Space & Atmospheric Physics

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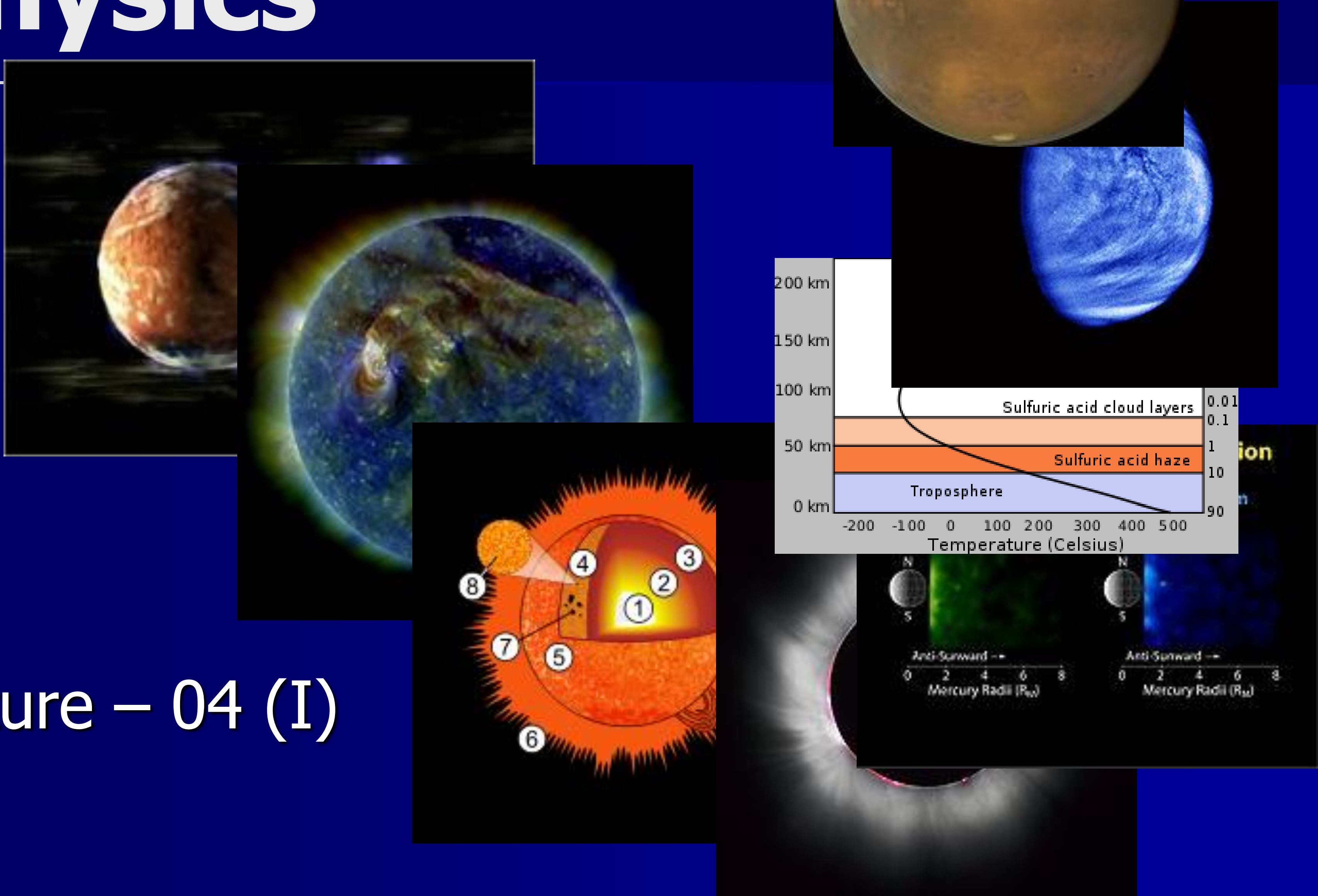


Lecture – 04 (I)

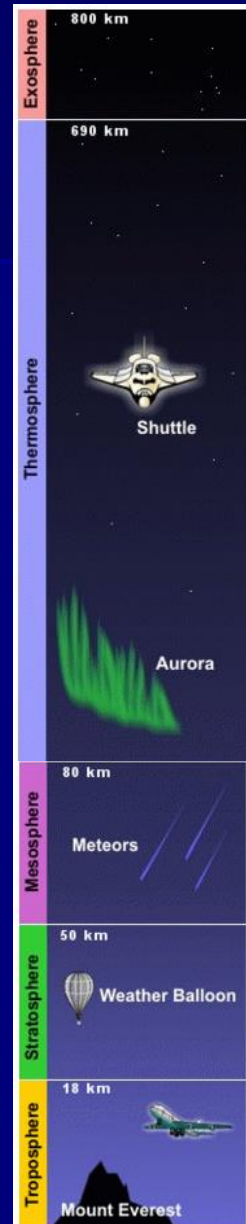
Planetary Atmospheres

Planetary Atmospheres

- Formation and Evolution of Planetary Atmospheres
- The Structure of the Terrestrial Atmosphere
- The Temperature of the Neutral Atmosphere
- The Escape of the Atmospheric Gases
- **The Atmospheres of the Planets**

Atmosphere of Earth

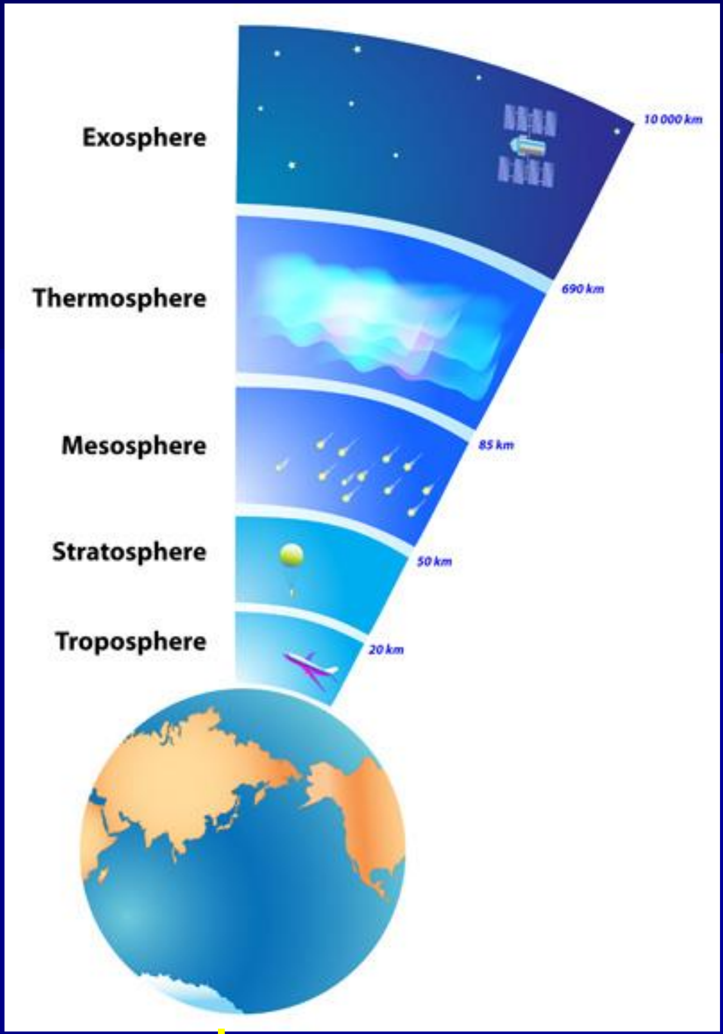
Atmosphere of Earth



Atmosphere of Earth

Atmospheric layers

The properties of the Earth's atmosphere vary with altitude. Based on these properties, the atmosphere may be regarded as having different layers or zones. According to one system of nomenclature, there are five layers:



the troposphere, stratosphere, mesosphere, thermosphere, and exosphere. The boundaries between these regions are called the tropopause, stratopause, mesopause, and exobase.

Atmosphere of Earth

Troposphere

The troposphere is the atmosphere's lowest and densest layer, and it is also known as the *lower atmosphere*. It starts from the Earth's surface and reaches up to about 7 km at the poles and 17 km at the equator, with some variation caused by weather factors. The upper boundary of this layer is called the *tropopause*.

The temperature of the **troposphere decreases with height**. At middle latitudes, the temperature drops from about +17° C at sea level to about -52° C at the beginning of the tropopause. At the poles, the troposphere is thinner and the temperature falls to only -45° C , while at the equator, the temperature at the top of the troposphere can reach -75° C.

Atmosphere of Earth

Stratosphere

The stratosphere is situated directly above the troposphere and just below the mesosphere. In terms of its altitude range, it lies between about 10 km and 50 km at moderate latitudes, but it starts at about 8 km at the poles. This layer is dynamically stable, with no regular mixing of air and associated turbulence.

The upper layers of the stratosphere are heated by the presence of an Ozone Layer that absorbs UV radiation from the Sun radiation that would otherwise be harmful to living organisms on Earth. The *stratopause* (at the top of the stratosphere) has a temperature of about 270K fairly close to the temperature at ground level.

Atmosphere of Earth

Mesosphere

The mesosphere is the layer between about 50 km and about 80–85 km above the Earth's surface. It is sandwiched between the stratosphere and the thermosphere. The temperature in this layer decreases with increasing altitude and can be as low as 200K (≈ -73° C), **varying according to latitude and season.**

Given that it lies between the maximum altitude for most aircraft and the minimum altitude for most spacecraft, this region of the atmosphere is directly accessible only through the use of sounding rockets. As a result, it is one of the most poorly understood regions of the atmosphere.

Atmosphere of Earth

Mesosphere….

Millions of meteors burn up daily in the mesosphere, as a result of collisions with the gas particles contained there, leading to a high concentration of iron and other metal atoms. The collisions almost always create enough heat to burn the falling objects long before they reach the ground. Thus the mesosphere protects the Earth from a barrage of would-be meteorites.

The stratosphere and mesosphere are referred to as the *middle atmosphere*. Regions above the mesosphere are called the *upper atmosphere*.

The *mesopause*, at an altitude of about 80 km, separates the mesosphere from the thermosphere. The mesopause lies near the *turbopause*, the band below which different chemical species are well mixed by turbulent eddies.

Atmosphere of Earth

Thermosphere

The thermosphere extends from an altitude of 80–85 km to 640+ km. It lies directly above the mesosphere and right below the exosphere.

At these high altitudes, the residual atmospheric gases sort into strata according to their molecular masses. The temperature in this layer increases with altitude, **due to the absorption of extremely energetic solar radiation by the small amount of oxygen present.**

Atmosphere of Earth

Thermosphere

Temperatures are highly dependent on solar activity and can rise to 2,000° C. Solar radiation causes the air particles in this layer to become ionized, that is, electrically charged.

Astronauts travel at altitudes that exceed 80 km, which means that they travel within or go beyond the thermosphere. An altitude of 120 km marks the boundary where atmospheric effects become noticeable during re-entry.

Atmosphere of Earth

Exosphere

The exosphere is the uppermost layer of the atmosphere. Its lower boundary at the edge of the thermosphere is estimated to be 500 km to 1,000 km above the Earth's surface, and its upper boundary at about 10,000 km.

Atmosphere of Earth

Exosphere

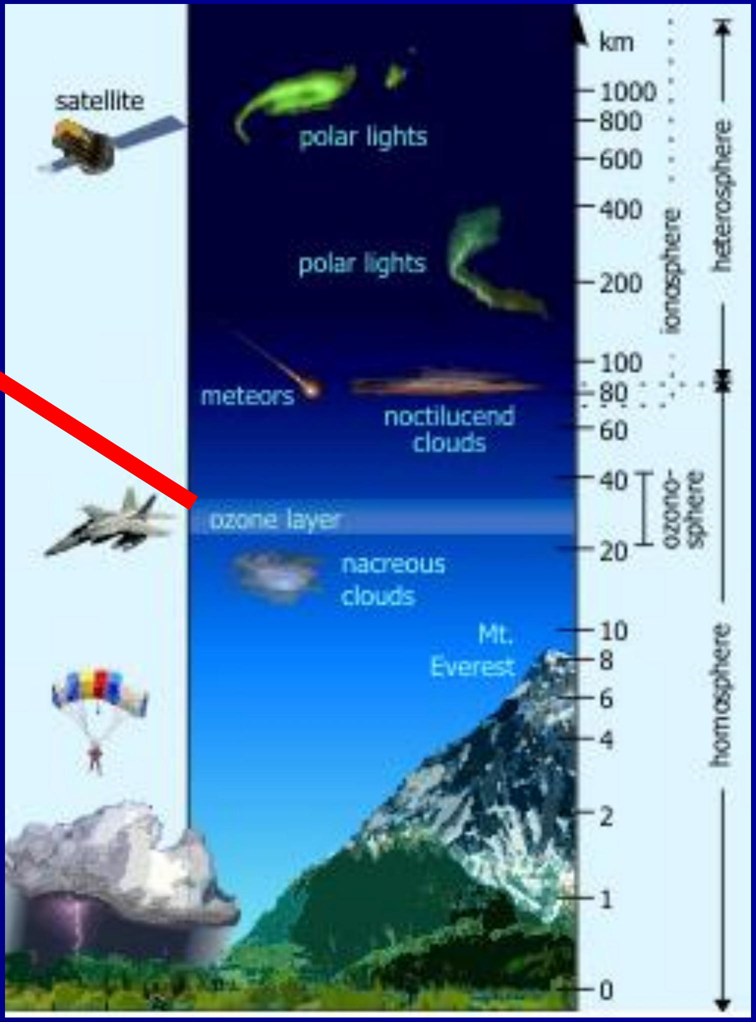
It is only from the exosphere that atmospheric gases can, to any appreciable extent, escape into outer space. The main gases in the exosphere are the lightest ones, mainly hydrogen and helium, with some atomic oxygen near the exobase (the lowest altitude of the exosphere). The few particles of gas here can reach 2,500° C during the day.

Atmosphere of Earth

Additional atmospheric regions

Atmospheric regions are also named in other ways, as follows.

Ozone layer (Ozonosphere):
In the stratosphere, in an altitude range of about 10–50 km, the concentration of ozone (O3) is a few parts per million, which is much higher than the ozone concentration in the lower atmosphere **This layer, absorbs biologically harmful UV radiation from the Sun**.



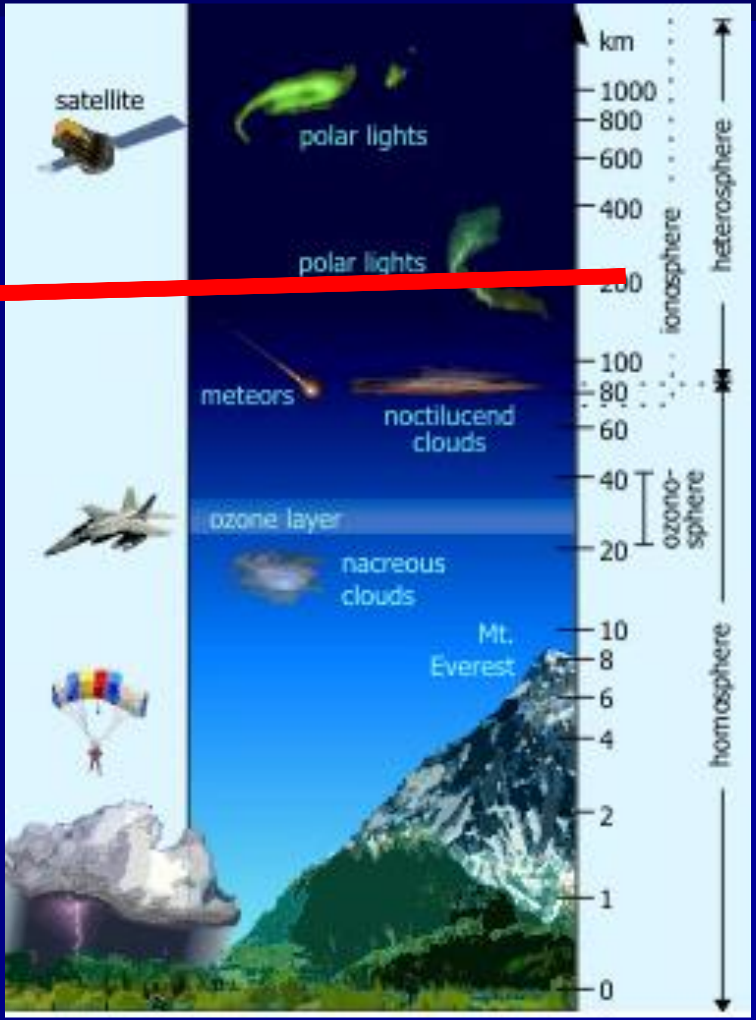
Atmosphere of Earth

Additional atmospheric regions

Atmospheric regions are also named in other ways, as follows.

