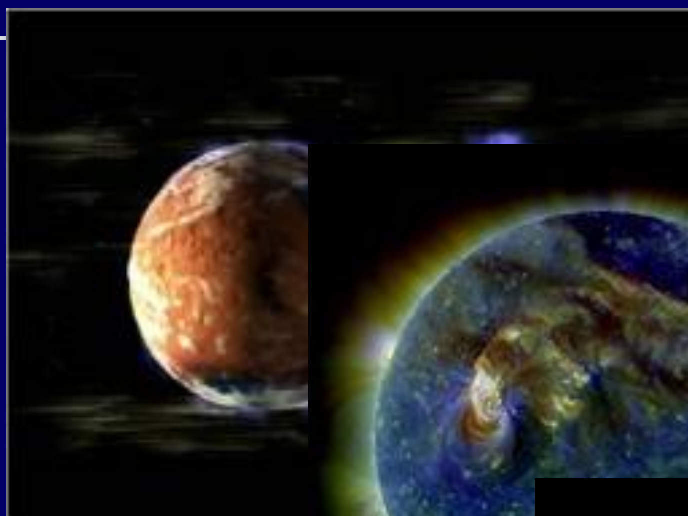
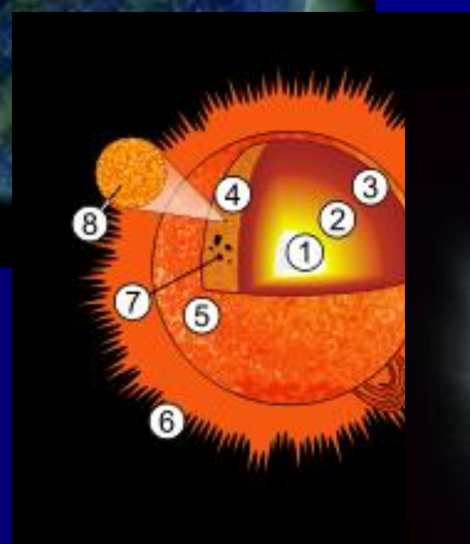
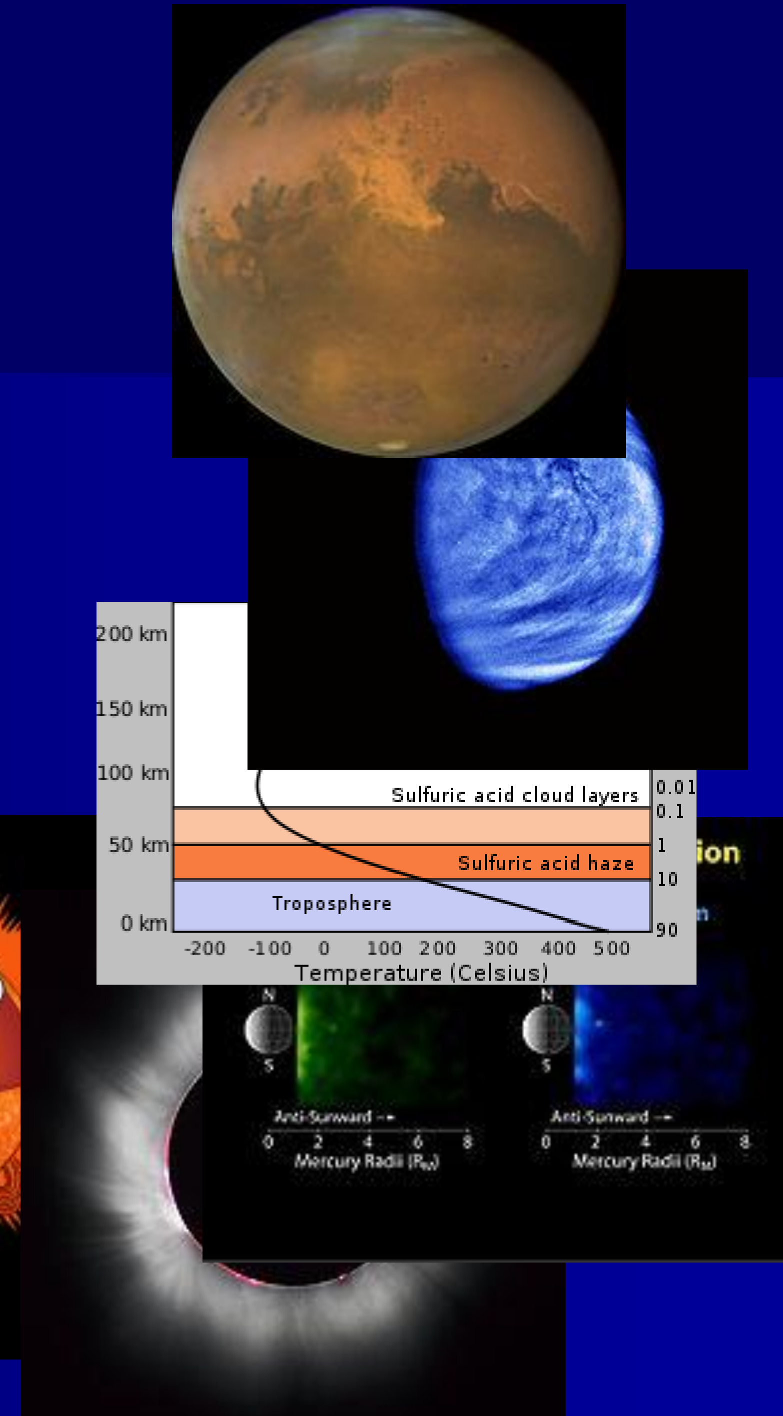
Space Physics

