On The Atmospheres Of Different Planets

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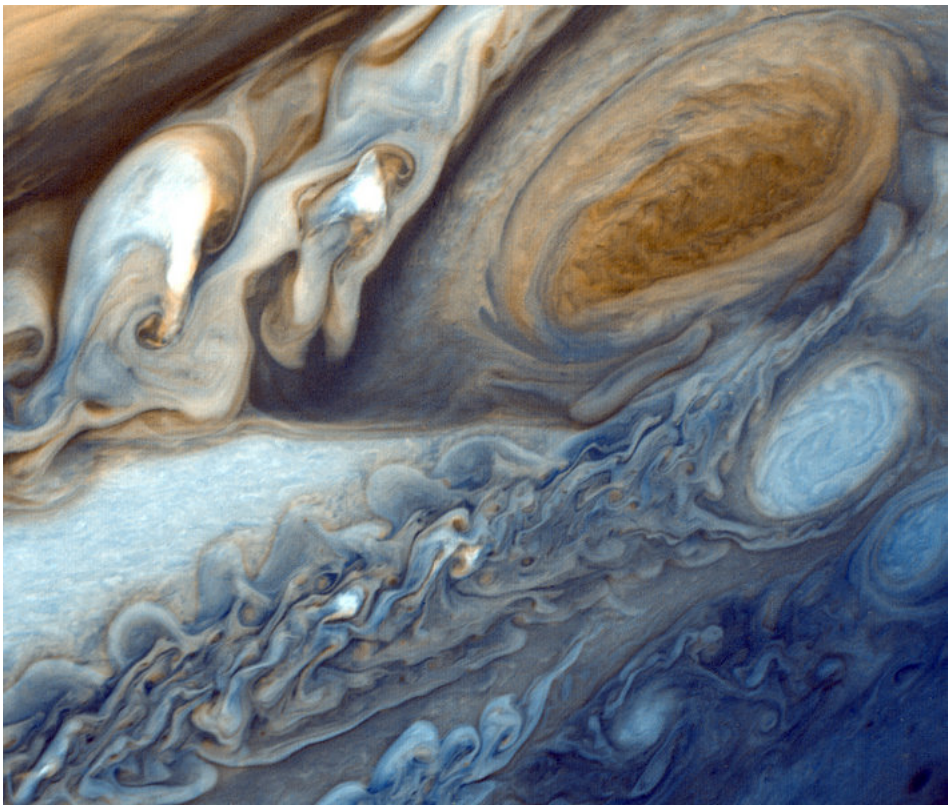

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1 Introduction

In this project I want to compare the atmospheres of different planets with the atmosphere of the Earth. I will start with the introduction of the basic terms when talking about atmospheres by using the Earth as an example, which atmosphere is of course best known and investigated. After that I will present the atmospheres of the other eight planets, point out their special, unique and sometimes strange features and compare them with the other planets. In the Appendix I included tables with the chemical composition and some other plain facts of the atmospheres.

2 Terran Atmosphere

2.1 General

The Atmosphere of a planet are the gas layers around its solid core, which are in an equilibrium state between attracting and repelling forces.

The main attracting force is the gravity of a planet, the main repelling factor is the temperature of the gas molecules heated by the sun or the planet. If those are heated to overcome the escape velocity of a planet they can escape into outer space, lighter particles are of course more easily heated to do so than heavier. This has the interesting consequences, for example because of its high mass Jupiter still has a lot Hydrogen while other planets lost it or the moon Titan is able to retain its atmosphere despite its low mass because it is so far away from the sun.

Therefore the **mass of a planet** as well as its **distance from the sun** are major factors influencing its atmosphere.

2.2 Composition

The composition of an atmosphere depends on the properties of the solar nebula during the formation of the planet, the emission of gases from the interior of the planet, sequestration (as explained in Mars chapter), the existence of life and extra-planetary factors such as solar wind or impactors.

Earth's atmosphere consists of 78% Nitrogen, 21% Oxygen and traces of other molecules (see Table 3). The composition of the atmosphere is unstable and quite different from the other planets due to the existence of life.

