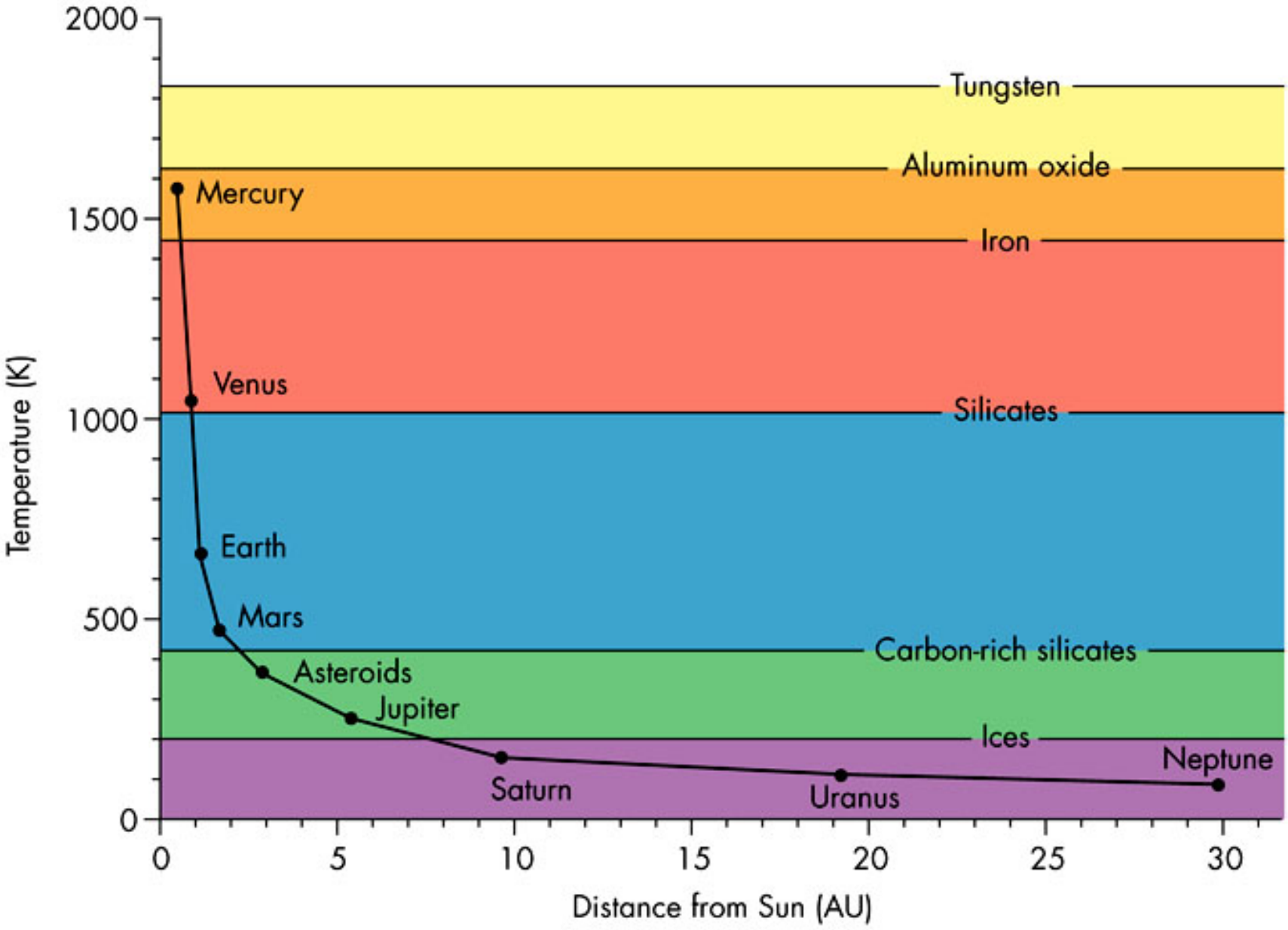

2000
1500
1000
500
0
Temperature (K)
Tungsten
Aluminum oxide
Iron
Silicates
Carbon-rich silicates
Ices
Mercury
Venus
Earth
Mars
Asteroids
Jupiter
Saturn
Uranus
Neptune
0
5
10
15
20
25
30
Distance from Sun (AU)

Properties of Solar System Objects

With an overall goal of perhaps understanding the origins of the solar system, we begin to discuss some of the properties of objects within our solar system (focusing on the most interesting or dramatic examples)

- **Motion (Revolution and Rotation)**
- **Crust: Composition and Dynamics**
- **Core: Composition and Dynamics**
- **Atmosphere: Composition and Dynamics**
- **Magnetic Field**

Public Observing Sessions at SUNY Oneonta

- The observatory (located at College Camp) is open for public viewing:
  - March 12 8:00 PM
  - April 9 8:00 PM
  - April 30 8:00 PM
- Sessions include a movie followed by a telescope observing session.
- Extra credit is available by attending an Astronomical Video and Public Telescope Observing session (up to 5% of final grade) and submitting a two page word processed paper describing the session's video and celestial objects observed with the telescope(s) no later than one week after the particular session you attended. The actual amount of extra credit received will be based upon your grade on the paper.

Image of the Moon from the Galileo Space Craft

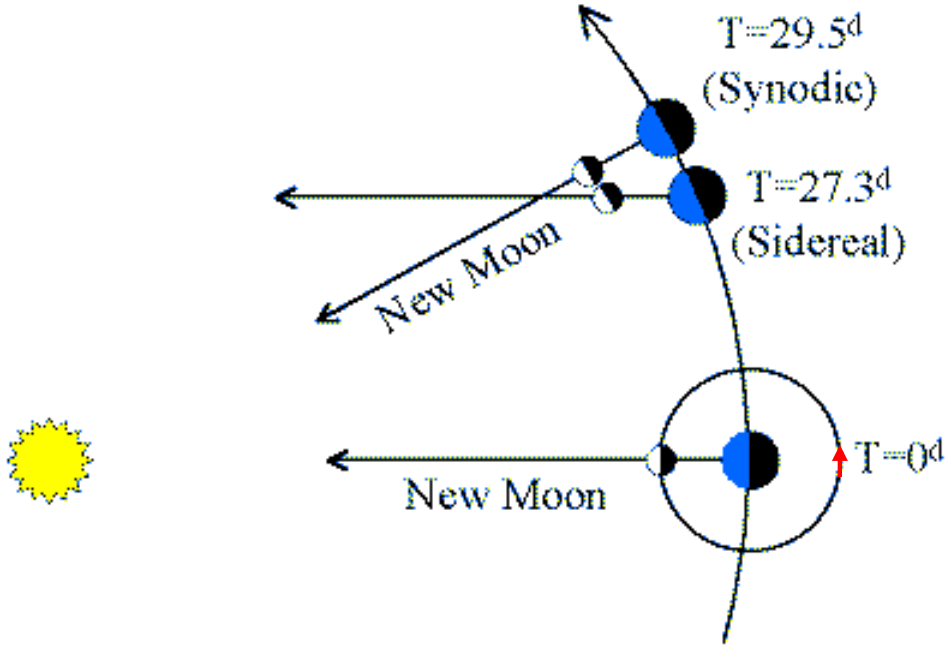
Moon: Overview

Due to its size (diameter 3476 km, Mercury's diameter is 4880 km) and composition, the moon is sometimes considered as a terrestrial planet along with Mercury, Venus, Earth and Mars.

In addition to being the only body visited by humans, it is also the only object from which physical sample have been brought back to Earth (Radioactive dating found the youngest rocks formed 3 .1 billion years ago and the oldest formed 4.4 billion years ago).

In addition to centuries of Earth bound observations, several space based missions have made observations of the Moon: Apollo (Dates), Clementine, Lunar Prospector

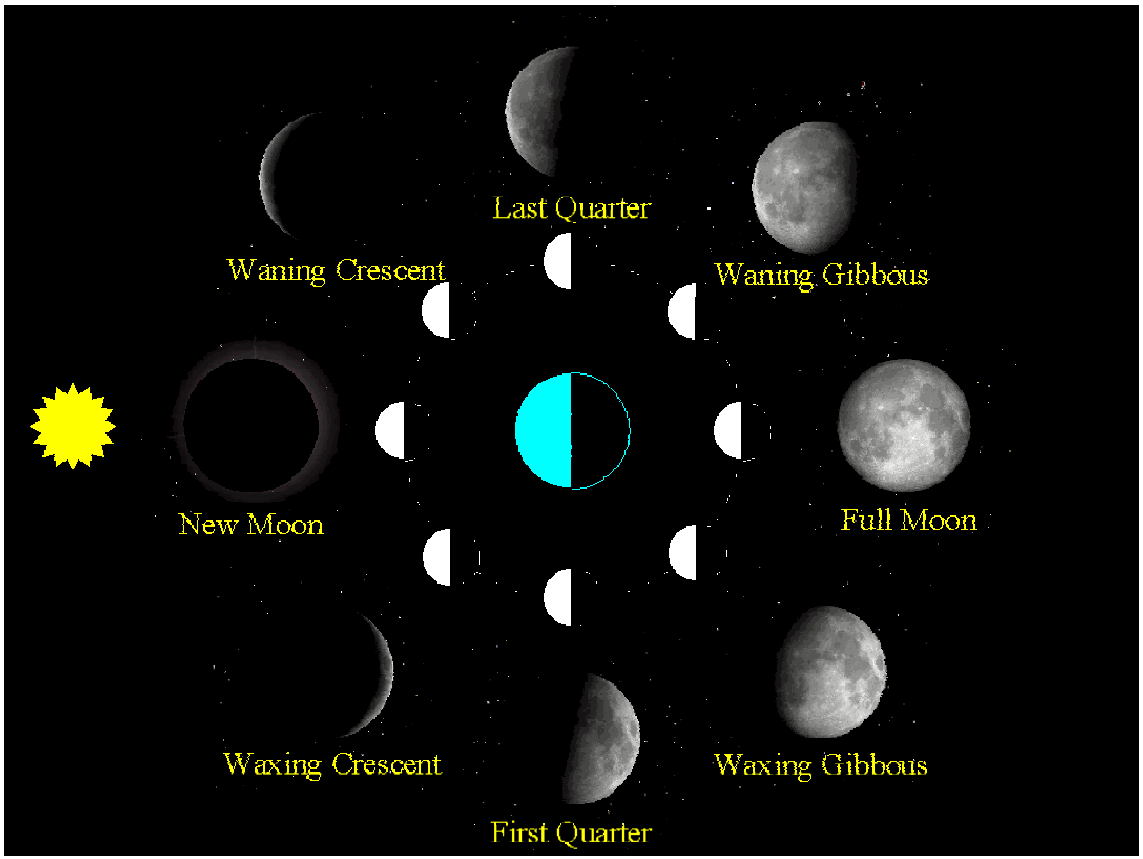
Moon: Revolution



The Moon revolves around the Earth in 27.3 days (Sidereal Period, revolution in the same sense as Earth about the Sun).

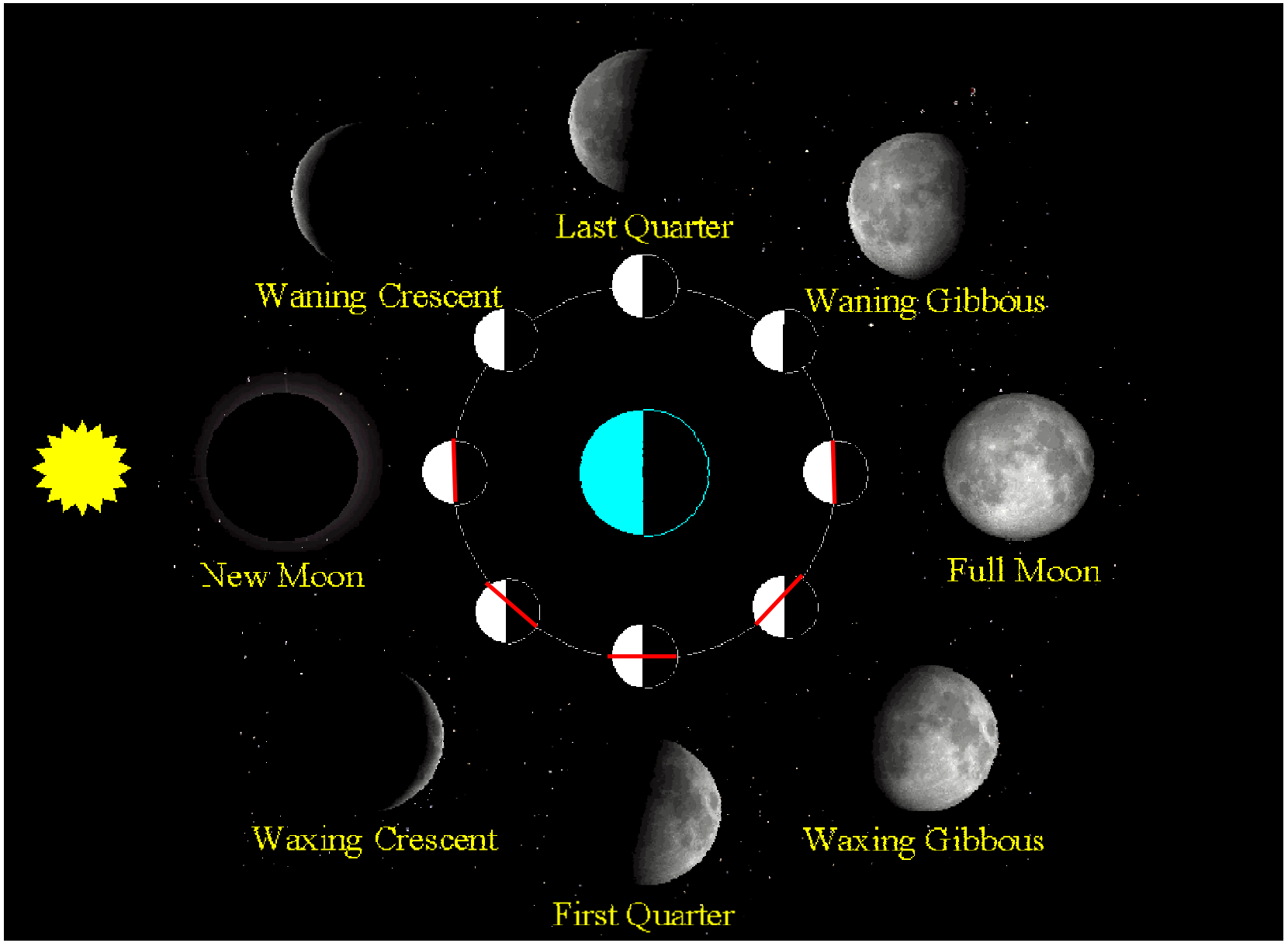
Since the Earth moves in its orbit about the Sun (~27° during this time) it takes about 2 more days for the moon to return to the same position relative to the Earth and Sun. Thus the Synodic Period is 29.5 days.

Moon: Revolution



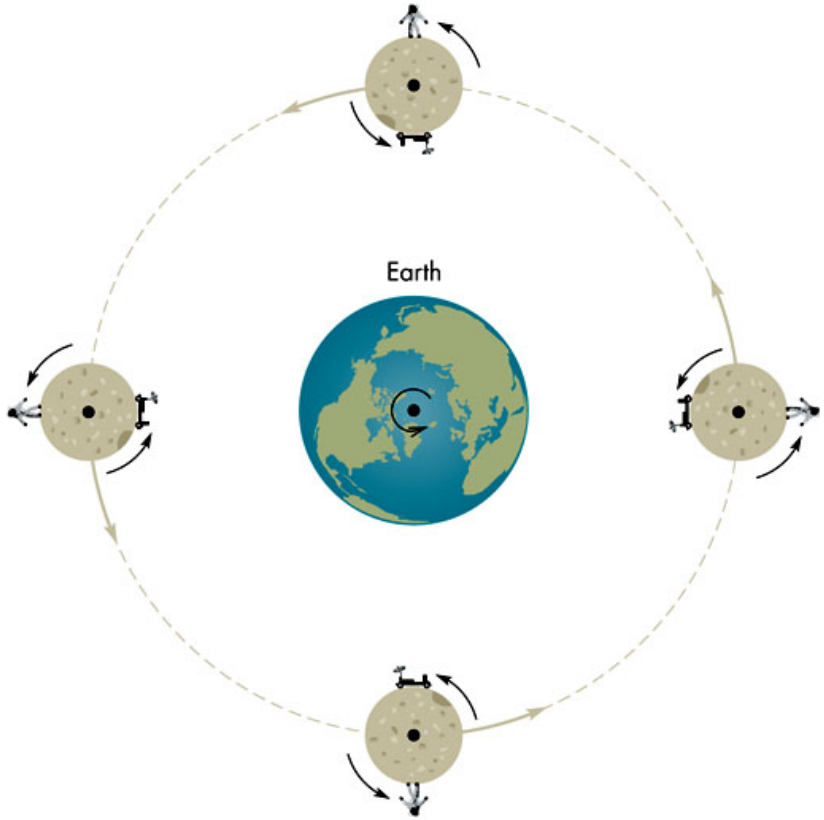
The revolution of the moon about the Earth produces the phases of the moon which complete one cycle during the synodic period.

Moon: Revolution



http://www.astronomy.ohio-state.edu/~pogge/Ast161/Unit2/lunation.gif

Moon: Rotation



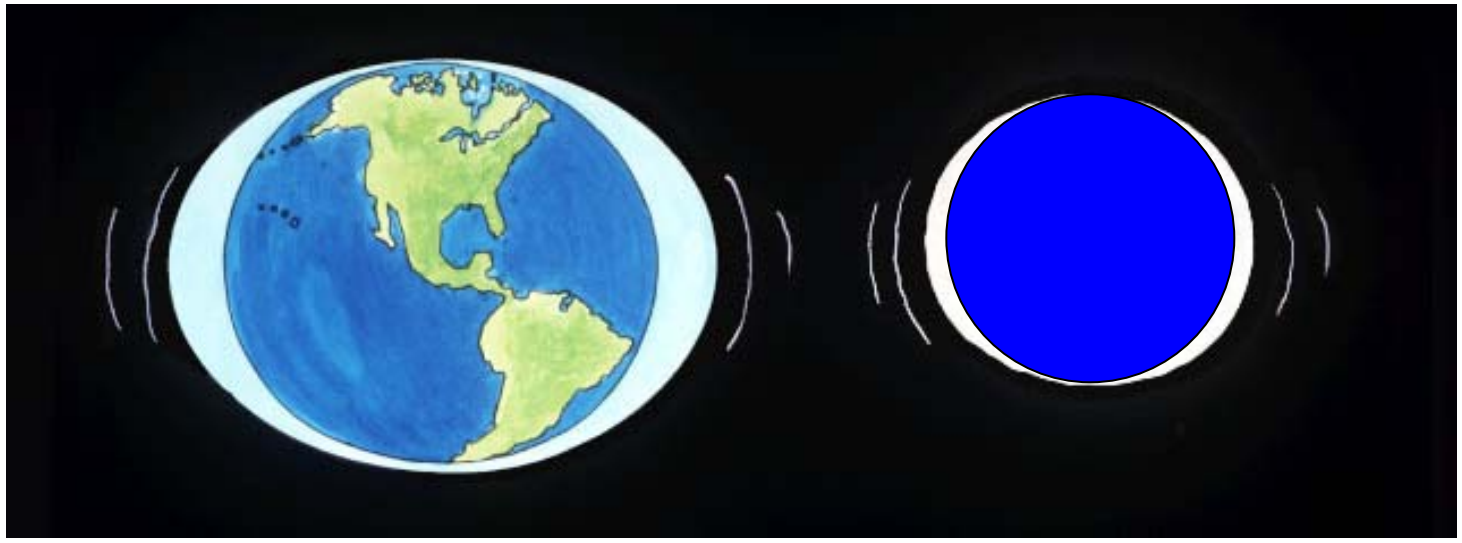
B Synchronous rotation: Only one face visible from Earth

The moon rotates with a period of 27.3 days, which is the same as the sidereal period. When the period of rotation and revolution of an object are the same, it is in synchronous rotation. In synchronous rotation, the same side of the Moon (called the near side) always faces Earth.

Moon: Rotation

Many of the natural satellites of the planets are in synchronous rotation.

If the moon is elongated in one direction (as it is due to the tidal force of the Earth) the gravitational force of the Earth on the elongated portion will tend to keep the elongation directed towards Earth.



Moon: Rotation

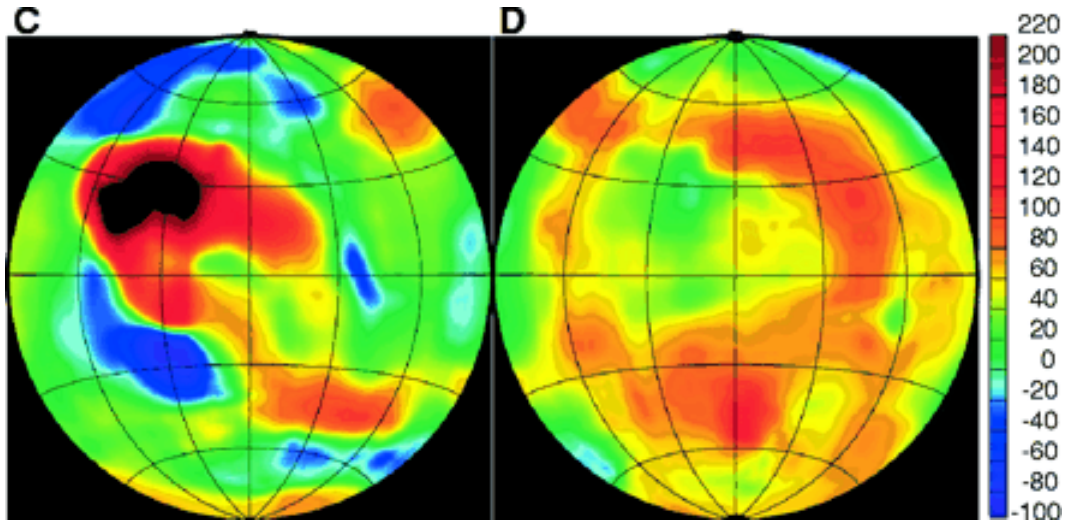
If tidal forces between the Earth and the Moon have led to the synchronization of the Moon's rotation, why hasn't the Earth's rotation also synchronized so that the same side of the Earth always faces the moon? It's happening.

Fossil evidence indicates that the Earth's rotation is slowing causing our days to lengthen by about 0.0015 seconds per century.

(To conserve angular momentum the moon's orbit moves slowly (very slowly) outward with time)

Moon: Rotation

If there is any asymmetric concentration of mass (mass con), the gravitational force of the Earth on this concentration of mass will tend to keep the mass concentration of the side towards Earth.



Gravitational measurements from Lunar Prospector (above, and Clementine) indicate a large concentration of mass associated with the near side of the moon (left).

Moon: Atmosphere

Due to its smaller mass, any atmosphere that the moon had initially, would have dissipated more quickly than the Earth's.

Moon's atmosphere is extremely thin consisting of helium, neon, hydrogen and argon.

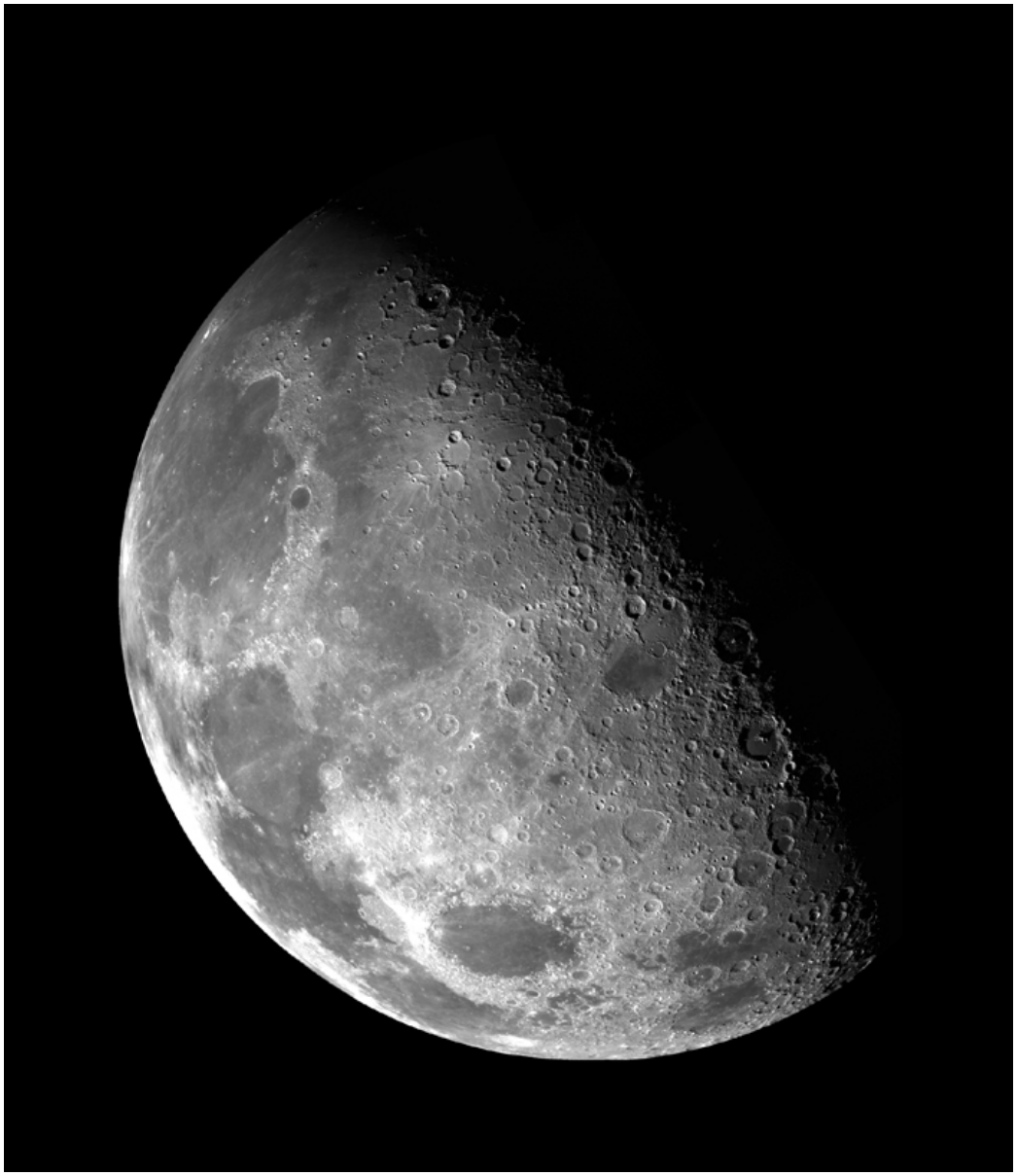
If compressed to the density of water, the entire moon's atmosphere would fit in a 1 m square box. (Earth's atmosphere would fit in a 170 km square box.)

