On The Atmospheres Of Different Planets

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**General**

- **Atmosphere**: gas layers around a planet’s solid core being in equilibrium between attracting and repelling forces
- **Main attractor**: gravity of a planet
- **Main repeller**: thermal velocity of gas molecules heated by the sun or the planet

Molecule’s thermal velocity $> \text{escape velocity of the planet}$
⇒ Molecule can escape into outer space

Lighter particles are more easily heated to do so than heavier
⇒ Jupiter has lots of H because of high gravity
    Titan able to retain atmosphere despite low mass

**Mass of a planet** and **distance from sun** are major factors influencing its atmosphere
Composition

Composition of atmosphere depends on:

- properties of the solar nebula during the formation of the planet
- emission of gases from the interior of the planet
- existence of life
- sequestration
- extra-planetary factors (solar wind or impactors)

Terra: 78% nitrogen, 21% oxygen and traces of other molecules

Values only true < 100 km: uniform atmosphere (homosphere)

Above 100 km: heterosphere

- composition depending on the molecular mass
- upper altitudes mainly H and He

Composition of the atmosphere always changes due to the existence of life on this planet
Evolution

1. Earth formed from solar nebula (H, He and others)
2. Early atmosphere composed of H and He
3. Escaped because of high temperature
4. Gases of $CO_2$ and ammonia ($NH_3$) steamed out of the Earth’s core
5. Anoxic atmosphere
6. Bacteria started to convert carbon dioxide into oxygen
7. Present day’s composition (N, O)
Layers

The layers of the atmosphere are usually distinguished into:

- troposphere (convection)
- stratosphere (radiation)
- mesosphere ($CO_2$ radiation)
- thermosphere (dissociation and ionisation of molecules)
- exosphere (border to outer space)

Temperature between layers varies greatly (see lecture [1])

Some planets might lack some of those layers

Exploration of the atmosphere depends on altitude:

- troposphere is the subject of meteorology
- middle layers studied by aerology
- upper layers are being measured with rockets, lidars, radar, radio probes and satellites
Pressure is a result of the weight of the atmosphere.

Atmospheres influence surface of a planet in many ways: (temperature, wind speeds, climate, ...)

Highest density at surface and fades out into space with altitude.

Our atmosphere absorbs UV radiation which is dangerous for life.

⇒ Allows life to exist on this planet.

Therefore

We love our atmosphere.
Quiz Time

Why is the sky blue?
Blue light is scattered about 5 times more than red light

Why does Earth look blue from space?
Water absorbs red light
FALSE: Water reflects the sky
Mercury

- Mercury’s atmosphere: vacuum \((1.5 \cdot 10^{-9} \text{ mbar})\)
  - surface of Mercury is covered by many craters
  - temperature changes very strong between day and night phases \((427^\circ C \text{ to } -173^\circ C)\)
- proximity to the sun \(\rightarrow\) high temperatures \(\rightarrow\) high velocity of particles \(\rightarrow\) overcome gravity force \(\rightarrow\) escape Mercury very easily to outer space
- actually only the Exosphere
- Hydrogen and Helium particles are mostly from the Solar wind, Oxygen, Natrium and Kalium from the surface
- NASA mission: MESSENGER to investigate atmosphere (March 2011)
Venus

- Thick atmosphere, composition (96.5% $CO_2$, 3.5% $N_2$)
- Surface pressure 90x and density 50x higher than Earth’s
- Closed cloud layer reflects about 76% of sunlight
- Most is absorbed, only 2% reach surface and heat planet
- $CO_2 \rightarrow$ green house effect: surface temperature 400°C hotter than usually: mean 464°C
- Strong winds (360 km/h), 60x faster than surface rotation: "Superrotation" $\Rightarrow$ Homogenous Temperature
- Atmosphere around Venus is single convection cell
- already many missions made, ESA: Venus Express in 2006
Mars

- Thin atmosphere, surface pressure of only 0.75% of Earth’s
- Heat escapes $\Rightarrow$ high temperature differences ($20^\circ C$ to $-85^\circ C$)
- Mainly $CO_2$ (small amounts of N, Ar and Methane in patches)
- Methane source unidentified, approach over side gases
  - volcanic activity
  - impacts
  - life
- Poles: frozen regions of $CO_2$ and $H_2O$, sublimate in summer time
- During dark winter poles grow, 25% of atmosphere condenses
- Mars missions results: millions of years ago the atmosphere was a lot denser, water existed
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Jupiter

- Atmosphere of Jupiter (about 1.4% of the planet’s radius)
- 90% H, 10% He, traces: similar composition of the solar nebular
- Upper atmosphere rotates 5 minutes slower at poles than at equator
- Dark and bright band patterns of clouds flow depending on latitude in opposing directions
- cause storms with speeds about 600 km/h
- most prominent storm: Great Red Spot (three times the size of Earth) lives for more than 300 hundred years.
- energy partly from adiabatic contraction of gas (Kelvin-Helmholtz-mechanism)
- 1995: Galileo satellite released probe to collect data for almost an hour before being destroyed by high pressure
Saturn

- Composed mainly of H and He
- Different concentration than Jupiter (less helium because its temperature is lower and the helium was able to condensate)
- This unique property decreases mean density $0.687 \text{g/cm}^3$ (lower than water density)
- Faint cloud bands, wider at the equator
- Yellow-brownish clouds contain ammonia crystals
- Long-living ovals, storms
- Unique feature: Saturn has warm poles
- Saturn’s equatorial regions rotate faster than the polar region
- Interior of the planet has even slower rotational period
Uranus

- Cyan color: caused by methane which absorbs red light
- Observations showed cloud bands
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Neptune

- Blue appearance: Hydrogen, Helium and Methane
- Highest wind speeds in solar system: 2,000 km/h
- Caused by an internal energy source (also heating lower layers of atmosphere)
- Southern hemisphere: Earth-sized Great Dark Spot
- Upper layers: mainly Hydrogen and Helium
- Lower layers: also Methane, Ammonia and Water
- Shadows of clouds can be observed on surface
Pluto

- Thin atmosphere consisting mainly of nitrogen and carbon monoxide
- In equilibrium with frozen nitrogen and carbon monoxide on the surface
- Two measurements in 1988 and 2002 during occultation
- First observation 0.15 Pa second 0.3 Pa

But since Pluto’s distance to the Sun increased it was expected that more of the atmosphere was frozen and thus the pressure lower.

Beginning of 2006: New Horizons mission launched to investigate Pluto. In 2015 the first measurements are expected (characterization of its neutral atmosphere and escape rate)
Conclusion

- planets started with same initial conditions during formation
- now: great differences
- with observations we learned a lot about
  - factors influencing atmospheres
  - evolution of atmospheres
  - also a lot about the atmosphere of our own planet

We learned how **vulnerable** our own atmosphere is and how it is **affected** by small changes of the environment.

Most important we learned that we should **appreciate** this precious hull of molecules since without it **no life** on this planet could exist.
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