Actually the mentioned composition works only below 100 km where the atmosphere is uniform (homosphere), above this the composition changes depending on the molecular mass (heterosphere) so that in high altitude mainly Hydrogen and Helium are found (for a more detailed description see [1])

Also the composition changes over time, for example are Mars and Venus thought to have lost their water because UV radiation separates the water molecule and the Hydrogen was lost

2.3 Evolution

Right after the formation in the solar nebula Terra's atmosphere was composed of Hydrogen and Helium, but most of it escaped the Earth due to its high temperature. Then gases of carbon dioxide and ammonia steamed out of the Earth's core and created an anoxic atmosphere. This changed when bacteria started to convert carbon dioxide into oxygen leading to present day's composition of mainly nitrogen and oxygen.

2.4 Layers

The layers of the atmosphere are usually distinguished into: troposphere, stratosphere, mesosphere, thermosphere and the exosphere, but there are also many other possible ways to order atmospheric layers: (i.e. ionosphere, magnetosphere, biosphere, homosphere, ...).

It is worth to note that temperature within these layers varies greatly as has been discussed in the lecture [1].

Some planets lack some of those layers for example has Venus no stratosphere and Mercury actually only maintains an exosphere.

The Exploration of the atmosphere depends on altitude. The troposphere is the subject of meteorology while aerology studies the middle layers. The upper layers are being measured with rockets, lidars, radar, radio probes and satellites.

2.5 Influence

Atmospheres are also important since they influence the surface of a planet in many ways for example temperature, wind speeds, climate and much more.

The terran atmosphere absorbs UV radiation which is dangerous for life and thus an important factor allowing life to exist on this planet.

Pressure for example is just a consequence of the weight of an atmosphere, which therefore usually is the most dense at its surface and fades out into space with altitude.

It is possible to describe this fading with equations. One approximation for low altitudes on the Earth is the barometric formula:

$$p(h) = p_0 e^{\frac{\rho_0}{p_0} g h} \tag{1}$$

where g is the Earth acceleration and p_0 and ρ_0 the pressure respectively the density at height $h = 0$. In this approximation the temperature is assumed to be constant.

At higher altitudes this equation is not accurate anymore because of increasing influences of the magnetic field which forces the particles to move along the field lines so that the molecules do not interact in this low density medium as often.

3 Other Planets

3.1 Mercury

The atmosphere of Mercury is practically a vacuum with a pressure of only about $1.5 \cdot 10^9 mbar$ on the surface. An interesting result of the lack of the atmosphere is that the surface of Mercury is covered by many craters, because objects falling from the sky are not being decelerated. Also the temperature changes very strong between day and night phases (427°C to 173°C).

The reason why Mercury does not have an atmosphere is its proximity to the sun which causes very high temperatures and thus a high velocity of particles. The low mass of the planet produces a low gravitational force and therefore a low flight velocity. Thus the particles escape from Mercury very easily into outer space. Because of this any original atmosphere is lost and the atmosphere of Mercury is actually only the Exosphere.

The traces of elements found in the atmosphere are Hydrogen and Helium which mostly come from the Solar wind and Oxygen, Natrium and Kalium raised from the surface.

NASA is having a mission to Mercury with his MESSENGER satellite to further investigate the atmosphere among other measurements. It will enter the orbit of Mercury in March 2011.

3.2 Venus

Venus' thick atmosphere, which has a surface pressure 90 times and an atmospheric density 50 times higher than Earth's, consists almost completely of carbon dioxide with only a small amount of nitrogen. The planet's thick always closed cloud layer reflects about 76% of the sunlight, within the cloud layer most is absorbed and only 2% reach the surface. This absorption leads to wind speeds up to 360 km/h, which is about 60 times higher than the rotation of Venus and called "Superrotation". Those winds distribute the heat in a single global convection cell and create an almost homogenous temperature on the surface.

The CO_2 and traces of water vapor and sulfur dioxide are responsible for the green house effect heating the surface to temperatures up to 500°C (mean 464°C), which is about 400°C more than usually, without it the temperature would resemble Earth's.

The first atmospheric measurements were made by Venera 4 in 1967. ESA starts its Venus Express mission in 2006 to further examine the atmosphere and surface.

3.3 Mars

Mars has a thin atmosphere with a surface pressure of only 0.75 % of the Earth. Therefore the heat escapes back into space causing high temperature differences between day and night (20°C--85°C). Almost the whole atmosphere consists of Carbon Dioxide, with small amounts of Nitrogen and Argon, but also some in patches appearing Methane was found in 2003, which source is yet unidentified but could be:

volcanic activity, impacts or even life. With the help of other gases created during those processes it is to be determined which source is the most probable.