Ionosphere:

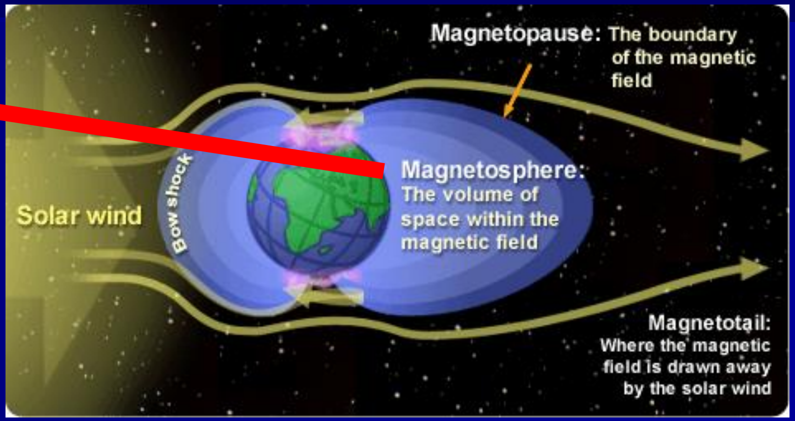
This is the region of the atmosphere that contains ions (that form a "plasma"), created by the interaction of solar radiation with gas particles.



Atmosphere of Earth

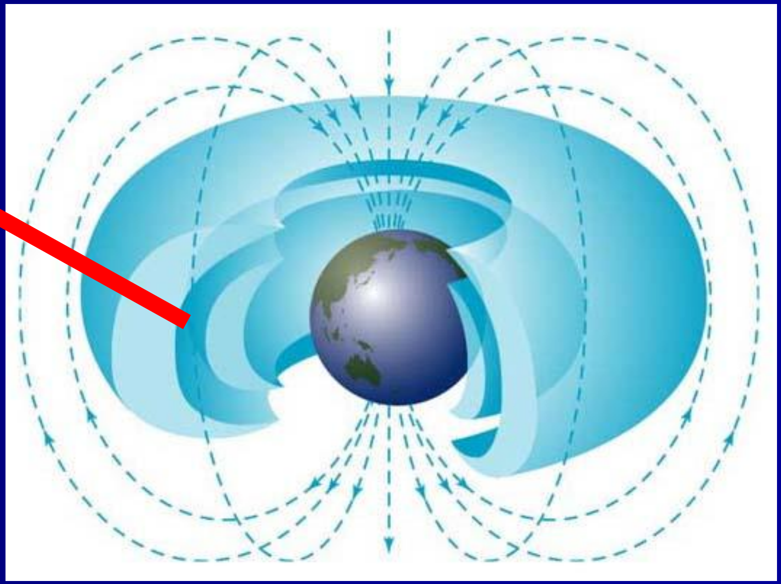
Additional atmospheric regions

Atmospheric regions are also named in other ways, as follows.



Magnetosphere:

It is the region where the Earth's magnetic field interacts with the solar wind.



Van Allen radiation belts:

These are regions where charged particles (forming a plasma) from the solar wind are trapped by the Earth's magnetic field.

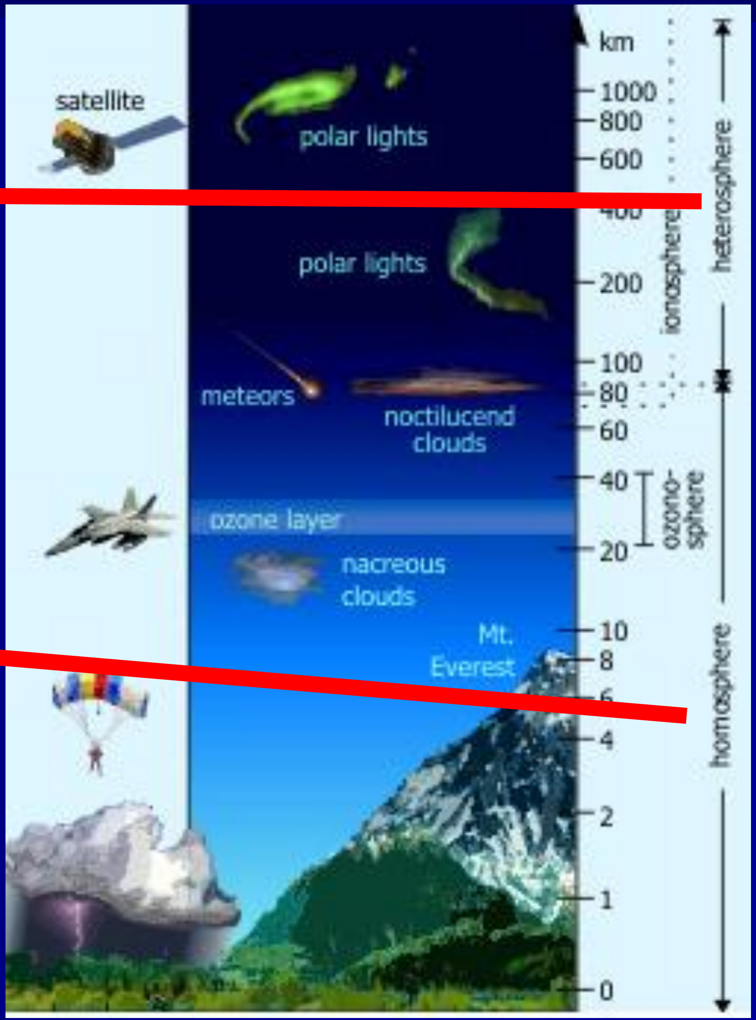
Atmosphere of Earth

Additional atmospheric regions

Atmospheric regions are also named in other ways, as follows.

Homosphere (or Turbosphere) and Heterosphere:

The region below the turbopause (that is, below an altitude of about 100 km) is known as the *homosphere* or *turbosphere*, where the chemical constituents are well mixed and the composition of the atmosphere remains fairly uniform.



Atmosphere of Earth

Pressure, density, and mass

Atmospheric pressure (or barometric pressure) is a direct result of the weight of the air. It is highest at the Earth's surface and decreases with altitude. This is because air at the surface is compressed by the weight of all the air above it. Air pressure varies with location and time, because the amount (and weight) of air above the Earth varies with location and time.

Atmosphere of Earth

Pressure, density, and mass

Atmospheric pressure drops by approximately 50 percent at an altitude of about 5 km. The average atmospheric pressure at sea level is about 101.3 kilopascals.

The density of air at sea level is about 1.2 kg/m3, and it decreases as altitude increases.

The average mass of the atmosphere is about 5,000 trillion metric tons.

Atmosphere of Earth

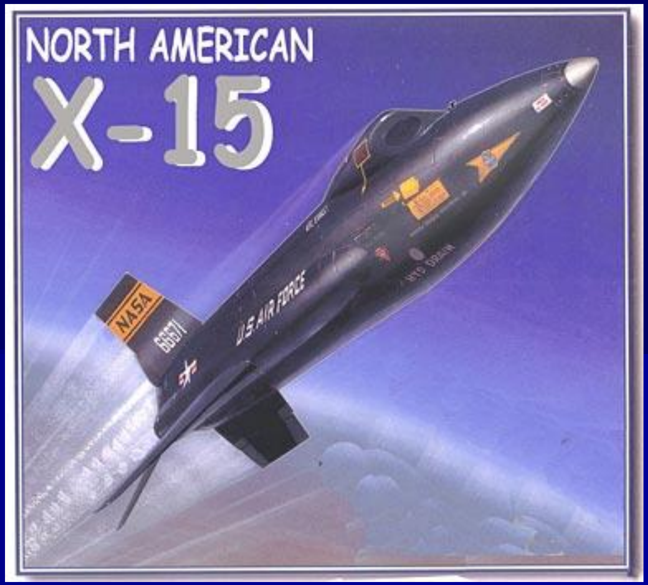
Thickness of the atmosphere

57.8 percent of the atmosphere is below the summit of Mount Everest.

72 percent of the atmosphere is below the common cruising altitude of commercial airliners (about 10,000 m).

Atmosphere of Earth

Thickness of the atmosphere



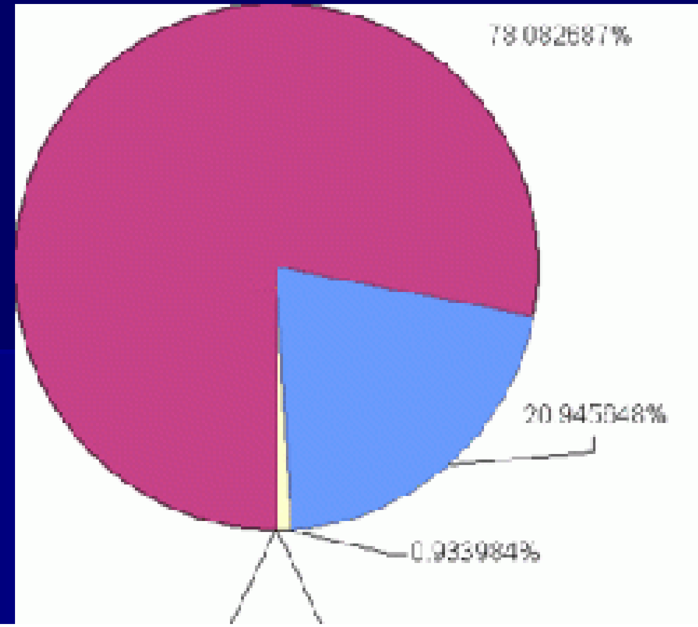
99.99999 percent of the atmosphere is below the highest flight altitude of the aircraft X-15, which reached 108 km on August 22, 1963. Therefore, most of the atmosphere (99.9999 percent) is below 100 km, although in the rarified region above this there are auroras and other atmospheric effects.

The atmosphere exists at altitudes of 1,000 km and higher, but it is so thin as to be considered nonexistent.

Atmosphere of Earth

Composition of the atmosphere

Composition of dry atmosphere (homosphere), by volume	
ppmv: parts per million by volume	
Gas	**Volume**
Nitrogen (N_2)	780,840 ppmv (78.084%)
Oxygen (O_2)	209,460 ppmv (20.946%)
Argon (Ar)	9,340 ppmv (0.9340%)
Carbon dioxide (CO_2)	350 ppmv
Neon (Ne)	18.18 ppmv
Helium (He)	5.24 ppmv
Methane (CH_4)	1.745 ppmv
Krypton (Kr)	1.14 ppmv
Hydrogen (H_2)	0.55 ppmv
Not included in above dry atmosphere:	
Water vapor (highly variable)	typically 1%



Minor components of air not listed above include:

Gas	Volume
nitrous oxide	0.5 ppmv
xenon	0.09 ppmv
ozone	0.0 to 0.07 ppmv
nitrogen dioxide	0.02 ppmv
iodine	0.01 ppmv
carbon monoxide	trace
ammonia	trace

Atmosphere of Earth

Biological significance

The Earth's atmosphere plays a vital role in sustaining life on this planet. **Oxygen is needed for respiration by animals, plants, and some bacteria.**

Plants that perform **photosynthesis** take up carbon dioxide from the air and release oxygen.

Atmosphere of Earth

Biological significance

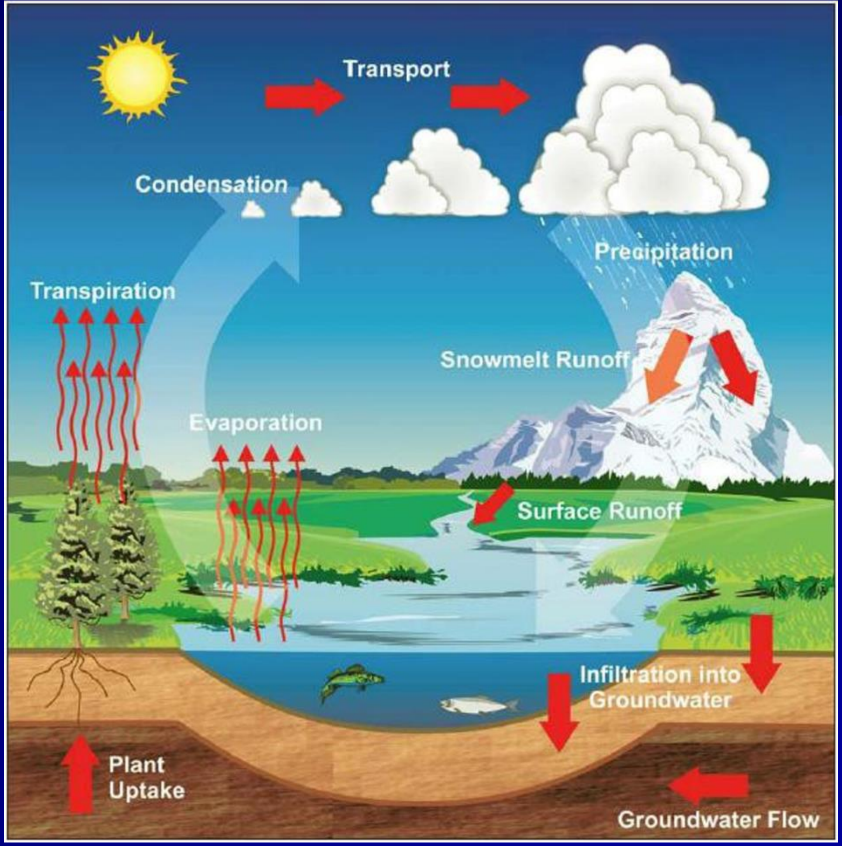
Carbon dioxide and water vapor act as "greenhouse gases" that keep the Earth sufficiently warm to maintain life.

Atmosphere of Earth

Biological significance

Water vapor in the air is part of the water cycle that produces **precipitation** (such as rain and snow) that replenishes **moisture in the soil**.

In addition, water vapor prevents **exposed living tissue** from drying up.

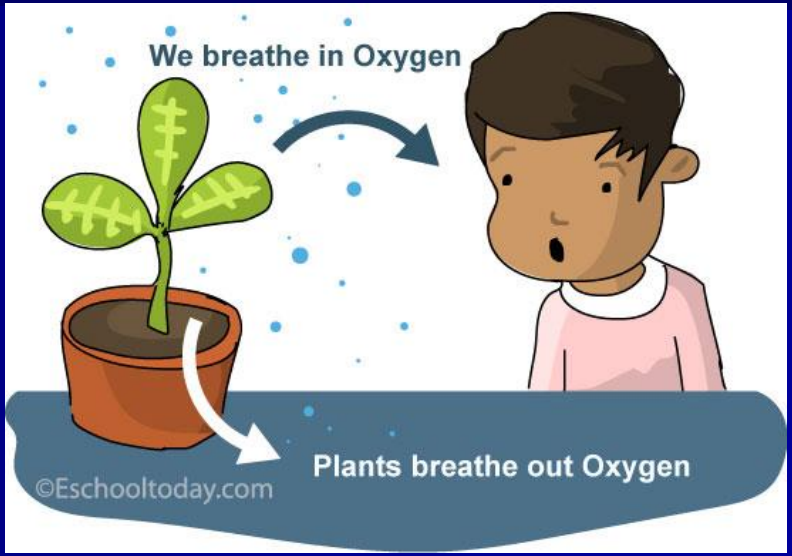


Atmosphere of Earth

Biological significance

Oxygen & Water

Oxygen helps organisms grow, reproduce, and turn food into energy. Humans get the oxygen they need by breathing through their nose and mouth into their lungs. Oxygen gives our cells the ability to break down food in order to get the energy we need to survive.



