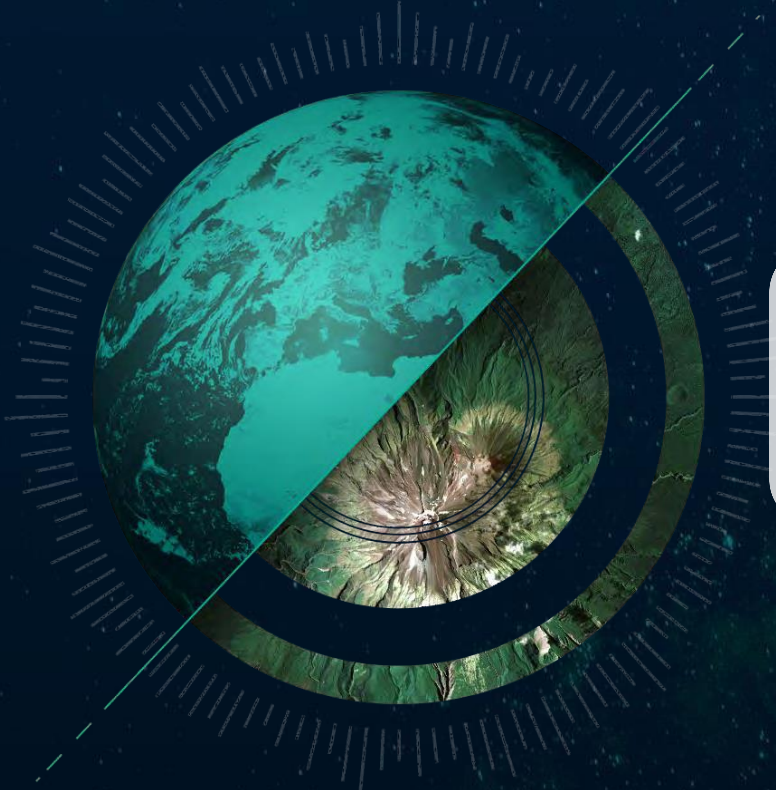
esa space solutions

Copernicus Academy

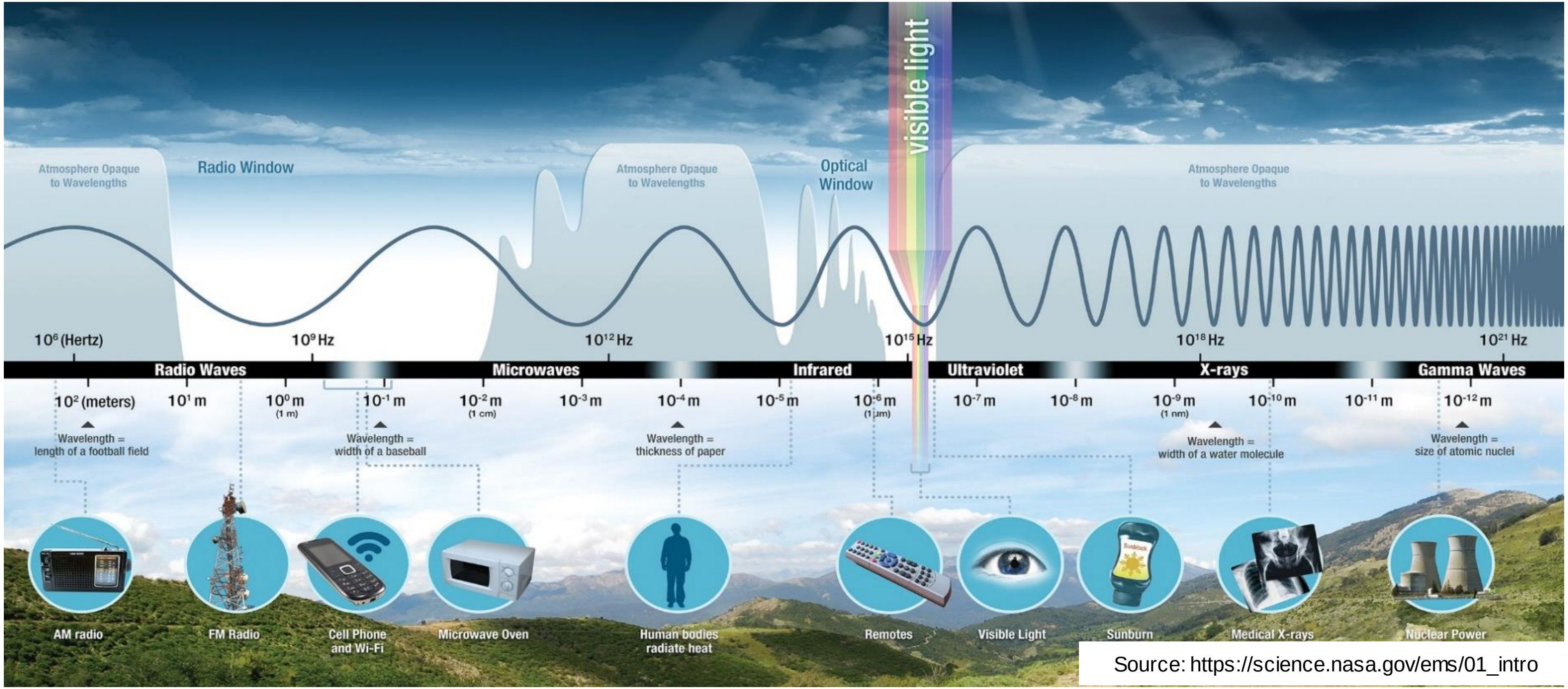
ÚSTAV GEOGRAFIE
Prírodovedecká fakulta UPJŠ v Košiciach