The thin atmosphere is a poor insulator thus the variation in temperature between day and night is extreme (-280°F to 260°F).

Moon: Magnetic Field

There is no magnetic field to speak of on the moon. This suggests a non iron core and/or a core that is not rotating.

Moon: Surface



An examination of the Moon's Surface reveals:

Maria: relatively smooth and dark areas

Craters: pockmarked structures generally with raised circular boundaries that are sometimes quite light.

Moon: Surface

Since there is little atmosphere on the moon to erode craters and the amount of surface regeneration that occurred during the moons history is small, the number of craters in a given area would be a very good indicator of the age of the moon.

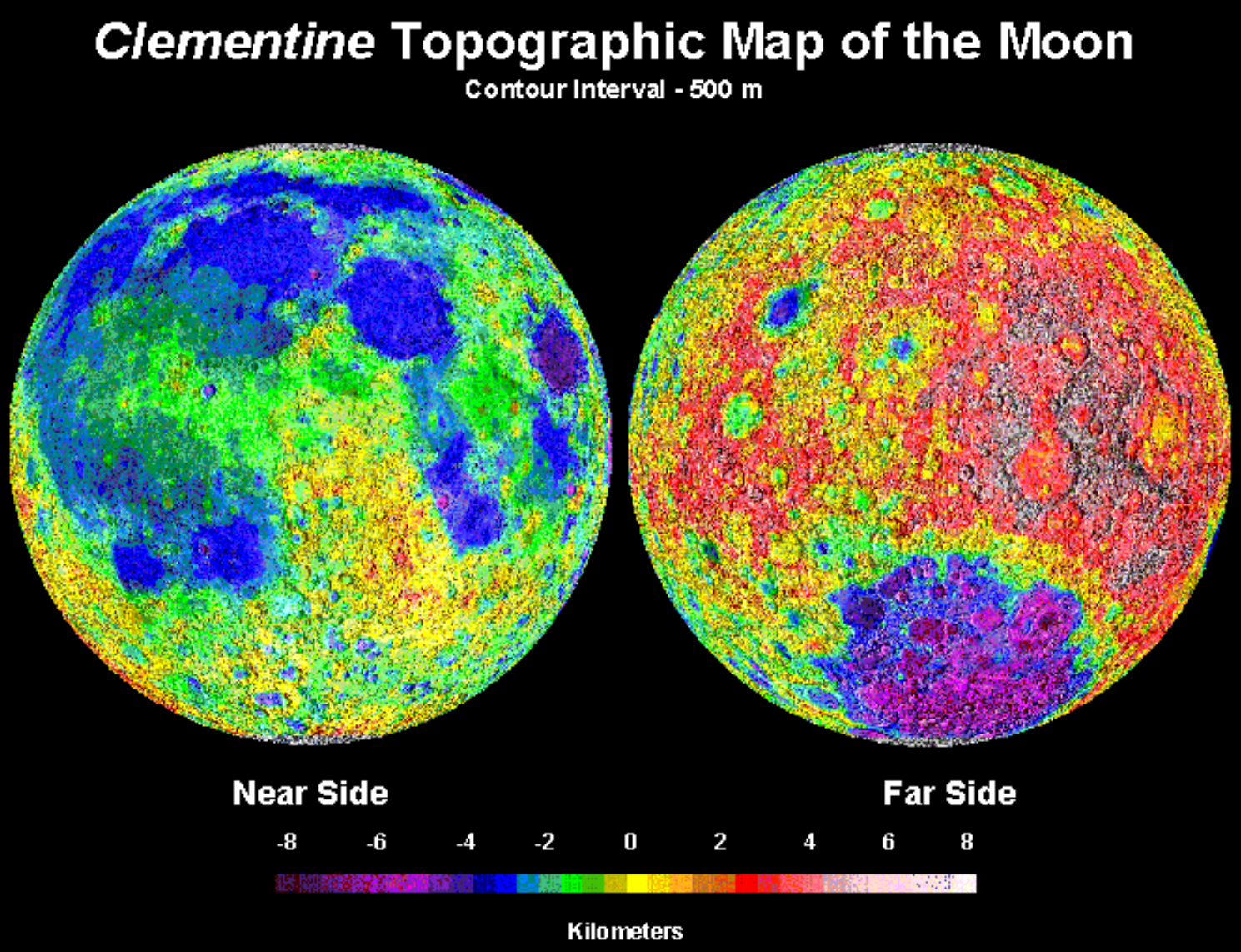
It is generally believed that a significant number of the craters occurred during the early stages of the solar system (3 to 4 billion years ago) when there was intense bombardment of the surface.

Since that time number of new craters in a give time has been relatively constant. More recent impacts show up as bright features. Surface material darkens with time and impacts turn over this material.

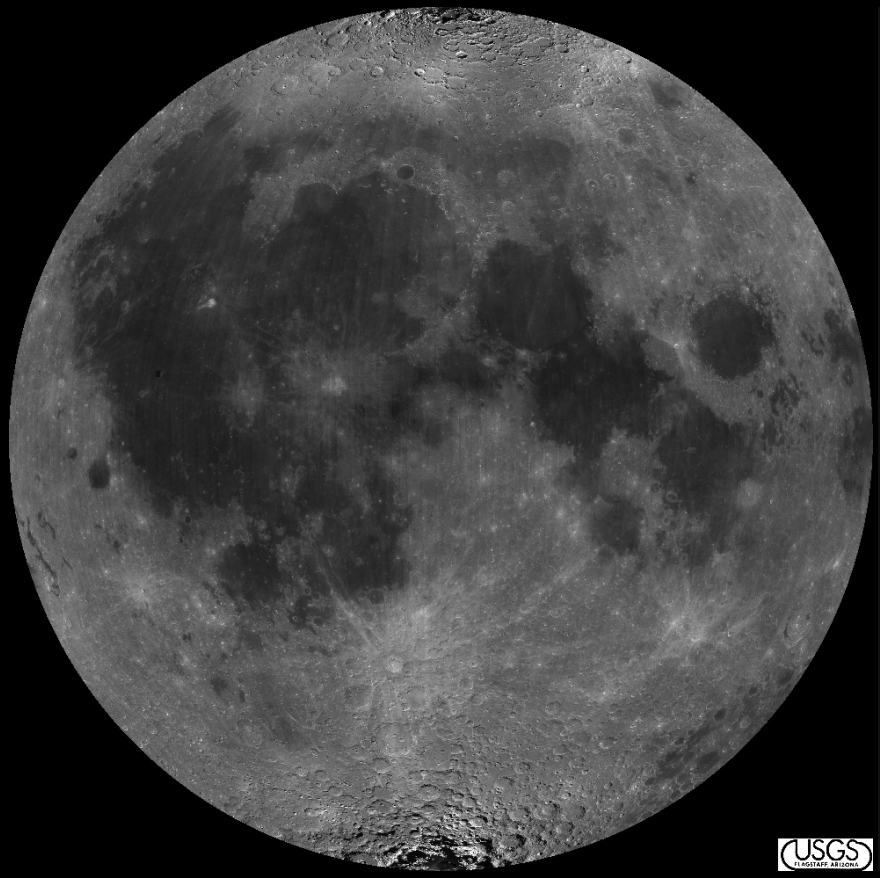
Some surface regeneration did occur in the past as indicated by the presence of maria which result from volcanism and lava flow into early impact regions.

Moon Albedo (Fraction of Reflected Light)

Moon Topography



Moon Features



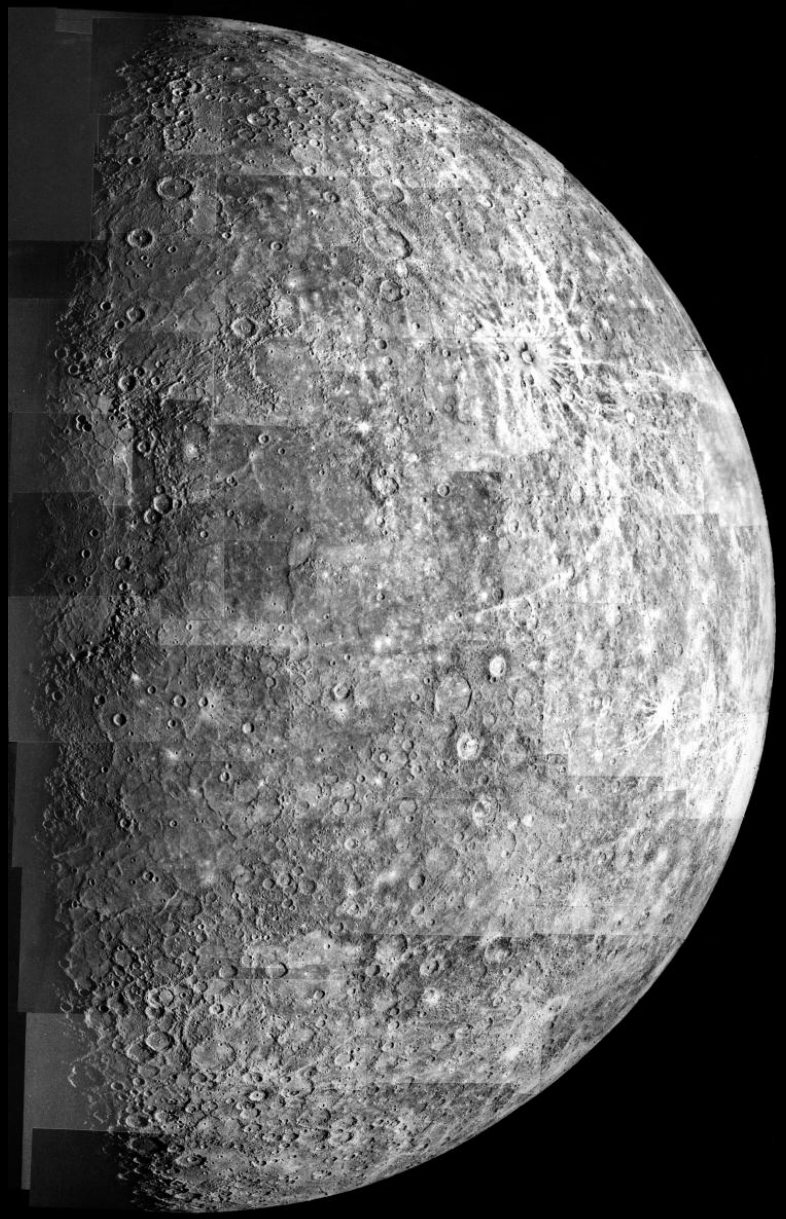
Moon: Origin

1) **Fission: The Moon was separated from the material that formed the Earth.**
2) **Capture: The Moon was formed in another part of the Solar System and was later captured by Earth's gravity.**
3) **Binary Accretion: The Moon was formed near the Earth in time and space**
4) **Giant Impact Theory: Moon formed from residual debris from the impact of a large body with Earth.**

Moon: Origin

1) **The composition of Earth and the Moon is similar enough to eliminate the Capture Model.**
2) **On the other hand differences between the composition of the Earth and Moon are significant enough (notably lack of iron on the moon and difference in densities) to rule out Binary Accretion.**
3) **Fission can explain the composition if the fission occurred after the iron in the Earth had descended to the core. But the high rotation speed needed to create the fission seems improbable.**
4) **As with Fission, Giant Impact can account for the composition. This is currently the favored theory.**

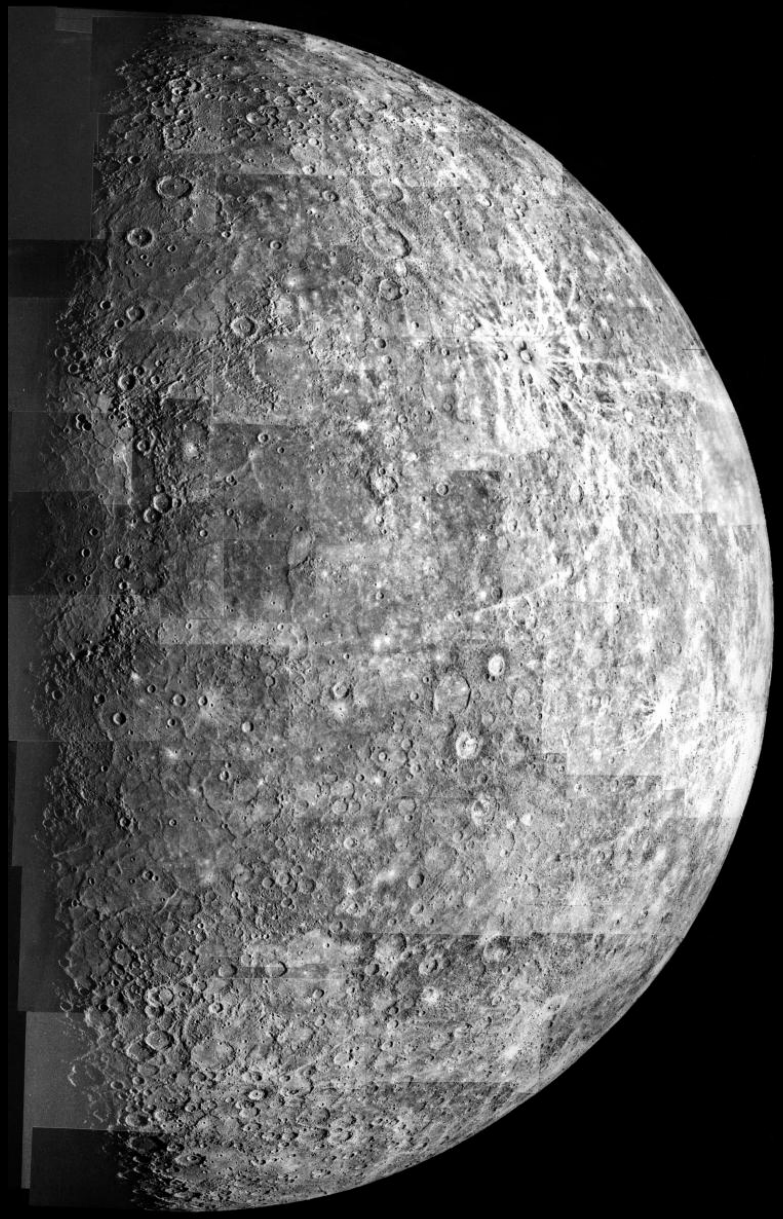
Mercury: Overview



At first glance the surfaces of Mercury and the Moon look strikingly similar because of the substantial number of well preserved craters.

Due to its proximity to the Sun, Mercury is difficult to observe. It is too close to the Sun to be imaged safely by the Hubble Space Telescope. Mariner 10 flew by 3 times in 1974 and 1975 imaging 45% of the surface.

Mercury: Overview



Another mission, MESSENGER is planned for launch in 2004 will fly by in Mercury in 2008 and begin orbiting Mercury in 2009.

http://messenger.jhuapl.edu/the_mission/gallery.html

Mercury: Orbit and Rotation

Mercury's orbital period about the Sun is about 88 days.

Due to the tidal influence of the Sun, Mercury's rotational period has slowed to 58.65 days (2/3 of Mercury's year).

The planets extremely slow rotation and thin unstable atmosphere result in a huge (largest in the solar system) day night temperature variation (-100°F to 800°F)

While it's rotation is slow, over time, all portions of the planet do face the Sun.

Mercury: Magnetic Field

Surprisingly (because of Mercury's slow rotation), Mariner 10 discovered that Mercury had a magnetic field (1% the strength of Earth's but significant).

The magnetic field and high average density (5440 kg/m^3, Earth's which is more compressed is 5520 kg/m^3) are suggestive of an iron core.

Is the core rotating or does the magnetic field result from the permanent magnetism of a stationary and solidified iron core?

Is a giant impact similar to what the moon experienced, responsible for the high proportion of iron?

Mercury: Surface

In the Mariner 10 images of Mercury's surface, we see craters, long *scars* continuous for 100s of km, and *smooth* planes.

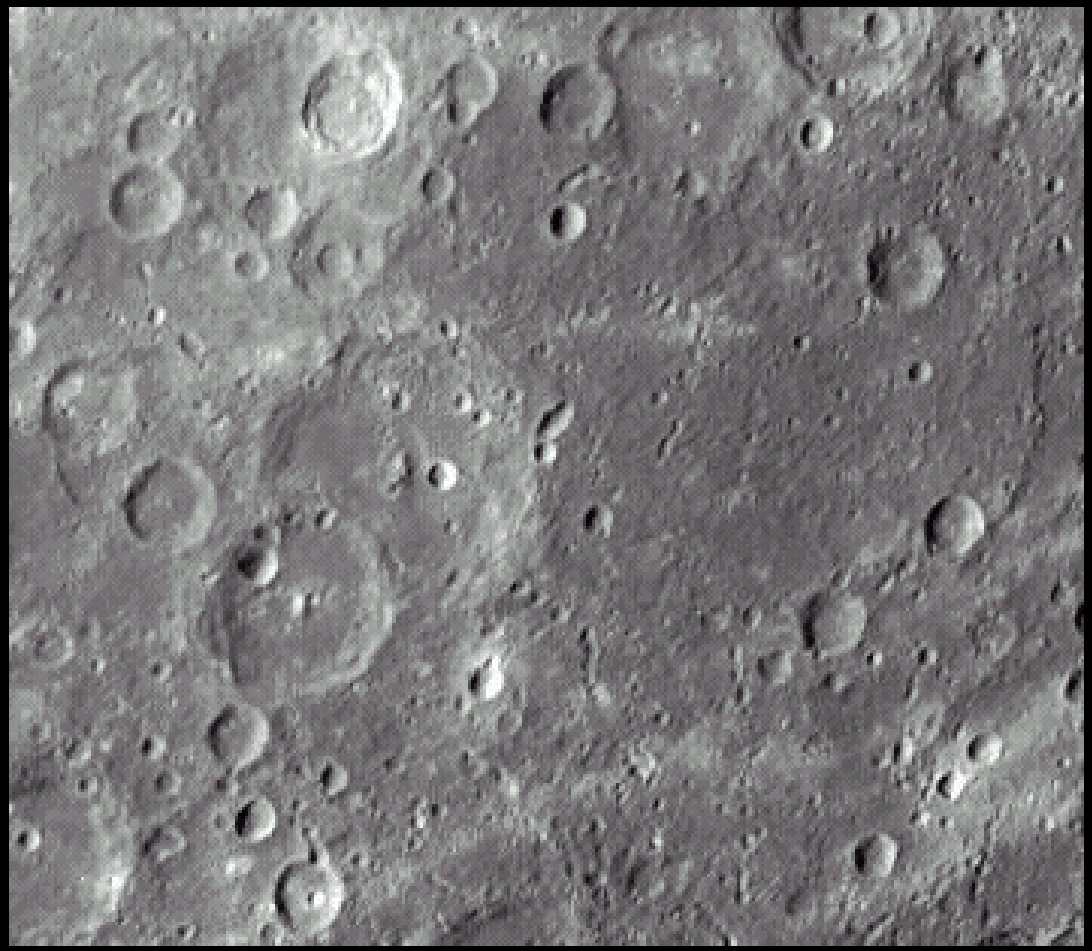
Mercury: Surface

Scarps appear like fractured cliffs. They may have formed as the planet cooled and shrank (1 to 2 km). The shrinking could have resulted in the steep fractures that sometimes divide craters.

Mercury: Surface

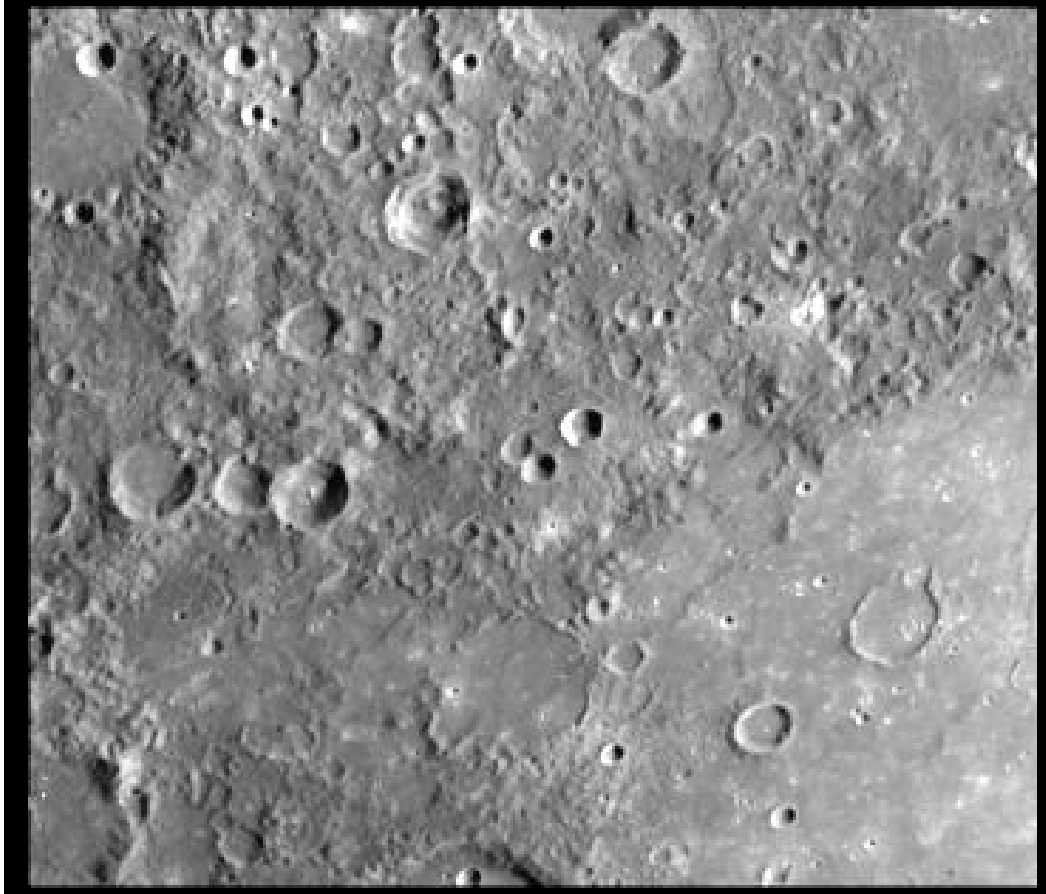
Mercury was likely subject to the same intense early cratering experience by the rest of the Solar System. Like on the Moon, Mercury's craters are well preserved.