Atmosphere of Earth

Biological significance

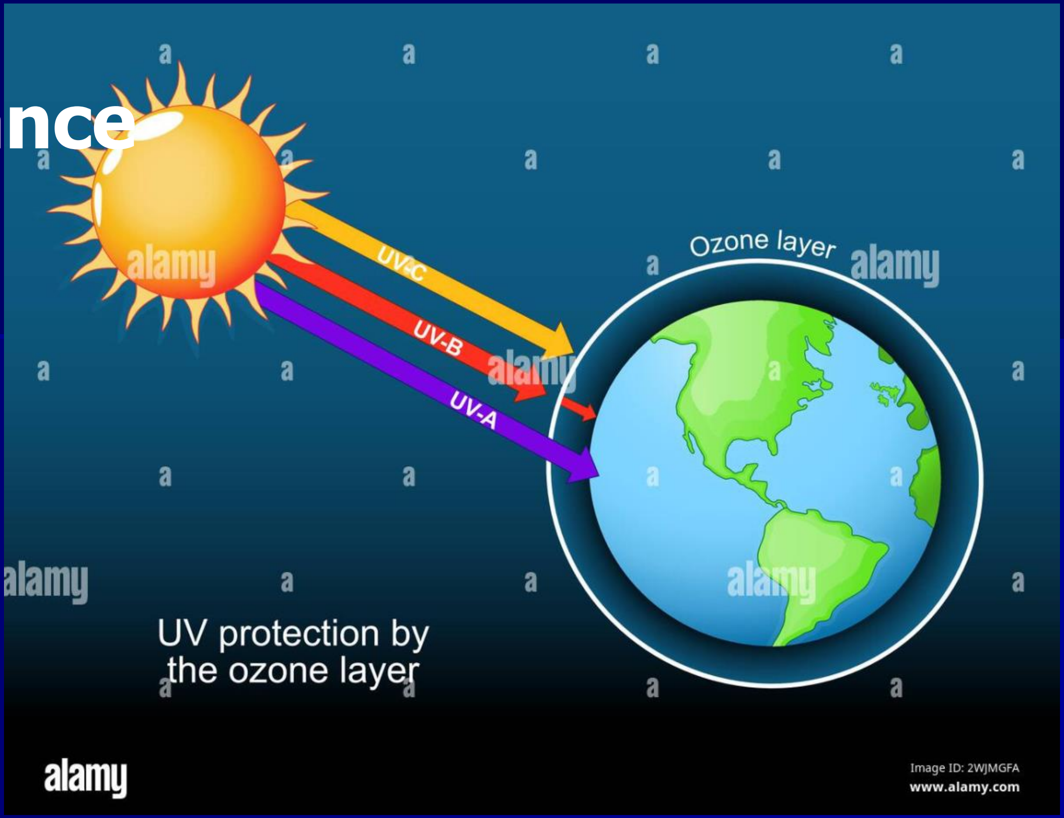
Oxygen & Water

On a biological level, **water**'s role as a solvent helps cells transport and use substances like oxygen or nutrients. Water-based solutions like blood help carry molecules to the necessary locations.

Atmosphere of Earth

Biological significance

Ozone Layer



The ozone layer **protects us from the UV radiation**, known as UV-B, which causes sunburn. Long-term exposure to high levels of UV-B threatens human health and damages most animals, plants and microbes, so the ozone layer protects all life on Earth.

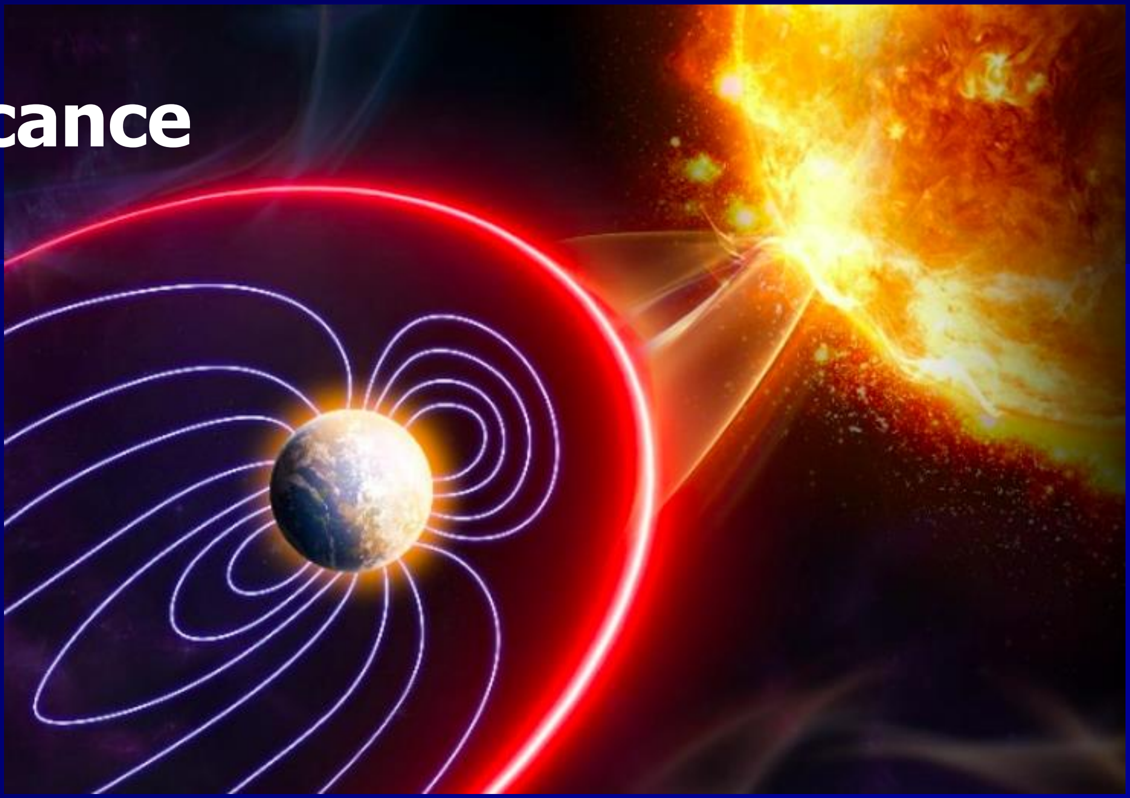
Atmosphere of Earth

Biological significance

Gravity

We could not live on Earth without it. The sun's gravity keeps Earth in orbit around it, keeping us at a comfortable distance to enjoy the sun's light and warmth. It holds down our atmosphere and the air we need to breathe. Gravity is what holds our world together.

Biological significance



Magnetic Field

Generated by the motion of molten iron in Earth's core, the magnetic field protects our planet from cosmic radiation and from the charged particles emitted by our Sun.

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Atmosphere of Earth

Air pollution

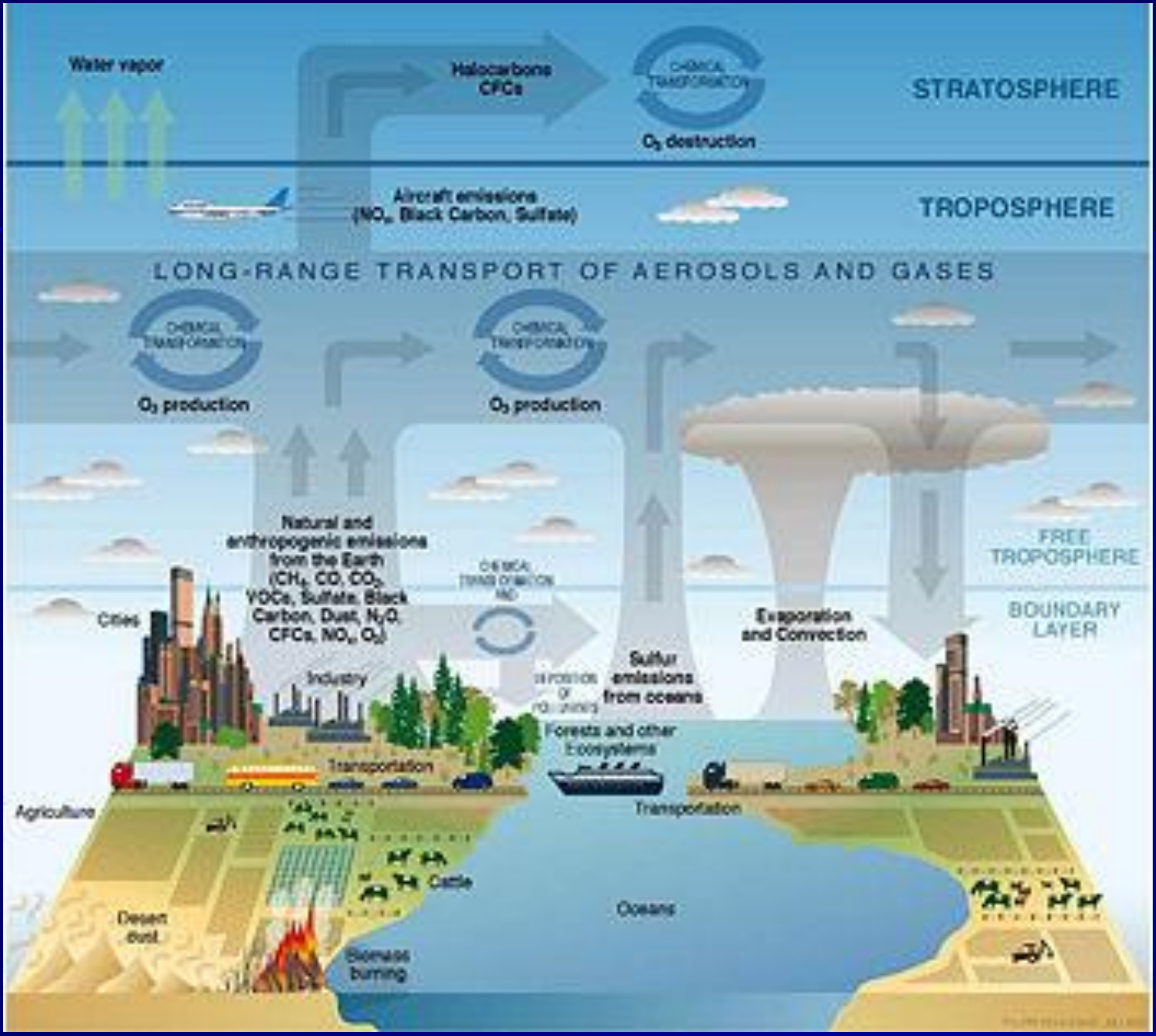


Diagram of chemical and transport processes related to atmospheric composition.

Air pollution

Although technological advances have benefited humankind in numerous ways, they have been accompanied by adverse effects on the environment, including pollution of the air.

Common air pollutants include carbon monoxide (**CO**), nitrogen oxides (NOx), sulfur oxides (SOx), ozone, and particulate matter (PM). They are generally produced by such activities as

Air pollution

Common air pollutants include carbon monoxide (**CO**), nitrogen oxides (NOx), sulfur oxides (SOx), ozone, and particulate matter (PM). They are generally produced by such activities as

(a) combustion (burning) of fuels for transportation and the generation of heat and electricity, and

(b) industrial processes, including petroleum refining, cement manufacturing, and metal processing.

Air pollution

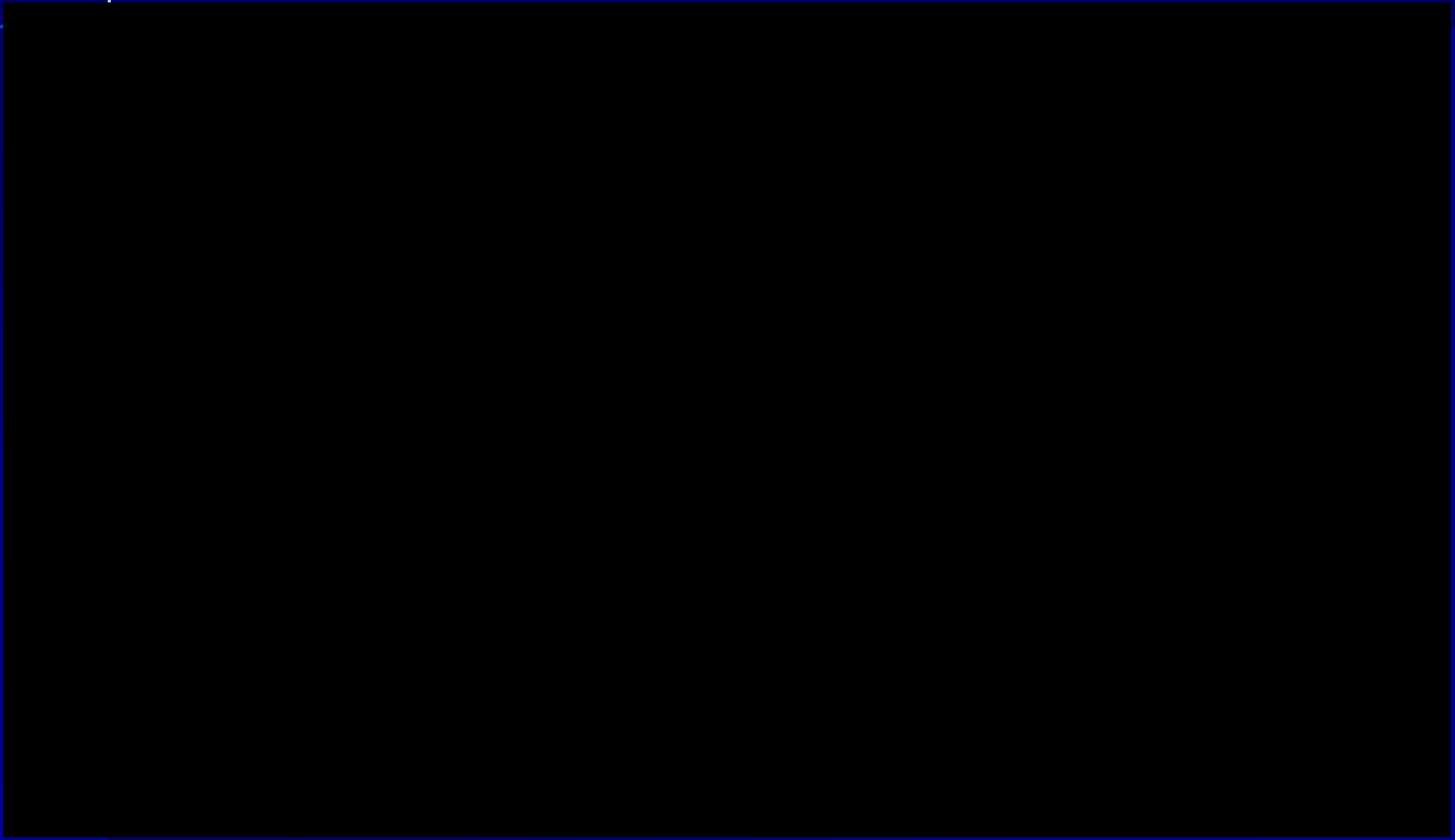
To reduce such pollutants, the governments of various nations have mandated measures such as the use of reformulated gasoline, catalytic converters in motor vehicle exhaust systems, and effluent traps for industrial wastes.

In addition to the problem of pollution, there is concern that global temperatures are rising as a result of increasing levels of greenhouse gases such as carbon dioxide and methane in the atmosphere.

