Planetary Atmospheres Part 2
Atmospheric Layers:

The temperature ‘gradient’ (whether it increases or decreases with altitude) is set by the type of absorption that occurs. *We can affect this!*
Radiative Transfer:

Light interacts with the gases in the atmosphere in several ways:

1. **Scattering**: photons interact with the medium and continue in a different direction.
2. **Photo-dissociation/photo-ionization**: photons ionize atoms and molecules or dissociate molecules.
3. **Fast particle**: collisions cause an electron to jump energy levels and fall; a photon is emitted.
4. **Airglow**: recombination, chemical reactions, & cosmic rays.

Scattering of incoming light

Photo-dissociation or Photo-ionization

Incoming light

Fast particle *(aurora)*

Spontaneous Internal Source *(airglow)*
An Example: The Role of Ozone

Atomic oxygen doesn’t like to be alone, so it binds with something. In the dark that can be $O_2$.

$O_3$ only stable in the low pressures of the stratosphere

Ozone production is most effective in darkness and the poles have extended periods of darkness. Destruction happens in daylight.
An Example: The Role of Ozone
**Why we should care....**

Human activity is destroying the Ozone layer!! Chlorofluorocarbons (from spray cans) are transported to the stratosphere. They contain *chlorine*. Chlorine is very bad, because it destroys Ozone.

\[
\text{Cl} + \text{O}_3 \rightarrow \text{ClO} + \text{O}_2
\]
\[
\text{ClO} + \text{O} \rightarrow \text{Cl} + \text{O}_2
\]

The above is called a *catalytic* reaction. The O\(_3\) is destroyed, but *not* Cl!

Because the stratosphere is stable, the Cl is trapped. This is a big problem....

Ozone destroying chemicals are regulated by the Montreal Protocol.

Scientists estimate the ozone will return to pre 1980 conditions by 2050-2075.
Another Example: Aurora, Airglow, Ions

The highest energy photons from the Sun are absorbed at the top of the atmosphere.

Much of this light is energetic enough to create ions.

The upper atmosphere has a series of `regions` dominated by different ions. We call these regions the *ionosphere and magnetosphere*.
Aurora

- **Energetic electrons and ions** from the magnetosphere slam into nitrogen and oxygen in the upper atmosphere (100-400 km alt)

- Excited N and O eventually relax back and emit **photons**
Another Example: Airglow

Ions will `recombine` with electrons to produce neutral atoms that emit aurora-like emissions over the full sky (airglow).

Molecules at a certain temperature can emit rotational and vibrational energy that takes energy out of the atmosphere (also airglow).
Airglow
Airglow photochemistry

**OH bands (87 km)**

\[
\begin{align*}
\text{O}_2 + h\nu & \rightarrow \text{O} + \text{O} & \text{photo-dissociation (solar UV, daytime)} \\
\text{O} + \text{O}_2 + \text{M} & \rightarrow \text{O}_3 + \text{M} & \text{ozone production} \\
\text{O}_3 + \text{H} & \rightarrow \text{OH}^* + \text{O}_2 & \text{OH production} \\
\text{OH}^* & \rightarrow \text{OH} + h\nu & \text{airglow emission (visible, IR)} 
\end{align*}
\]
Airglow photochemistry

**OH bands (87 km)**

\[ \text{O}_2 + \text{hv} \rightarrow \text{O} + \text{O} \]  
photo-dissociation (solar UV, daytime)

\[ \text{O} + \text{O}_2 + \text{M} \rightarrow \text{O}_3 + \text{M} \]  
ozone production

\[ \text{O}_3 + \text{H} \rightarrow \text{OH}^* + \text{O}_2 \]  
OH production

\[ \text{OH}^* \rightarrow \text{OH} + \text{hv} \]  
airglow emission (visible, IR)

**O}_2\text{ Atmospheric band (95 km)**

\[ \text{O}_2 + \text{hv} \rightarrow \text{O} + \text{O} \]  
photo-dissociation (solar UV, daytime)

\[ \text{O} + \text{O} + \text{M} \rightarrow \text{O}_2^* + \text{M} \]  
production of excited \text{O}_2

\[ \text{O}_2^* + \text{O} \rightarrow \text{O}_2^{1\Sigma} + \text{O} \]  
transfer of excitation

\[ \text{O}_2^{1\Sigma} \rightarrow \text{O}_2^{3\Sigma} + \text{hv} \]  
airglow emission (near IR)

Emission intensity depends on atomic oxygen concentration.  
Steep [O] mixing ratio gradient => good vertical wind monitor
Airglow and Aurora ... on Mars
One More Example: Photon Conversion

• Consider the spectrum of incoming and outgoing energy at the Earth.

• Incoming sunlight heats the ground.

• The incoming spectrum carries the signature of a 5800K object.

• The heated Earth re-radiates as a 280K object.

• The atmosphere responds very differently to the Earth`s emission.
Atmospheric Transmission:

Not all of the Sun’s Light Reaches the Ground!
Sagan`s Discovery:

Three planets in the solar system have large amounts of H$_2$O, CO$_2$, or both…Venus, Earth, and Mars.

In 1960 Carl Sagan suggests that the planet Venus is HOT (870K!! – hotter than Mercury) because of CO$_2$ absorbing the surface blackbody emission. This process is called the `Greenhouse Effect`. It works on Earth and Mars too, but not as well.

The greenhouse effect is like a blanket, Venus` blackbody temperature is what we expect given the input from the Sun.
Infrared radiation on Venus is trapped by scattering in the atmosphere.

Eventually the atmosphere begins to thin so that the infrared can escape.

At that altitude the emission appears to be `spontaneous` and the heat is rapidly vented to Space.

This happens on Earth too, in the **mesosphere**.
Greenhouse Effect

Visible light from sun passes through atmosphere

Sun light heats earth which radiates back as colder blackbody in the infrared. Infrared trapped by CO2 and H2O in atmosphere
Titan’s atmosphere
Where we are headed in the next 4-5 lectures

- Nuclear energy
- Sun’s energy production and transport
- Solar Neutrinos
- Layers of the Sun
- Helioseismology
The Sun
Diameter:
860,000 mi
1,390,000 km

- Plage
- Filament
- Sunspot
- Active Region