Space Physics

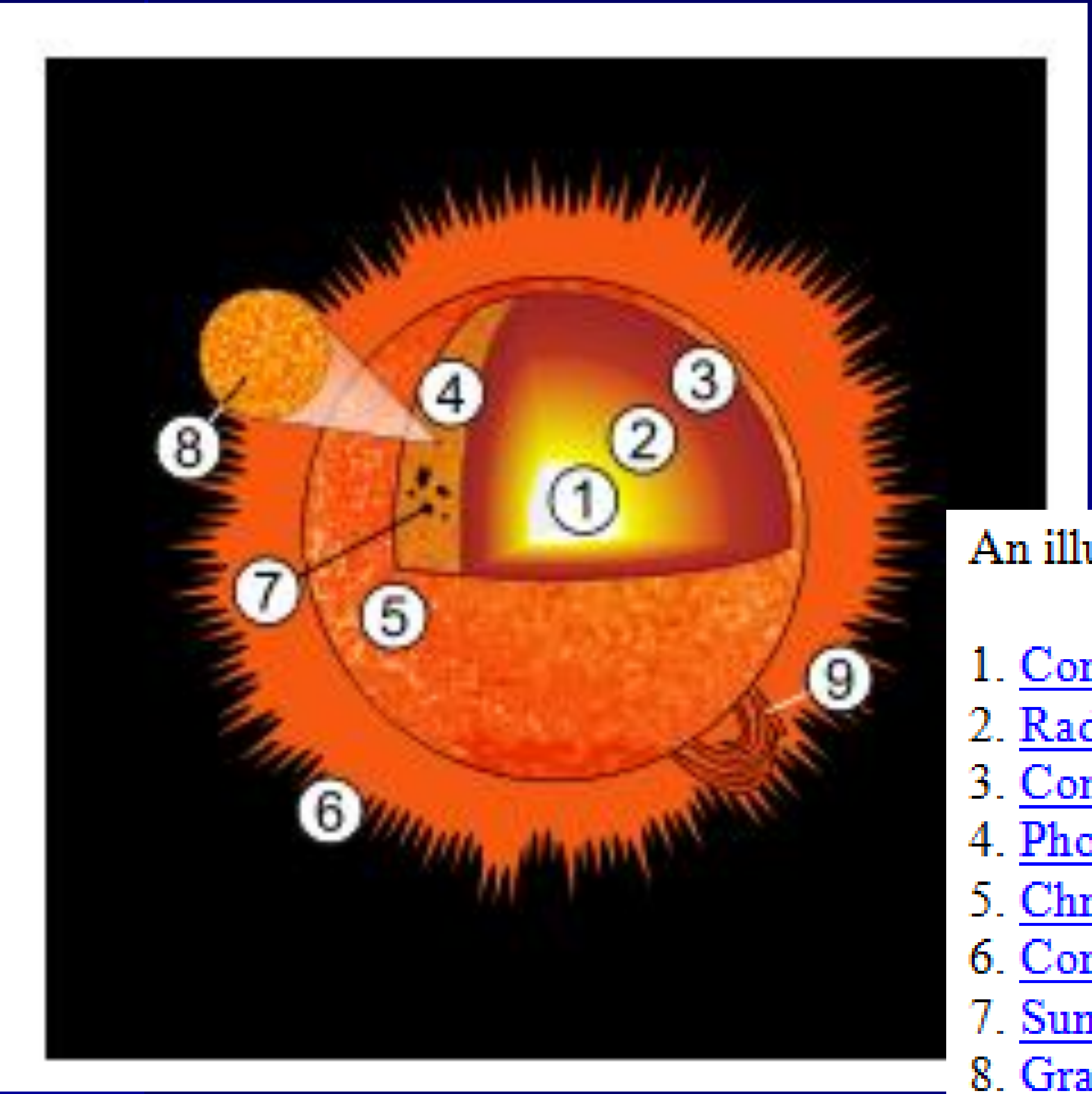






Lecture – 12

Structure of the Sun



An illustration of the structure of the Sun:

1. Core
2. Radiative zone
3. Convective zone
4. Photosphere
5. Chromosphere
6. Corona
7. Sunspot
8. Granules
9. Prominence

Sunspots & the Solar Cycle

It was not until 1843 that **Heinrich Schwabe** announced in Germany that his long sunspot observations had shown that the average number of sunspots on the Sun varies with a **period of approximately 10 years**.

Further studies in past records by **Rudolf Wolf** confirmed the existence of an **11 year sunspot cycle** and in 1851, Wolf introduced his relative sunspot number R which is given in the relation,

Calibration Factor

Relative Sunspot Number

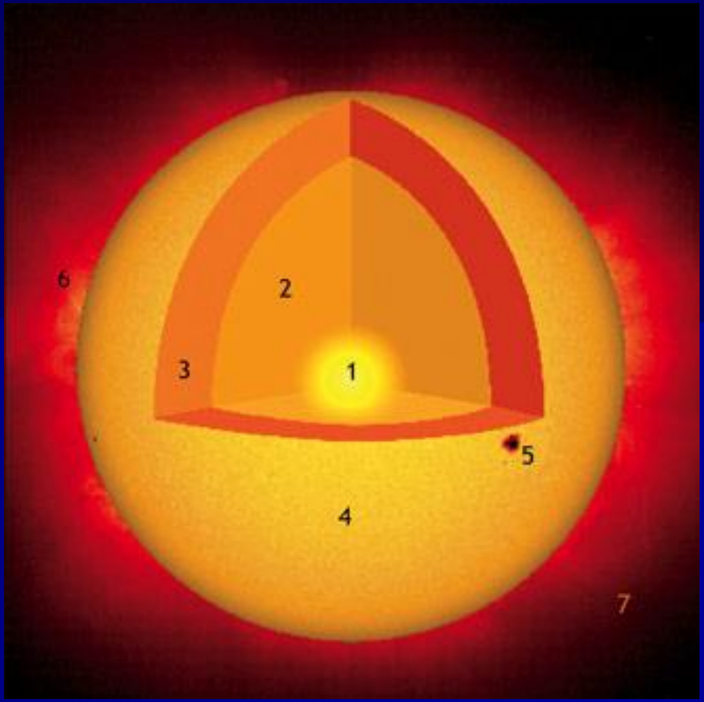
$$R = k\,[10\,g + f]$$

Number of individual sunspots on the disk of the Sun

Number of sunspot groups on the disk of the Sun

Where, **k** is a coefficient assigned to each observing station to assure uniformity in the R numbers obtained by the different stations. This k is called "**Calibration Factor**" of the equation.

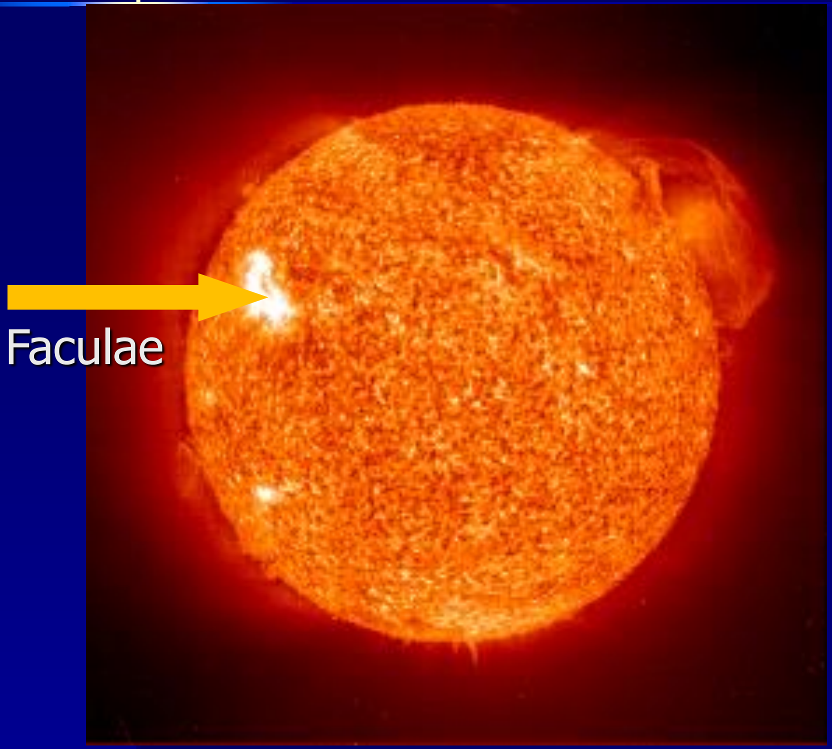
The Active Sun



The Sun and Stars
Introduction of the Active Sun
The Photosphere
The Chromosphere and the Corona
Sunspots and the Solar Cycle
Faculae, Flares and Prominences
Radio and X-ray Bursts from the Sun
The Development of an Active Region on the Sun
Effect of the Solar Cycle
Life Cycle of the Sun