Atmosphere of Earth

Air pollution :

UN issues warning over air pollution



Atmosphere of Moon

Atmosphere of Moon

For most practical purposes, the Moon is considered to be surrounded by vacuum. The elevated presence of atomic and molecular particles in its vicinity (compared to interplanetary medium), referred to as 'lunar atmosphere' for scientific objectives is negligible in comparison with gaseous envelope surrounding Earth and most planets of the solar system - less than one hundred trillionth of Earth's atmospheric density at sea level.

Atmosphere of Moon

One source of the lunar atmosphere is out gassing: the release of gases such as radon and helium that originate from radioactive decay within the crust and mantle. Another important source is the bombardment of the lunar surface by micrometeorites, the solar wind, and sunlight, in a process known as sputtering.

Gases that are released by sputtering can either:

- be re-implanted into the regolith as a result of the Moon's gravity;
- be lost to space either by solar radiation pressure or, if the gases are ionized, by being swept away in the solar wind's magnetic field.

Atmosphere of Moon

The elements sodium and potassium have been detected in the Moon's atmosphere using Earth-based spectroscopic methods, whereas the isotopes radon-222 and polonium-210 have been inferred from data obtained by the Lunar Prospector alpha particle spectrometer. Argon-40, helium-4, oxygen and/or methane (CH4), nitrogen (N2) and/or carbon monoxide (CO), and carbon monoxide (CO2)) were detected by in-situ detectors placed by the Apollo astronauts.

Atmosphere of Moon

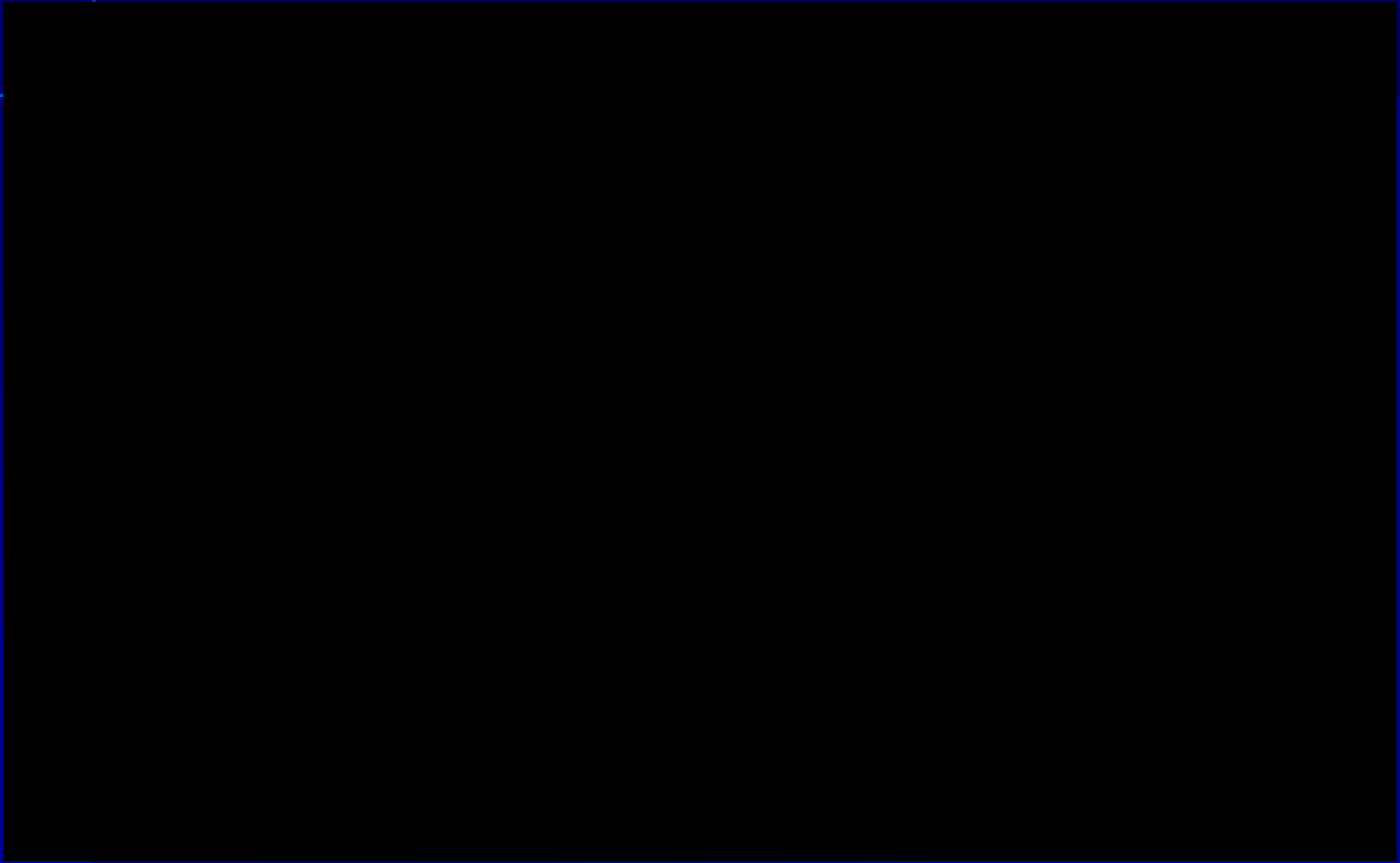
The average daytime abundances of the elements known to be present in the lunar atmosphere, in atoms per cubic centi-meter, are as follows:

- Argon: 40,000
- Helium: 2,000-40,000
- Sodium: 70
- Potassium: 17
- Hydrogen: fewer than 17

The **Moon is often considered to not have an atmosphere**, as it cannot absorb measurable quantities of radiation and does not appear layered or self-circulating.

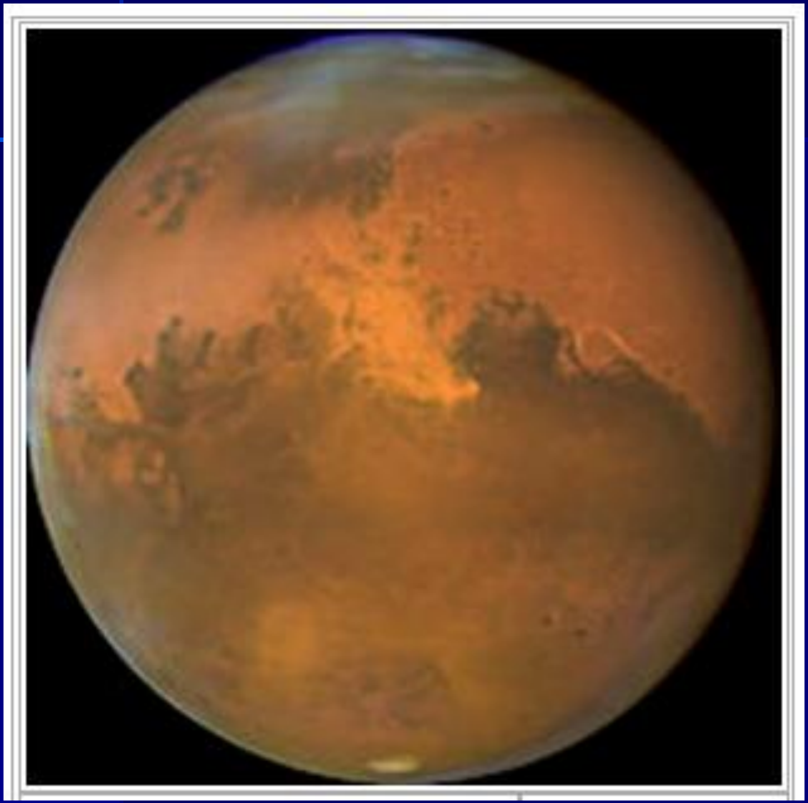
Atmosphere of Moon

Moon's Strange Atmosphere: NASA to Probe Lunar Dust | Video



Atmosphere of Mars

Atmosphere of Mars



Carbon dioxide	95.32%
Nitrogen	2.7%
Argon	1.6%
Oxygen	0.13%
Carbon monoxide	0.07%
Water vapor	0.03%
Nitric oxide	0.013%
Neon	2.5 ppm
Krypton	300 ppb
Formaldehyde	130 ppb
Xenon	80 ppb
Ozone	30 ppb
Methane	10.5 ppb

Atmosphere of Mars

History

Mars' atmosphere is believed to have changed over the course of the planet's lifetime, with evidence suggesting the possibility that Mars had large oceans a few billion years ago.

As stated in the **Mars Ocean Hypothesis**, atmospheric pressure on the present day Martian surface only exceeds that of the triple point of water (6.11 hectopascals in the lowest elevations; at higher elevations water can exist only in solid or vapor form)

Atmosphere of Mars

History

Annual mean temperatures at the surface are currently less than 210 K (−63 °C), significantly less than what is needed to sustain liquid water. However, early in its history Mars may have had conditions more conducive to retaining liquid water at the surface.

Atmosphere of Mars

Structure

Mars' atmosphere is composed of the following major layers:

Lower atmosphere: This is a warm region affected by heat from airborne dust and from the ground.

Middle atmosphere: Mars has a Jetstream, which flows in this region.

Atmosphere of Mars

Structure

Upper atmosphere, or thermosphere: This region has very high temperatures, caused by heating from the Sun. Atmospheric gases start to separate from each other at these altitudes, rather than forming the even mix found in the lower atmospheric layers.

Exosphere: Typically stated to start at 200 kilometers and higher, this region is where the last wisps of atmosphere merge into the vacuum of space. There is no distinct boundary where the atmosphere ends; it just tapers away.

Atmosphere of Mars

Composition…

Potential for use by humans

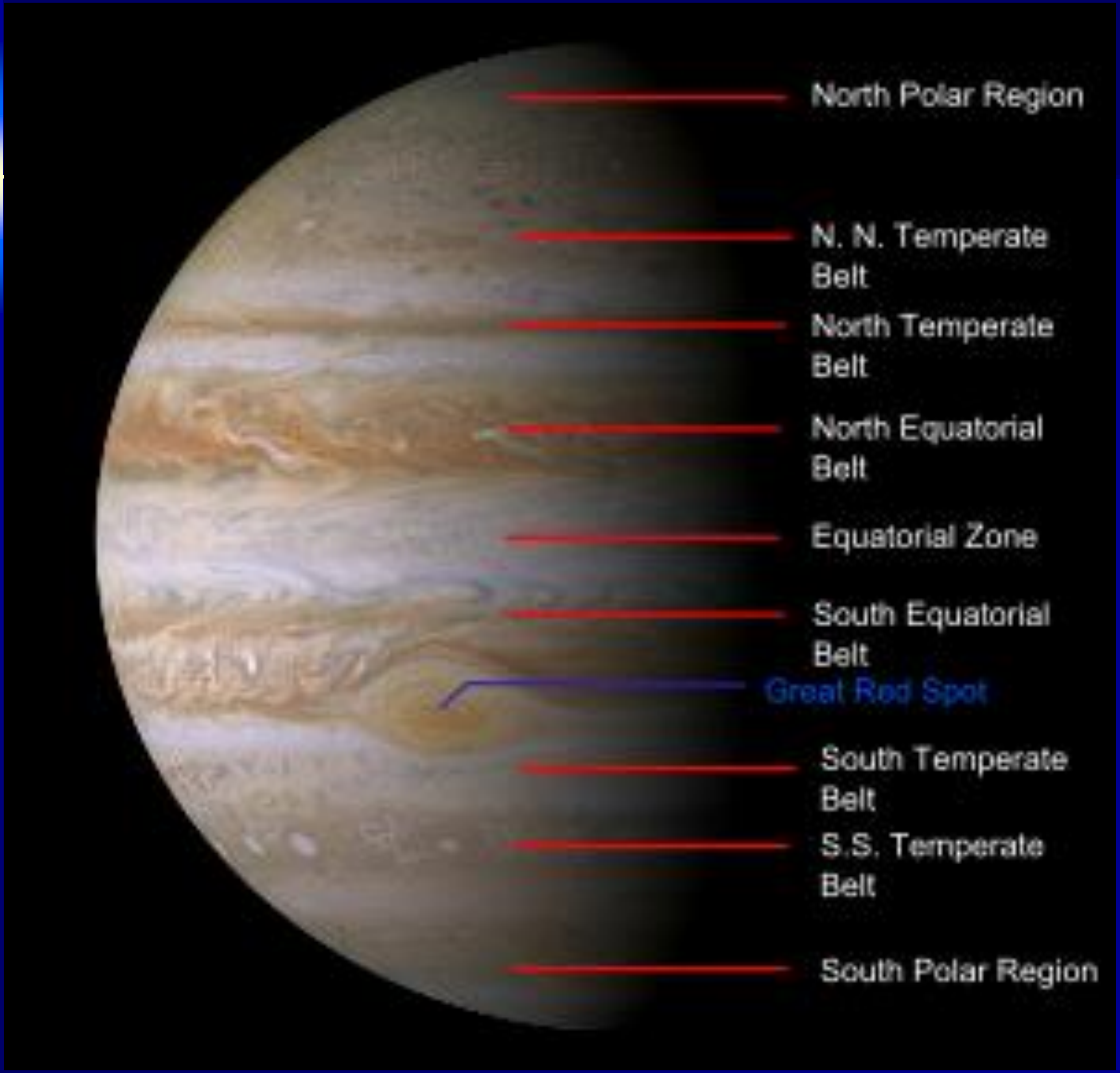
The atmosphere of Mars is a resource of known composition available at any landing site on Mars. It has therefore been proposed that human exploration of Mars could use carbon dioxide from Martian atmosphere as feedstock to make rocket fuel for the return mission.

Atmosphere of Mars

The Mars Atmosphere

Atmosphere of Jupiter

Atmosphere of Jupiter



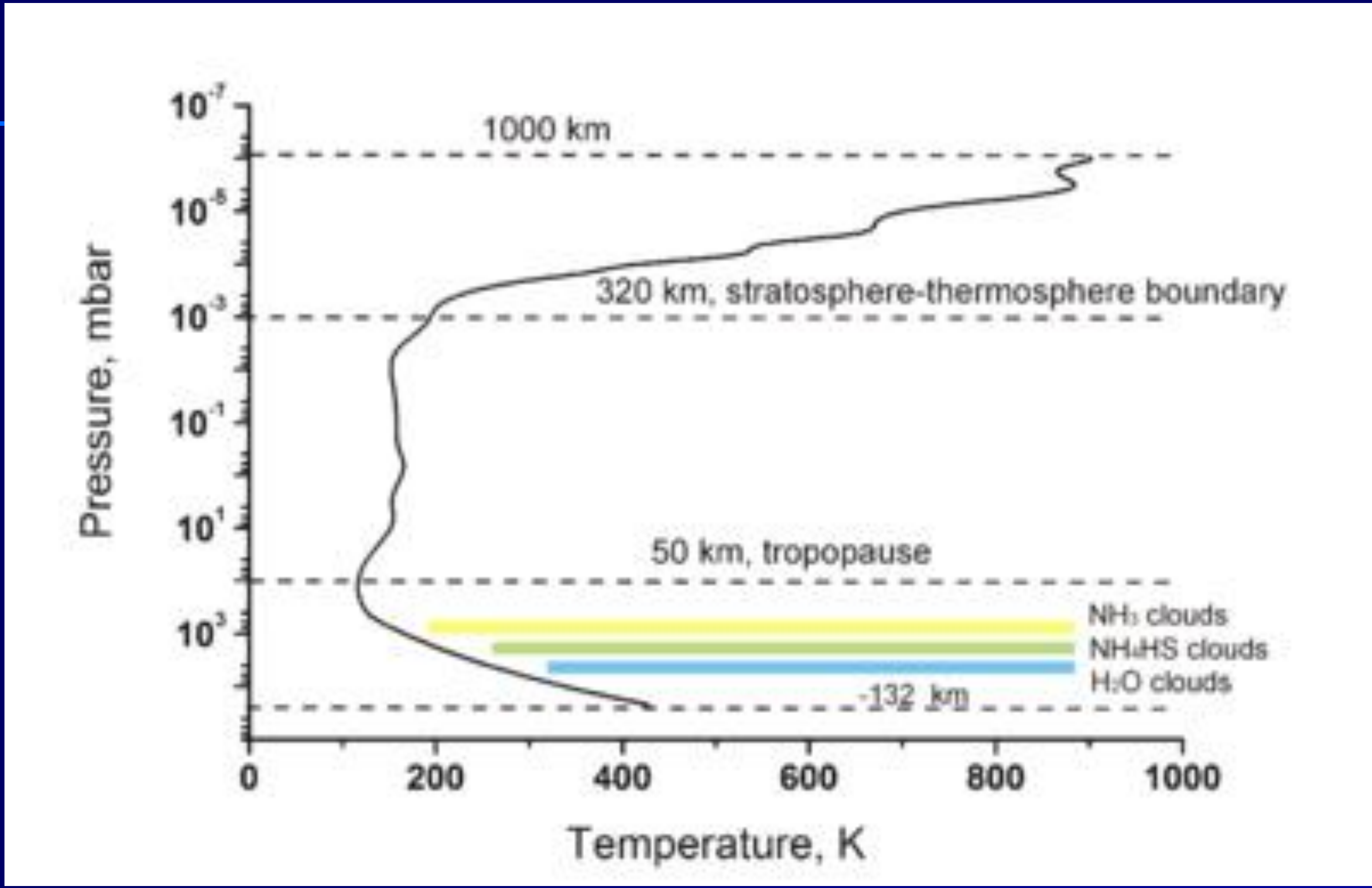
Cloud pattern
on Jupiter in 2005

Atmosphere of Jupiter

Jupiter: Crash Course Astronomy #16

Atmosphere of Jupiter

Vertical structure



Vertical structure of the atmosphere of Jupiter. Note that the pressure drops together with altitude. The Galileo atmospheric probe stopped transmitting at a depth of 132 km below the 1 bar "surface" of Jupiter.