At the poles are regions of frozen CO_2 and H_20, which sublimates in the summer time creating large cirrus clouds due to increased sunlight, this also causes strong dust winds to occur. During the dark winter the poles grow, since 25% of the atmosphere condenses into ice.

The results of missions to Mars let assume that millions of years ago the atmosphere was a lot denser and water existed on the surface, but most probably this atmosphere was carried away into outer space by the steady flow of the solar wind even supported by the Mars' low magnetic field and gravity.

3.4 Jupiter

The atmosphere of Jupiter (about 1,4% of the planets radius) consists of about 90% Hydrogen and 10% Helium, with only traces of other elements such as for example ammonia crystals in the upper atmosphere. This is similar to the composition of the solar nebular .

The upper atmosphere rotates about 5 minutes slower at the poles than at the equator. Dark and bright band patterns of clouds that can be very well distinguished flow depending on the latitude in opposing directions, which causes many storms with speeds about 600 km/h. The most prominent storm is the Great Red Spot, which is three times the size of the Earth in diameter and circles around Jupiter already for more than 300 hundred years.

The gas planets' energy partly comes from the adiabatic contraction of the gas (Kelvin-Helmholtz-mechanism).

In 1995 a probe was released from the Galileo spacecraft which could collect data for almost an hour before being destroyed by the high pressure.

3.5 Saturn

As the jovian atmosphere, Saturn's atmosphere consists mainly of hydrogen and helium but they differ in the concentration. Whereas the atmosphere of Jupiter has a composition similar to the solar composition, the atmosphere of Saturn does not contain as much helium because its temperature is lower and the helium was able to condensate. This unique property decreases the mean density to about 0.687 g/cm which is lower than the density of water.

As Jupiter Saturn also features cloud bands, but fainter and wider at the equator, the yellow-brownish clouds contain ammonia crystals. Also Saturn features long-living ovals stroms as can also be observed on Jupiter. Another unique feature is that Saturn has warm poles.

Saturn's equatorial regions (System I) rotate faster than the polar region (System II). The interior of the planet (System III) has an even slower rotational period.

3.6 Uranus

The cyan color of Uranus is caused by the presence of methane in the atmosphere, which absorbs red light. The first observations of Uranus showed faint cloud bands, but newer observations with the Hubble Space Telescope have shown that those are stronger than originally thought.

3.7 Neptune

The blue appearance of Neptune is due to the hydrogen, helium and methane. Neptune's wind speeds of up to 2,000 km/h are the highest in the solar system and in the southern hemisphere it features an Earth-sized Great Dark Spot similar to the one of Jupiter. The high winds speeds are assumed to be caused by an internal energy source which also heat the lower layers of the atmosphere, which goes to about 10 to 20 percent into the center.

In the upper layers of the atmosphere are mainly hydrogen and helium, in the lower layers is also methane, ammonia and water.

Neptune is the only gas giant where shadows of clouds can be observed.

3.8 Pluto

Pluto has a very thin atmosphere consisting mainly of nitrogen and carbon monoxide, which is in equilibrium with frozen nitrogen and carbon monoxide on the surface.

Two measurements of the atmosphere pressure were made in 1988 (0.15 Pa) and 2002 (0.3 Pa), when Pluto occulted a star by determining the star's dimming rate. The results were strange because since Pluto's distance to the Sun increased it was expected that more of the atmosphere was frozen and thus the pressure lower.

In the beginning of 2006 the New Horizons mission will launch the first manmade spacecraft to investigate Pluto making the first measurements in 2015.

4 Conclusion

The study of the different atmospheres is interesting because they more or less started with the same initial conditions of the solar nebulae, but in the present state differ in a large range. In exploring this we have learned a lot about factors influencing the atmosphere and its evolution over time. By exploring other planets we learned also a lot about the atmosphere of our own planet and how it is vulnerable and affected by small changes of the environment. But most importantly we learned that we should appreciate this precious hull of molecules since without it no life on this planet could exist.