Mercury: Surface



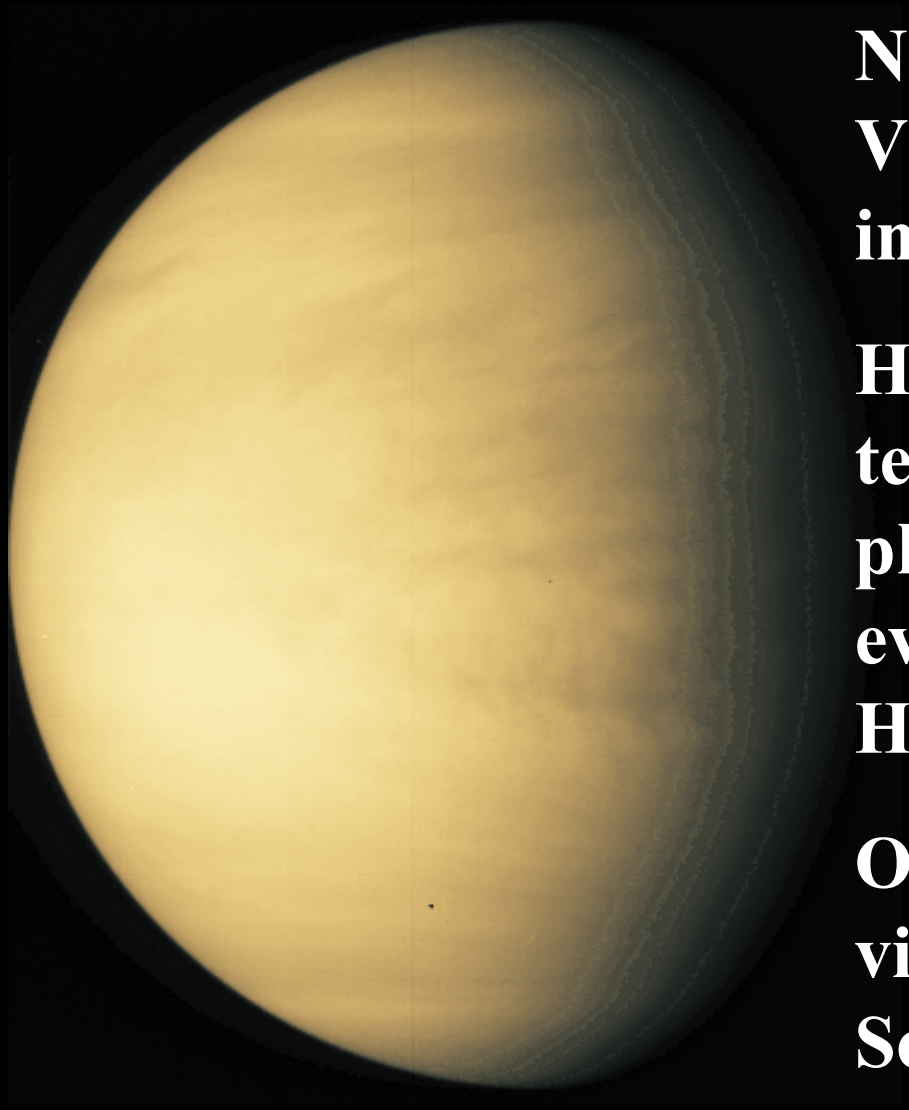
This picture shows fairly uniform distribution of craters in a relatively smooth (likely volcanic material) background. This would suggest volcanic activity prior to the cratering period

Mercury: Surface



This picture shows cratering superposed on rough terrain adjacent to smooth and relatively crater free terrain (lava filled basin). This suggests that volcanic activity continued after the major cratering events.

Venus Overview



Next to the Sun and Moon, Venus is the brightest object in the sky.

Historically, Galileo's telescopic observations of the phases of Venus were evidence in favor of the Heliocentric theory.

Over 20 spacecraft have visited Venus including the Soviet Venera series and most recently Magellan.

Venus Overview

Venus is particularly important because its mass, radius, density, gravitational acceleration and composition are similar to Earth's.

However, it has evolved quite differently.

Venus: Orbit and Rotation

Venus's orbit is the most circular of the planets and it orbits the Sun in about 225 days. (The direction of the orbit is the same as the other planets, CCW looking down from above the North Pole.)

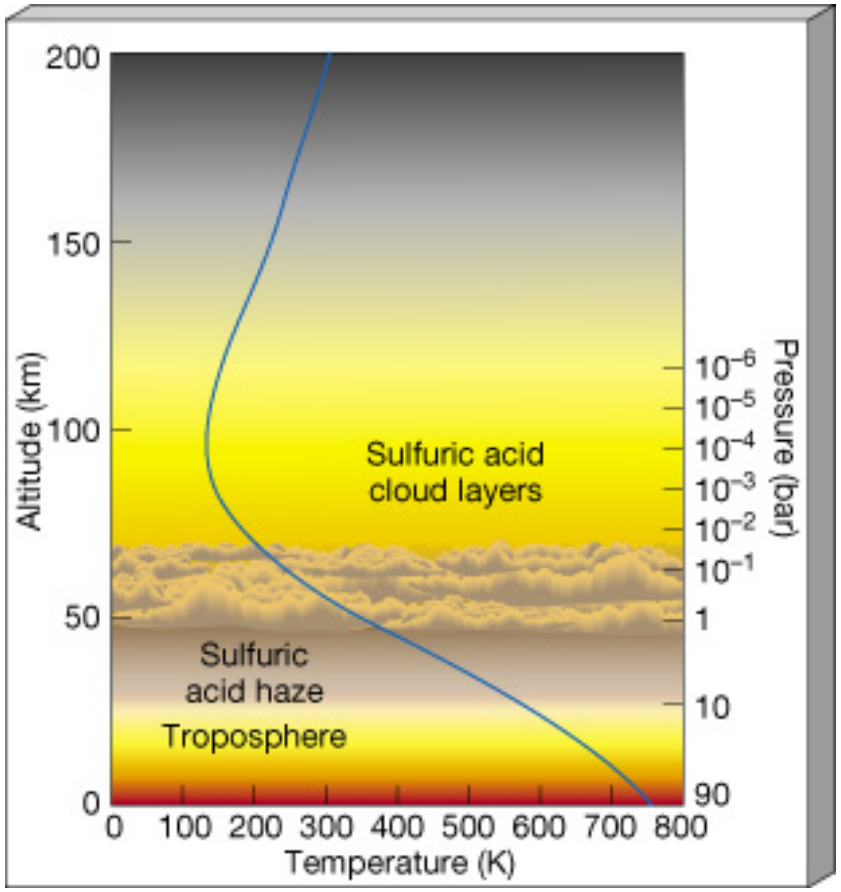
Venus rotation is slow taking approximately 243 days. Interestingly, it rotates in the opposite direction of most of the other solar system bodies (CW looking down from the North Pole).

Venus: Orbit and Rotation

Venus's orbital and rotational motion (which is in the opposite direction of other planets) combine to produce a solar day (Sun returns to the same location) of about 117 days. Thus even though the orbital and rotational periods are close, every part of Venus faces the Sun in 117 days.

It seems reasonable to expect that Venus formed with the same direction of rotation as the other planets in the solar system (assuming formed out of cloud of matter swirling in the same direction). According to physical law, something must have exerted a force on Venus to get it to change its rotation, perhaps a substantial collision.

Venus: Atmosphere



The atmosphere of Venus is thick. The pressure at the surface is 90 atmospheres (90 times greater than at Earth's surface).

With temperatures of 800 °F at the surface, it is the hottest planet in the solar system (unlike Mercury thick atmosphere traps the heat)

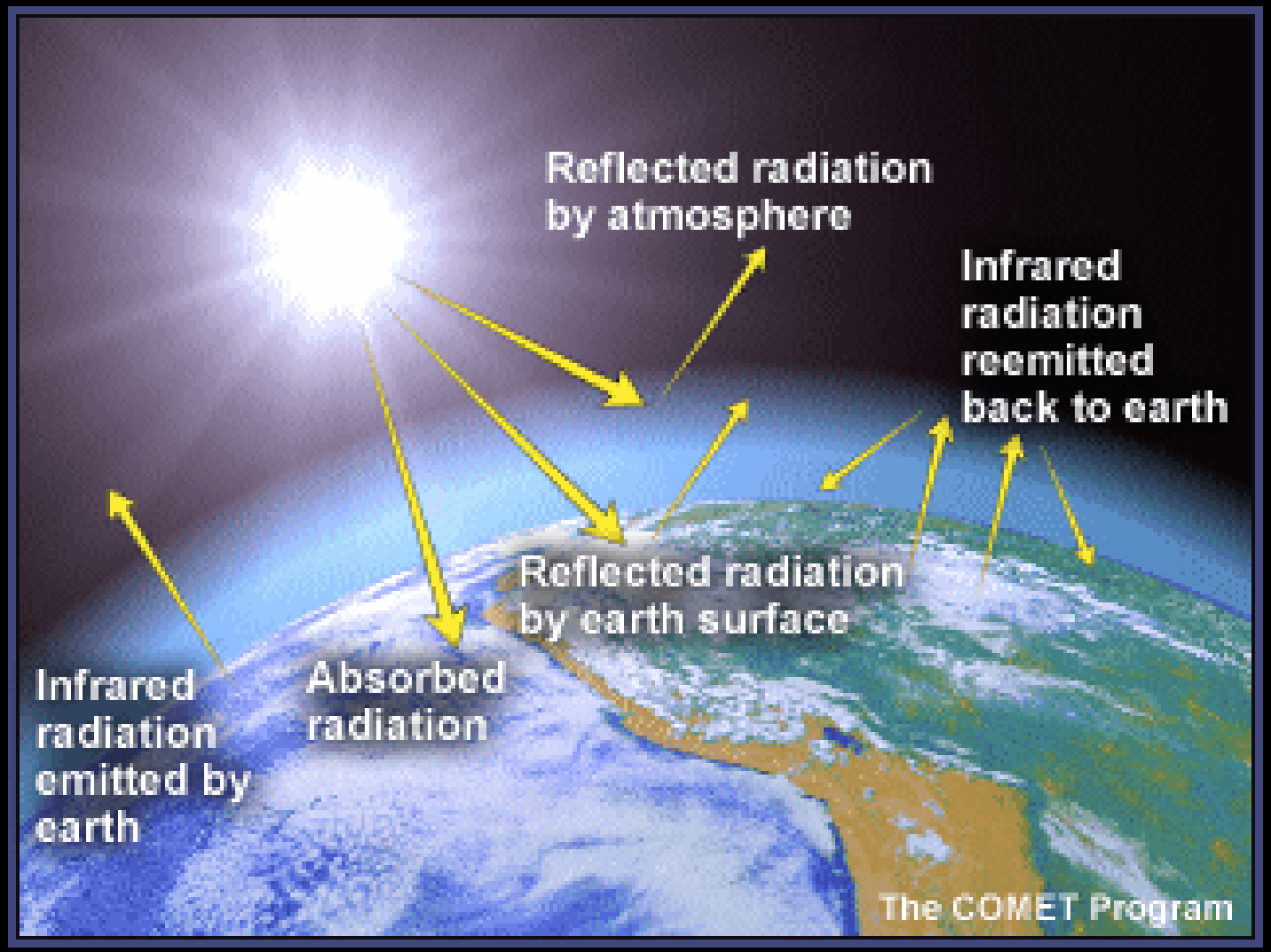
Venus: Atmosphere

Venus has thick (not necessarily dense) clouds composed of sulfuric acid droplets with some water droplets. (Earth to has a significant layer of sulfuric acid in the stratosphere.)

Venus atmosphere is dominated by CO_2, which is largely responsible for the great pressure of the atmosphere. (It is believed that Earth has a similar amount of CO_2, stored in some type of terrestrial rock and seawater.)

Why is the Venus atmosphere so different from the Earth's? Important question given our current concern over global warming.

Venus: Atmosphere and Greenhouse Effect

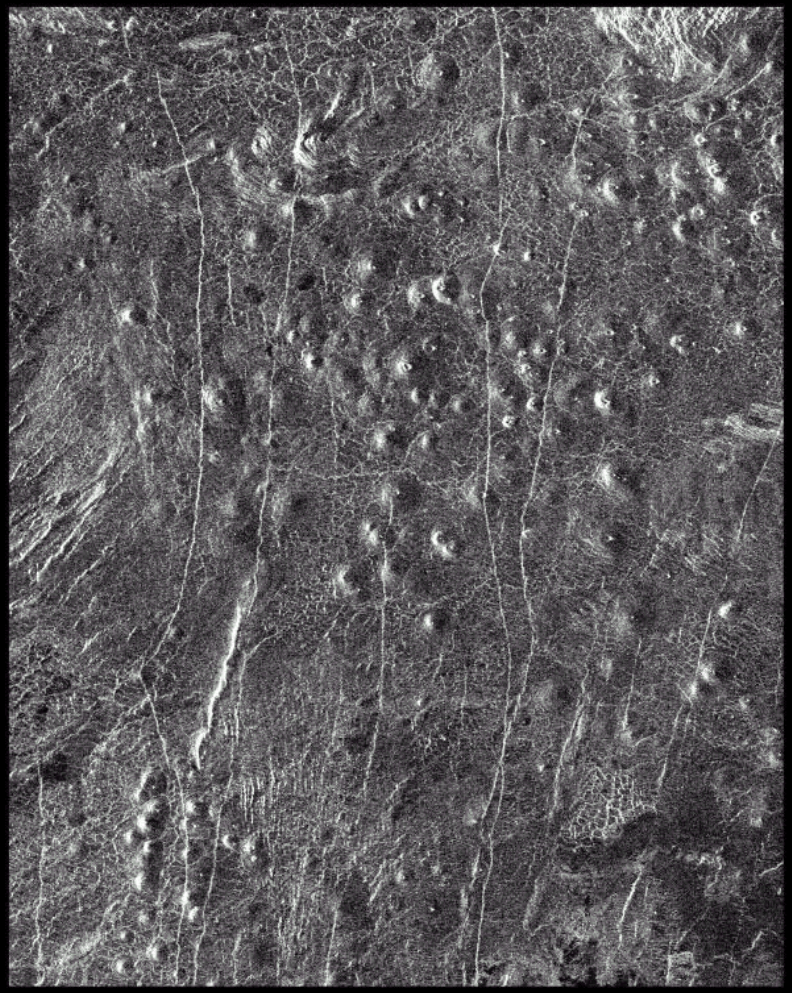


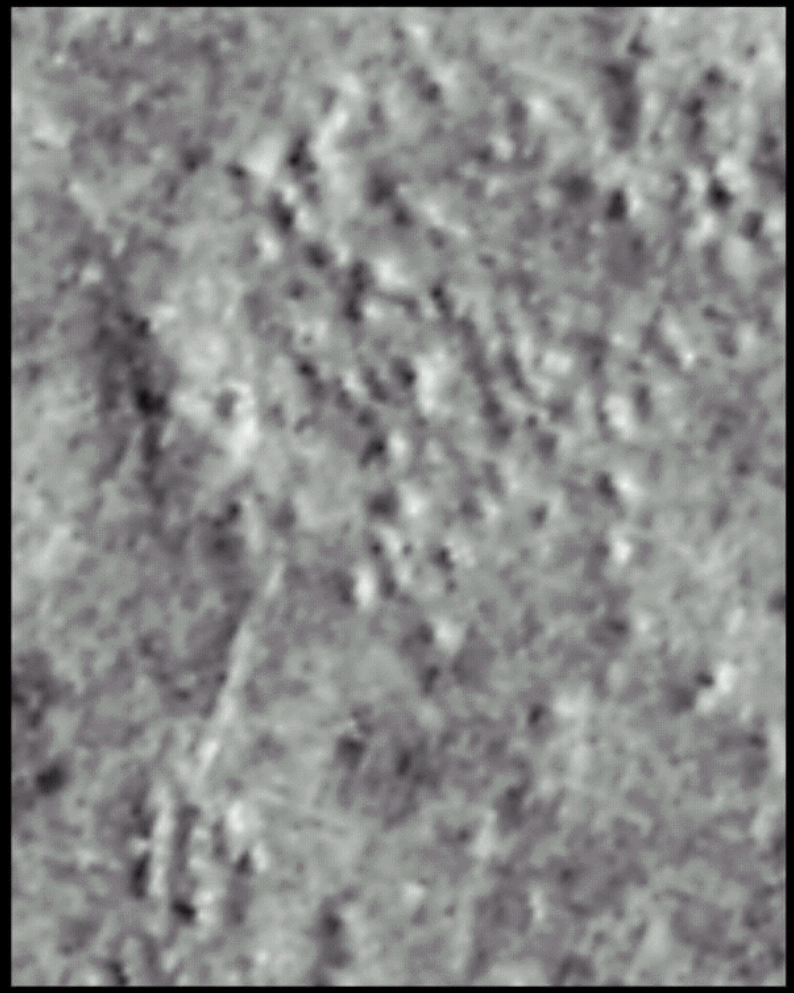
Venus: Core and Magnetic Field

Soviet spacecraft landed on Venus in the 1970's and 1980's and found that the soil resembles Earth's basalt in chemical composition. This and the fact that the density of Venus is similar to Earth's indicate similar composition and suggest an iron core.

However, Venus has no magnetic field indicating that the core is not liquid or that Venus is rotating too slowly to produce a magnetic field.

Venus Surface:Magellan

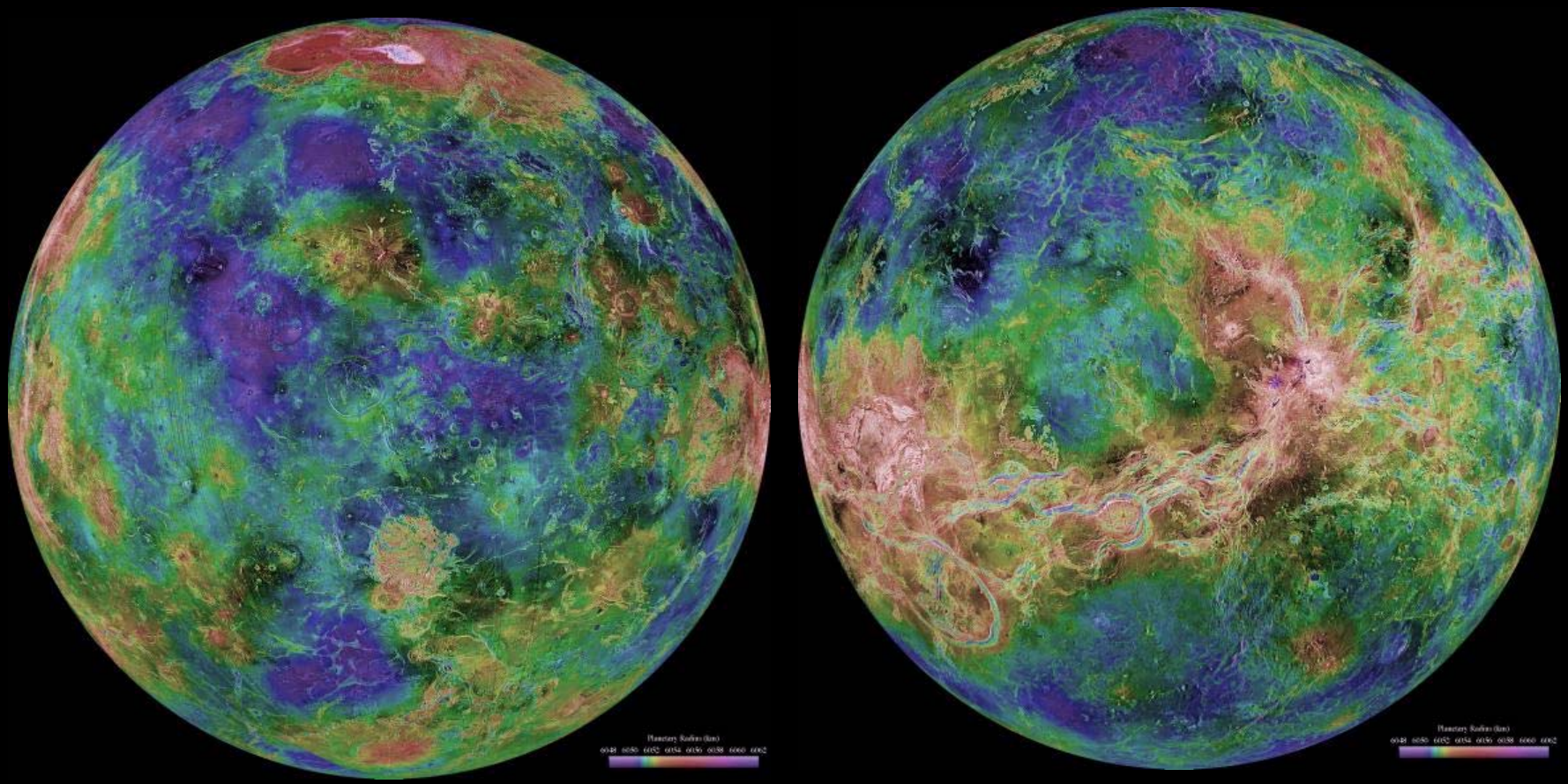




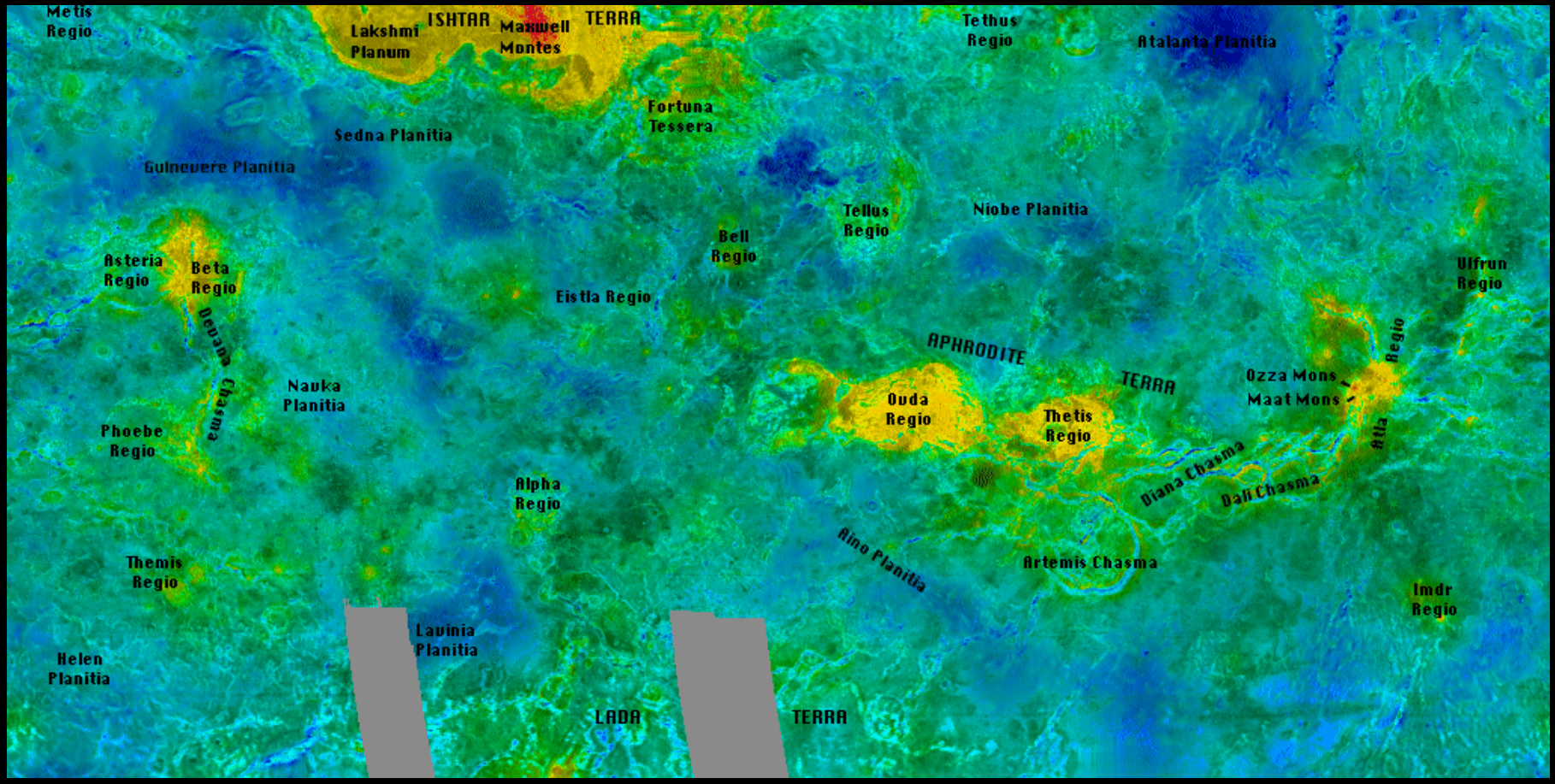
Images of the Venus Surface from Magellan and Venera 15/16.