Atmosphere of Jupiter

Vertical structure…

The atmosphere of Jupiter is classified into four layers, by increasing altitude: the troposphere, stratosphere, thermosphere and exosphere. Unlike the Earth’s atmosphere, Jupiter's lacks a mesosphere. Jupiter does not have a solid surface, and the lowest atmospheric layer, the troposphere, smoothly transitions into the planet's fluid interior.

The temperature of the troposphere decreases with height until it reaches a minimum at the tropopause, which is the boundary between the troposphere and stratosphere. On Jupiter, the tropopause is approximately 50 km above the visible clouds (or 1 bar level), where the pressure and temperature are about 0.1 bar and 110 K.

Vertical structure…

In the stratosphere, the temperatures rise to about 200 K at the transition into the thermosphere, at an altitude and pressure of around 320 km and 1 μbar. In the thermosphere, temperatures continue to rise, eventually reaching 1000 K at about 1000 km, where pressure is about 1 nbar.

The high temperatures prevalent in the thermosphere (800–1000 K) have not been fully explained yet; existing models predict a temperature no higher than about 400 K. They may be caused by absorption of high-energy solar radiation (UV or X-ray), by heating from the charged particles precipitating from the Jovian magnetosphere, or by dissipation of upward-propagating gravity waves.

Atmosphere of Jupiter

Vertical structure…

The thermosphere and exosphere at the poles and at low latitudes emit X-rays, which were first observed by the Einstein Observatory in 1983.

The thermosphere was the first place outside the Earth where the trihydrogen cation (H+3) was discovered. This ion emits strongly in the mid-infrared part of the spectrum, at wavelengths between 3 and 5 μm; this is the main cooling mechanism of the thermosphere.

Atmosphere of Jupiter

Chemical composition

Elemental abundances relative to hydrogen in Jupiter and Sun		
Element	Sun	Jupiter/Sun
He/H	0.0975	0.807 ± 0.02
Ne/H	1.23×10^{-4}	0.10 ± 0.01
Ar/H	3.62×10^{-6}	2.5 ± 0.5
Kr/H	1.61×10^{-9}	2.7 ± 0.5
Xe/H	1.68×10^{-10}	2.6 ± 0.5
C/H	3.62×10^{-4}	2.9 ± 0.5
N/H	1.12×10^{-4}	3.6 ± 0.5 (8 bar) 3.2 ± 1.4 (9–12 bar)
O/H	8.51×10^{-4}	0.033 ± 0.015 (12 bar) 0.19–0.58 (19 bar)
P/H	3.73×10^{-7}	0.82
S/H	1.62×10^{-5}	2.5 ± 0.15

Isotopic ratios in Jupiter and Sun		
Ratio	Sun	Jupiter
$^{13}C/^{12}C$	0.011	0.0108 ± 0.0005
$^{15}N/^{14}N$	$<2.8 \times 10^{-3}$	$2.3 \pm 0.3 \times 10^{-3}$ (0.08–2.8 bar)
$^{36}Ar/^{38}Ar$	5.77 ± 0.08	5.6 ± 0.25
$^{20}Ne/^{22}Ne$	13.81 ± 0.08	13 ± 2
$^{3}He/^{4}He$	$1.5 \pm 0.3 \times 10^{-4}$	$1.66 \pm 0.05 \times 10^{-4}$
D/H	$3.0 \pm 0.17 \times 10^{-5}$	$2.25 \pm 0.35 \times 10^{-5}$

Atmosphere of Jupiter

Zones, belts and jets

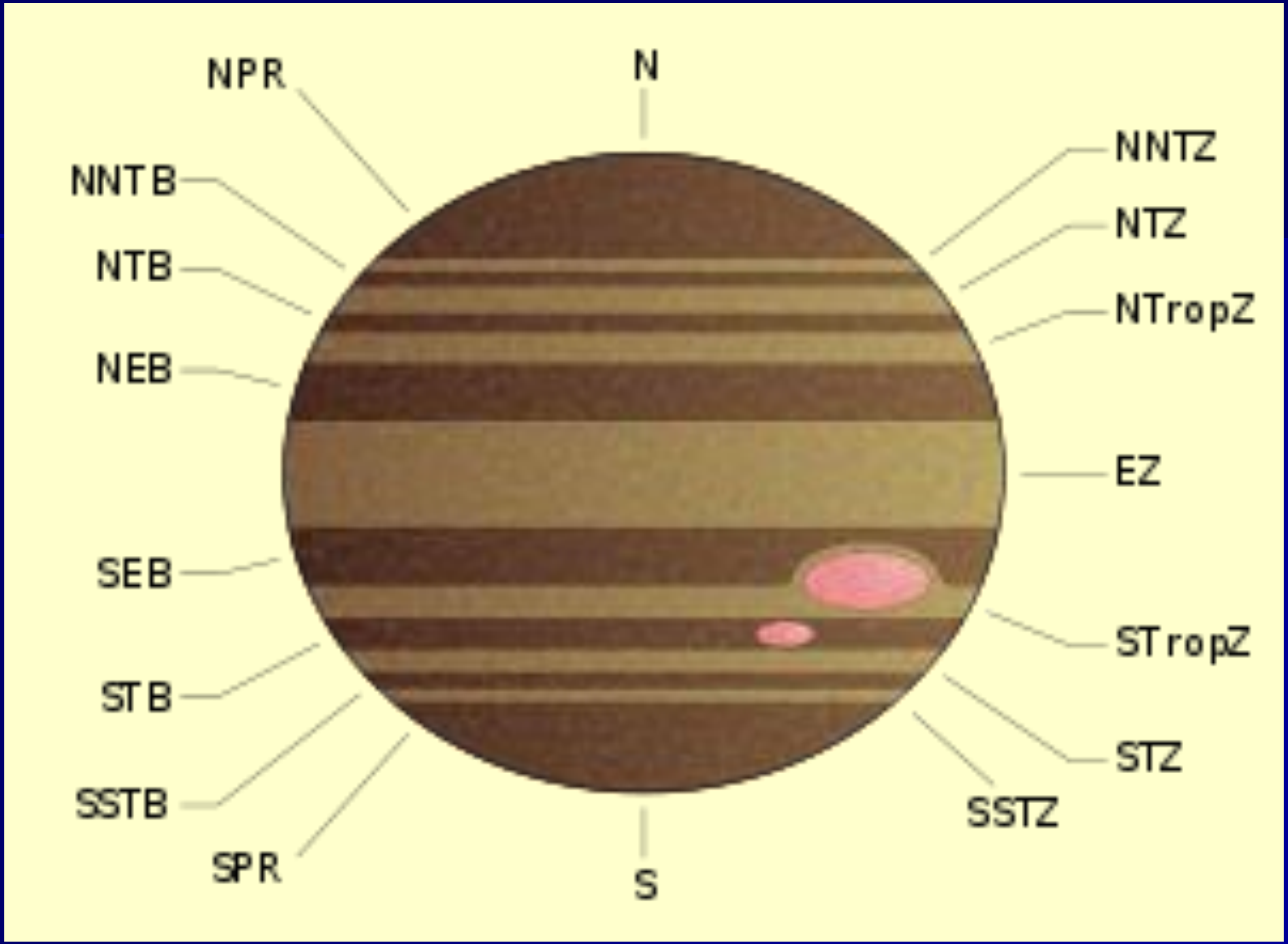
The most detailed map of Jupiter ever produced; taken by Cassini.

The visible surface of Jupiter is divided in a number of bands parallel to the equator.

There are two types of bands:
lightly colored *zones* and **relatively dark *belts*.**
Farther from the equator lie the **North and South Tropical zones** (NtrZ and STrZ).

Atmosphere of Jupiter

Specific bands



Idealized illustration of Jupiter's cloud bands, labeled with their official abbreviations. Lighter zones are indicated to the right, darker belts to the left. The Great Red Spot and Oval BA are shown in the South Tropical Zone and South Temperate Belt, respectively.

Atmosphere of Jupiter

Dynamics

2009

2010

Circulation in Jupiter's atmosphere is markedly different from that in the atmosphere of Earth. The interior of Jupiter is fluid and lacks any solid surface. Therefore, convection may occur throughout the planet's outer molecular envelope.

Atmosphere of Jupiter

Internal heat

As has been known since 1966, Jupiter radiates much more heat than it receives from the Sun.

It is estimated that the ratio between the power emitted by the planet and that absorbed from the Sun is 1.67 ± 0.09.

The internal heat flux from Jupiter is 5.44 ± 0.43 W/m2, whereas the total emitted power is 335 ± 26 petawatts. The latter value is approximately equal to one billionth of the total power radiated by the Sun. This excess heat is mainly the primordial heat from the early phases of Jupiter's formation, but may result in part from the precipitation of helium into the core.

Atmosphere of Jupiter

Discrete features - Vortices

The atmosphere of Jupiter is home to hundreds of vortices circular rotating structures that, as in the Earth’s atmosphere, can be divided into two classes:

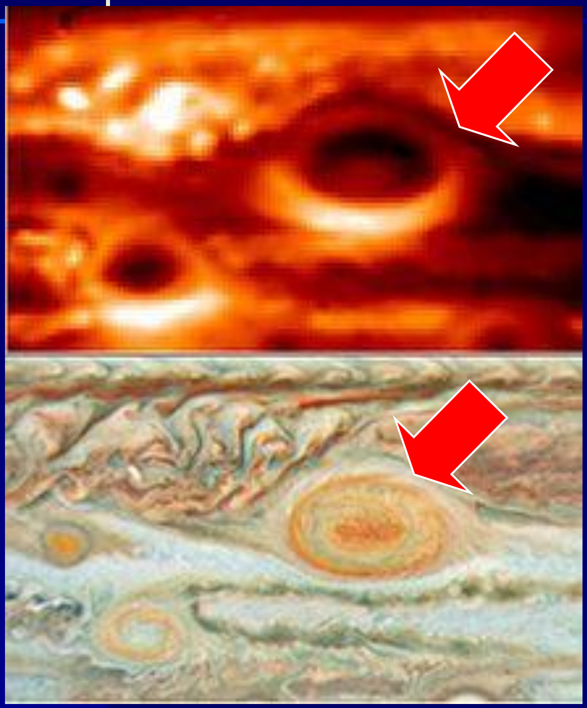
cyclones and anti cyclones.

The former rotate in the direction similar to the rotation of the planet (counter- clock-wise in the northern hemisphere and clock-wise in the southern)

Atmosphere of Jupiter

Discrete features

- Great Red Spot



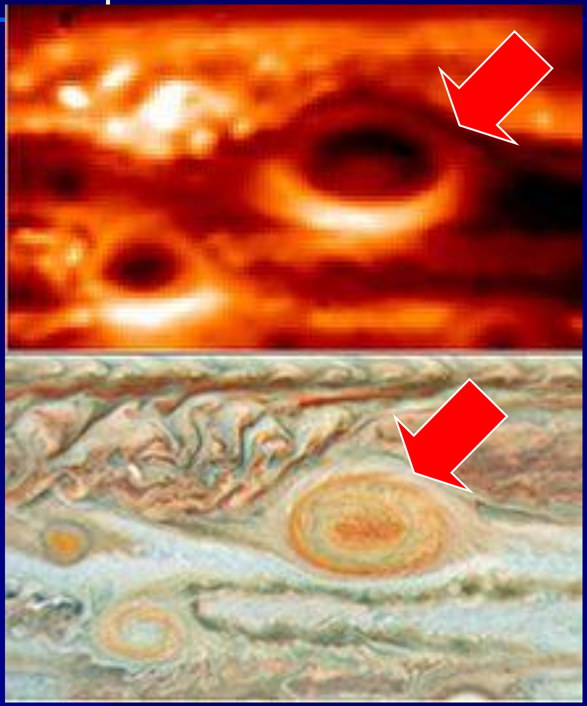
An infrared image of GRS (top) showing its warm center, taken by the ground based Very Large Telescope. An image made by the Hubble Space Telescope (bottom) is shown for comparison.

The Great Red Spot (GRS) is a persistent anticyclonic storm, 22° south of Jupiter's equator, which has lasted for at least 181 years and possibly as long as 346 years or more. The storm is large enough to be visible through Earth-based telescopes.

The GRS rotates counterclockwise, with a period of about six Earth days or 14 Jovian days. Its dimensions are 24 – 40,000 km west–to–east and 12 – 14,000 km south–to–north. The spot is large enough to contain two or three planets the size of Earth.

Atmosphere of Jupiter

Discrete features - Great Red Spot



An infrared image of GRS (top) showing its warm center, taken by the ground based Very Large Telescope. An image made by the Hubble Space Telescope (bottom) is shown for comparison.