Faculae (දීදුල) **, Flares & Prominences**

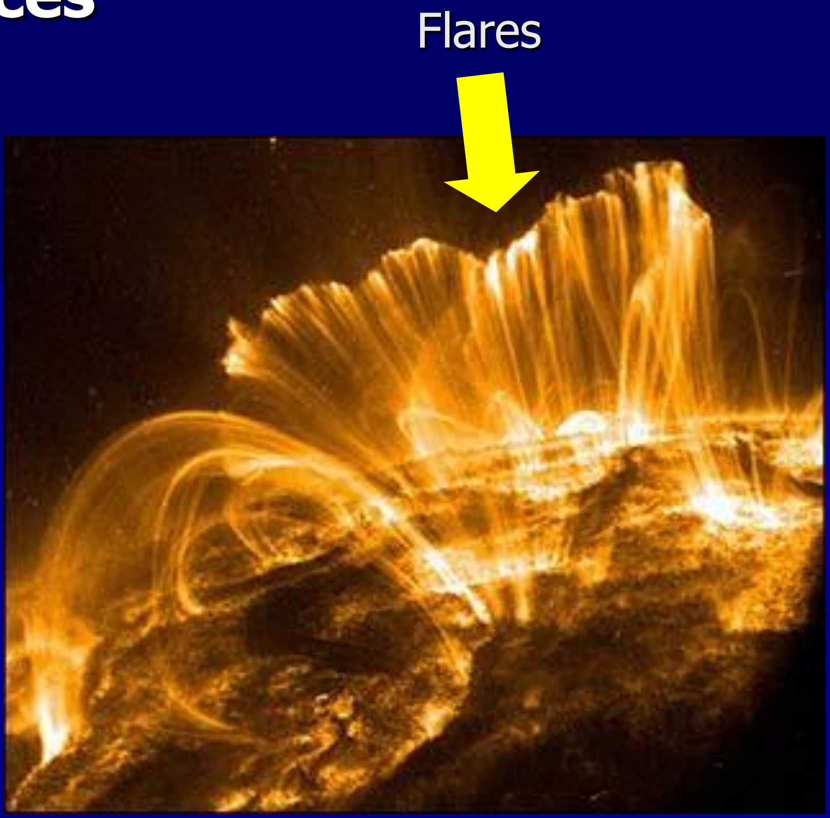
In this section we will discuss the different **optical manifestations of the active Sun**.



The first sign of solar activity is the appearance of a bright area which, when near the limb of the Sun, is brighter than the photosphere even in white light. These bright areas are called "**Faculae**", or more precisely "**Photospheric Faculae**"

Faculae usually engulf (swallow) a sunspot group, but they become noticeable before the appearance of the sunspots and often survive them by a month or two.

Faculae , Flares & Prominences



A **flare** is a sudden local increase in the brightness of the solar surface which lasts for nearly one hour. **Flares appear in an active region**, i.e.; a pelage (birth) area with sunspots the eruption (very fast explosion) of a **Solar Flare** is the culmination (get a peak) of the activity that has been mounting up in the sunspot region.

A flare is the optical effect produced by the sudden release of tremendous (very large) amount of energy ($6x10^{25}$ J/s) in the upper chromosphere or the lower corona. This explosion, which probably takes place above the layers where the optical flare appears, produces also a strong outburst (blast to the outside) of X-ray and Radio Emission which we will discuss in the next section.

Solar Activity & Solar Flares

The incidence of solar flares is another measure of solar activity and is related to the sunspot number by,

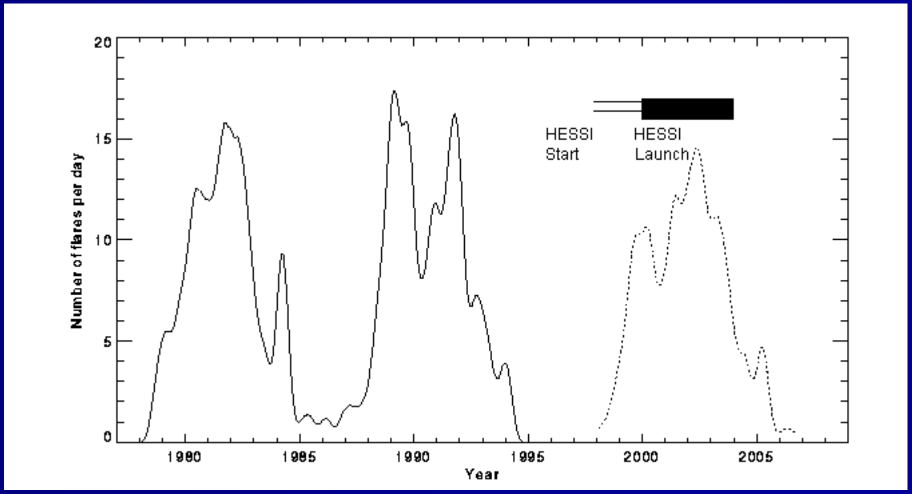
Number of Solar Flares observed

Mean Sunspot Number

$$N_t = \alpha \left[\bar{R} - 10\right]$$

Observatory Constant ~ 1.5 – 2.0

Where, N_t is **Number of Solar Flares observed during one solar rotation,** $\bar{R}$ is the **Mean Sunspot Number** and α (alpha) is an **Observatory Constant** of value between ~1.5 – 2.0.



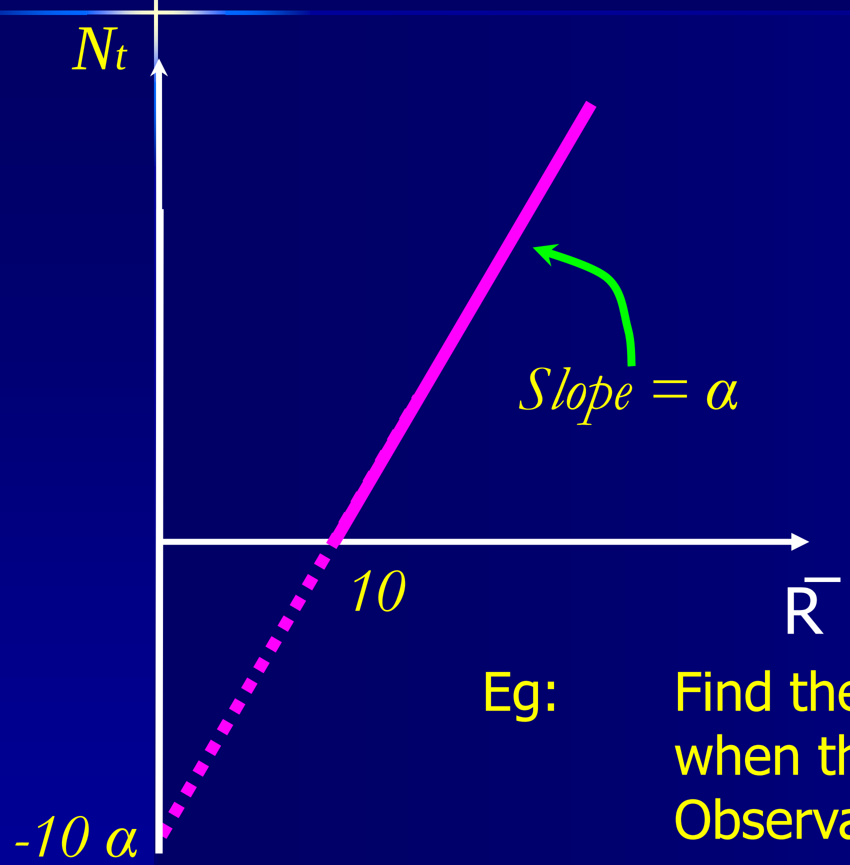
Solar Activity & Solar Flares

The graph of Number of solar flares observed per solar rotation verse mean sunspot number :

$$N_t = \alpha\,[\bar{R} - 10]$$

$$N_t = \alpha\,\bar{R} - 10\,\alpha$$

$N_t \rightarrow$ y, $\alpha \rightarrow$ m, $\bar{R} \rightarrow$ x, $10\,\alpha \rightarrow$ - c