Venus Surface: Venera 9

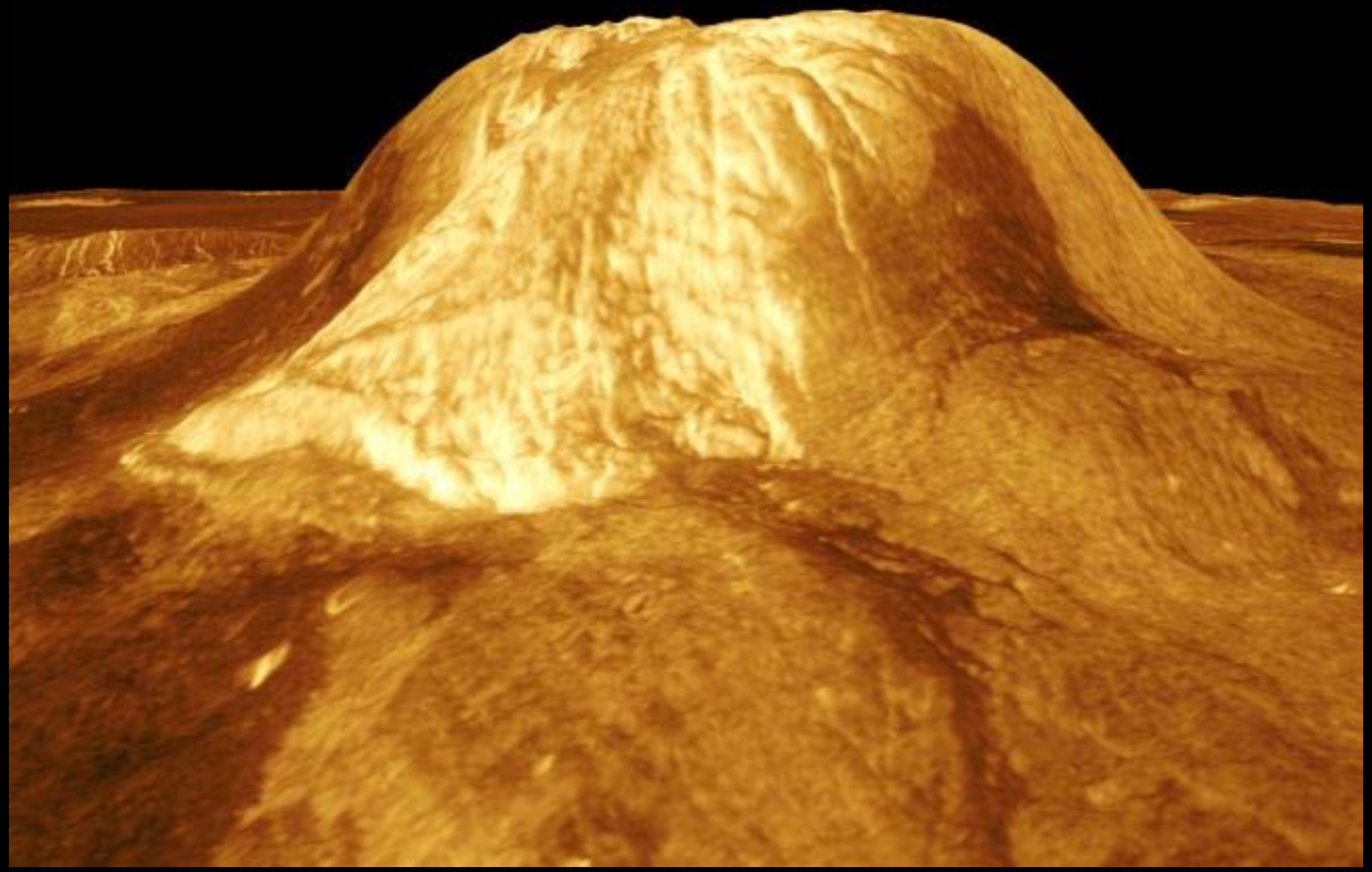
Venus Surface:Magellan



Venus Surface: Features



Venus Surface: Volcano

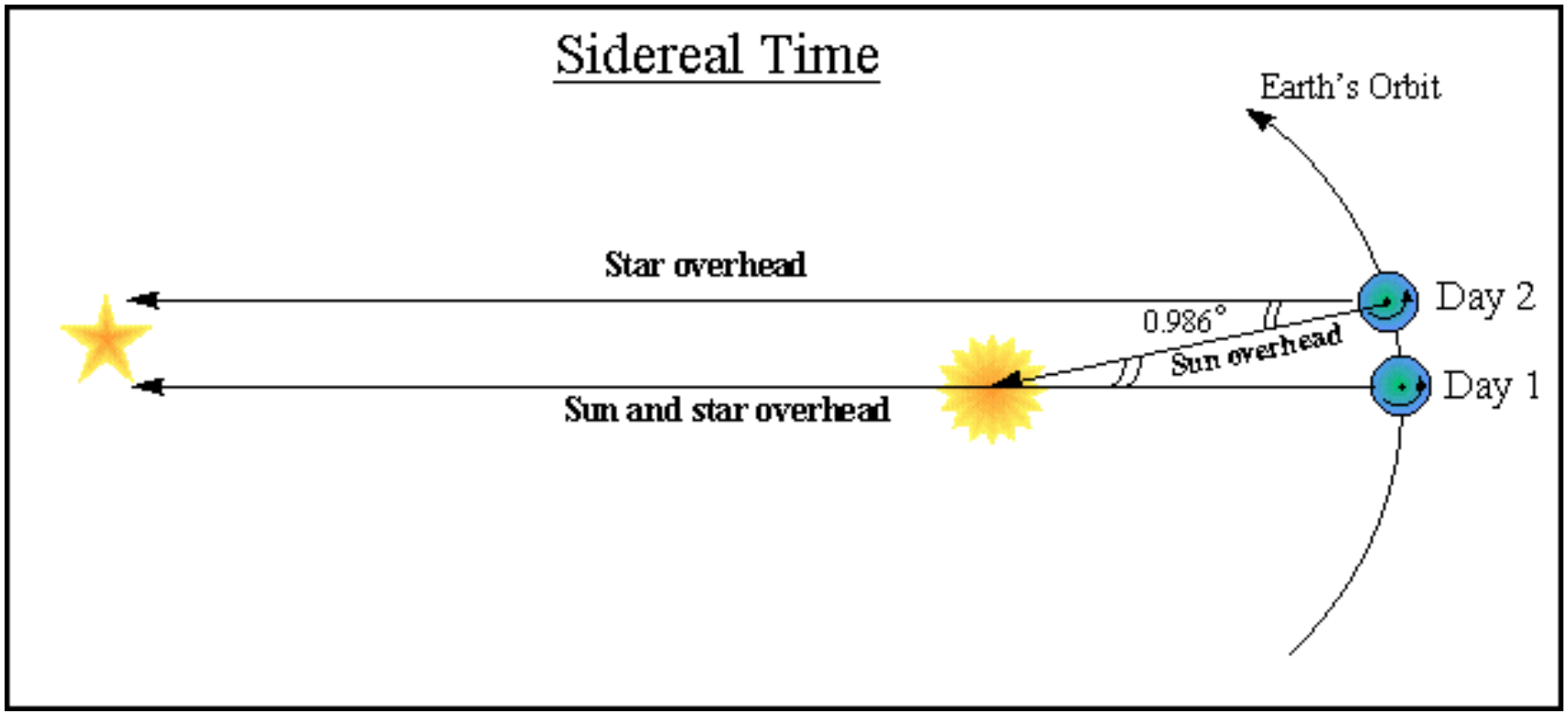


Rotation of the Earth

The Earth completes one rotation (360 degrees) every 23 hours and 56 minutes (and ~4 seconds). This period is known as a Sidereal Day.

Due to its revolution about the Sun, the Earth must rotate a little more than 360 degrees for the Sun to appear in the same place. The time it takes for the Sun to appear at the same place is about 24 hours (Solar Day).

Sidereal and Solar Day



Our time keeping is based on the (Mean) Solar Day and thus stars a star that appears at one location at a certain time will be at that same location the next day approximately four minutes earlier.

Surface and Interior

The composition and structure of the Earth can hold some clues to the properties and origins of the planets and solar system. Much of the understanding in this area is achieved through geological studies. However a brief overview of the general structure of the Earth is important.

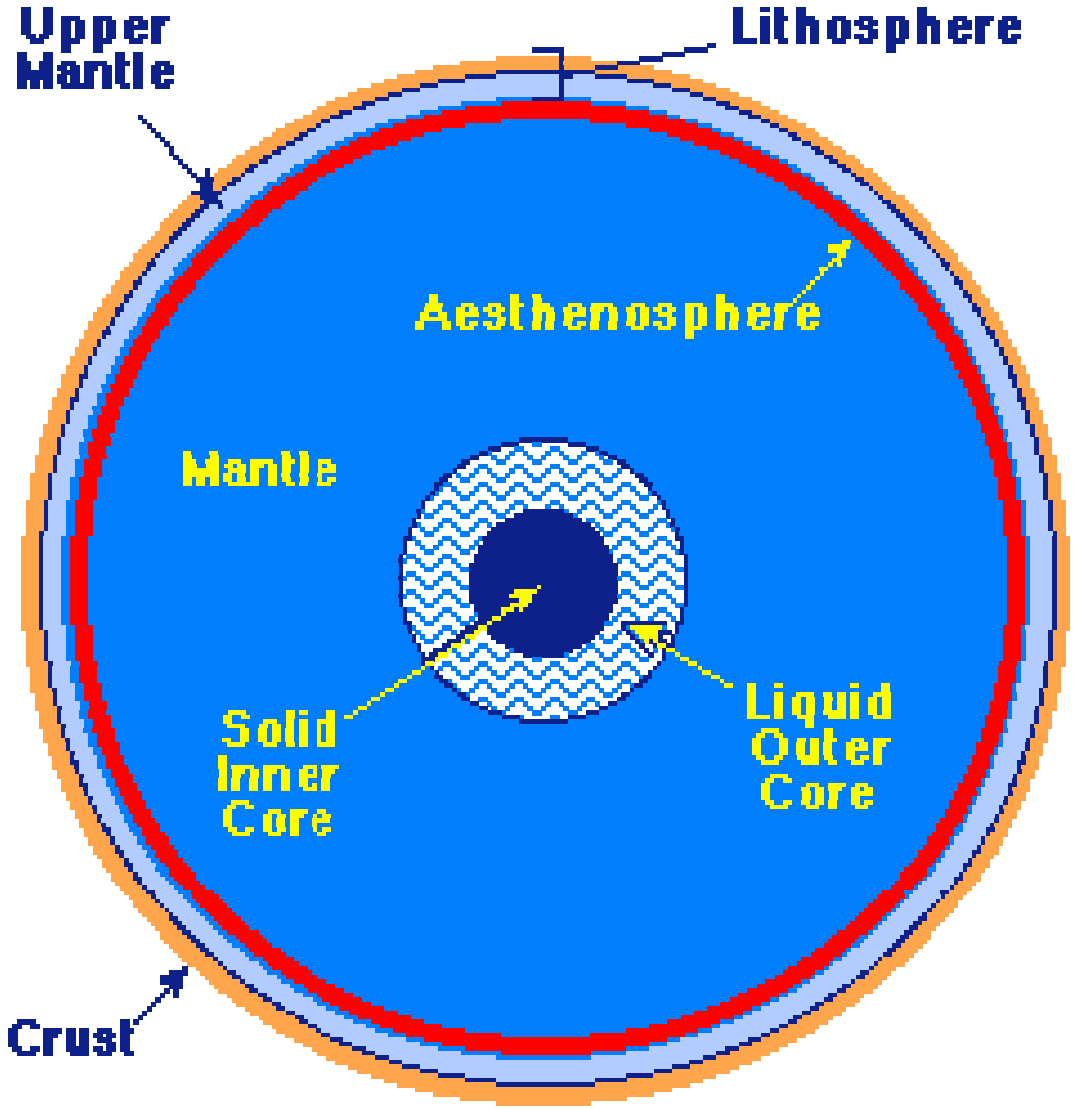
Earth Surface and Interior

The Earth's surface and interior may be divided into four regions:

Crust: Outer most layer consisting of rock with a thickness of ~30 km. Along with the upper mantle (upper mantle and crust form the lithosphere) dynamic region with plate motion and sea floor spreading etc.

Mantle: Consists of the upper mantle, aesthenosphere and mantle. Approximately 2800 km thick. Temperature ranges from about 1000 C to 3700 C (what is melting point of iron?)

Earth Surface and Interior



Earth Surface and Interior

The Earth's surface and interior may be divided into four regions:

Outer Core: The outer core is metallic (iron and nickel) because of the high density of this material and liquid. This region is approximately 1300 km thick and the temperature ranges from about 3700 C to 4300 C. This region is likely the source of the Earth's magnetic field.

Inner Core: Despite very high temperatures, the pressure is so great at this depth (think of going deeper in a pool) that the inner core is solid. This layer is approximately 1200 km thick.

Earth Surface and Interior

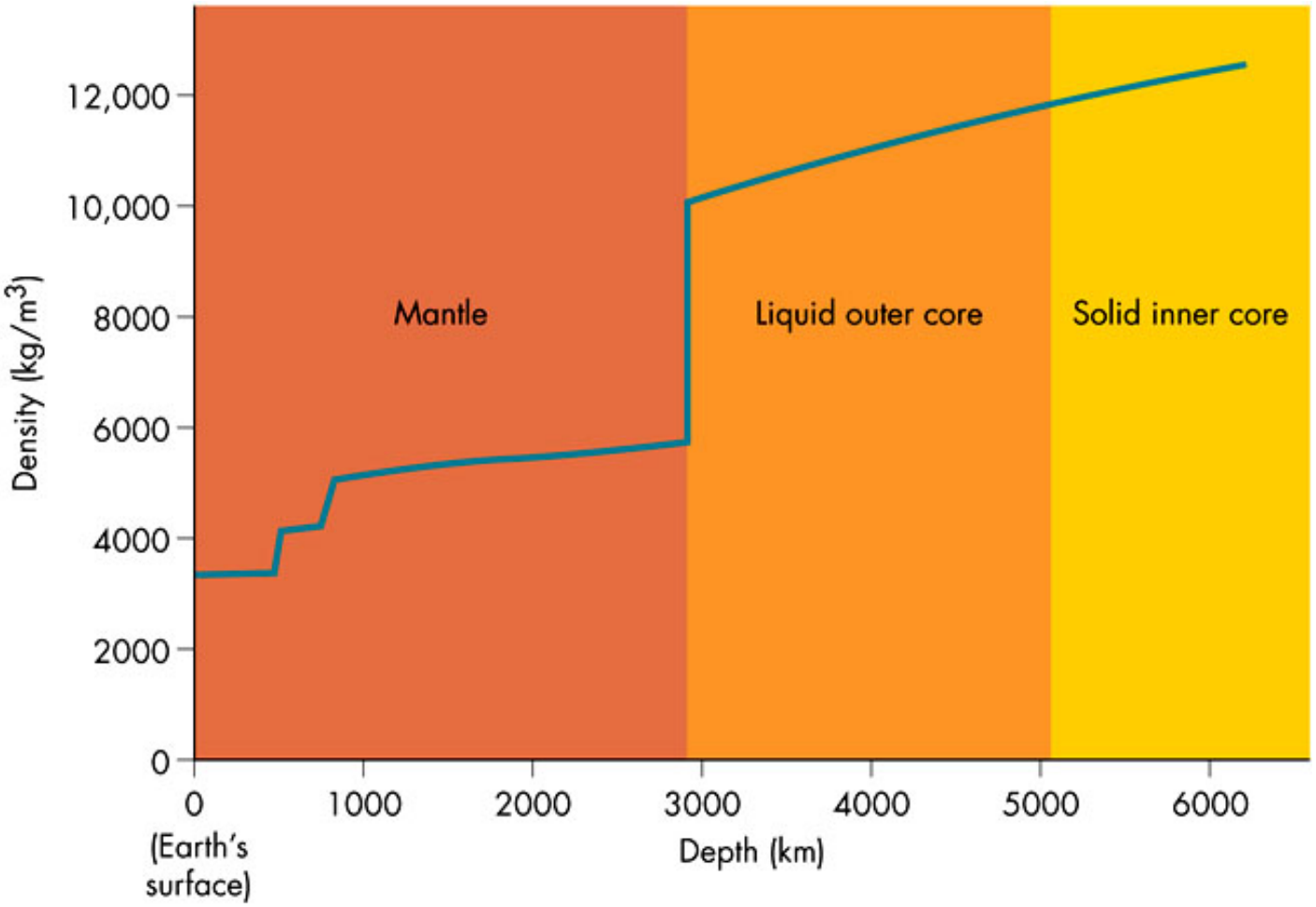
Earthquakes are one consequence of the active lithosphere (crust and outer mantle). Like a mallet ringing a bell, earthquakes produce waves in the Earth (seismic waves). The speed of these waves varies depending on the composition of the material that the pass through. Thus by analyzing seismic waves we can deduce the structure of the material that the pass through. This is how the regions of the Earth's interior were determined.

Earth Surface and Interior

The *average* density (mass divided by volume, cork small density, lead large density) of the Earth could have been determined in the 1800's. It is around 5500 kg/meter^3. (Water has a density of 1000 kg/meter^3.)

The average density of stuff found on the surface of the Earth is around 3000 kg/meter^3. Thus the density of the interior must be significantly greater than the average of 5500 kg/meter^3 to balance the less dense surface.

Earth Surface and Interior



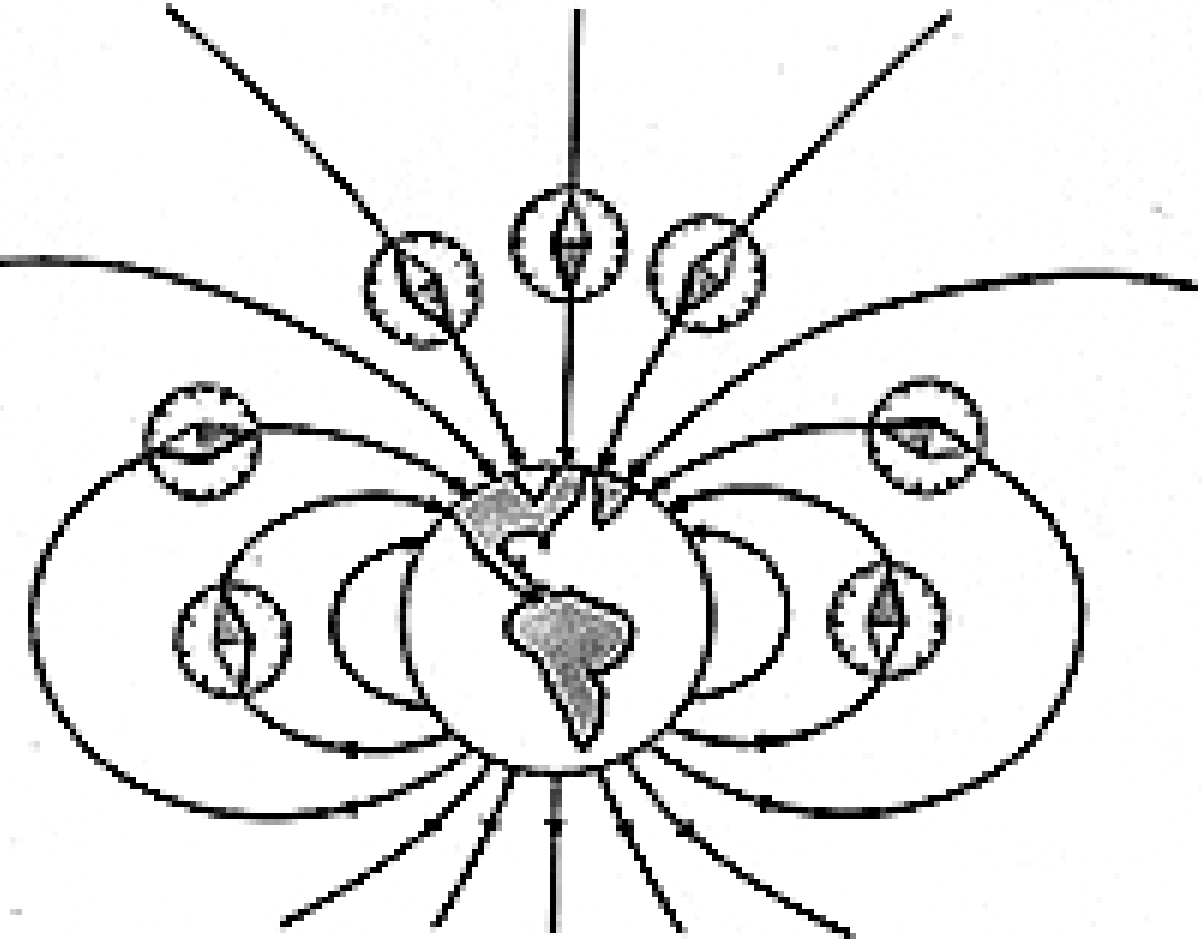
The density of material increases somewhat irregularly as you go deeper into the Earth

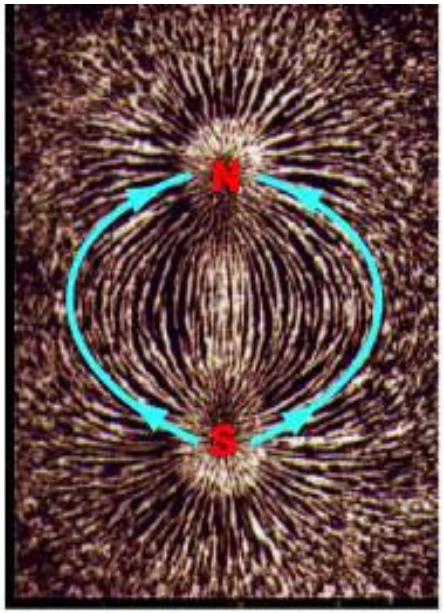
Magnetic Field

Magnetic Fields are produced by moving electric charges, that is, electric current. For example, a wire carrying electric current to light a lamp will produce a magnetic field the circles the wire.

Magnetic Fields are produced by *permanent magnets*. For example, a bar magnet. The fields produced by permanent magnets are actually generated by electric current on molecular scales. The overall shape of the magnetic field produced by a bar magnet is that of a magnetic dipole.

The Earth's Dipole Magnetic Field Is The Same Shape As A .....

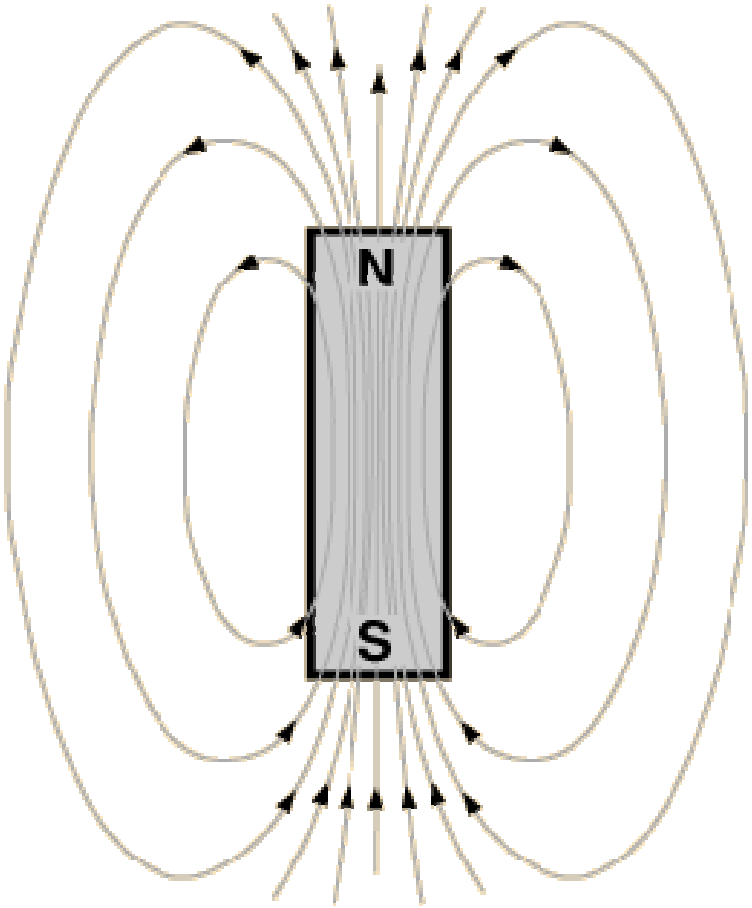




... Simple Bar Magnet

Magnetic Field Representation

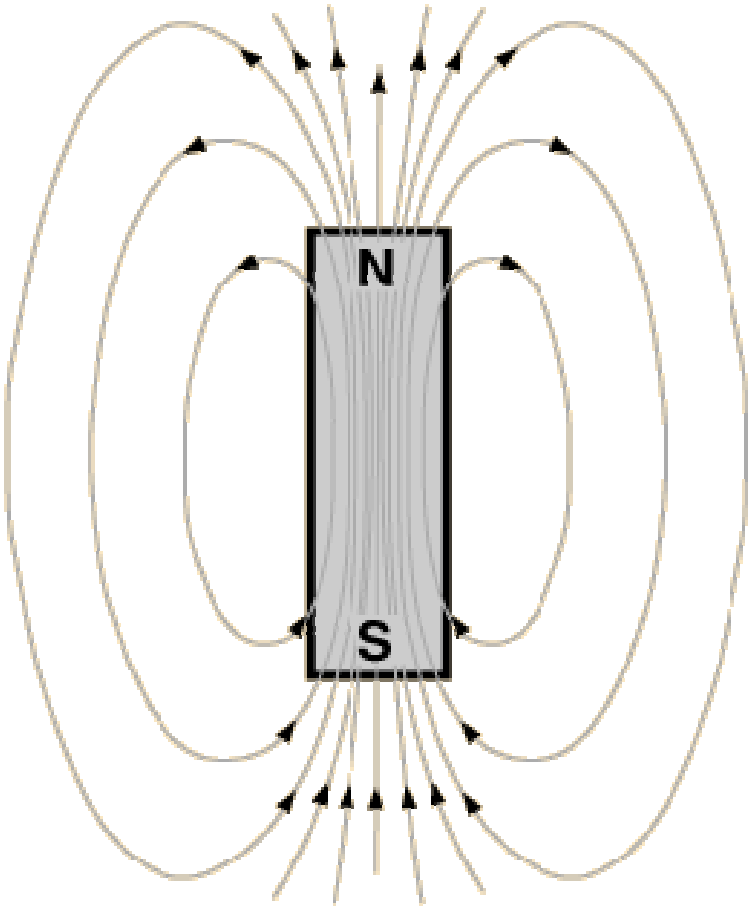
- **Magnetic field lines (e.g., for the bar magnet in the figure) indicate the shape and direction of the magnetic field.**
- **Direction: is along the field lines as indicated by the arrows.**
- **Strength: the magnetic field is strongest where the field lines are closest together.**