5 Appendices

A References

References

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[4] http://de.wikipedia.org Keywords: Atmosphäre, Erdatmosphäre, Erde_(Planet), Jupiter_(Planet), Mars_(Planet), Merkur_(Planet), Neptun_(Planet), Pluto_(Planet)_(Planet), Saturn_(Planet), Uranus_(Planet), Venus_(Planet)

B Atmosphere Facts

Surface pressure: Average temperature: Total mass of atmosphere:	10-15 bar (0.001 picobar) 440 K (167 C) (590-725 K, sunward side) $<$ 1000 kg
Composition:	
Oxygen	42 %
Natrium	29 %
Hydrogen	22 %
Helium	6 %
Kalium	0,5 %
Traces	Ar, CO_2, H_2O, N_2, Xe, Kr, Ne

Table 1: Mercurean Atmosphere Facts by NASA

Surface pressure:	92 bars
Surface density:	65. kg/m3
Atmosphere Height	250 km
Scale height:	15.9 km
Total mass of atmosphere:	4.8 x 1020 kg
Average temperature:	737 K (464 C)
Diurnal temperature range:	0
Wind speeds:	0.3 to 1.0 m/s (surface)
Mean molecular weight:	43.45 g/mole
Composition:	
Carbon Dioxide (CO2)	96,5 %
Nitrogen (N2)	3,5 %
Sulfur Dioxide (SO2)	150 ppm
Argon (Ar)	70 ppm
Water (H2O)	20 ppm
Carbon Monoxide (CO)	17 ppm
Helium (He)	12 ppm
Neon (Ne)	7 ppm
Traces	Carbonyl sulfide, Hydrogen chloride, Hydrogen fluoride

Table 2: Venerian Atmosphere Facts by NASA

Surface pressure:	1014 mb
Surface density:	1.217 kg/m3
Atmosphere height:	640 km
Scale height:	8.5 km
Total mass of atmosphere:	5.1 x 1018 kg (0,9 ppm total)
Total mass of hydrosphere:	1.4 x 1021 kg
Average temperature:	288 K (15 C)
Diurnal temperature range:	283 K to 293 K
Wind speeds:	0 to 100 m/s
Mean molecular weight:	28.97 g/mole
Composition:	
Nitrogen (N2)	78.084%
Oxygen (O2)	20.946%
Argon (Ar)	9340 ppm
Carbon Dioxide (CO2)	350 ppm
Neon (Ne)	18.18 ppm
Helium (He)	5.24 ppm
Methane (CH4)	1.7 ppm
Krypton (Kr)	1.14 ppm
Hydrogen (H2)	0.55 ppm
Comment:	Water highly variable $\sim$ 1%

Table 3: Terranean Atmosphere Facts by NASA

Surface pressure:	6.36 mb at mean radius (4.0 to 8.7 mb)
Atmospheric pressure	0.7-0.9 kPa
Surface density:	0.020 kg/m3
Scale height:	11.1 km
Total mass of atmosphere:	2.5 x 1016 kg
Average temperature:	210 K (-63 C)
Diurnal temperature range:	184 K to 242 K (-89 to -31 C)
Wind speeds:	2-7 m/s (summer), 5-10 m/s (fall), 17-30 m/s (dust storm)
Mean molecular weight:	43.34 g/mole
Composition:	
Carbon Dioxide (CO2)	95,32 %
Nitrogen (N2)	2,7 %
Argon (Ar)	1,6 %
Oxygen (O2)	0,13 %
Carbon Monoxide (CO)	0,08 %
Water (H2O)	210 ppm
Nitrogen Oxide (NO)	100 ppm
Neon (Ne)	2,5 ppm
Krypton (Kr)	300 ppm
Hydrogen-Deuterium-Oxygen (HDO)	850 ppm;
Xenon (Xe)	80 ppm
Ozone	30 ppm
Methane	10,5 ppm

Table 4: Martian Atmosphere Facts by NASA

Surface Pressure:	>> 1000 bars
Atmospheric pressure	70 kPa
Temperature at 1 bar:	165 K (-108 C)
Temperature at 0.1 bar:	112 K (-161 C)
Density at 1 bar:	0.16 kg/m3
Wind speeds	Up to 150 m/s (< 30 degrees latitude)
	Up to 40 m/s (> 30 degrees latitude)
Scale height:	27 km
Mean molecular weight:	2.22 g/mole
Composition:	
Molecular hydrogen (H2)	$89, 8 \pm 2.0$ %
Helium (He)	$10, 2 \pm 2.0$ %
Methane (CH4)	$3000 \pm 1000 ppm$
Ammonia (NH3)	$260 \pm 40 ppm$
Hydrogen Deuteride (HD)	28±10 ppm
Ethane (C2H6)	$5, 8 \pm 1, 5$ ppm
Water (H2O)	4 ppm
Aerosols	Ammonia ice, water ice, ammonia hydrosulfide, Phosphine