Approximate size comparison of Earth and the GRS

Atmosphere of Jupiter

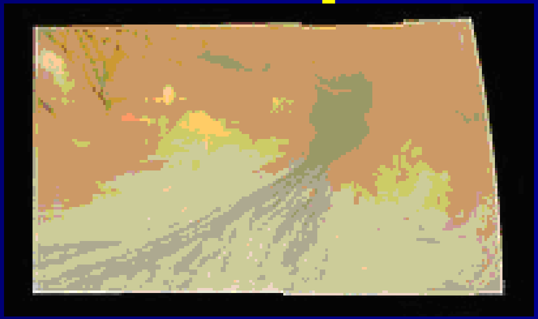
Discrete features - Oval BA

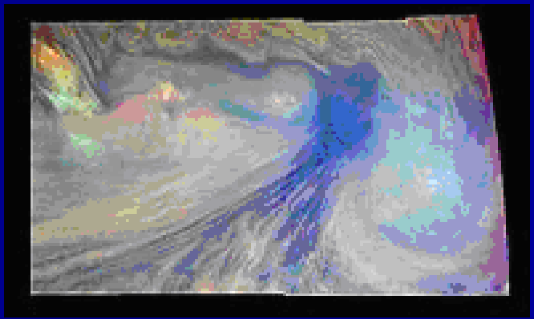
Oval BA (left)

- Storms and lightning

Lightning on Jupiter's night side, imaged by the Galileo orbiter in 1997

- Hot spots

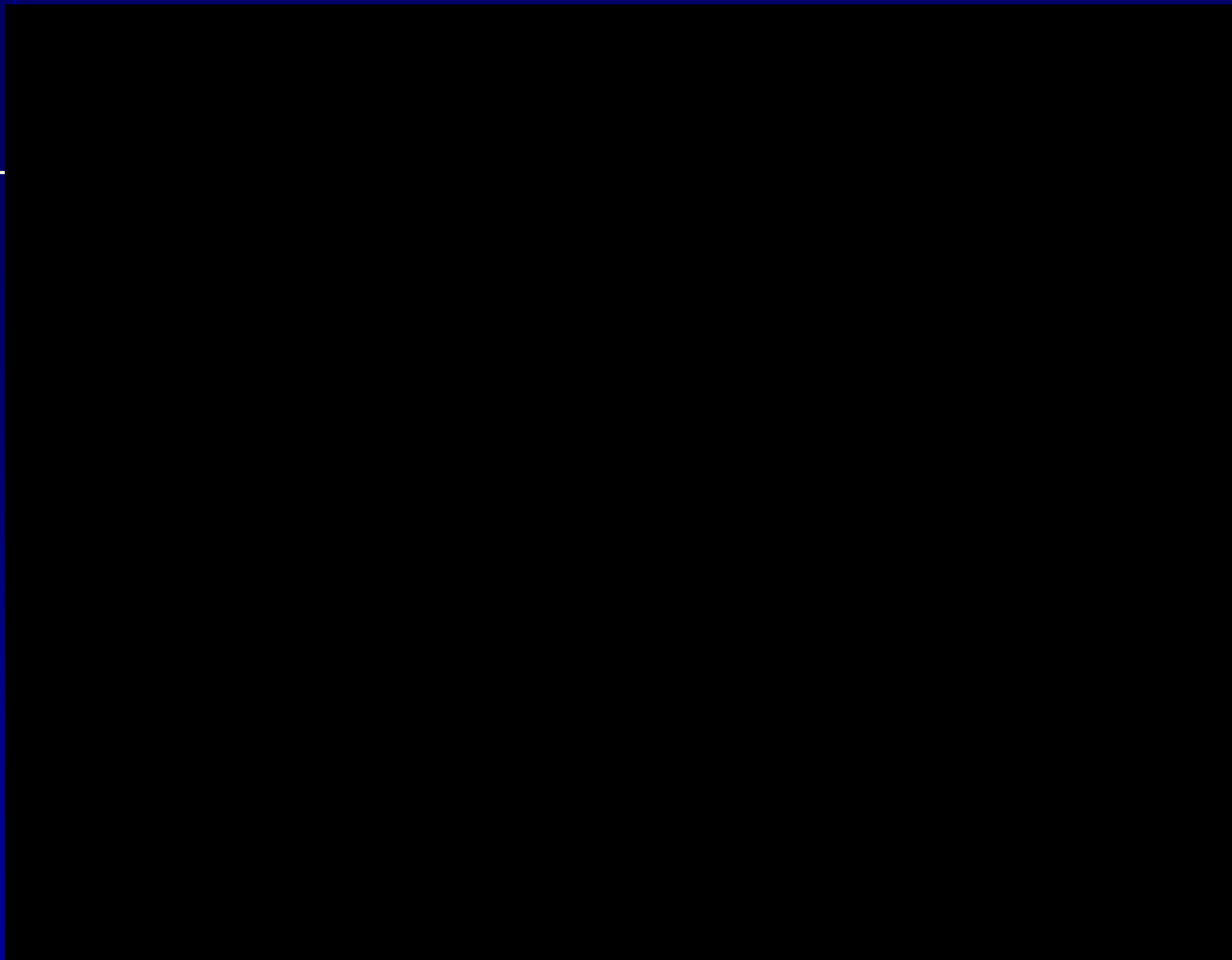




False color image of an equatorial hot spot

Atmosphere of Jupiter

Jupiter's atmosphere



Atmosphere of Saturn

Atmosphere of Saturn

False-colored composite image of Saturn taken
By Voyager-1 that highlights features of Saturn's belts

Atmosphere of Saturn

Saturn- Our Solar System

Atmosphere of Saturn

Cloud layers

Saturn's atmosphere exhibits a banded pattern similar to Jupiter's, but Saturn's bands are much fainter and are also much wider near the equator. At depth, extending for 10 km and with a temperature of −23 °C, is a layer made up of water ice. Above this layer is probably a layer of ammonium hydrosulfide ice, which extends for another 50 km and is approximately −93 °C. Eighty kilometers above that layer are ammonia ice clouds, where the temperatures are roughly −153 °C. Near the top of the atmosphere, extending for some 200 km to 270 km above the visible ammonia clouds, are gaseous hydrogen and helium. Saturn's winds are among the Solar System's fastest. Voyager data indicate peak easterly winds of 500 m/s (1800 km/h).

Atmosphere of Saturn

Cloud layers

Saturn's northern hemisphere, as seen by the Cassini-huygens space probe. (Note the planet's blue appearance through the ring.)

Atmosphere of Saturn

Cloud layers…

Saturn's usually bland atmosphere occasionally exhibits long-lived ovals and other features common on Jupiter. In 1990 the Hubble Space Telescope observed an enormous white cloud near Saturn's equator which was not present during the Voyager encounters and in 1994, another smaller storm was observed. The 1990 storm was an example of a Great White Spot, a unique but short-lived phenomenon which occurs once every Saturnian year, roughly every 30 Earth years, around the time of the northern hemisphere's summer solstice. Previous Great White Spots were observed in 1876, 1903, 1933 and 1960, with the 1933 storm being the most famous. If the periodicity is maintained, **another storm will occur in about 2020**.

Atmosphere of Saturn

Cloud layers…

In recent images from the Cassini spacecraft, Saturn's northern hemisphere appears a bright blue, similar to Uranus. This blue color cannot currently be observed from Earth, because Saturn's rings are currently blocking its northern hemisphere. The color is most likely caused by Rayleigh scattering.

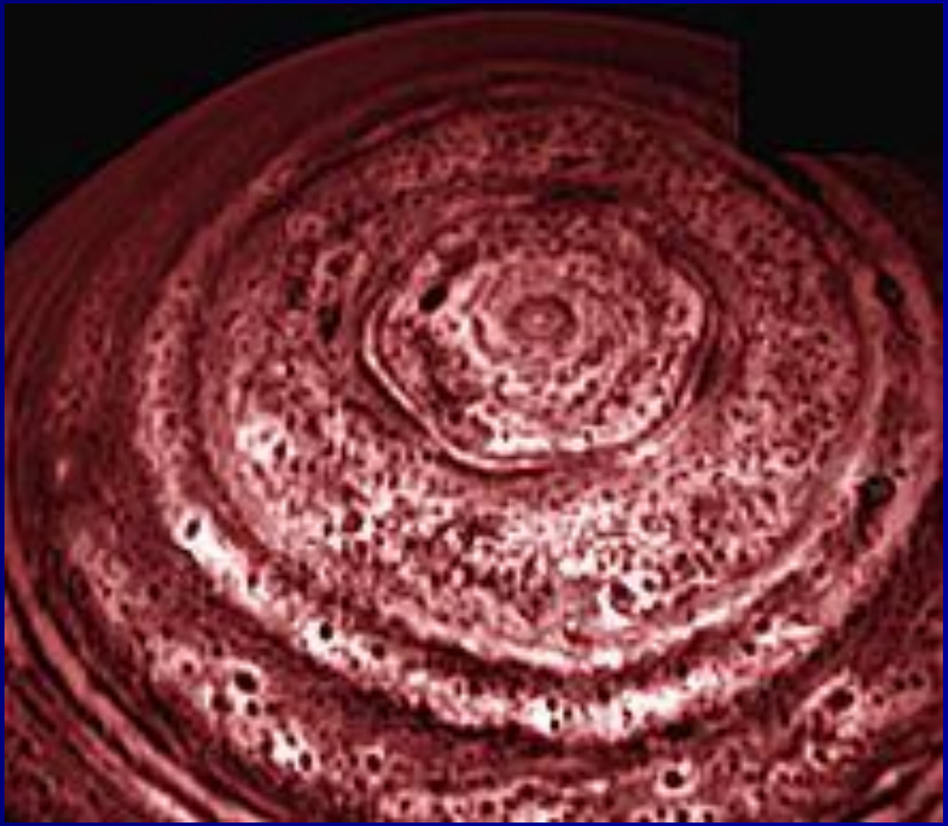
Infrared imaging has shown that Saturn's south pole has a warm polar vortex, the only example of such a phenomenon known to date in the Solar System.

Whereas temperatures on Saturn are normally −185 °C, temperatures on the vortex often reach as high as −122 °C, believed to be the warmest spot on Saturn.

Atmosphere of Saturn

North pole hexagonal cloud pattern

A persisting hexagonal wave pattern around the north polar vortex in the atmosphere at about 78°N was first noted in the Voyager images.



Discovered by Voyager-1 and confirmed in 2006 by Cassini.

Atmosphere of Saturn

Magnetosphere

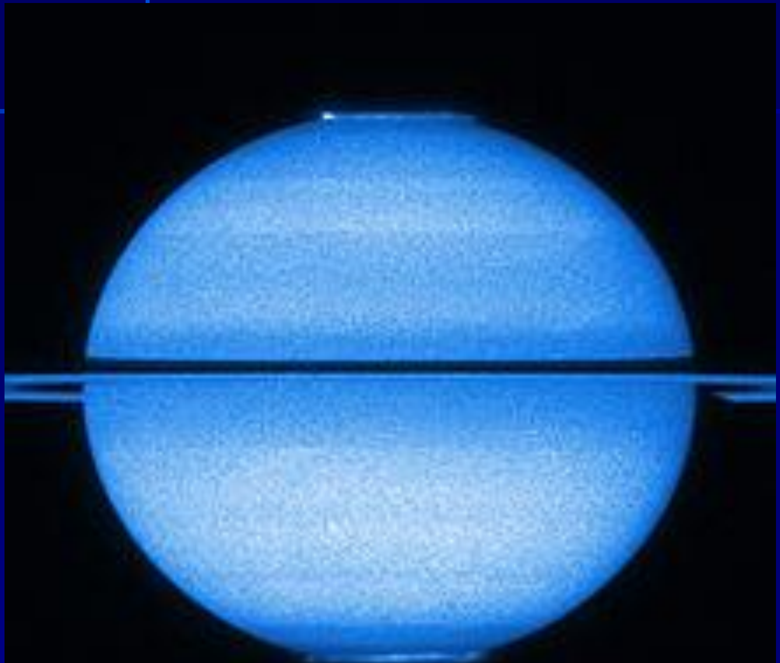


Photo of Saturn by Hubble showing both polar aurorae

Saturn has an intrinsic magnetic field that has a simple, symmetric shape a magnetic dipole. Its strength at the equator 0.2 Gauss (20 μT) is approximately one twentieth than that of the field around Jupiter and slightly weaker than Earth's magnetic field.

Most probably, the magnetic field is generated similarly to that of Jupiter by currents in the metallic-hydrogen layer, which is called a metallic-hydrogen dynamo. Similarly to those of other planets, this magnetosphere is efficient at deflecting the solar wind particles from the Sun.