Magnetic Field Representation

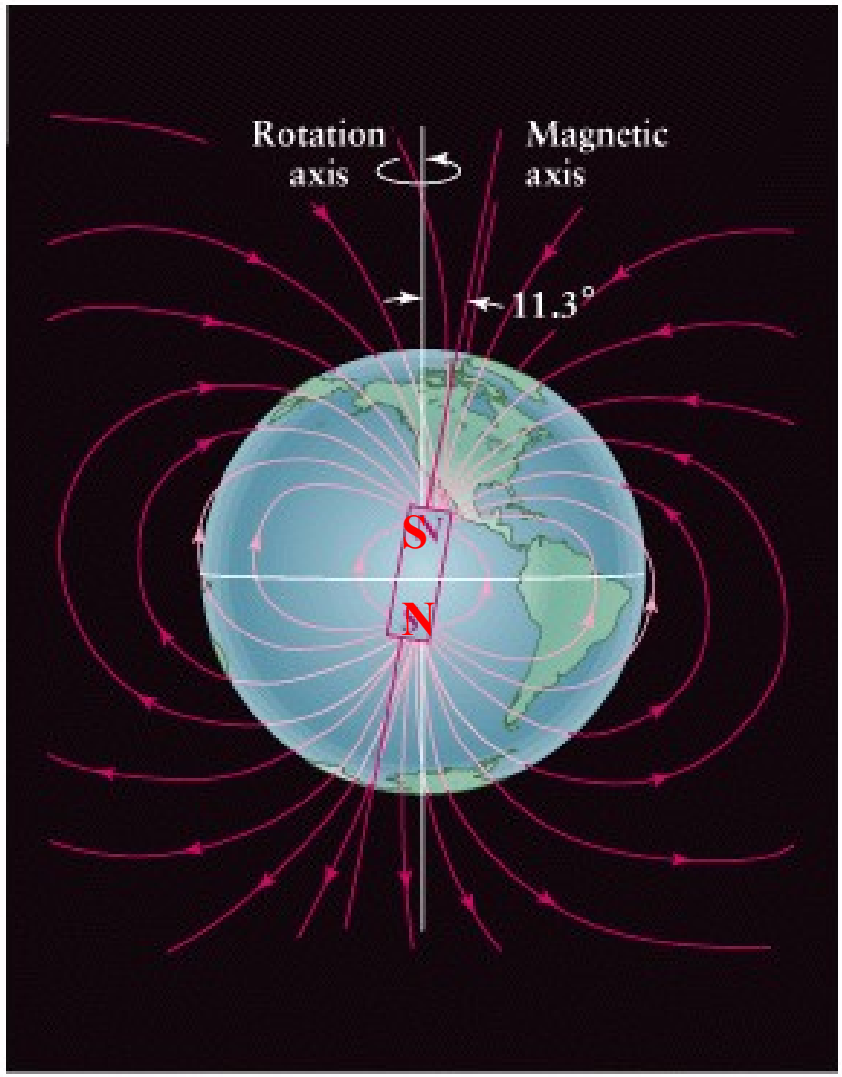
- **By convention, magnetic field lines originate on the North Pole of the magnet and terminate on the South Pole of the magnet**

- **From experience, you are likely aware that when like poles of magnets (e.g., North and North) are brought together, there is a strong repulsive force.**



Magnetic Field

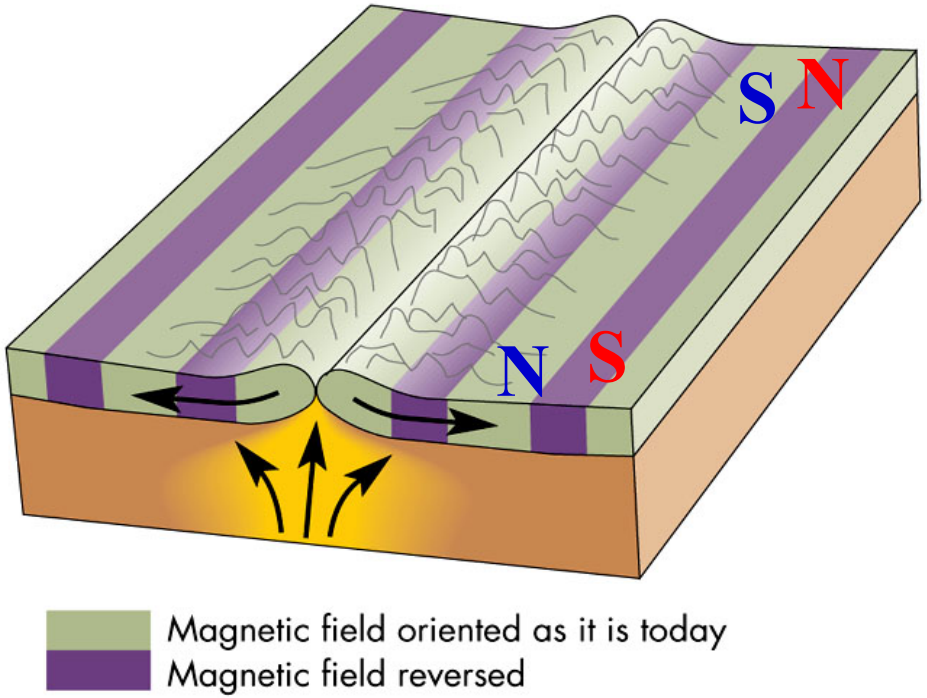
Note that the Earth's Magnetic Dipole Axis is tilted by about 11 degrees with respect to the rotational axis



b

Sea Floor Spreading

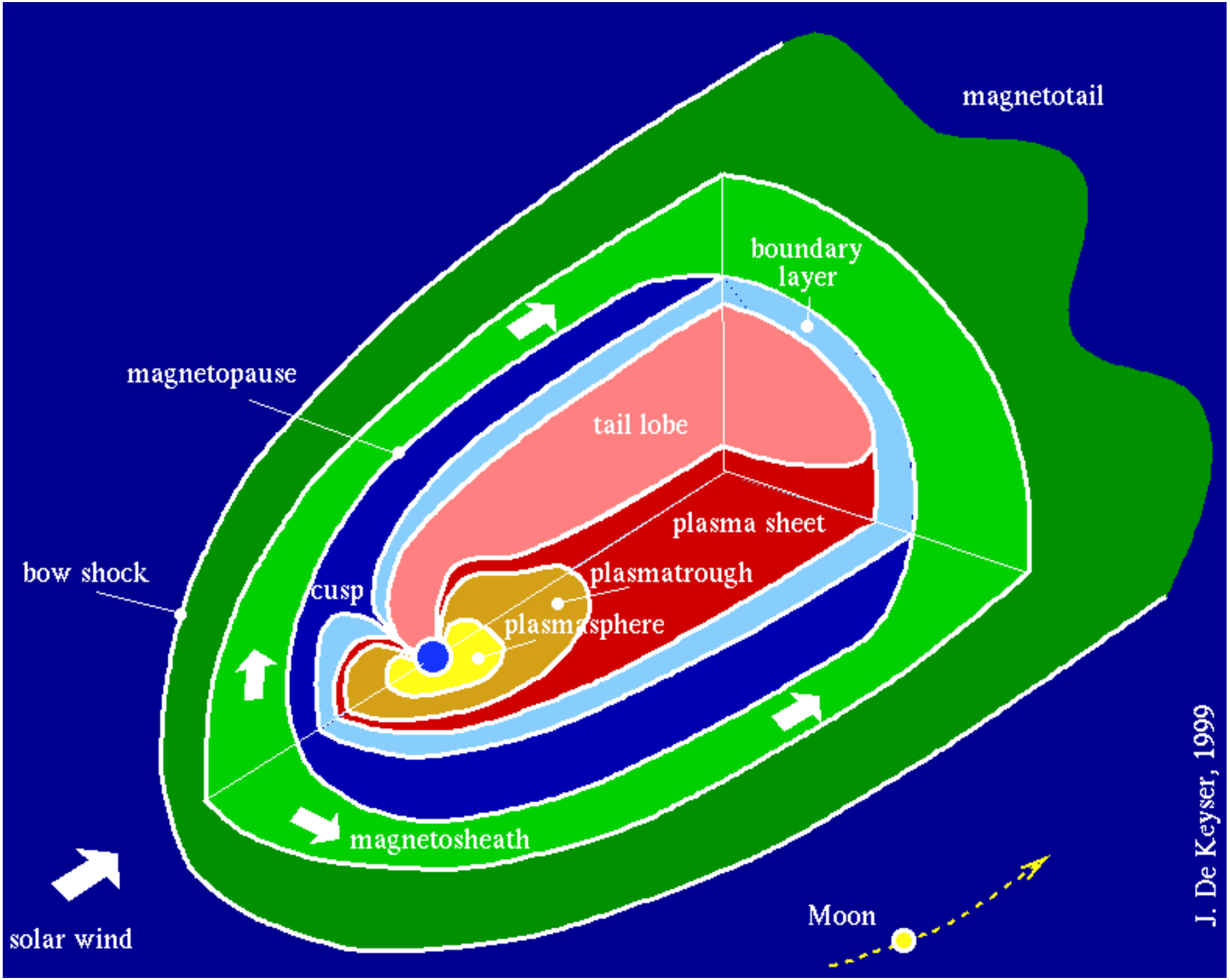
Throughout Earth's history, the magnetic field of the Earth has undergone periodic reversals on time scales of hundreds of thousands of years. The magnetic record is in magnetic materials embedded in cooled lava that are aligned to the magnetic field of the earth at the time they cooled.



Magnetosphere

The magnetic field of a planet can tell us something about the interior of the planet for example it suggests a rotating conductive core.

Additionally,
The terrestrial magnetic field forms a protective cavity about the Earth in which the Earth's magnetic field dominates. The cavity is known as the magnetosphere and it also protects us from very high energy solar particles.


magnetotail
boundary layer
magnetopause
tail lobe
plasma sheet
bow shock
cusp
plasmatrough
plasmasphere
magnetosheath
solar wind
Moon
J. De Keyser, 1999

Earth's Atmosphere

At the base of the Earth's atmosphere (sea level), the pressure is about 15 lb/in^2.

The pressure and density fall of steadily with increasing altitude.

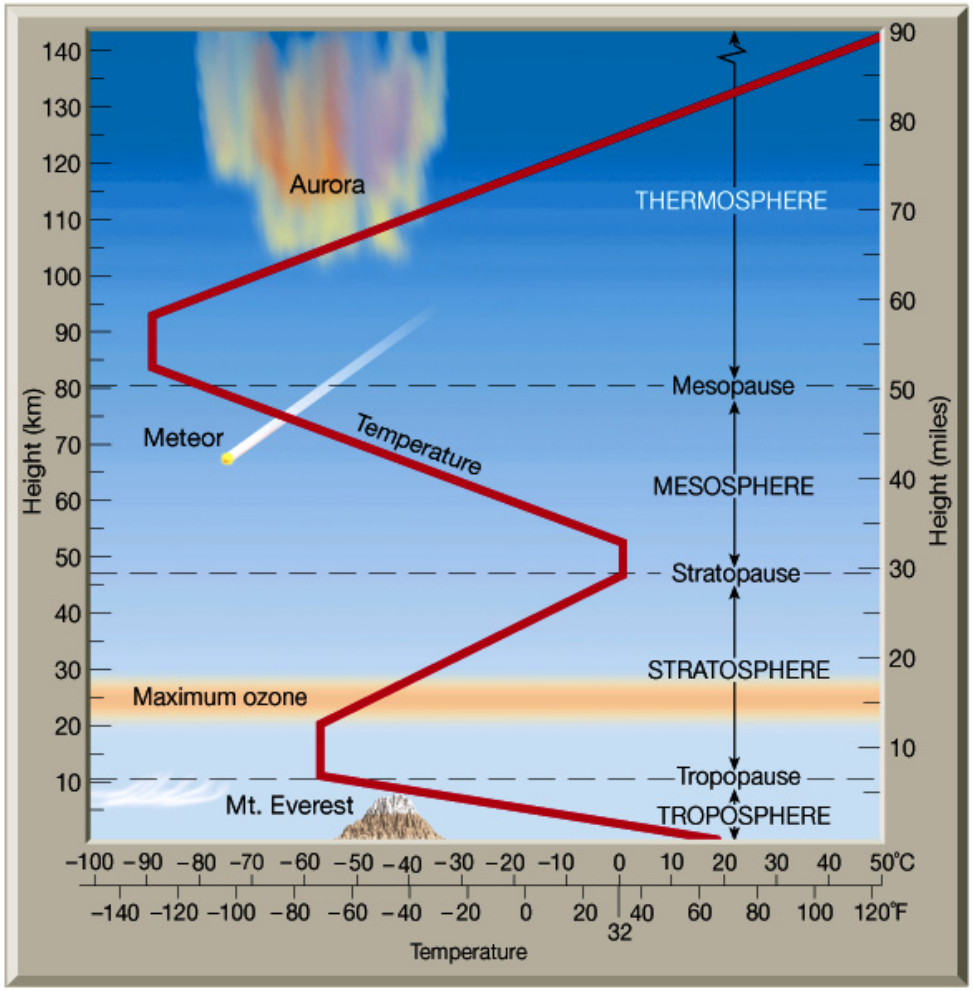
The composition of the Earth's atmosphere (which does change with altitude above 100 km) is approximately:

Earth:78% Nitrogen 21% Oxygen 1% Argon

Venus: 4% Nitrogen 0% Oxygen 96% $C0_2$

Mars: 3% Nitrogen 0% Oxygen 95% $C0_2$

Earth's Atmosphere



Troposphere

The troposphere is the lowest 10 km of our atmosphere.

The main source of heat for the troposphere is through contact with the ground, thus the temperature falls as we increase in altitude (lapse rate on the order of 1 degree every 150 m).

Warm air rises and cools then sinks setting up vertical convection pattern.

Statosphere

The stratosphere occurs between 10 and 50 km altitude.

The temperature in the stratosphere increase with altitude to about 50 km.

The ozone layer peaks around 20 km and extends up to 50 km. Ozone absorbs ultraviolet radiation (generally low energy UV radiation which penetrates the upper atmosphere) which heats the atmosphere.

Mesosphere

The mesosphere occurs between 50 and 90 km altitude.

As the mesosphere is above the ozone layer and there is thus no source of heating, the main feature of the mesosphere is the systematic decrease in temperature with altitude.

Thermosphere

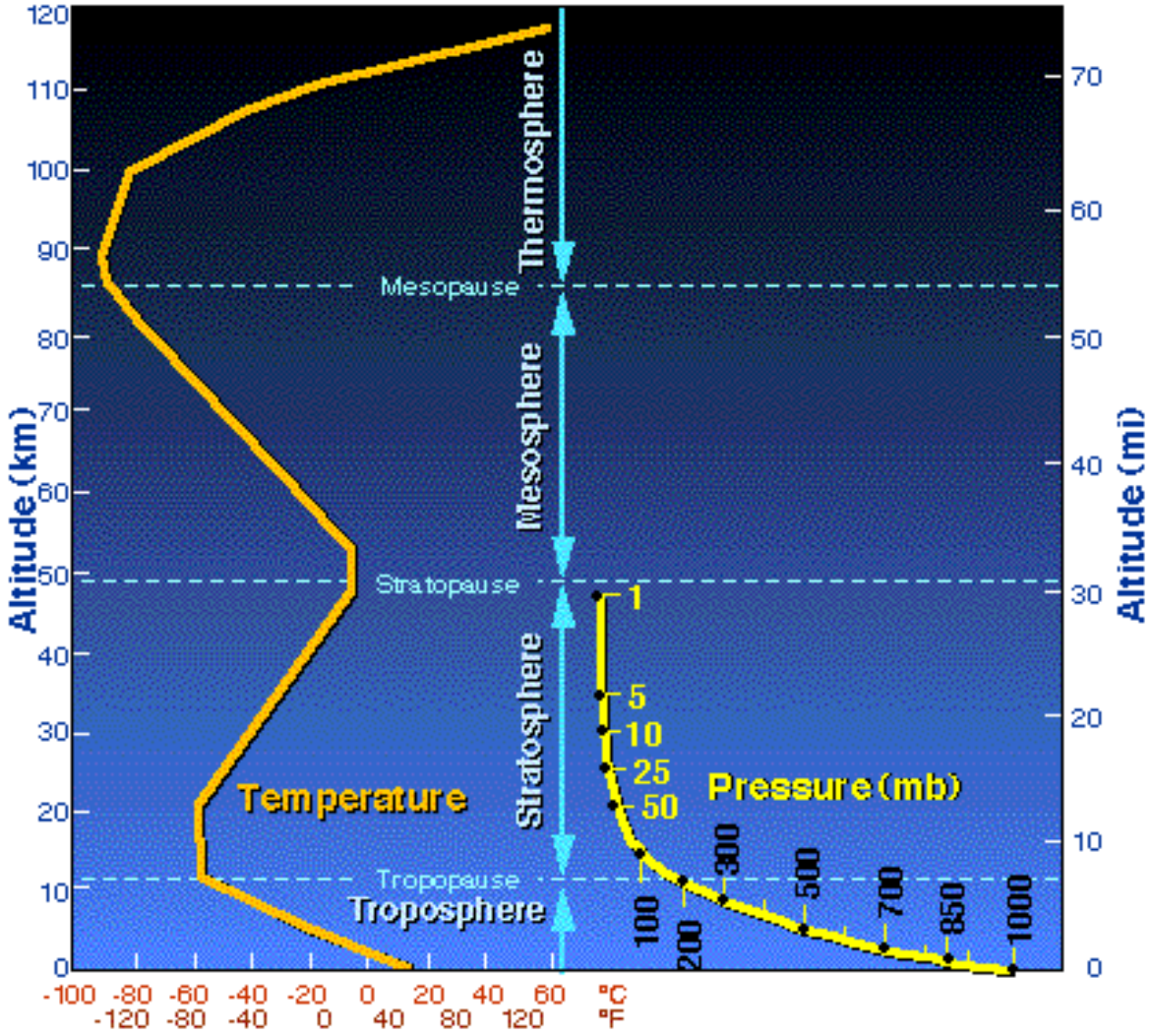
The thermosphere occurs above 90 km altitude (to say 1000 km).

High energy UV radiation is absorbed in this region and thus the temperature increases with altitude.

The radiation also ionizes the gases of the upper atmosphere. Thus a gas of electrically charged particles is embedded in the thermosphere. This is known as the ionosphere.

In the thermosphere, the gases start to stratify according to their mass with the heavier gases (O2, N2) on the bottom and the lighter gases O on top.

Average atmospheric temperature and pressure in the atmosphere



Aurora: Form and Color

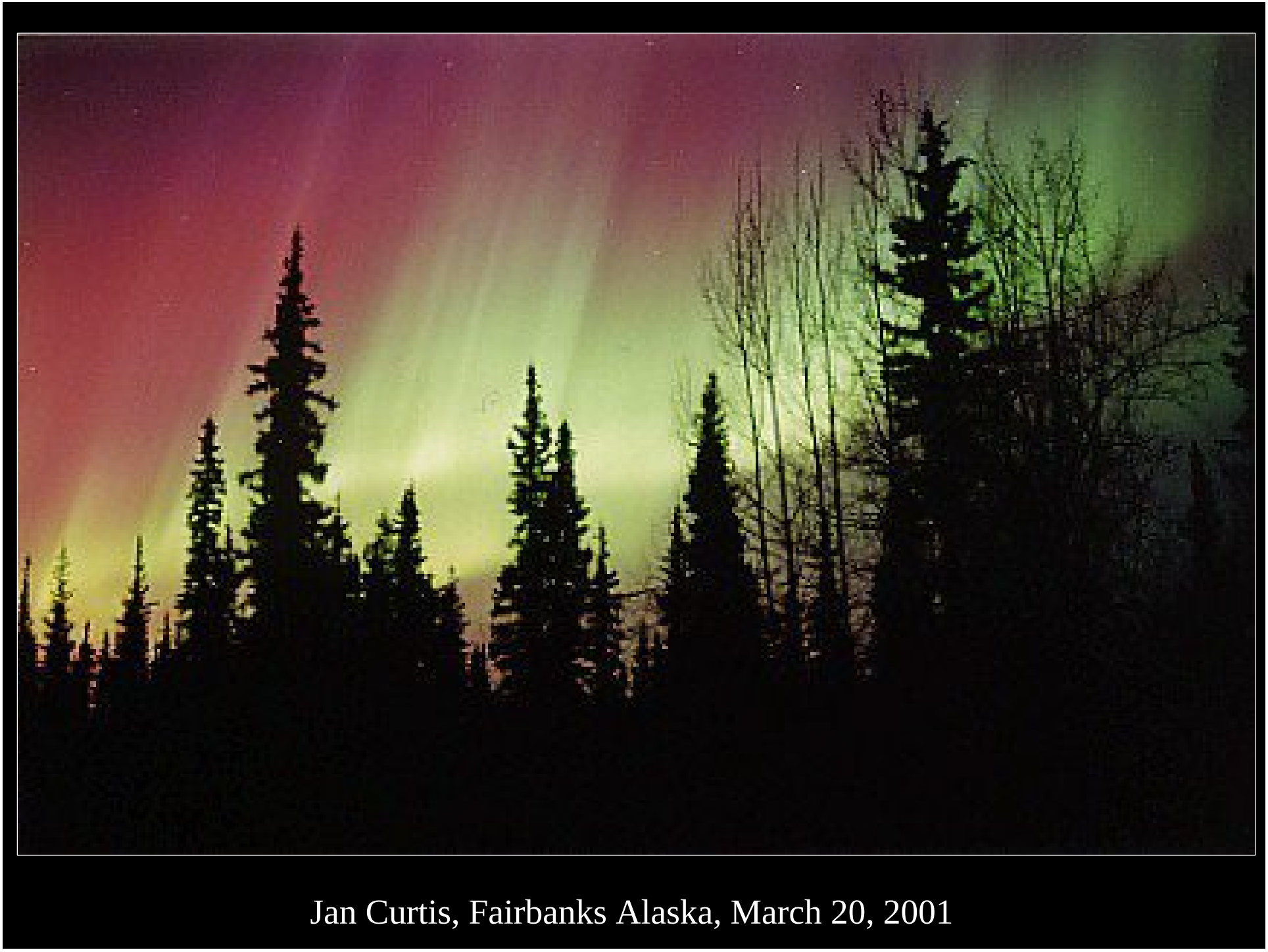
Hugh Gallagher Jr. February 1992 Sondrestromfjord Greenland