If, $N_t = 0 \rightarrow \bar{R} = 10$

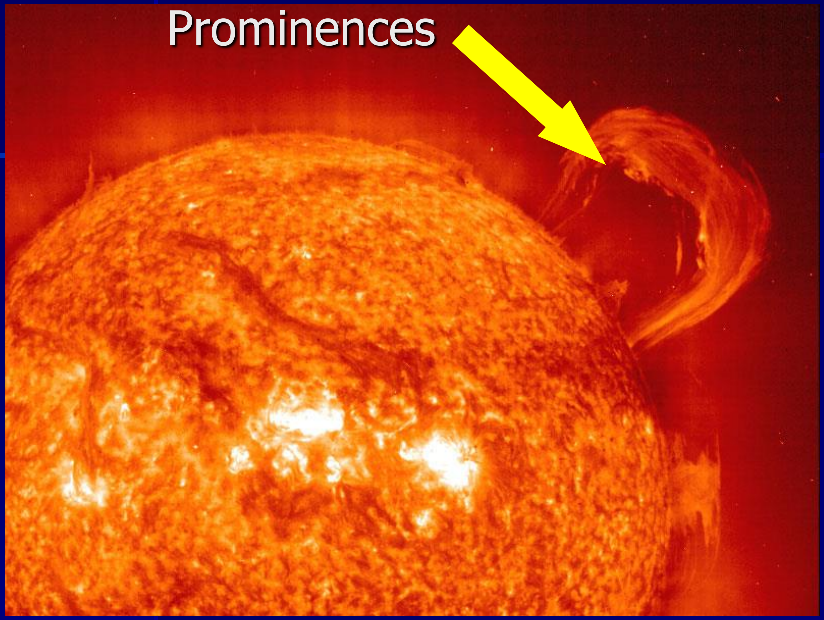
If, $\bar{R} = 0 \rightarrow N_t = -10\,\alpha$

Eg: Find the number of solar flares per solar rotation when the mean sunspot number is 25 and Observatory Constant 1.6.

$$N_t = \alpha\,[\bar{R} - 10] \Rightarrow N_t = 1.6\,[25 - 10]$$

$$\Rightarrow N_t = 24$$

Faculae , Flares & **Prominences** (නෙරුම)

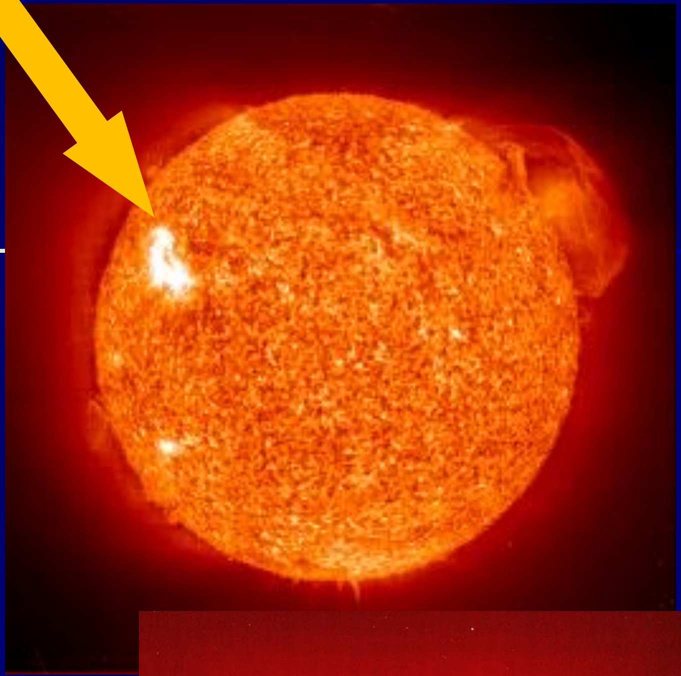


Solar **prominence** (**more gases emitted place**) have been recorded in same very impressive sequences with time-lapse photography. When seen at the limb of the Sun, prominence appear as luminous arch-like structures with continuous internal motion. These arches are about 200,000 km long but only a few thousand kilometers thick.

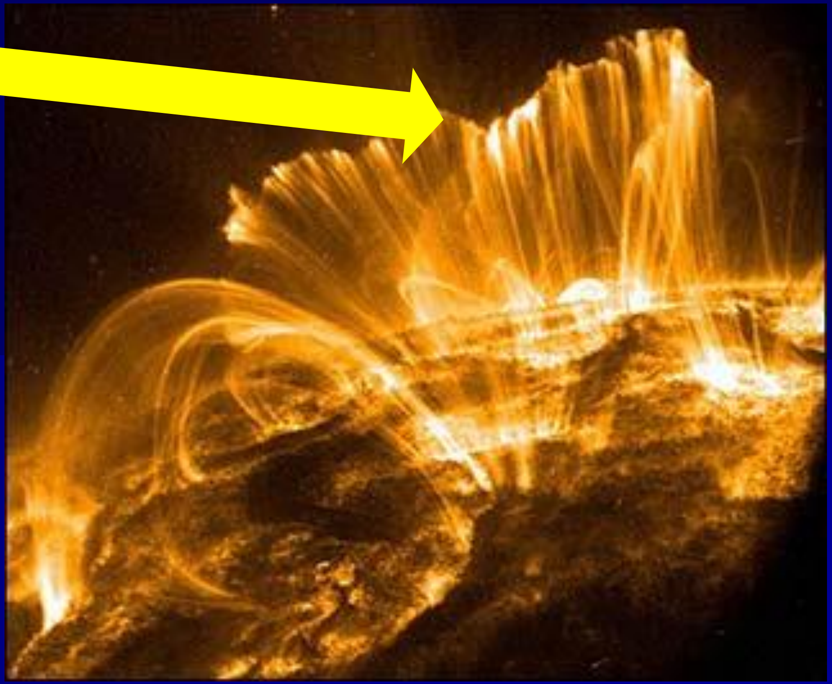
When they are projected on the luminous disk of the Sun they simply appear as **long dark filaments**.

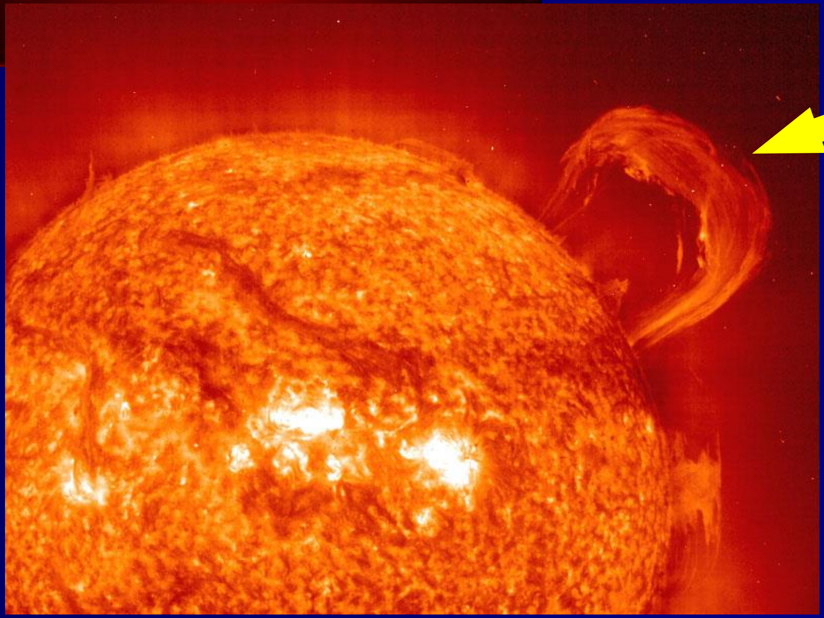
The **active prominences** which appear over a sunspot group and for this reason they are called **sunspot prominences**, and the **quiescent** (very calm) **prominences** which are associated with peculiar (own) regions without sunspots or with sunspot groups in their decaying stage.