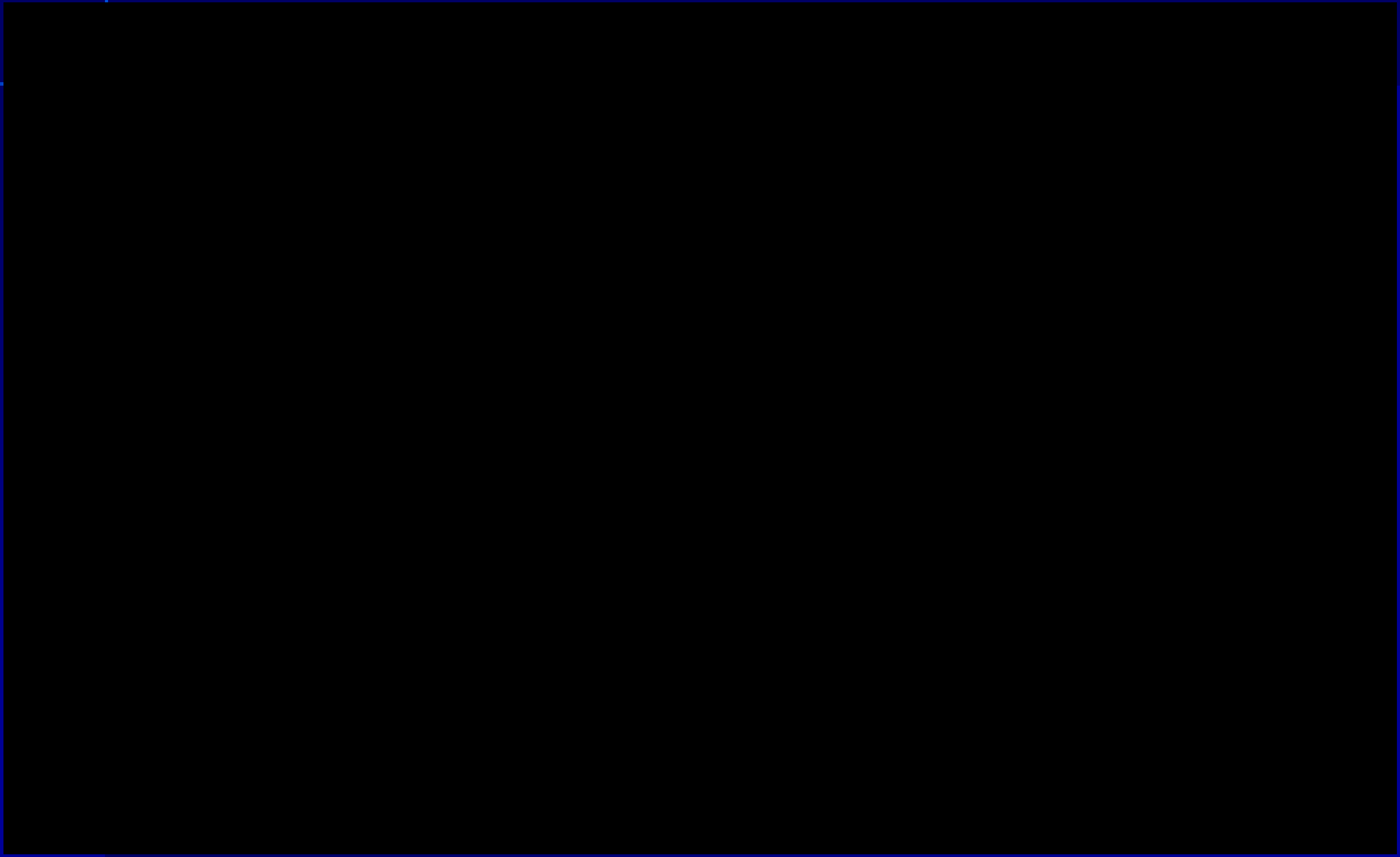
Atmosphere of Uranus

Atmosphere of Uranus

Face of Uranus, by Voyager-2

Atmosphere of Uranus

Uranus 101 | National Geographic



Atmosphere of Uranus

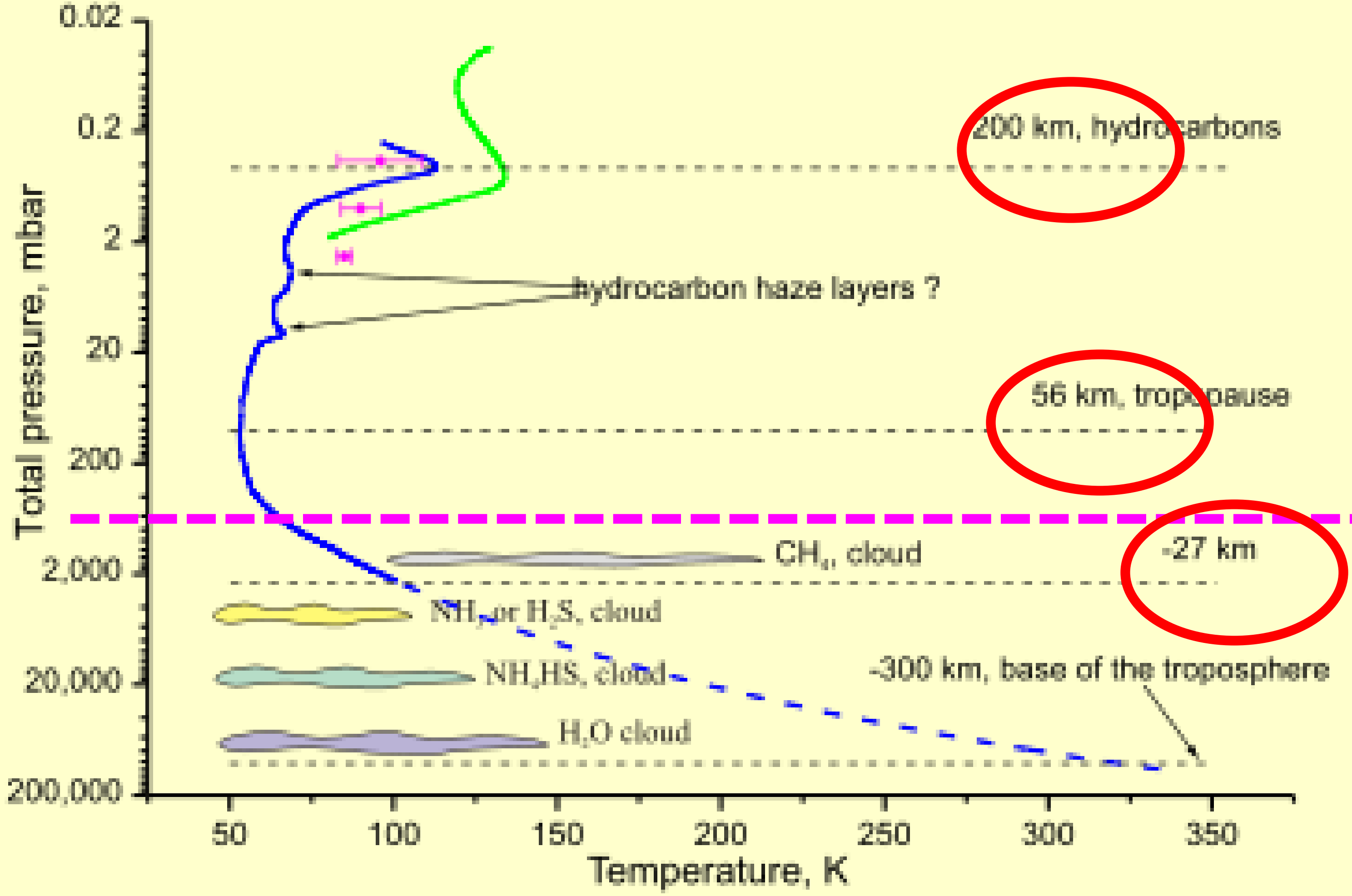
Observation and exploration

Although there is no well-defined solid surface within Uranus' interior, the outermost part of Uranus' gaseous envelope that is accessible to remote sensing, is called its atmosphere. Remote sensing capability extends down to roughly 300 km below the 1 bar level, with a corresponding pressure around 100 bar and temperature of 320 K.

The observational history of the Uranian atmosphere is long and full of errors and frustrations.

Atmosphere of Uranus

Composition



Temperature profile of the Uranian troposphere and lower stratosphere. Cloud and haze layers are also indicated

Atmosphere of Uranus

Composition…

The composition of the Uranian atmosphere is different from the composition of Uranus as a whole, consisting mainly of molecular hydrogen and helium. The helium molar fraction, i.e. the number of helium atoms per molecule of hydrogen/helium, was determined from the analysis of Voyeger-2 far infrared and radio occultation observations.

The fourth most abundant constituent of the Uranian atmosphere is methane (CH4), the presence of which has been known for some time as a result of the ground-based spectroscopic observations.

Atmosphere of Uranus

Composition…

The concentration of less volatile compounds such as ammonia, water and hydrogen sulfide in the deep atmosphere is poorly known.

Infrared spectroscopy, including measurements with Spitzer Space Telescope (SST), and UV occultation observations, found trace amounts of various hydrocarbons in the stratosphere of Uranus, which are thought to be produced from methane by photolysis induced by the solar UV radiation.

Atmosphere of Uranus

Composition…

They include ethane (C_2H_6), acetylene (C_2H_2), methyl acetylene (CH_3C_2H), diacetylene (C_2HC_2H). Infrared spectroscopy also uncovered traces of water vapour, carbon monoxide and carbon dioxide in the stratosphere, which can only originate from an external source such as infalling dust and comets.

Atmosphere of Uranus

Structure

The Uranian atmosphere can be divided into three layers: of

the troposphere, between altitudes of −300 and 50 km and pressures from 100 to 0.1 bar;

the stratosphere, spanning altitudes between 50 and 4000 km and pressures of between 0.1 and 10^(-10) bar; and

the thermosphere / exosphere extending from 4000 km to as high as a few Uranus radii from the surface. There is no mesosphere.

Atmosphere of Uranus

Structure…   Troposphere

The troposphere is the lowest and densest part of the atmosphere and is characterized by a decrease in temperature with altitude. The temperature falls from about 320 K at the base of troposphere at −300 km to 53 K at 50 km.

The temperature at the cold upper boundary of the troposphere (the tropopause) actually varies in the range between 49 and 57 K depending on planetary latitude, with the lowest temperature reached near 25° southern latitude.

Atmosphere of Uranus

Structure... Stratosphere

The middle layer of the Uranian atmosphere is the stratosphere, where temperature generally increases with altitude from 53 K in the tropopause to between 800 and 850 K at in the thermosphere.

The heating of the stratosphere is caused by the downward heat conduction from the hot thermosphere as well as by absorption of solar UV and IR radiation by methane and complex hydrocarbons that form in this part of the atmosphere as a result of methane photolysis.

Atmosphere of Uranus

Structure… Thermosphere and ionosphere

The outmost layer of the Uranian atmosphere extending for thousands kilometers is thermosphere, which has a uniform temperature around 800 to 850 K. This is much higher than, for instance, the 420 K in the thermosphere of Saturn. The heat sources necessary to sustain such a high value are not understood, since neither solar FUV/EUV radiation nor auroral activity can provide the necessary energy.

Atmosphere of Uranus

Structure… Thermosphere and ionosphere

The thermosphere as well as the upper part of the stratosphere contain a large concentration of ions and electrons forming the ionosphere of Uranus.

The electron density in the Uranian ionosphere is on average 10^4 cm−3, reaching to as high as 10^5 cm−3 in the narrow layers in the lower ionosphere. This fact may be related to the low concentration of hydrocarbons in the stratosphere. The ionosphere is mainly sustained by solar UV radiation and its density depends on the solar activity. The auroral activity on Uranus is not as powerful as at Jupiter and Saturn and contributes little to the ionization.

Atmosphere of Uranus

Structure… **Hydrogen corona**

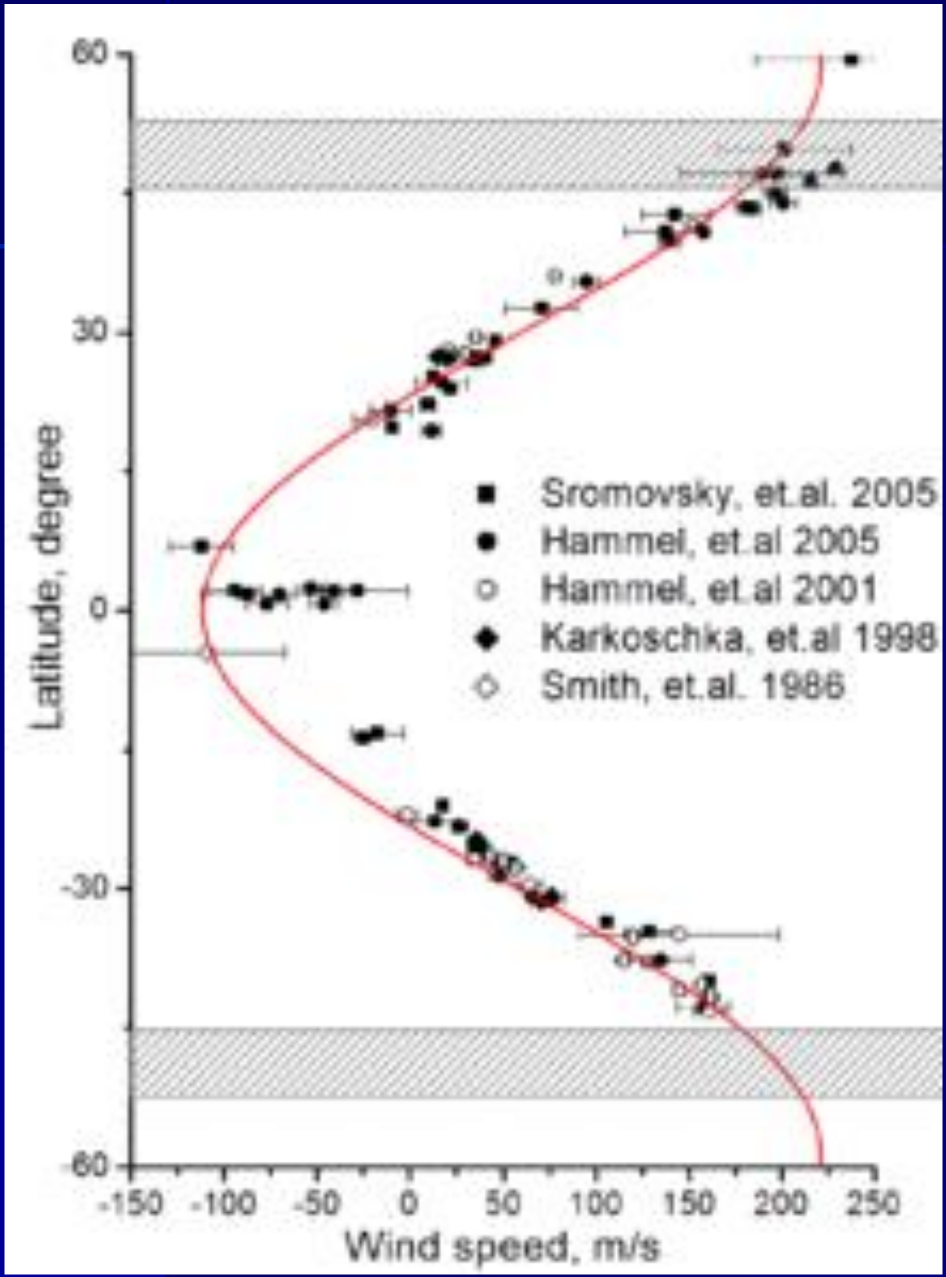
The upper part of the thermosphere, where the mean free path of the molecules exceeds the scale height, is called exosphere.

The lower boundary of the Uranian exosphere the exobase is located at the height of about 6,500 km or 1/4 of the planetary radius over the surface.

The exosphere is unusually extended reaching as far as several Uranian radii from the planet. It is made mainly of hydrogen atoms including a substantial non-thermal population and is often called the hydrogen corona of Uranus.

The effects of this bloated exosphere include a drag on small particles orbiting Uranus, causing a general depletion of dust in the Uranian rings, which may contaminate the upper atmosphere of the planet.

Atmosphere of Uranus



Dynamics

Zonal **wind speeds on Uranus**. Shaded areas show the southern collar and its future northern counterpart. The red curve is a symmetrical fit to the data.

Atmosphere of Uranus

Dynamics…

Uranus, being generally cyan in color, has a bland appearance lacking broad colorful bands and large clouds prevalent on Jupiter and Saturn.

In 1986 the most conspicuous features on Uranus observed by Voyager 2 were the dark low latitude region between $-40°$ and $-20°$ and bright southern polar cap.

The southern polar cap, which existed near the solstice in 1986, faded away in 1990s.

Atmosphere of Uranus

Dynamics…

The atmosphere of Uranus is relatively calm as compared to those of other giant planets. Only a limited number of small bright clouds at middle latitudes in both hemispheres and one **Uranus Dark Spot** have been observed since 1986. One of those bright cloud features located at –34° of latitude probably existed continuously since at least 1986.

The wind speeds are from −50 to −100 m/s at the equator increasing to 240 m/s near 50° latitude in the northern hemisphere.

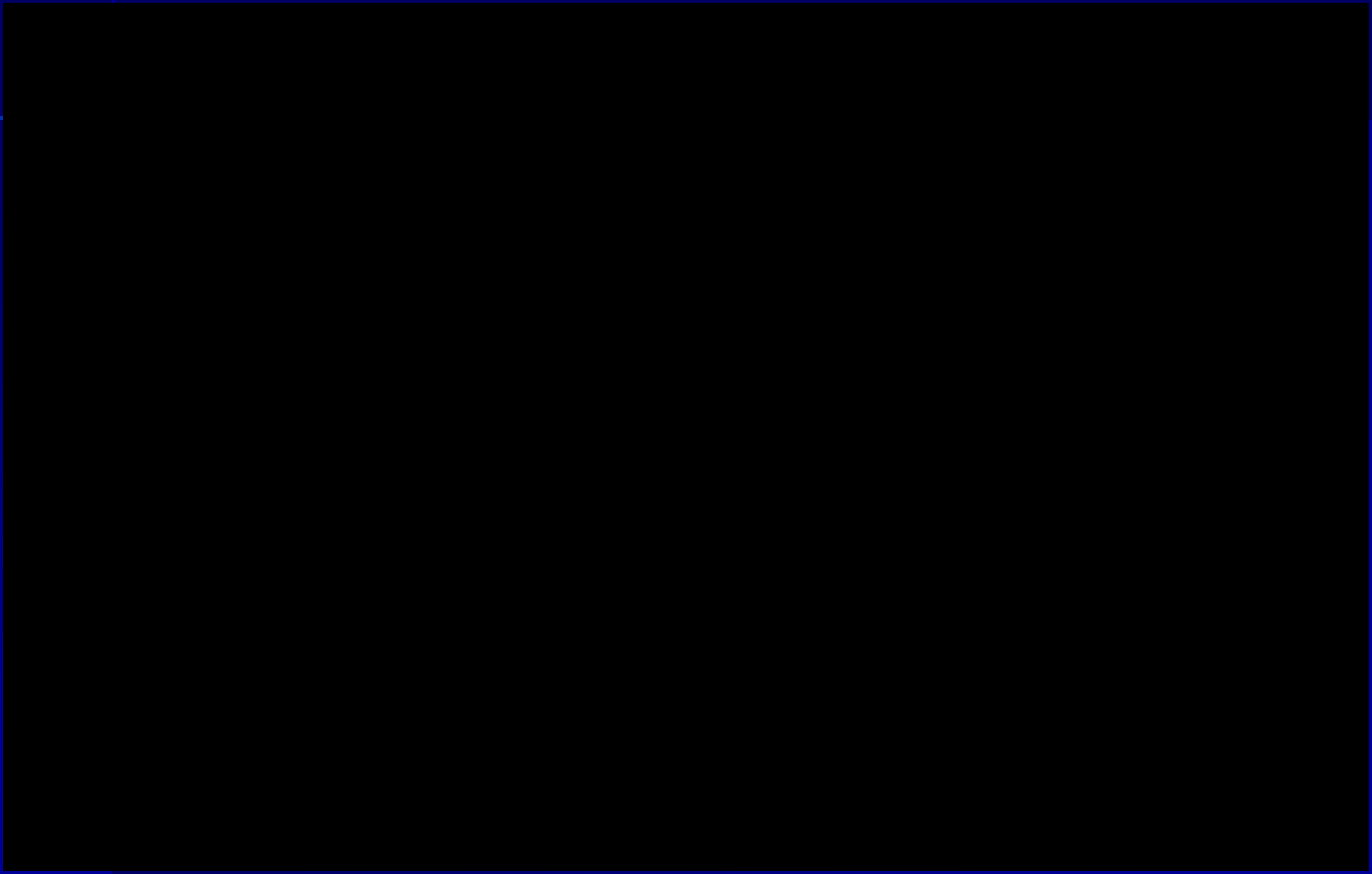
Atmosphere of Neptune

Atmosphere of Neptune

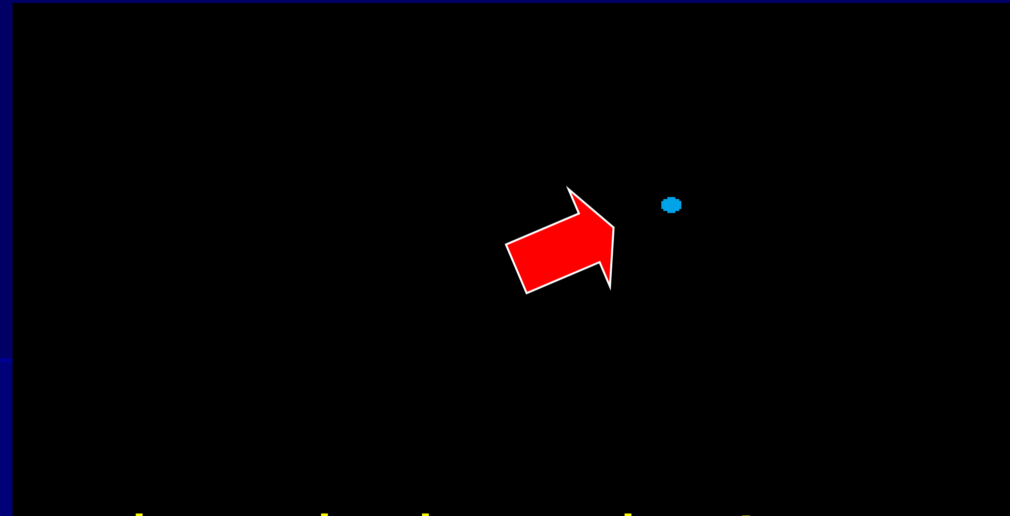
Combined color and near-infrared image of Neptune, showing bands of methane in its atmosphere, and its four moons, Proteus, Larissa, Galatea, and Despina.