Marko Gronroos, Turku, Finland, March 19, 2001

Tom Eklund,Valkeakoski,Finland, March 19, 2001

Jan Curtis, Fairbanks Alaska, March 20, 2001

Jan Curtis, Fairbanks Alaska, March 20, 2001



Jan Curtis, Fairbanks Alaska, March 20, 2001

Philippe Moussette, Quebec, Canada, October 28, 2001

Chuck Adams, Statesville, NC, November 5, 2001

John Russell, Nome, Alaska, October 28, 2001

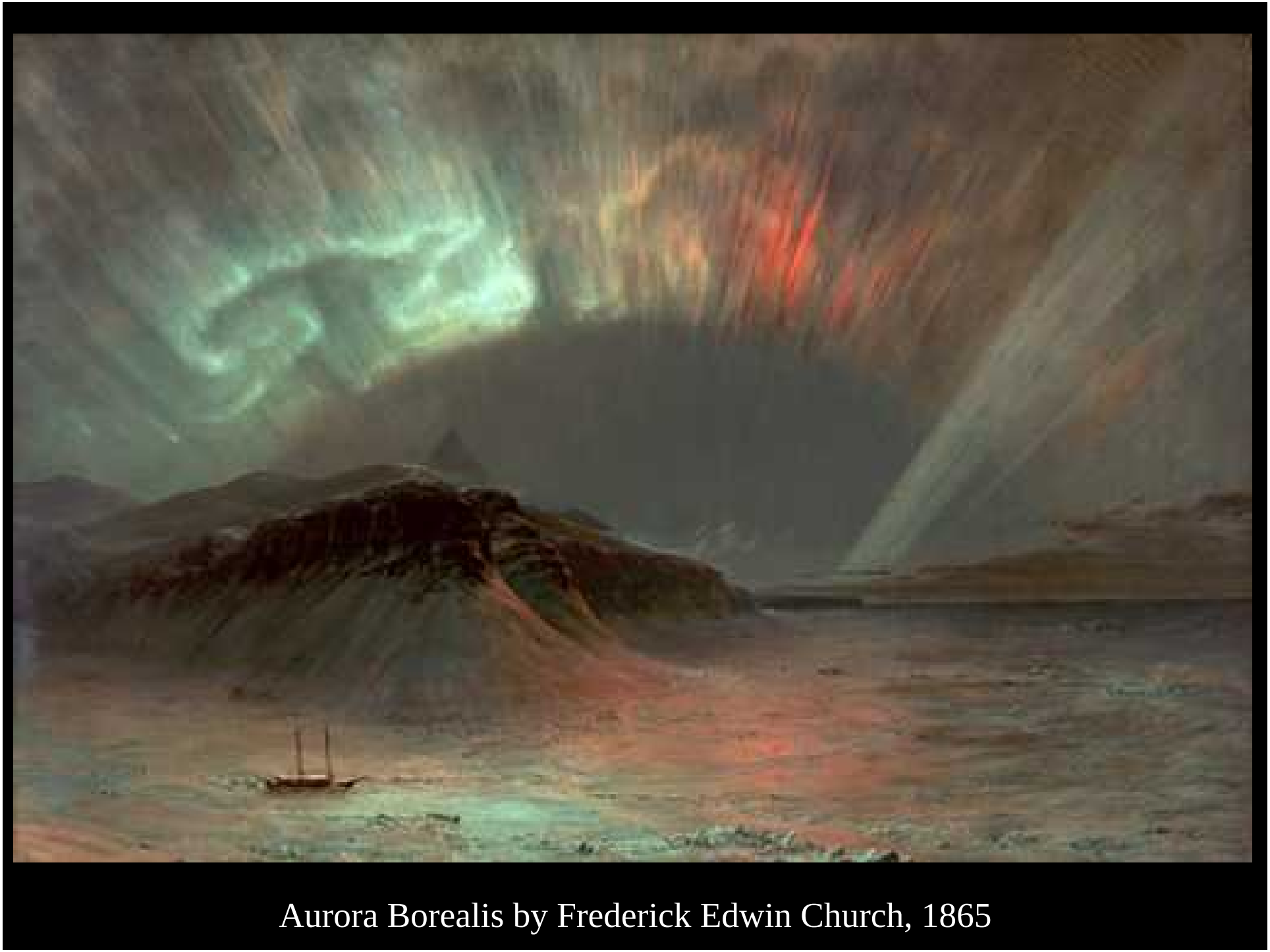
Vesa Särkelä, Kemijärvi Finland, November 5, 2001

Jan Curtis
March 20,2001
Fairbanks Alaska

Brett Walker, Chippewa Falls, Wisconsin, November 5, 2001

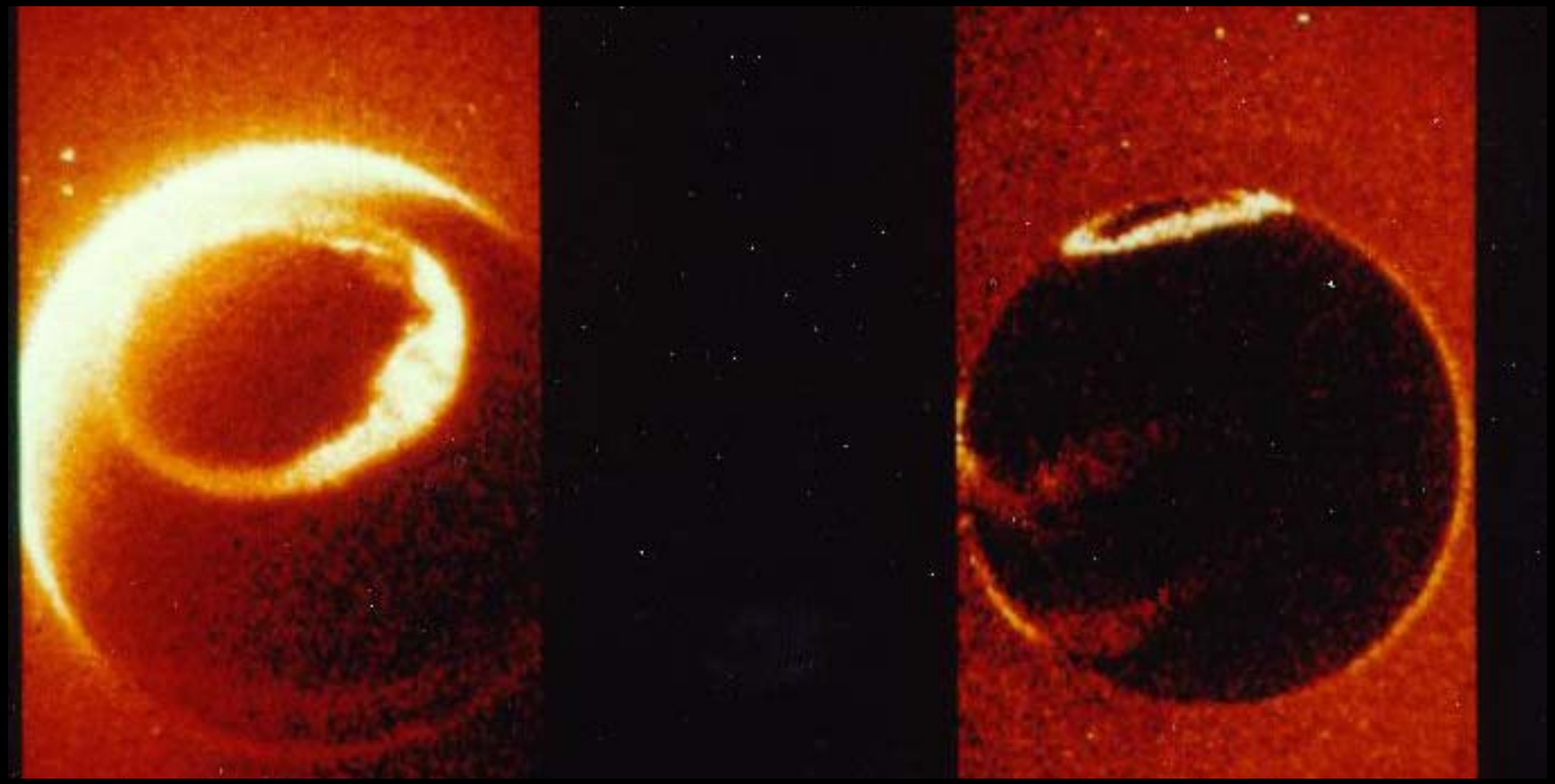
Steven Lichti, West Lafayette, Indiana, November 5, 2001

Dennis L. Mammana, San Diego, CA, November 5, 2001

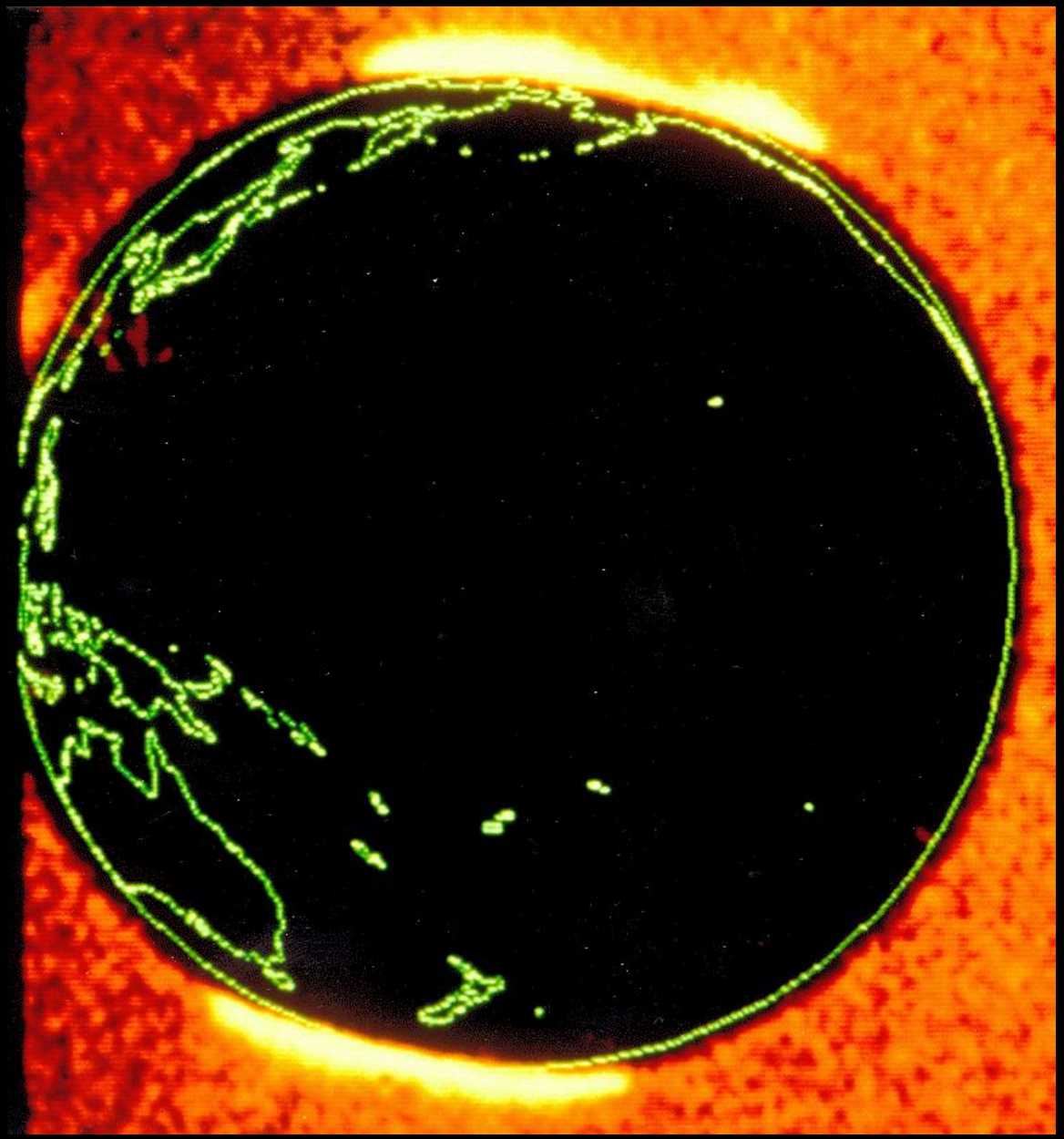


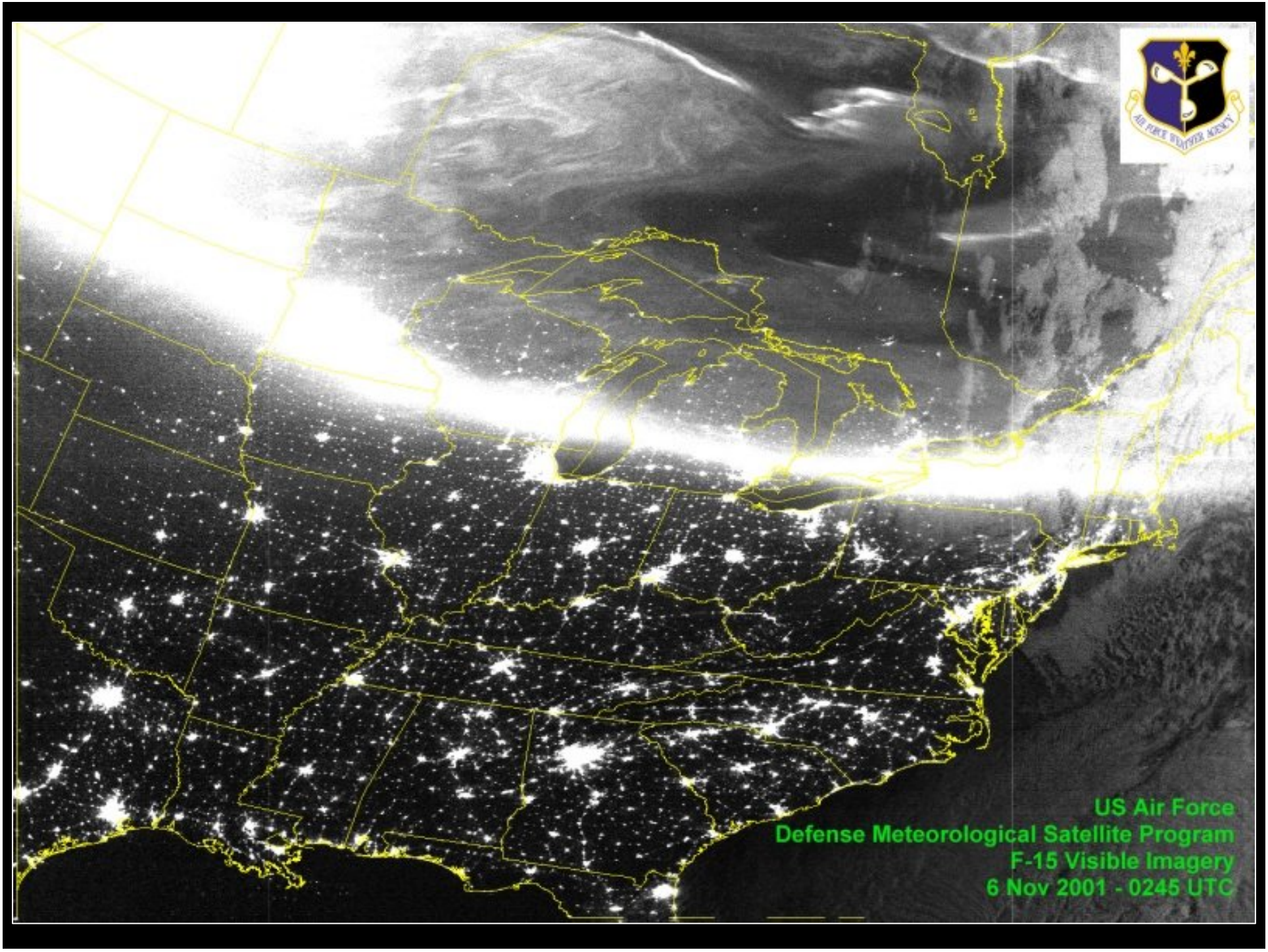
Aurora Borealis by Frederick Edwin Church, 1865

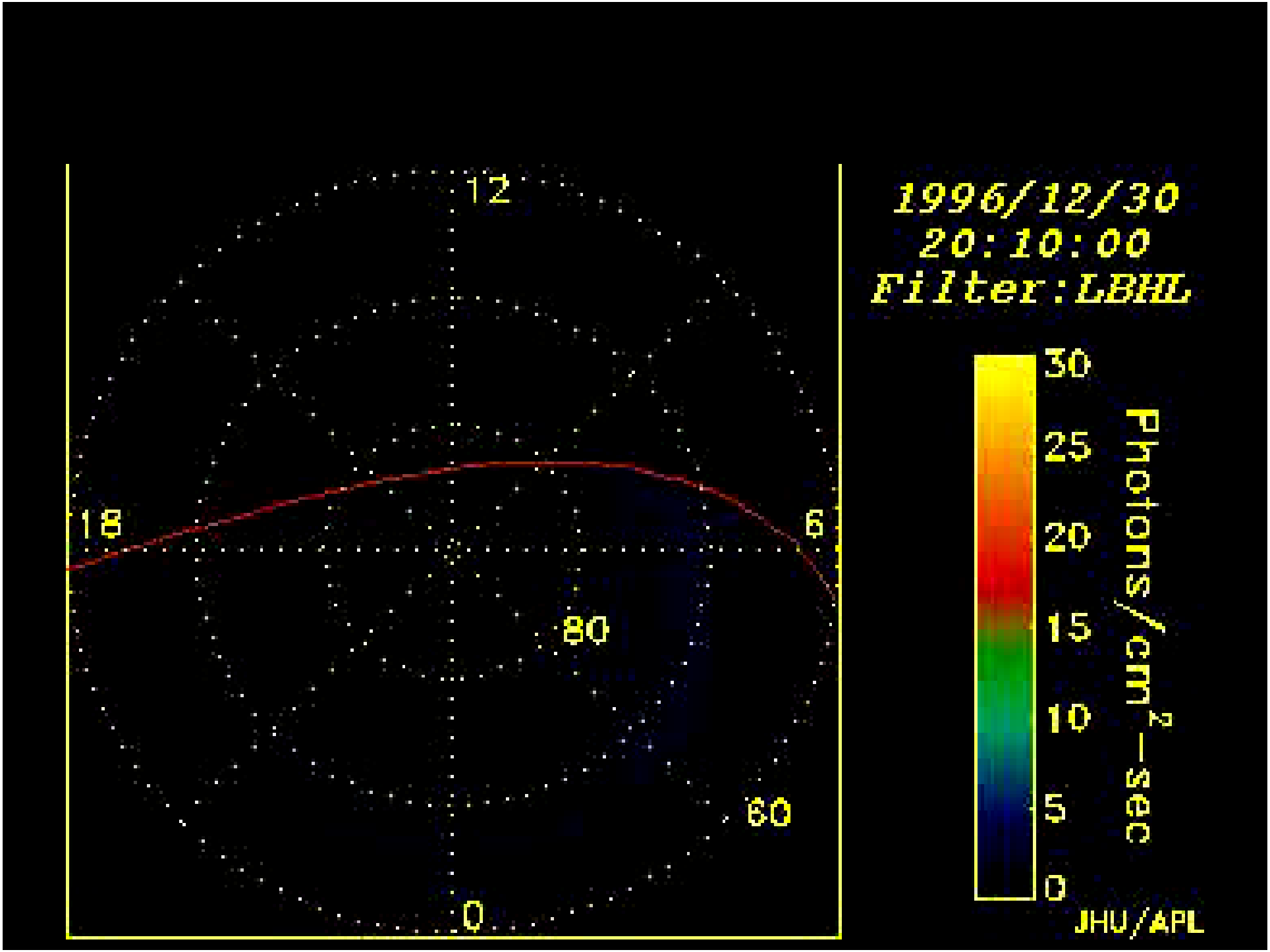
Dynamics Explorer Satellite
Dr. Lou Frank, University of Iowa



DE: Simultaneous Northern and Southern Lights




US Air Force
Defense Meteorological Satellite Program
F-15 Visible Imagery
6 Nov 2001 - 0245 UTC


12
18
6
80
60
0
1996/12/30
20:10:00
Filter:LBHL
30
25
20
15
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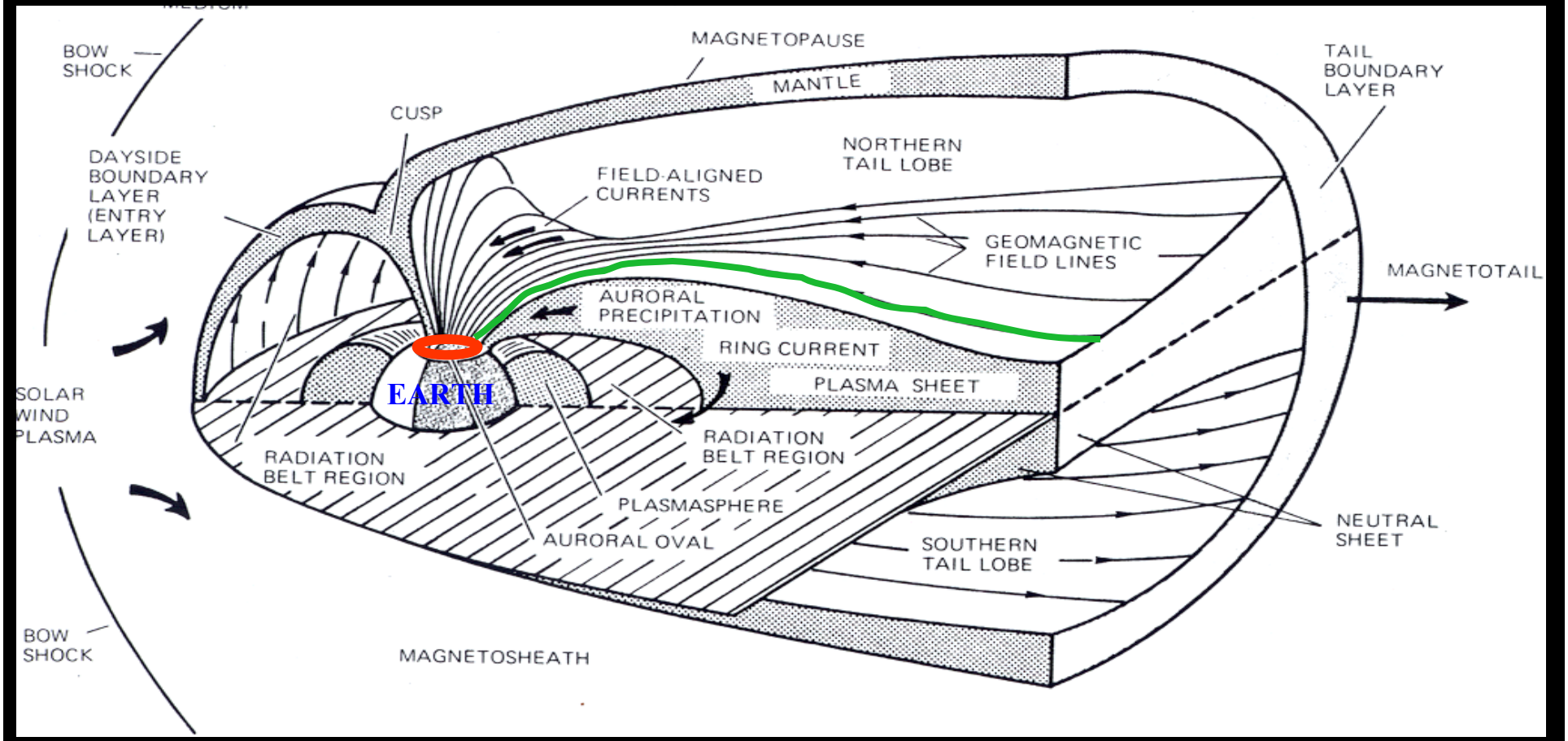
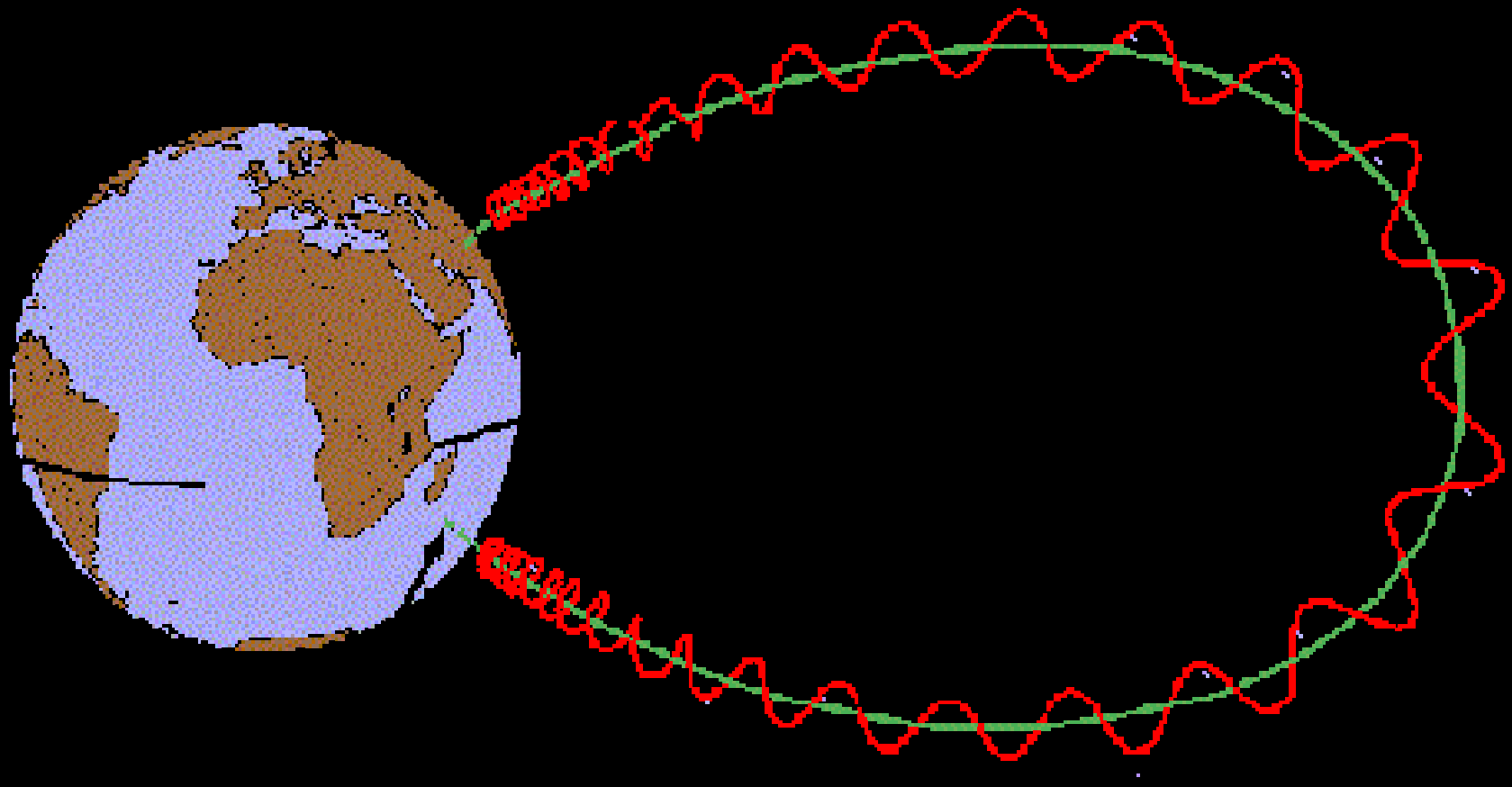
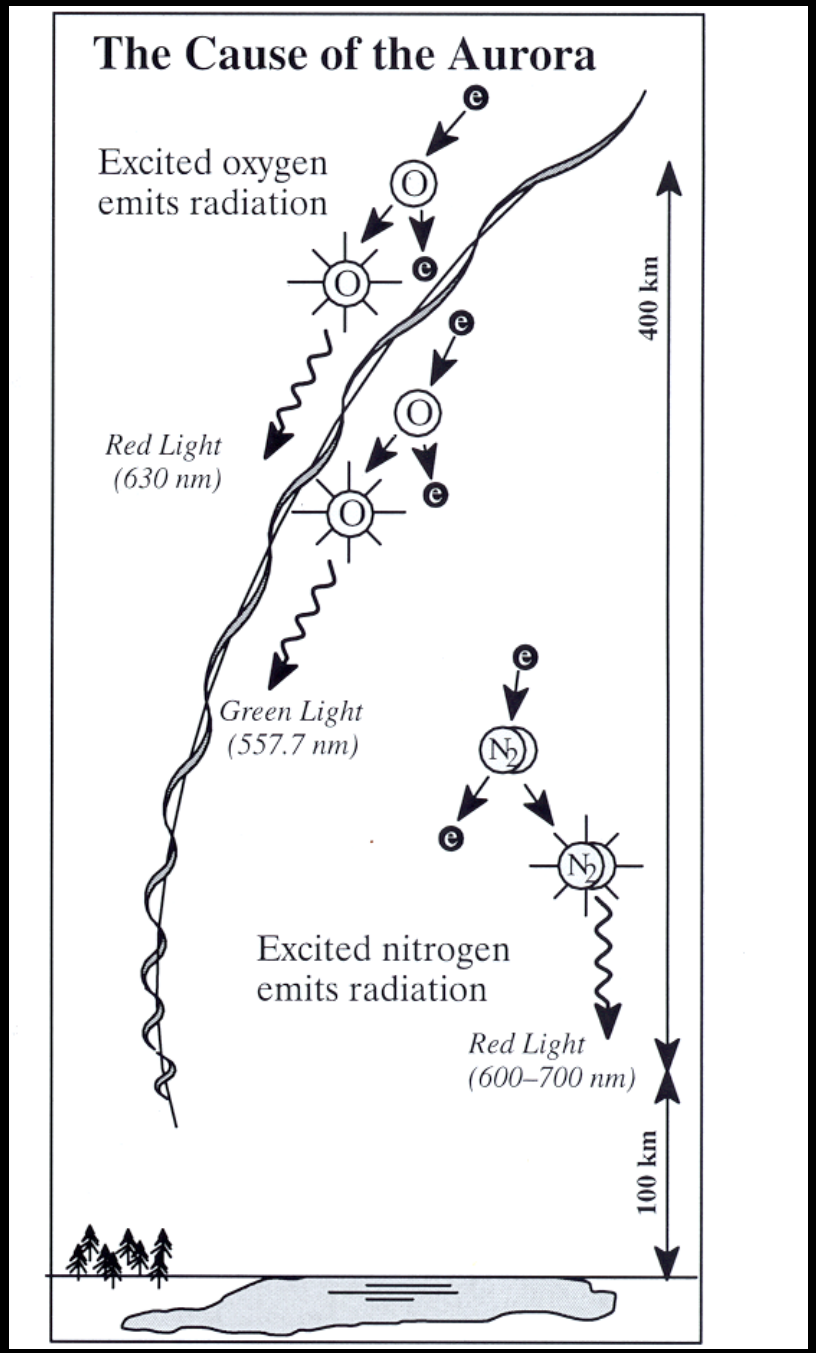
Photons/cm²—sec
JHU/APL