Faculae (දීදුල)



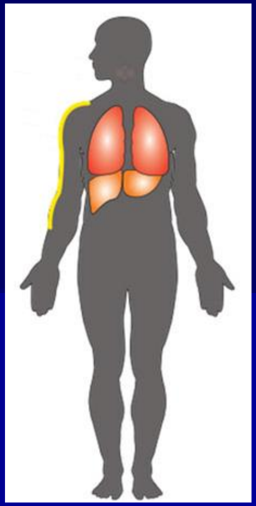
Flares





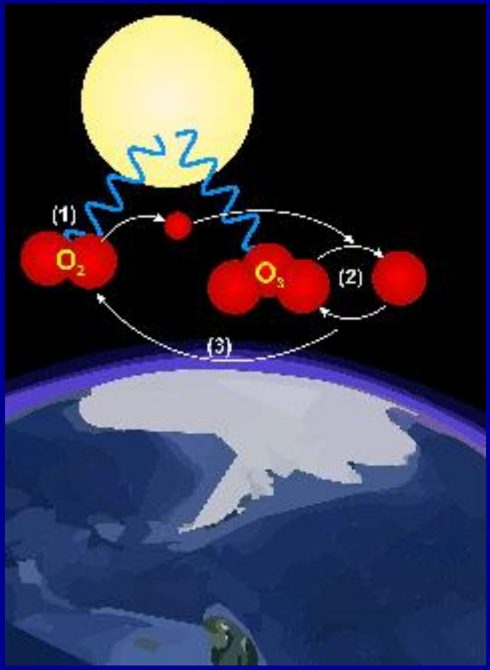
Prominences (නෙරුම)

The Solar Cycle, Effects on Earth



- The impact of Solar cycle on living organisms has been investigated (see chronobiology). Some researchers claim to have found connections with human health.

- The amount of UV-B light at 300 nm reaching the Earth varies by as much as 400% over the solar cycle due to variations in the protective Ozone Layer. In the stratosphere, ozone is continuously regenerated by the splitting of O_2 molecules by ultraviolet light. During a solar minimum, the decrease in ultraviolet light received from the Sun leads to a decrease in the concentration of ozone, allowing increased UV-B to penetrate to the Earth's surface.

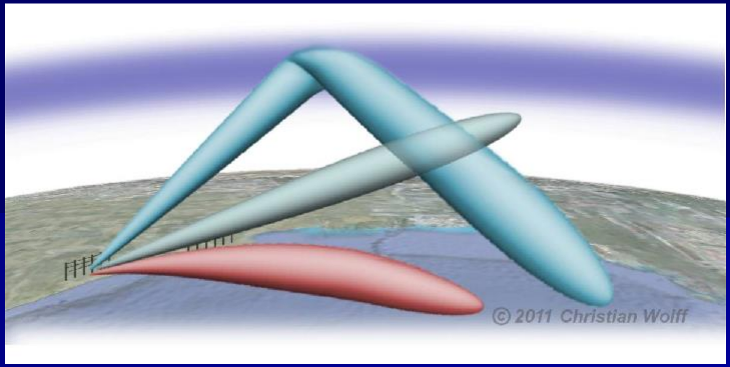


The Solar Cycle, Effects on Earth

- The sunspot cycle has been implicated in having effects on climate, and may play a part in determining global temperature.

The Solar Cycle, Effects on Earth

- Sky-wave modes of radio communication operate by bending (reflecting) radio waves (electro-magnetic radiation) off of the Ionosphere.



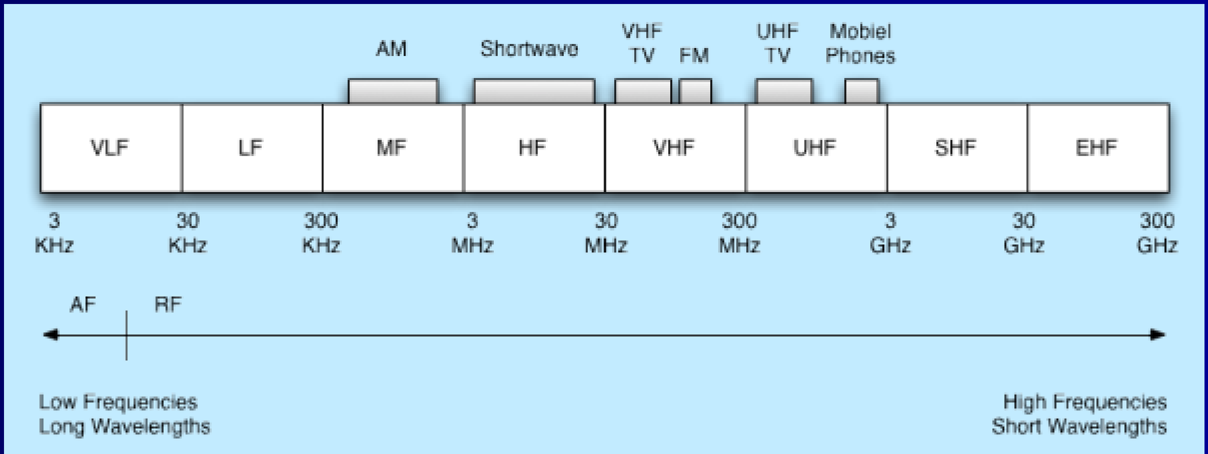
During the "peaks" of the solar cycle, the ionosphere becomes ionized by solar photons and cosmic rays.

This affects the path (propagation) of the radio wave in complex ways which can both facilitate (easy) or hinder (blocked) local and long distance communications.

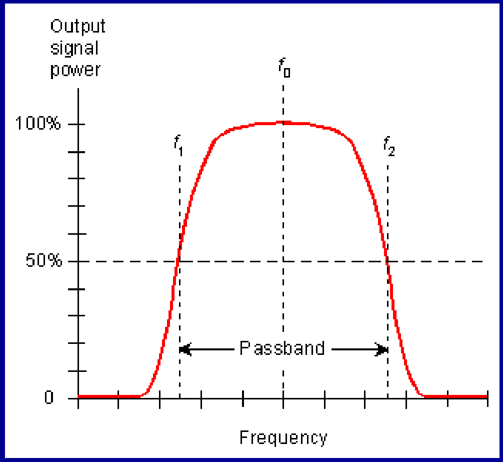
Forecasting of sky-wave modes is of considerable interest to commercial marine and aircraft communication, amateur radio operators, and short wave broad casters.

The Solar Cycle, Effects on Earth

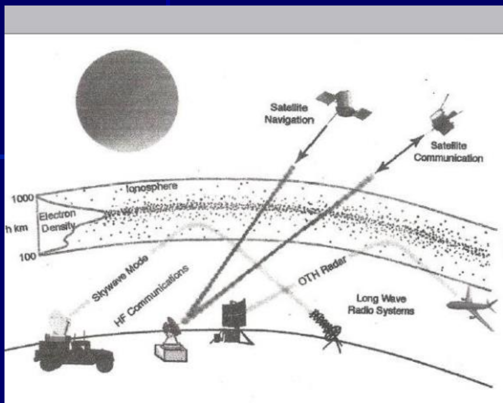
- These users utilize frequencies within the high-frequency or 'HF' radio spectrum which are most **affected by these solar and ionospheric variances**.



- Changes in solar output affect the maximum usable frequency, a limit on the highest frequency usable for communications.