Atmosphere of Neptune

What Would You See If You Fell Into Neptune?



Observation



Neptune is never visible to the naked eye, having a brightness between magnitudes +7.7 and +8.0.

A telescope or strong binoculars will resolve Neptune as a small blue disk, similar in appearance to Uranus.

Because of the distance of Neptune from the Earth, the angular diameter of the planet only ranges from 2.2 to 2.4 arcseconds, the smallest of the Solar System planets. Its small apparent size has made it challenging to study visually.

Atmosphere of Neptune

At high altitudes, Neptune's atmosphere is **80% hydrogen and 19% helium**. A trace amount of methane is also present. Prominent absorption bands of methane occur at wavelengths above 600 nm, in the red and infrared portion of the spectrum.

As with Uranus, this absorption of red light by the atmospheric methane is part of what gives Neptune its blue hue, although Neptune's vivid azure differs from Uranus's milder cyan.

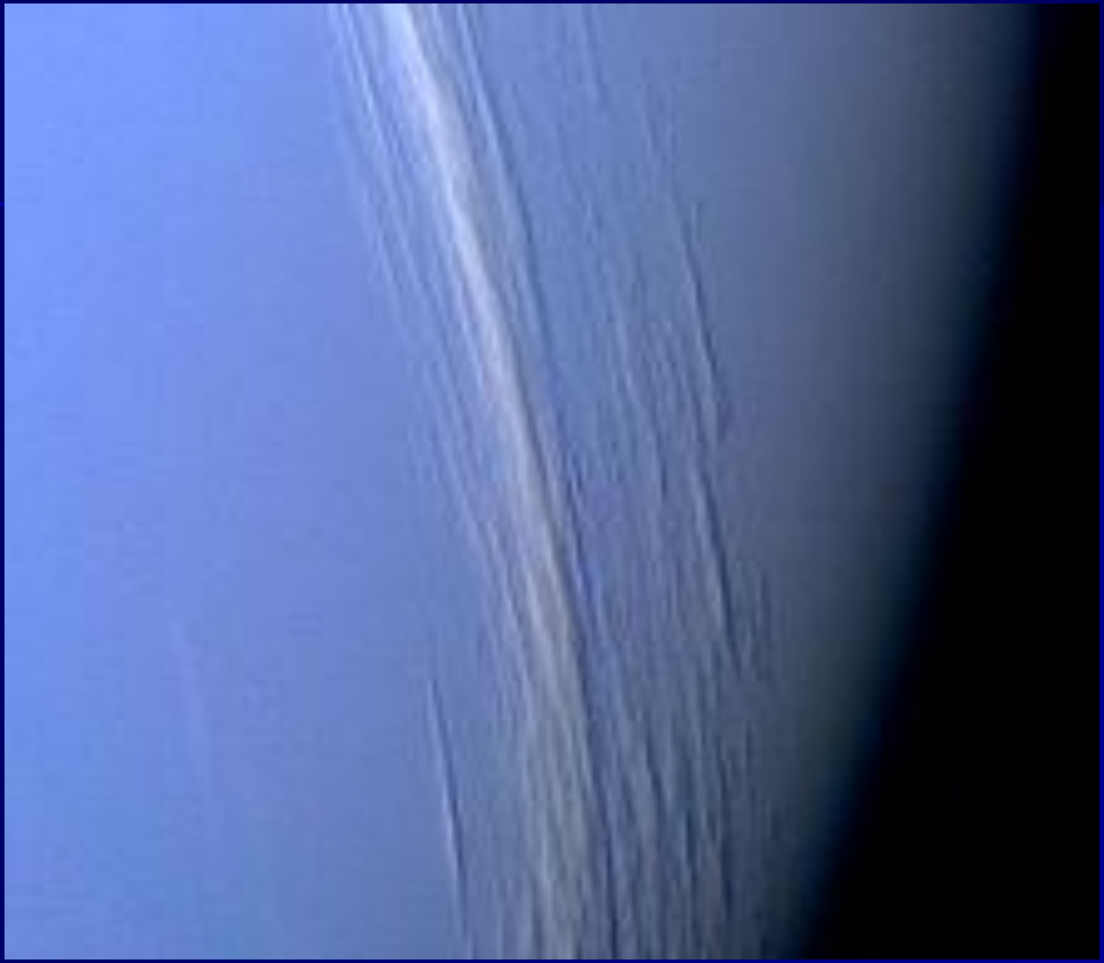
Atmosphere of Neptune

Neptune's atmosphere is sub-divided into two main regions;

1. The **lower troposphere,** where temperature decreases with altitude, and the stratosphere, where temperature increases with altitude. The boundary between the two, the tropopause, occurs at a pressure of 0.1 bars (10 kPa).

2. The stratosphere then gives way to the thermosphere at a pressure lower than 10^{-5} to 10^{-4} microbars (1 to 10 Pa). The thermosphere gradually transitions to the exosphere.

Atmosphere of Neptune



Bands of high-altitude clouds cast shadows on Neptune's lower cloud deck

Atmosphere of Neptune

Models suggest that Neptune's troposphere is banded by clouds of varying compositions depending on altitude.

The upper-level clouds occur at pressures below one bar, where the temperature is suitable for methane to condense.

For pressures between one and five bars (100 and 500 kPa), clouds of ammonia and hydrogen sulfide are believed to form.

Deeper clouds of water ice should be found at pressures of about 50 bars (5.0 MPa), where the temperature reaches 0°C. Underneath, clouds of ammonia and hydrogen sulfide may be found.

Atmosphere of Neptune

The stratosphere of Neptune is warmer than that of Uranus due to the elevated concentration of hydrocarbons.

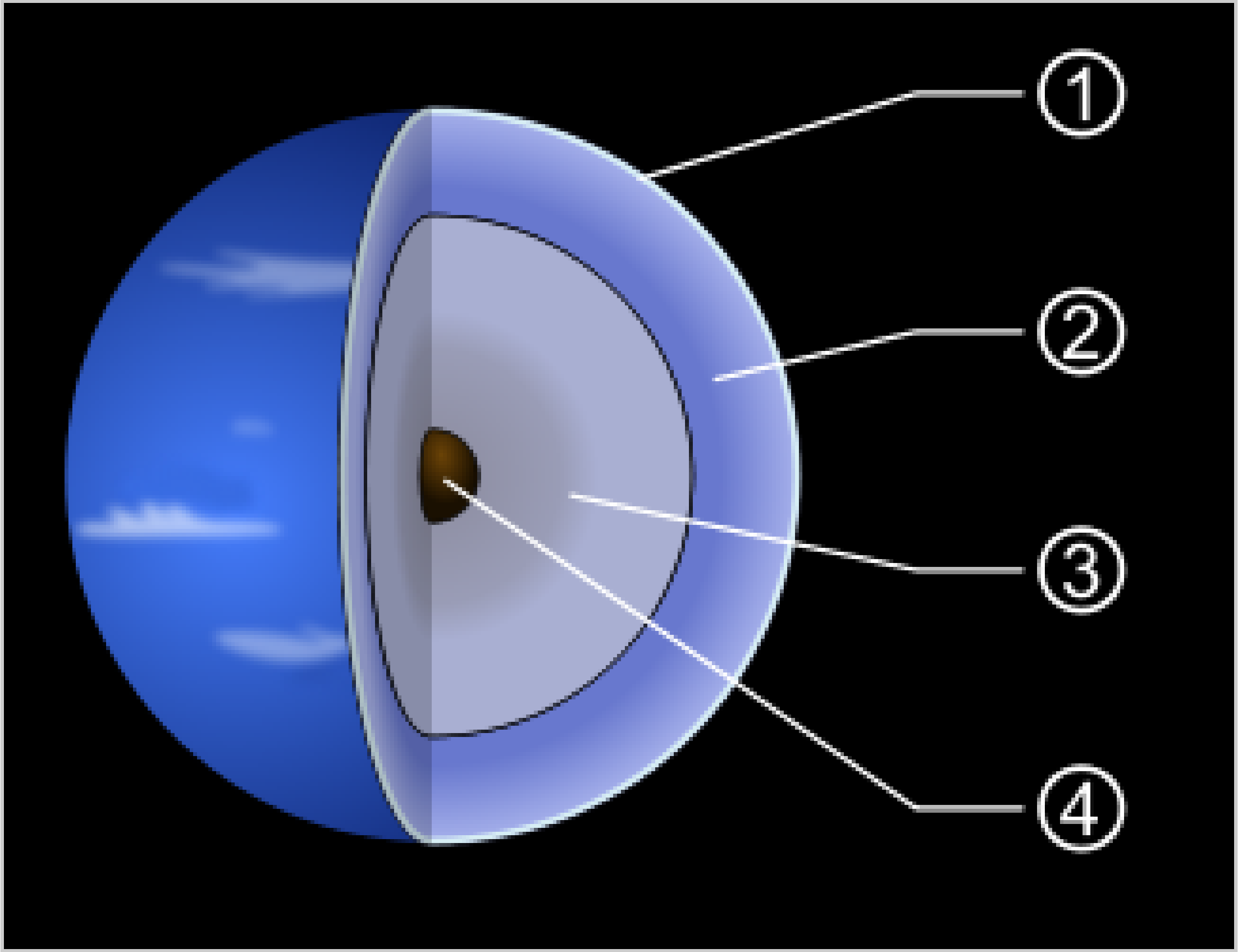
For reasons that remain obscure, the planet's thermosphere is at an anomalously high temperature of about 750 K.

The planet is too far from the Sun for this heat to be generated by ultraviolet radiation.

Atmosphere of Neptune

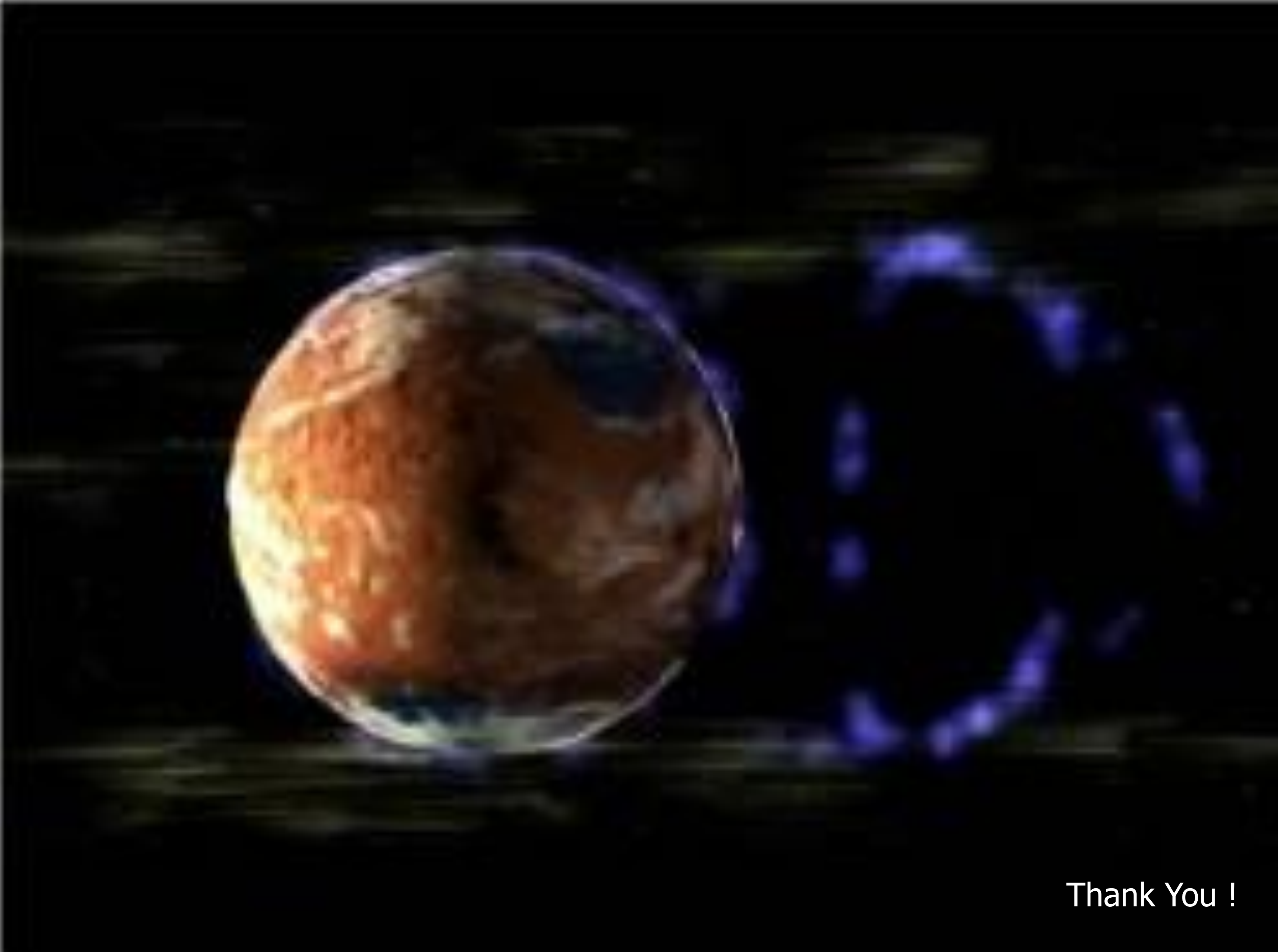
One candidate for a heating mechanism is atmospheric interaction with ions in the planet's magnetic field.

Other candidates are gravity waves from the interior that dissipate in the atmosphere.



The internal structure of Neptune:

1. Upper atmosphere, top clouds
2. Atmosphere consisting of hydrogen, helium and methane gas
3. Mantle consisting of water, ammonia and methane ices
4. Core consisting of rock (silicates and nickel-iron)


Thank You !