At the Base of the Magnetosphere: The Auroral Oval



Motion of Charged Particles in the Presence of a Magnetic Field





Charged particles from the outer magnetosphere are guided towards the polar regions by the Earth's magnetic field.

Through collisions, the charged particles excite the atoms and molecules of the upper atmosphere which subsequently emit the auroral light.

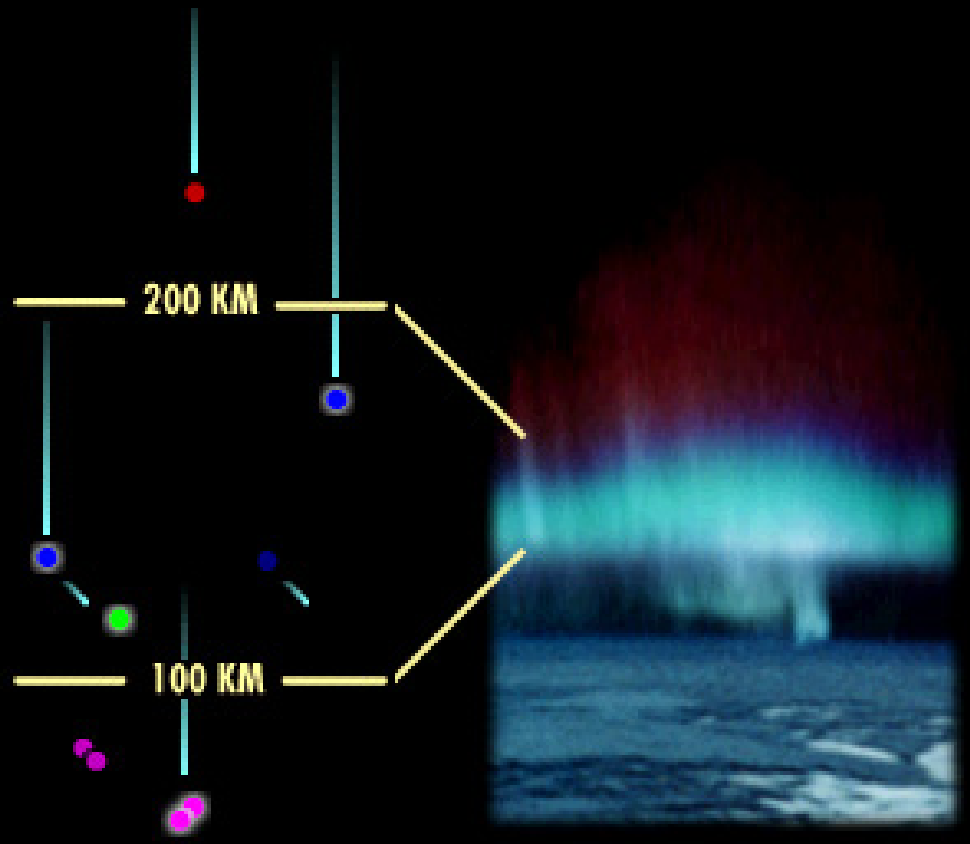
The color of the auroral emissions depends on the composition of the upper atmosphere and thus the altitude where the emissions are produced.

Electrons enter the atmosphere and collide with atoms.

Oxygen glows red.

Nitrogen glows blue and can emit a secondary electron which causes oxygen atoms to glow green.

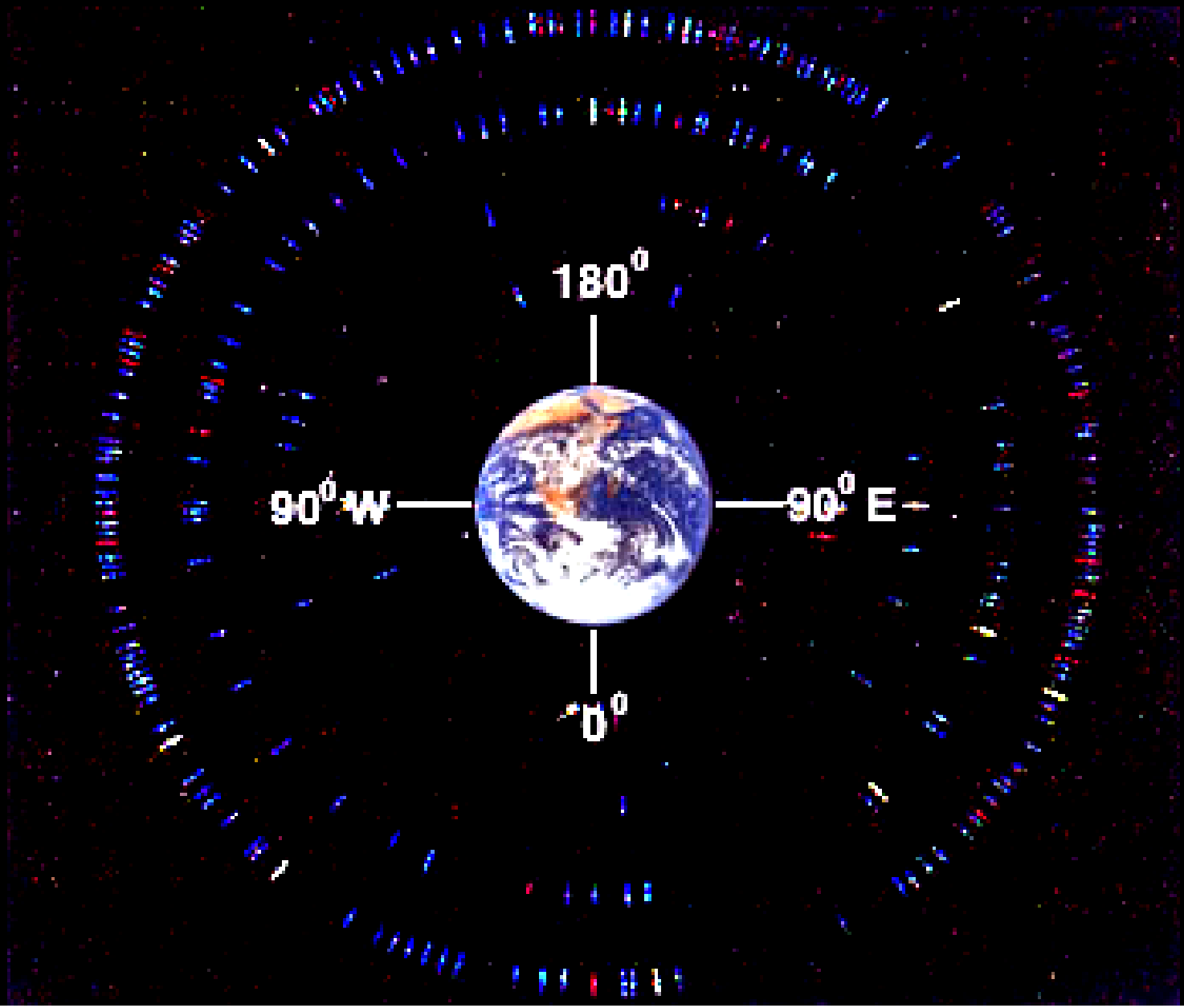
Nitrogen molecules glow crimson.



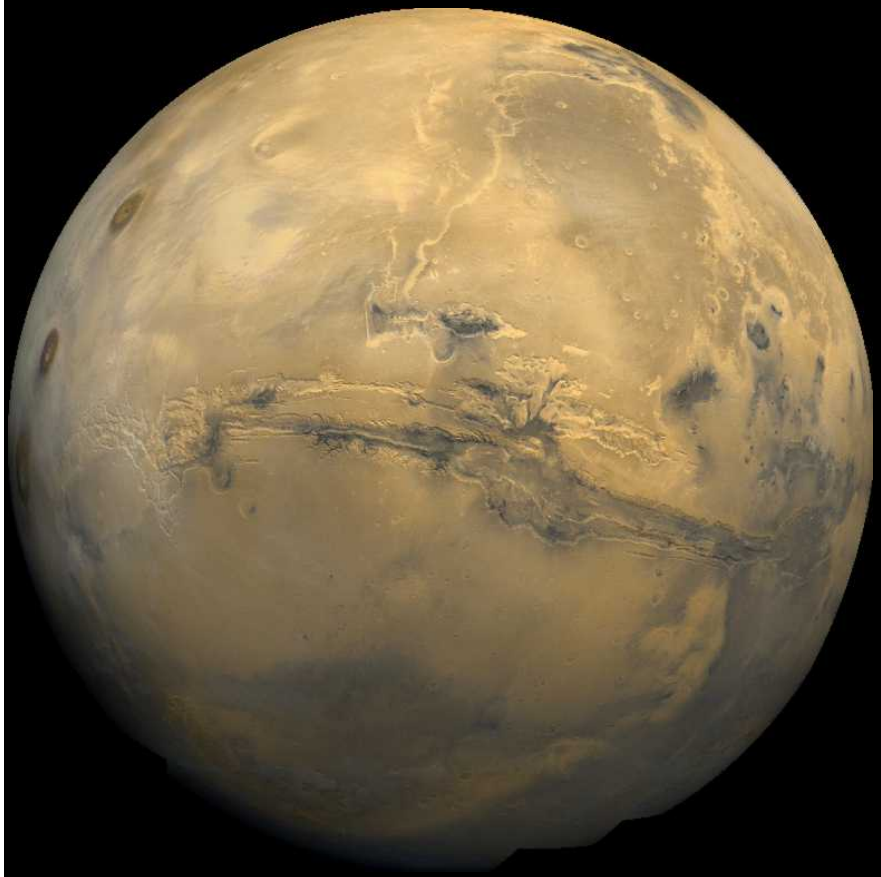
Some of the light is very hard for the naked eye to see, like the blue from the nitrogen atoms. The green light from the oxygen atoms is often so bright that it washes out the other colors, and photos of the aurora sometimes show more red and crimson than is noticeable with the naked eye.

from "Space Update" CD (http://spaceupdate.com)

Satellites In Geosynchronous Orbit



Mars:Overview



Telescopic observations of *canali* on Mars's surface by Schiaparelli published in 1877 followed by Percival Lowell's detailed map of elaborate canal systems on Mars have inspired our curiosity as to whether or not life ever flourished on Mars. Although the canals never existed, there is evidence that water has played a role in forming Mar's surface.

Mars:Overview

Mars orbits the Sun at a distance of about 1.5 AU (Earth 1 AU). Since its orbit is *outside* the Earth's orbit, it may (at times) be observed quite easily at night (we must look towards the Sun to observe Venus and Mercury). Thus, it may easily and safely be observed by the Hubble Space Telescope (left).

Mars: Highlight Missions

1965 Mariner 4 (U.S., first successful visit Mars)

1971 Mars 2 (U.S.S.R., first to land on the surface)

1972 Mars 3 (U.S.S.R, transmitted from surface for 20 s)

1971 Mariner 9 (U.S., orbiter transmitted over 7000 images)

1976 Viking 1 (U.S., lander and orbiter)

1976 Viking 2 (U.S., lander and orbiter)

1997 Mars Global Surveyer (U.S., orbiter, mapping mission)

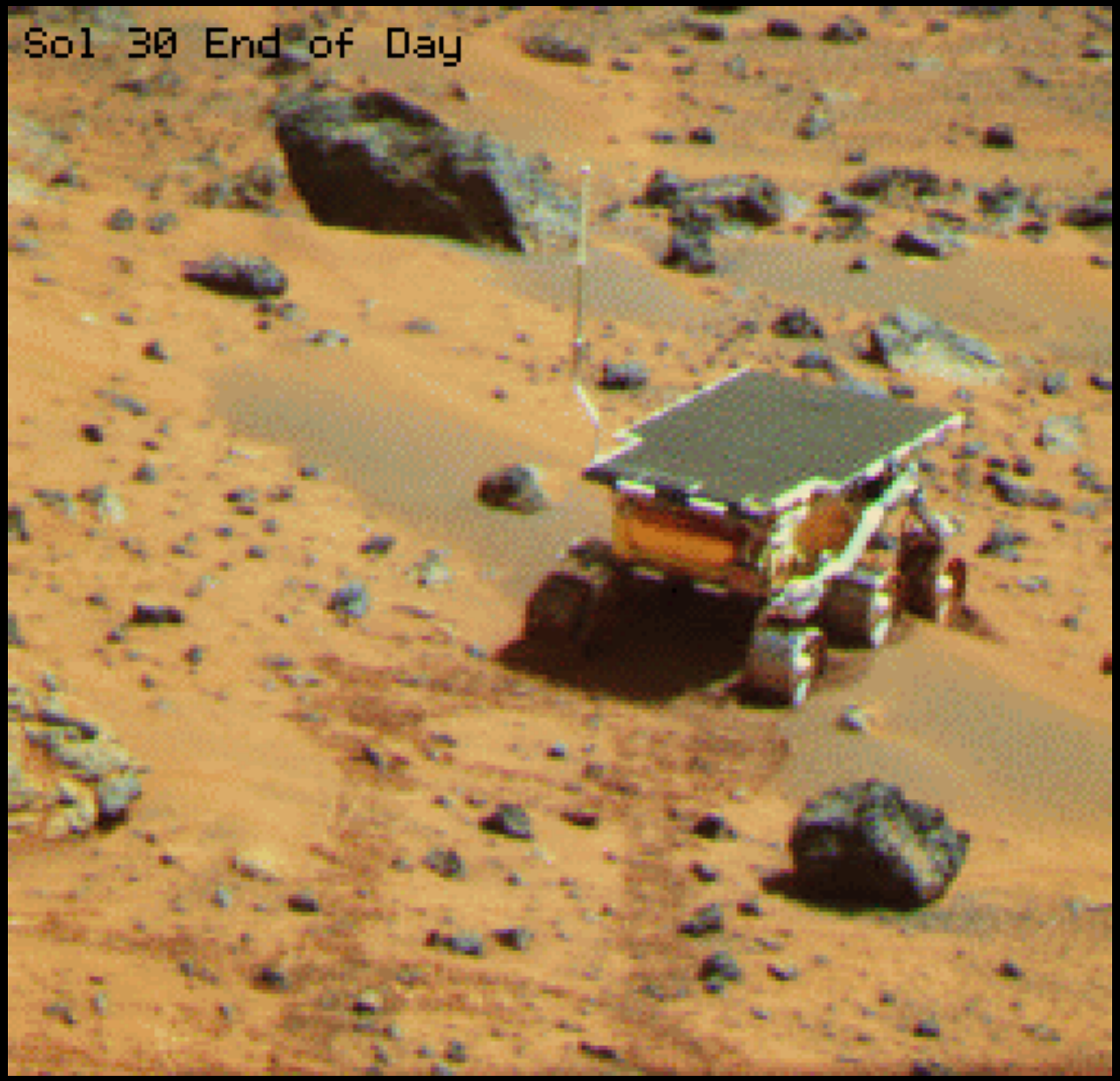
1997 Mars Pathfinder and Sojourner (U.S., orbiter and rover)

2001 Mars Odyssey (U.S. orbiter)

2003 Mars Express (ESA and NASA, orbiter, rover lost)

2006 Mars Reconnaissance Orbiter

Mars: Sojourner



Mars: Orbit and Rotation

Mars orbits the Sun in about 687 days (about twice Earth's orbital period).

Mars rotates in approximately 24.6 hours (Similar to Earth's 23.9 hours).

Mars rotational axis is tilted at an angle of 25.2° (compared to Earth's 23.5 °). As a result, Mars has seasons similar to Earth's and ice in Mars polar regions has be observed to recede and expand in response to seasonal changes.

Mars:Core and Magnetic Field

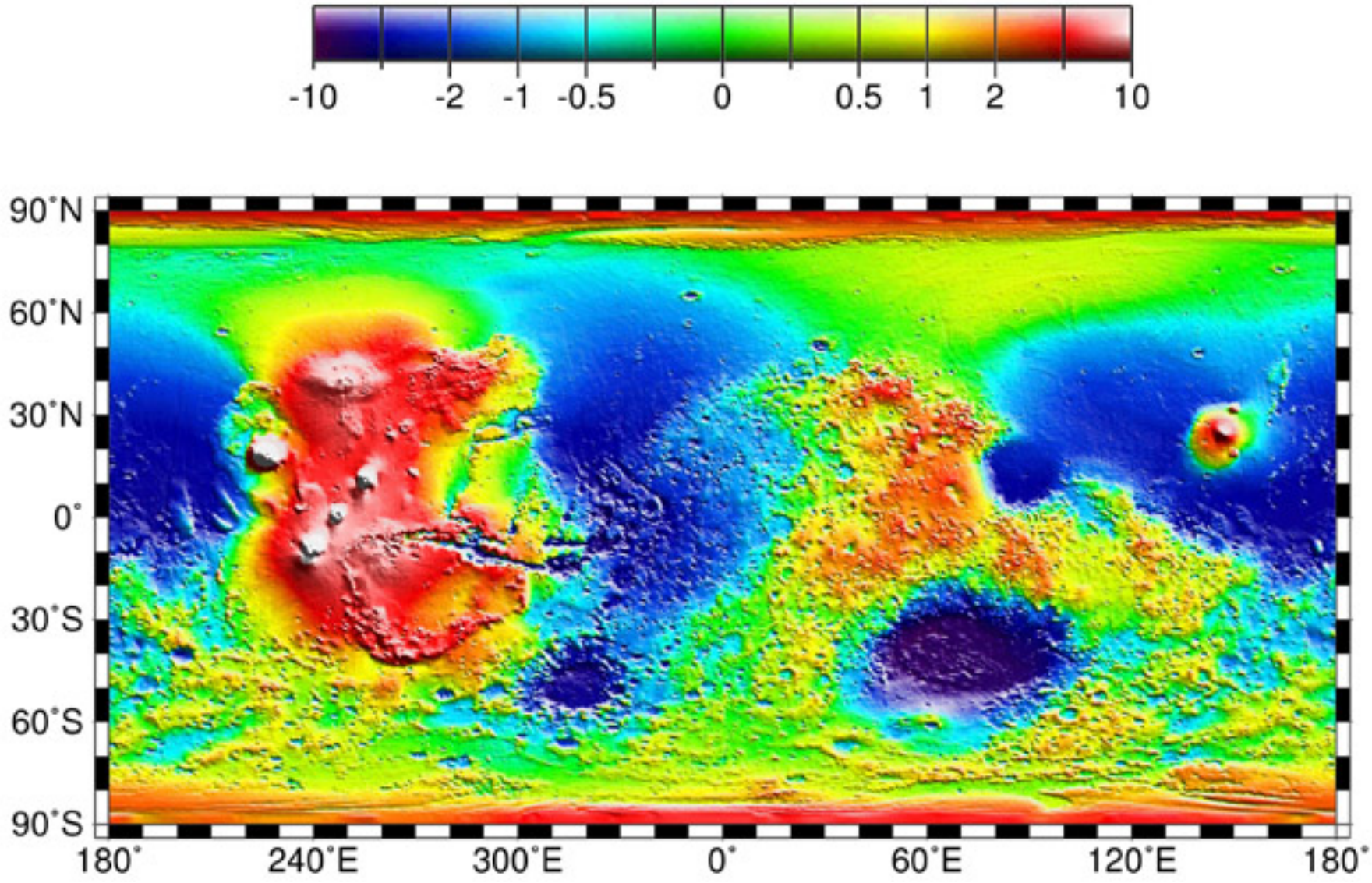
On average, Mars magnetic field is much weaker (at least 1000 times weaker) than the Earth's. Recent results from the Mars Global Surveyor, indicate that Mars there are localized regions where the magnetic field is significant.

Mars average mass density of 3940 kg/m^3 is more like the Moon's (3340 kg/ m^3) than the Earth's (5515 kg/ m^3). This is partially because Mars is smaller than Earth (less pressure). However it is also likely that Mars iron core is relatively small.