Table 5: Jovenean Atmosphere Facts by NASA

Surface Pressure:	>> 1000 bars
Atmospheric pressure	140 kPa
Temperature at 1 bar:	134 K (-139 C)
Temperature at 0.1 bar:	84 K (-189 C)
Density at 1 bar:	0.19 kg/m3
Wind speeds	Up to 400 m/s (< 30 degrees latitude)
	Up to 150 m/s (> 30 degrees latitude)
Scale height:	59.5 km
Mean molecular weight:	2.07 g/mole
Composition:	
Molecular hydrogen (H2)	$96, 3\% \pm 2.4\%$
Helium (He)	$3, 25\% \pm 2.4\%$
Methane (CH4)	4.500±2.000 ppm
Ammonia (NH3)	125±75 ppm
Hydrogen Deuteride (HD)	110±58 ppm
Ethane (C2H6)	$7 \pm 1, 5$ ppm
Water vapor	0.1%
Phosphine	0.0001%
Aerosols:	Ammonia ice, water ice, ammonia hydrosulfide

Table 6: Saturnean Atmosphere Facts by NASA

Surface Pressure: Atmospheric pressure Temperature at 1 bar: Temperature at 0.1 bar: Density at 1 bar: Wind speeds: Scale height: Mean molecular weight:	>> 1000 bars 120 kPa (at the cloud level) 76 K (-197 C) 53 K (-220 C) 0.42 kg/m3 0-200 m/s 27.7 km 2.64 g/mole
Composition:	
Molecuilar Hydrogen (H2) Helium (He) Methane (CH4) Hydrogen Deuteride	$82\% \pm 3,3\%$ $15,2\% \pm 3,3\%$ 2,3% 148 ppm
Aerosols:	Ammonia ice 0.01%, Ethane 0.00025%, Acetylene 0.00001%, water ice, Hydrogen sulfide, methane ice(?), Carbon monoxide

Table 7: Uranean Atmosphere Facts by NASA

Surface Pressure: Temperature at 1 bar: Temperature at 0.1 bar: Density at 1 bar: Wind speeds: Scale height: Mean molecular weight:	>> 1000 bars 72 K (-201 C) 55 K (-218 C) 0.45 kg/m3 0-200 m/s 19.1 - 20.3 km 2.53 - 2.69 g/mole
Composition	
Hydrogen Helium Methane (CH4) Deuterium Ethane (C2H6)	$80\% \pm 3,2\%$ $19\% \pm 3,2\%$ $1,5\% \pm 0,5\%$ 192 ppm 1,5 ppm
Aerosols:	Ammonia ice, water ice, ammonia hydrosulfide, methane, ice(?)

Table 8: Neptunean Atmosphere Facts by NASA

Surface Pressure: Average temperature: Scale height: Mean molecular weight:	$0.15 - 0.30\mu$ bar 50 K (-223 C) 60 km 16-25 g/mole
Composition:	
Methane (CH4), Nitrogen (N2)	? ?

Table 9: Plutonean Atmosphere facts by NASA

Planet	Pressure (hPa)	H	He	N	O	CO2	CH4	H2O	Miscellaneous	Remarks
Mercury	10-15	22%	6%	42%	ja				29% Natrium; 0,5% Kalium	only Exosphere
Venus	92.000	yes	3,5%	96,5%						no Mesosphere
Earth	1.013	yes	yes	78%	21%	0,03%	yes	0-4%	Argon 1%	Earth atmosphere
Mars	6,36	2,7%	0,13%	95,32%	3 ppm				Argon 1,6%	
Jupiter	>106	89,8%	10,2%	yes						Gas giant
Saturn	>106	96,3%	3,25%	yes						Gas giant
Uranus	>106	82%	15%	2,3%						Gas giant
Neptune	>106	80%	19%	1,5%						Gas giant
Pluto	0-0,005	yes	yes							varying size

Table 10: Chemical Composition of all the planets