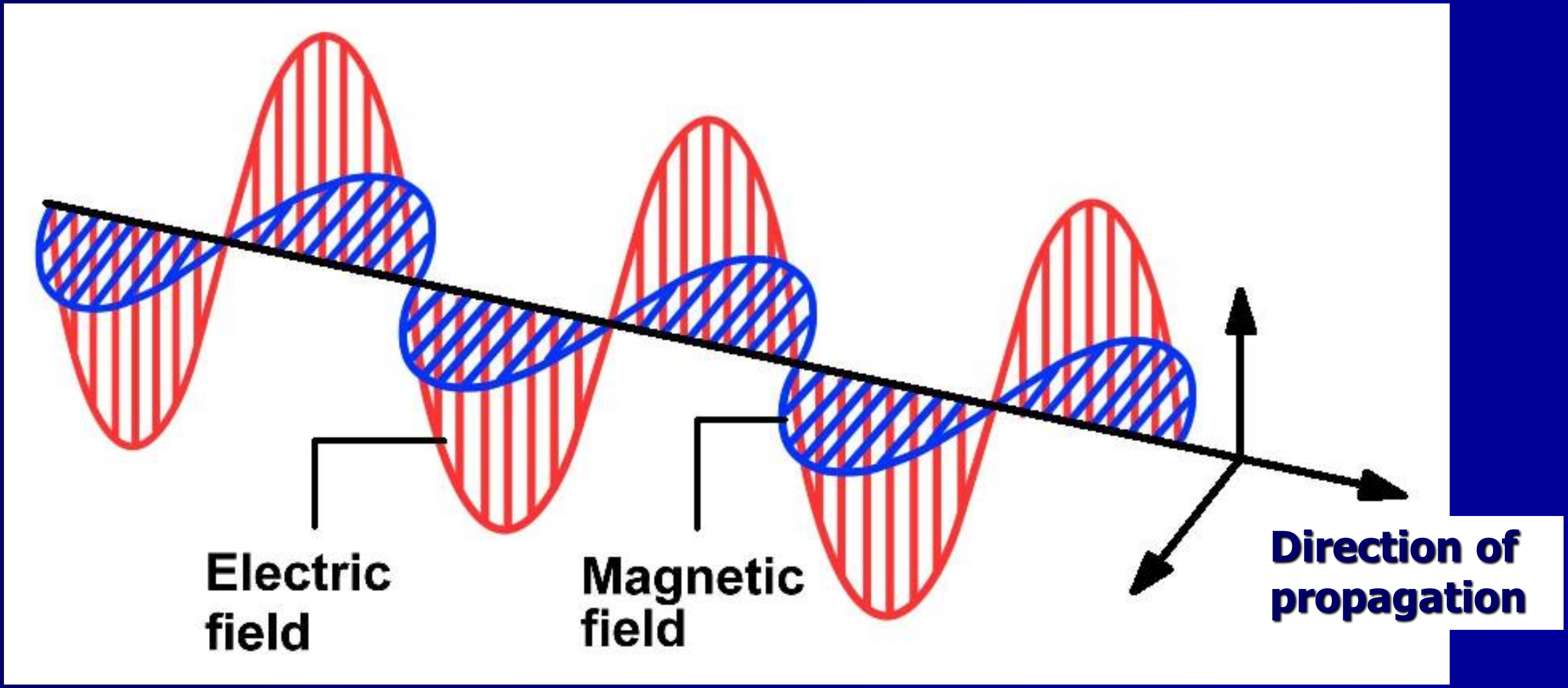
Radio Wave Communication



Reflection of Radio Waves
Absorption of Radio Waves
Complex Refractive Index
Reflection Heights
Deviating Region Absorption, Non- Deviating Region Absorption
Ionosphere – Sounding Techniques
Pulse Reflection Methods

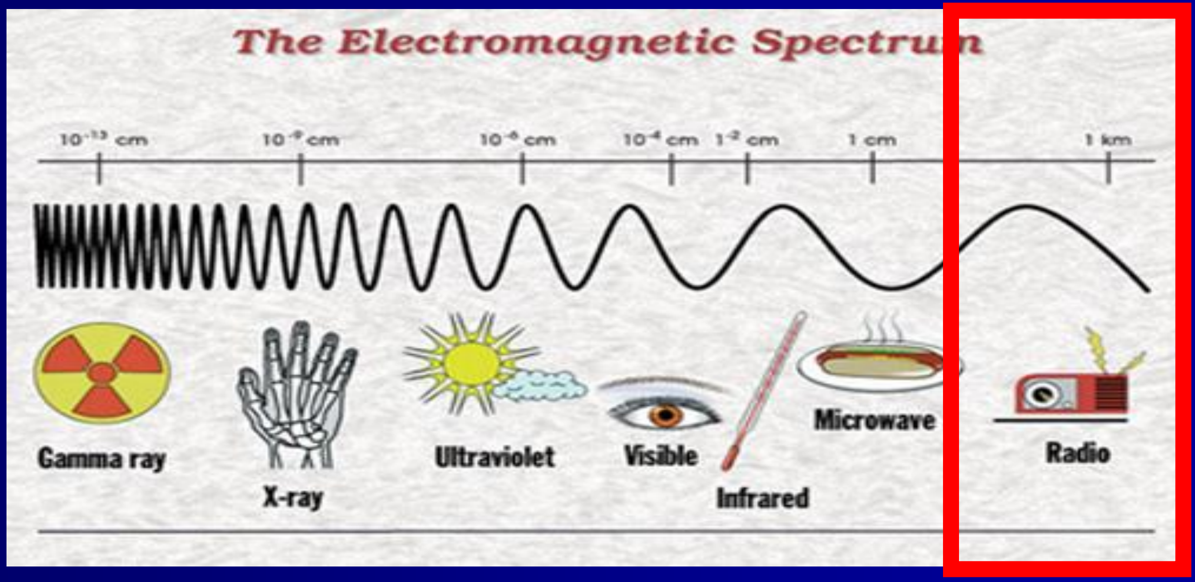
Radio waves

Radio waves are a type of **electromagnetic radiation** with wavelengths in the electromagnetic spectrum longer than infrared light. Like all other electromagnetic waves, they travel at the speed of light. Naturally-occurring radio waves are made by lightning, or by astronomical objects.