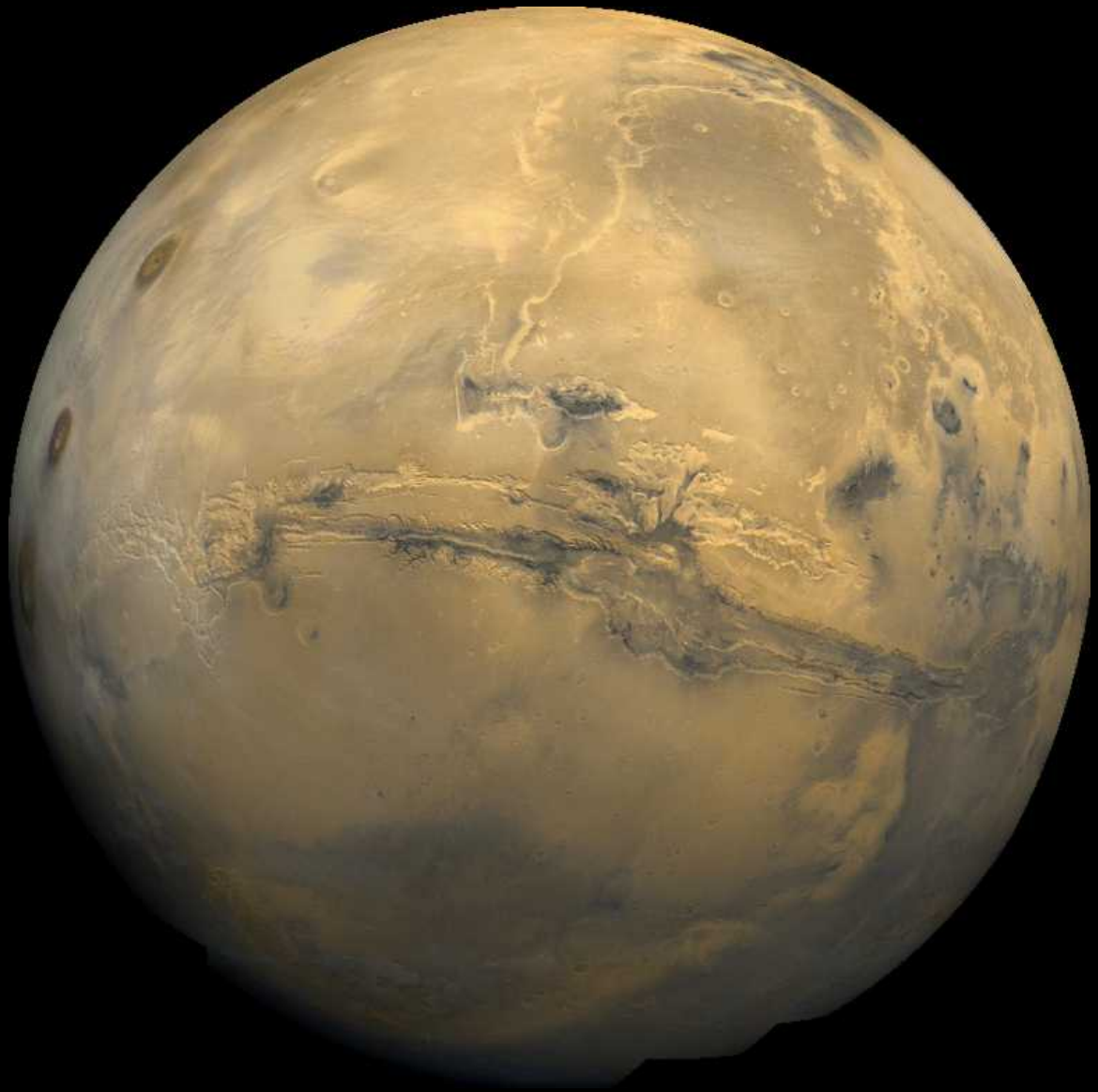
Mars:Core and Magnetic Field

Mars iron core may be completely solid (smaller planets cool faster) and thus not capable of producing a dynamo field despite having a rotation similar to that of Earth.

Mars: Surface

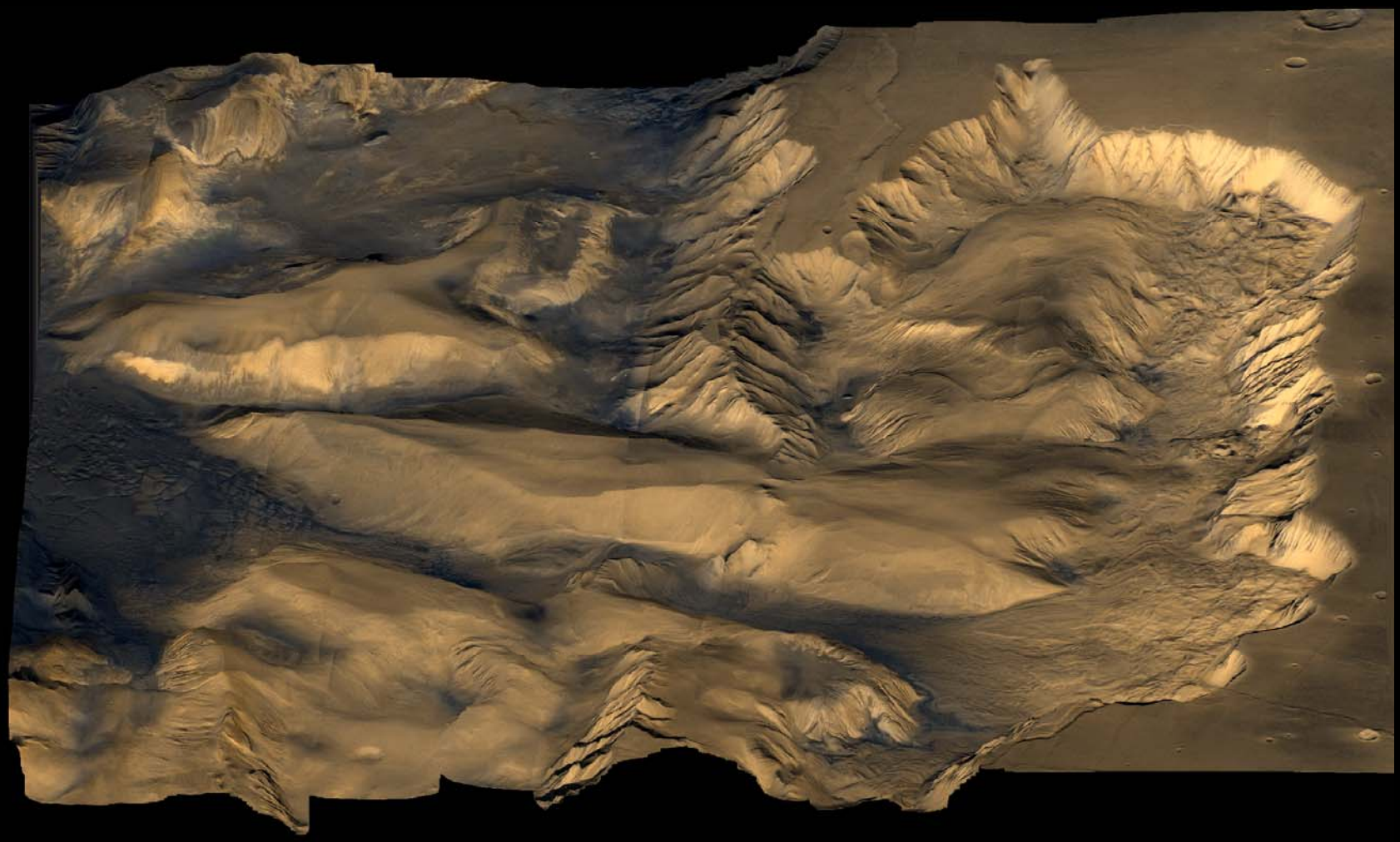


Mars: Surface, Valles Marineris

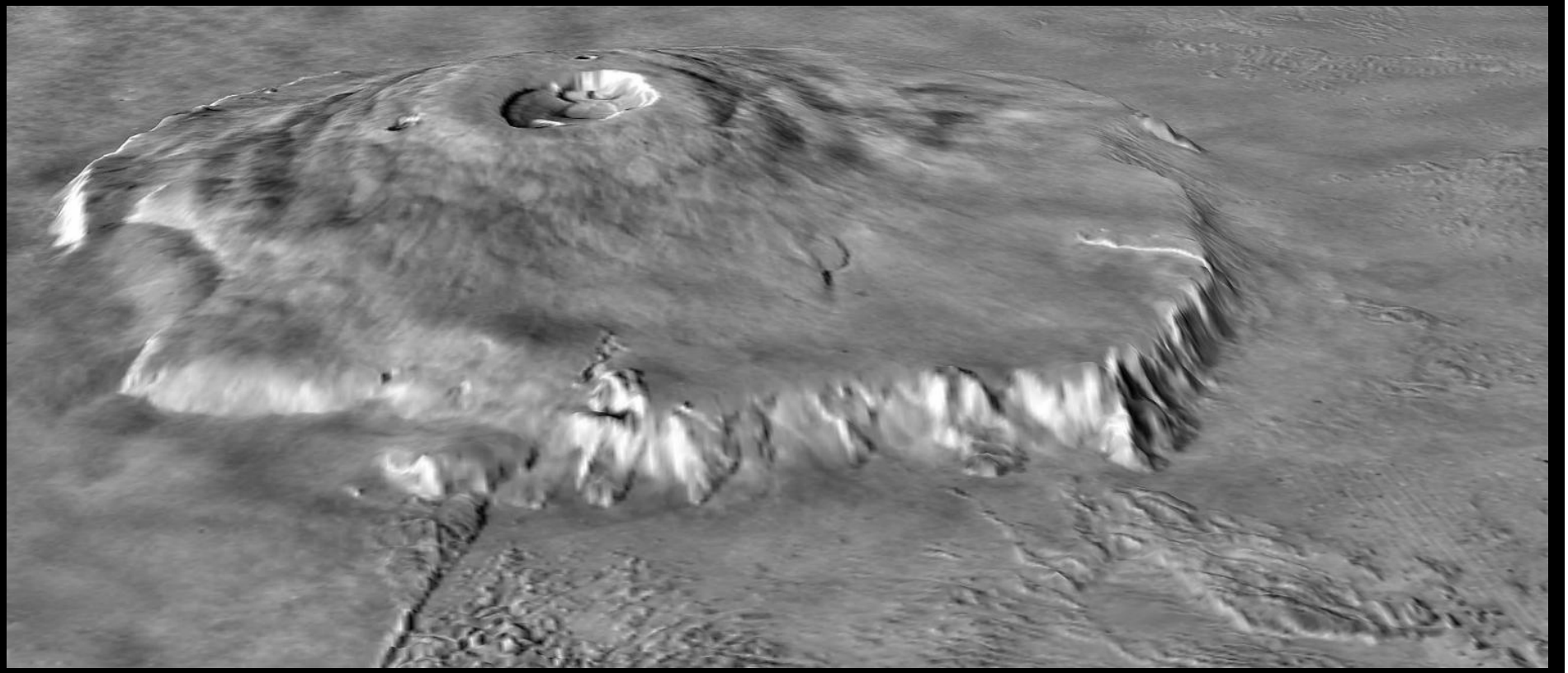


This great canyon 3000 km long and 8 km deep may have been partially shaped by forces that we associate with liquid water.

Mars: Surface
Candor Chasm in Valles Marineris

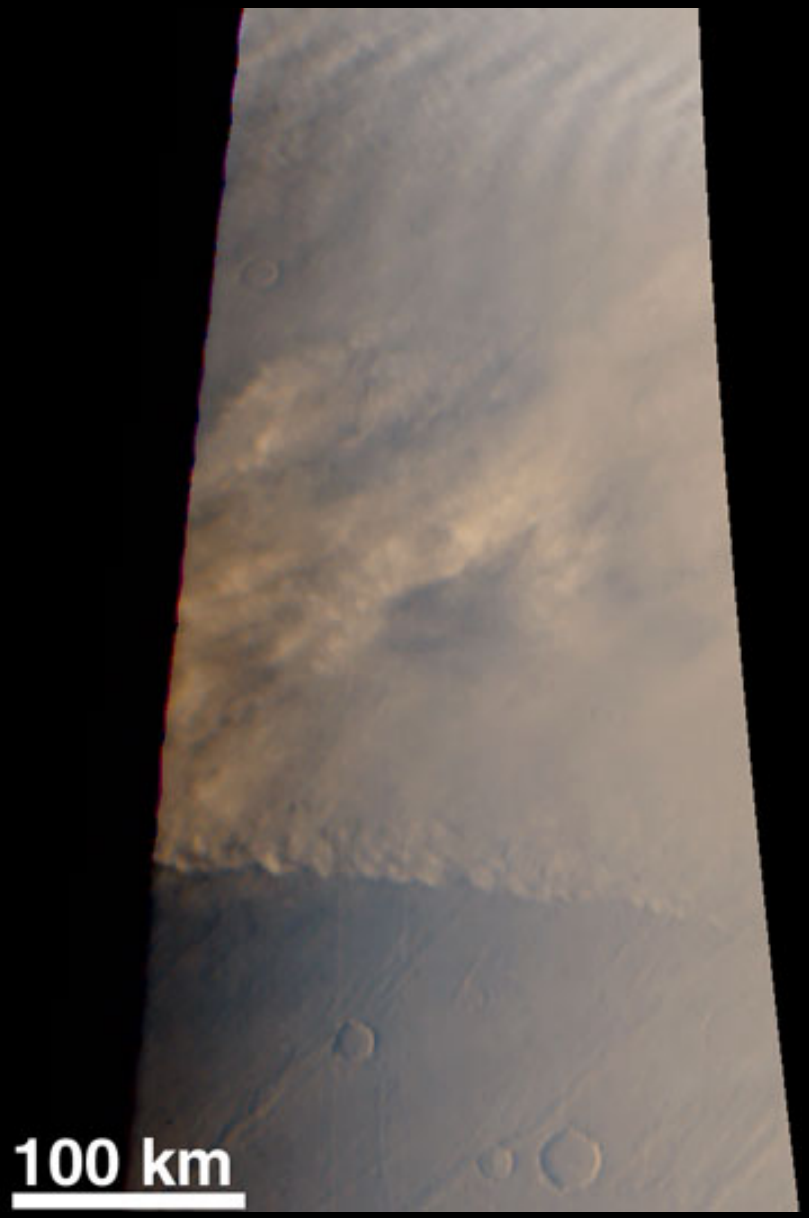


Mars: Surface, Olympus Mons



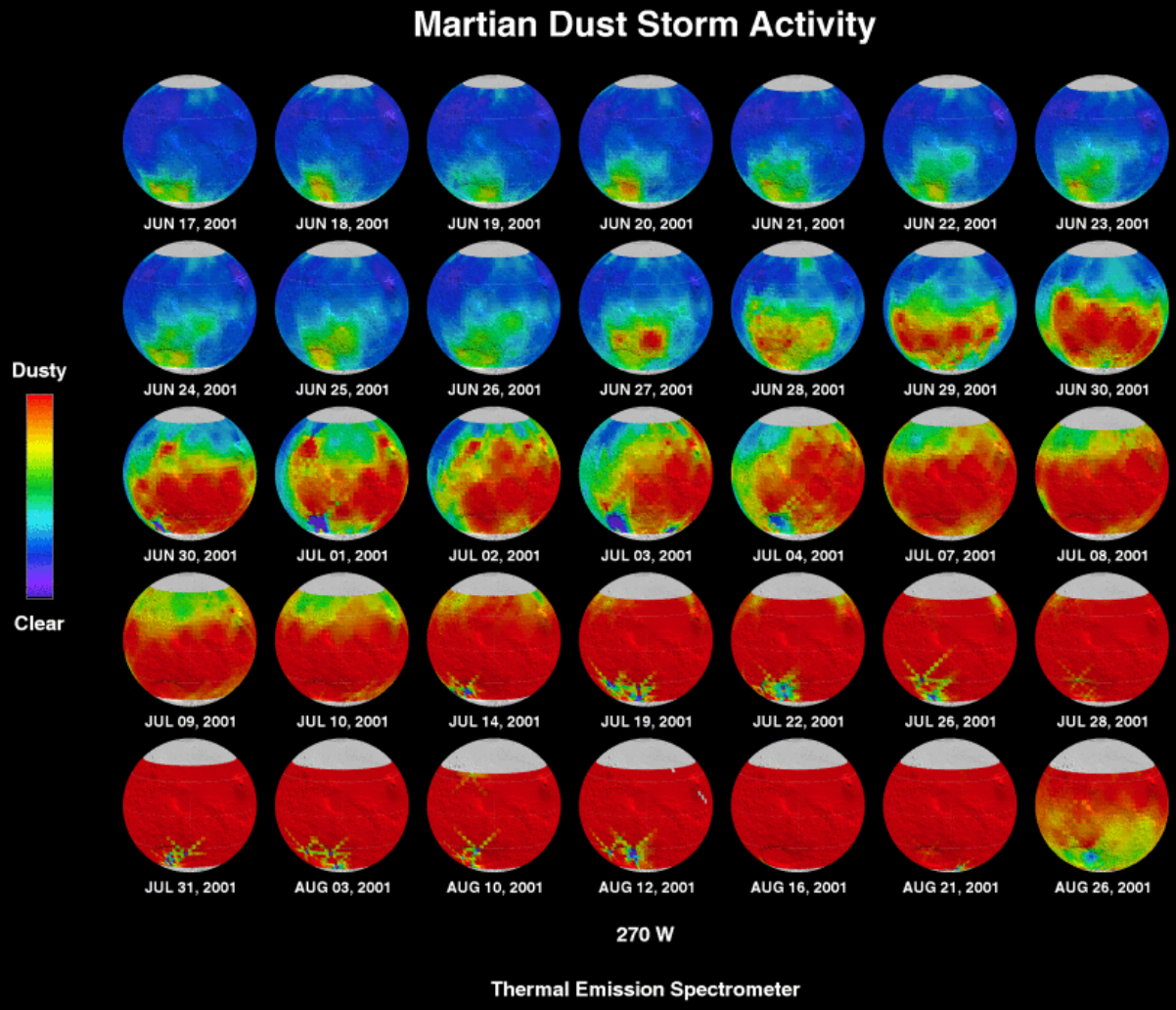
It seems that Mars plate tectonic activity ended long ago on Mars. Thus a volcanic hot spot is always below the same point and along with weaker gravity allowed large volcanos to be pushed up from the surface. (Olympus Mons rises 24 km above the surrounding plane)

Mars: Surface



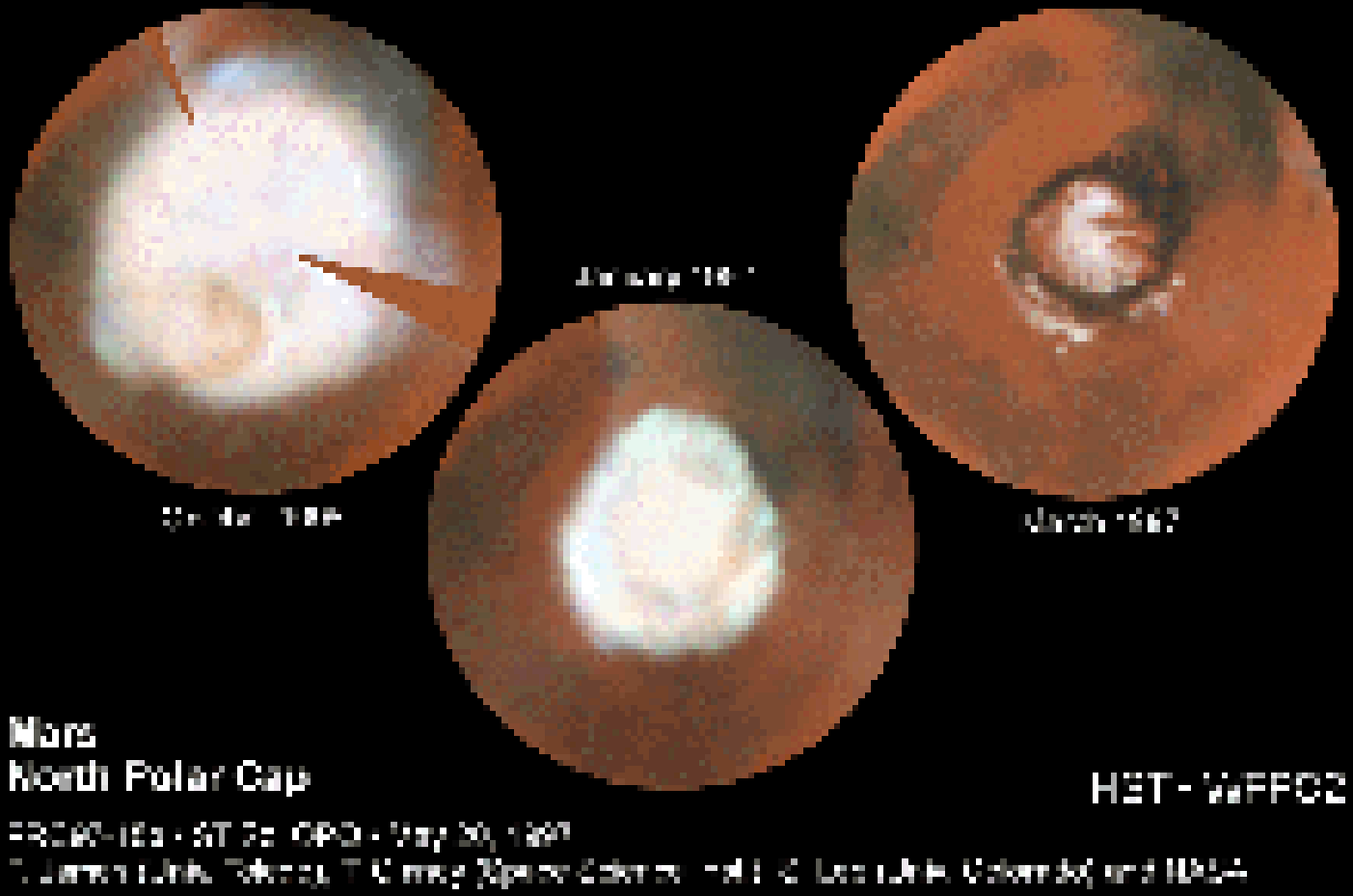
The reddish orange color of the soil on Mars is likely due to the presence of iron oxide (rust). Periodically, vast dust storms spread across the surface and envelope the whole planet. color Dust storms.

Mars: Surface



Infrared images show dust storm enveloping Mars from June 17 to August 25, 2001

Mars: Surface, Polar Cap Seasonal Variation



The size of the polar caps (regions of frozen CO2 surrounding the poles) varies clearly with season.

Mars: Atmosphere

Mars's atmosphere is extremely thin with a surface pressure about 1% of Earth's.

Mars's atmosphere is composed mainly (95%) of CO_2 with small amounts of Oxygen and Water.

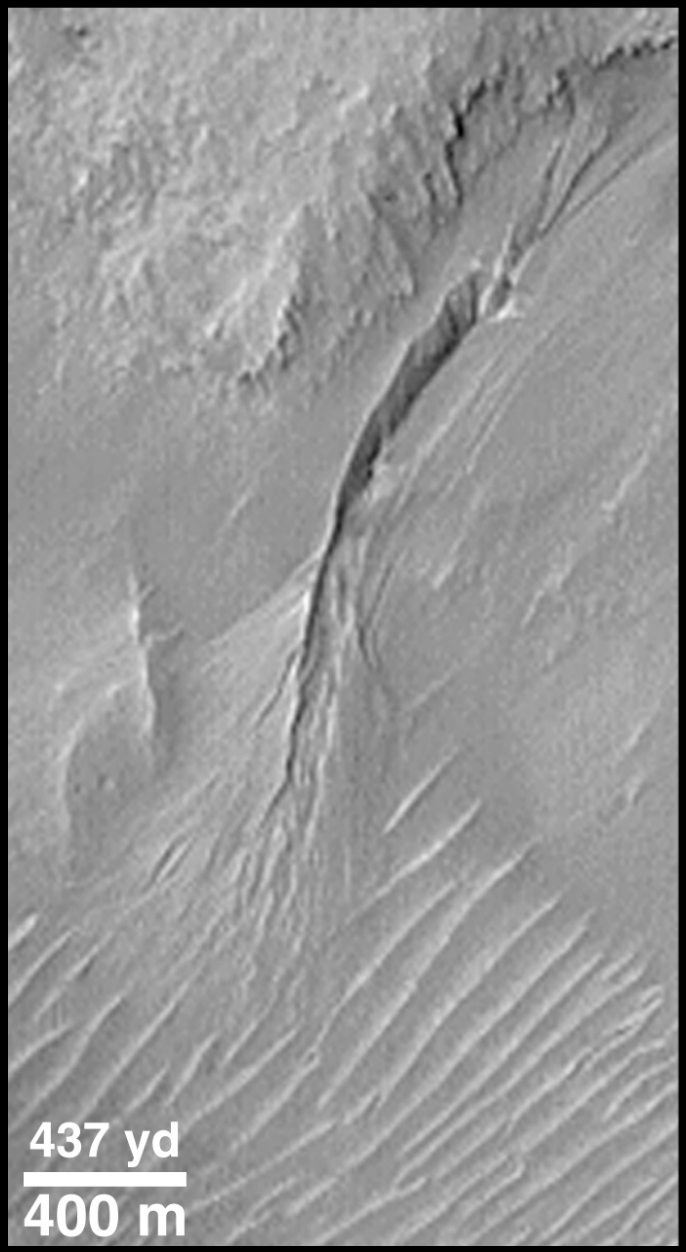
It is thought that long ago (1 billion years after it formed) Mars had a thicker atmosphere and hospitable climate.

Loss of the atmosphere could have led to cooling, freezing of CO_2 (polar caps) and thus more cooling.

Mars:Surface Water

Some large scale features on Mars seem to be clearly consistent with erosion by water in Mars history

Apron Covering Dunes



Mars:Surface Water

This image may suggest subsurface liquid water now or in Mars recent history. The outflow (similar to flash flooding on Earth covers a dune region were there is no evidence of cratering. It would appear that this feature is relatively modern.

Mars:Surface Water