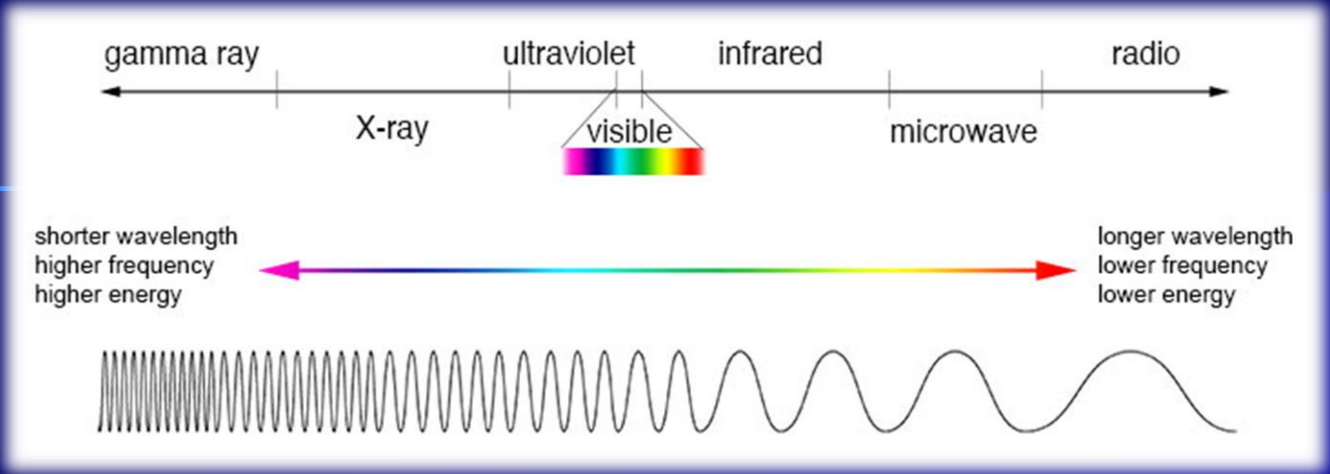


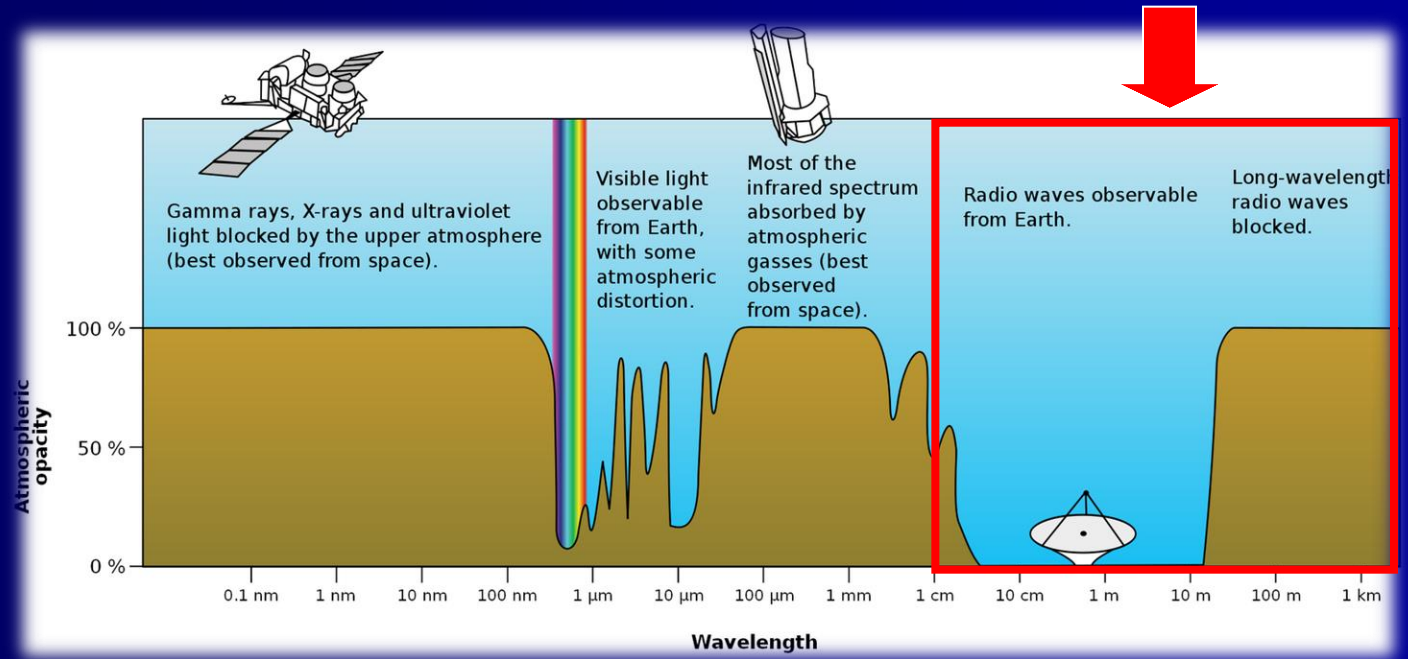
Radio waves

Artificially-generated radio waves are used for fixed and mobile radio communication, broadcasting, radar and other navigation systems, satellite communication, computer networks and innumerable other applications. Different frequencies of radio waves have different propagation characteristics in the Earth's atmosphere; **long waves may cover a part of the Earth very consistently**, **shorter waves can reflect off the ionosphere and travel around the world**, and **much shorter wavelengths bend or reflect very little and travel on a line of sight**.



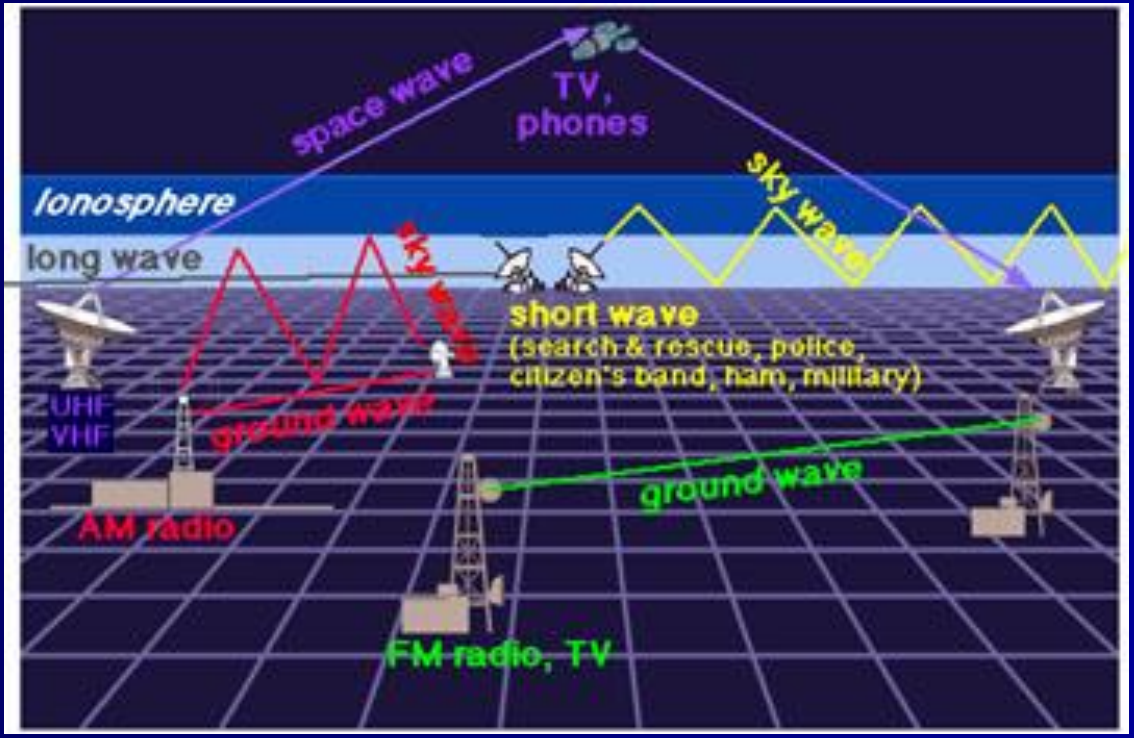
Radio waves


gamma ray
ultraviolet
infrared
radio
X-ray
visible
microwave
shorter wavelength
higher frequency
higher energy
longer wavelength
lower frequency
lower energy


Gamma rays, X-rays and ultraviolet light blocked by the upper atmosphere (best observed from space).
Visible light observable from Earth, with some atmospheric distortion.
Most of the infrared spectrum absorbed by atmospheric gasses (best observed from space).
Radio waves observable from Earth.
Long-wavelength radio waves blocked.
100 %
50 %
0 %
Atmospheric opacity
0.1 nm
1 nm
10 nm
100 nm
1 µm
10 µm
100 µm
1 mm
1 cm
10 cm
1 m
10 m
100 m
1 km
Wavelength

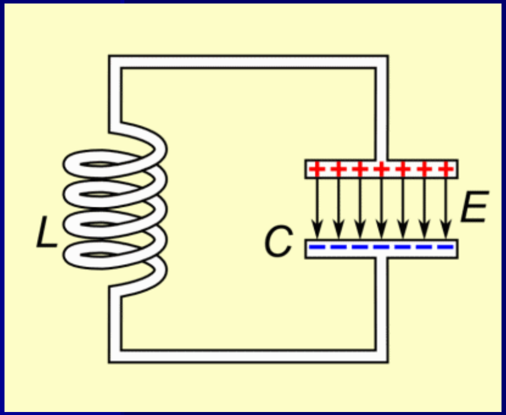
Propagation…

The study of electro magnetic phenomena such as reflection, refraction, polarization, diffraction and absorption is of critical importance in the study of how radio waves move in free space and over the surface of the Earth. Different frequencies experience different combination of these phenomena in the Earth's atmosphere, making certain radio bands more useful for specific purpose than others.



Radio Communication

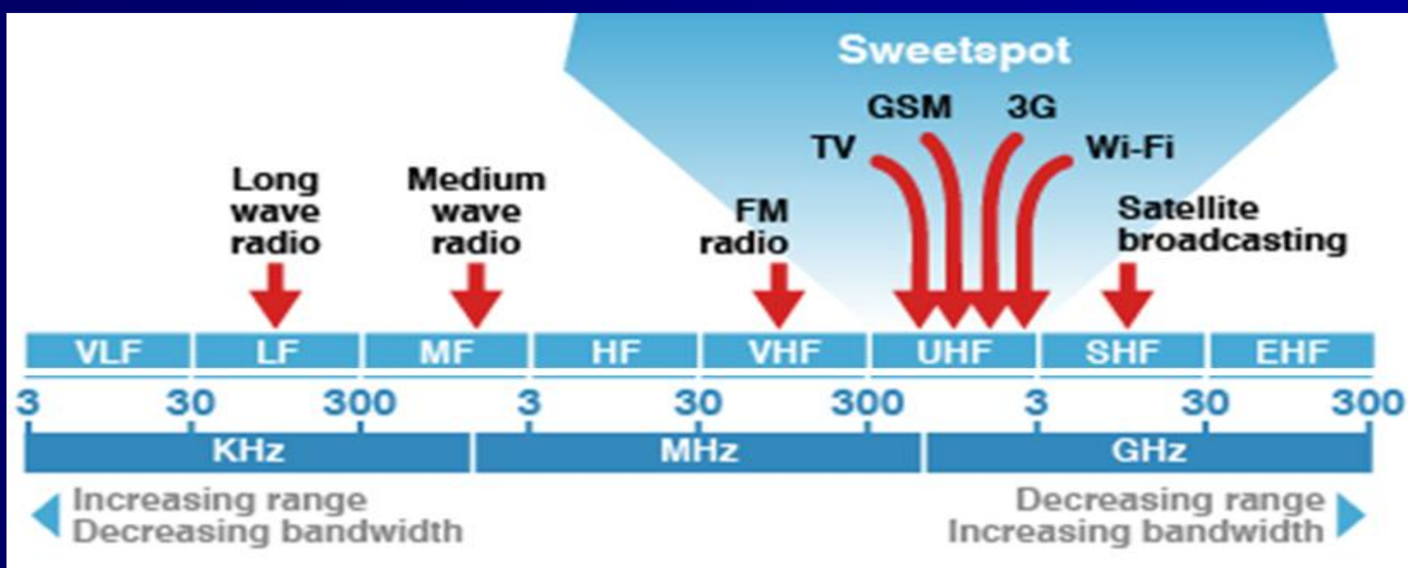
In order to receive radio signals, for instance from AM / FM radio stations, a radio antenna must be used. However, since the antenna will pickup thousands of radio signals at a time, a **radio tuner** is necessary to tune in to a particular frequency (or frequency range).

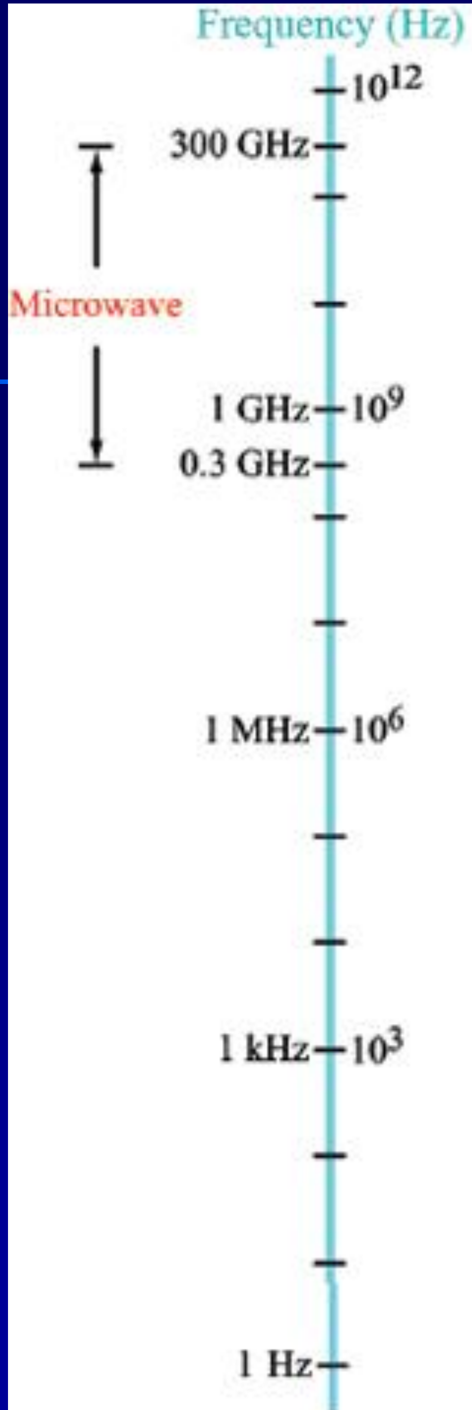


This is typically done via a **resonator** (in **the simplest form, a circuit with a capacitor and an inductor**). The resonator is configured to resonate at a particular frequency (or frequency band), thus amplifying since waves at that radio frequency, while ignoring other **sine waves**. Usually, either the inductor or the capacitor of the resonator is adjustable, allowing the user to change the frequency at which it resonates.

Radio Spectrum

Band	Frequency range	Wavelength range
Extremely low frequency (ELF)	< 3 kHz	>100 km
Very low frequency (VLF)	3 - 30 Hz	10 - 100 krn
Low frequency(LF)	30 - 300 kHz	1 - 10 km
Medium frequency (MF)	300 kHz - 3 MHz	100m - 1km
High frequency (HF)	3 - 30 MHz	10 - 100m
Very high frequency (VHF)	30 - 300 MHz	1 - 10m
Ultra high frequency (UHF)	300 MHz - 3 GHz	10cm - 1m
Super high frequency (SHF)	3 - 30 GHz	1 - 10cm
Extremely high frequency (EHF)	30 - 300 GHz	1mm - 1cm





Band	Applications
Extremely High Frequency (30–300 GHz)	Radar, advanced communication systems, remote sensing, radio astronomy
Super High Frequency (3–30 GHz)	Radar, satellite communication systems, aircraft navigation, radio astronomy, remote sensing
Ultra High Frequency (300 MHz – 3 GHz)	TV broadcasting, radar, radio astronomy, microwave ovens, cellular telephone
Very High Frequency (30–300 MHz)	TV and FM broadcasting, mobile radio communication, air traffic control
High Frequency (3–30 MHz)	Shortwave broadcasting
Medium Frequency (300 kHz – 3 MHz)	AM broadcasting
Low Frequency (30–300 kHz)	Radio beacons, weather broadcast stations for air navigation
Very Low Frequency (3–30 kHz)	Navigation and position location
Ultra Low Frequency (300 Hz – 3 kHz)	Audio signals on telephone
Super Low Frequency (30–300 Hz)	Ionospheric sensing, electric power distribution, submarine communication
Extremely Low Frequency (3–30 Hz)	Detection of buried metal objects
	Magnetotelluric sensing of the Earth's structure

How Radio Communication Works ?

Sound and **Radio Waves** are different phenomena.

Sound consists of pressure variations in matter, such as air or water.
Sound will not through a vacuum.

Radio Waves, like infrared, ultra-violet, visible light, X-rays and Gamma rays are **electro-magnetic waves** that do travel through a vacuum. When you turn-on a radio you have sounds because the transmitter at the radio station has converted the sound waves in to electro-magnetic waves, which are then encoded into an electro-magnetic wave in the radio frequency range
(generally in the range of

500 kHz - 1600 kHz for AM stations

or

86 MHz - 108 MHz for FM stations

).

How Radio Communication Works ?

Thank You !