3. Key concepts and physical principles of remote sensing methods: electromagnetic energy, its properties, spectral behaviour and interaction with the environment

Principle of Remote Sensing

Detection and discrimination of objects or surface features = detecting and recording of electromagnetic radiation reflected or emitted by objects or surface material

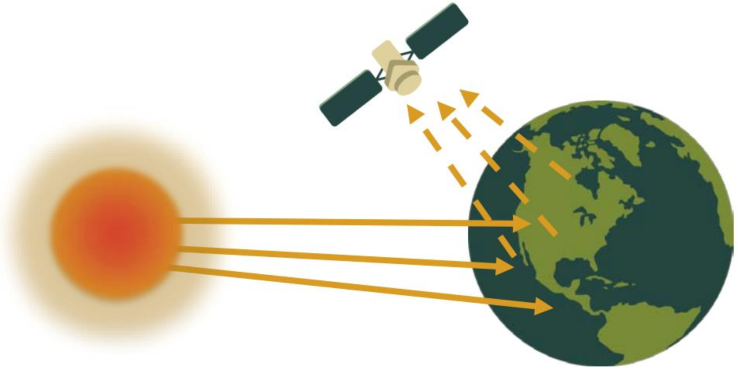


Source: https://science.nasa.gov/ems/01_intro

Different objects return different amount and kind of energy in different bands of the EMG spectrum.

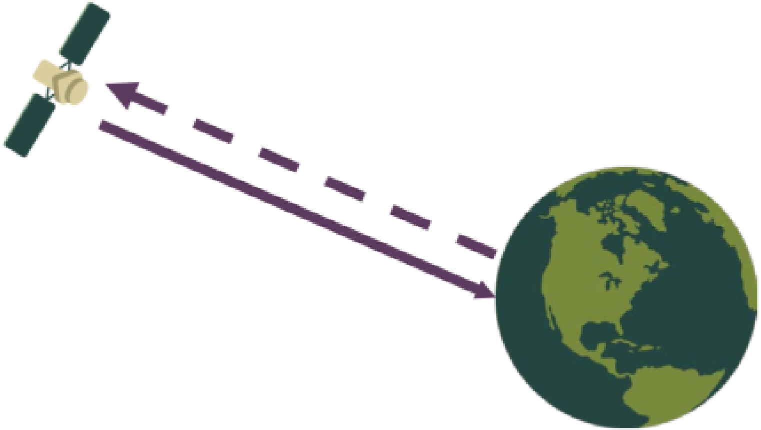
Remote Sensing Sensors

Passive Sensors



- Dependent on a natural source (e.g. Sun, Earth) to provide energy
- The satellite sensor records primarily the radiation that is reflected from the target

Active Sensors

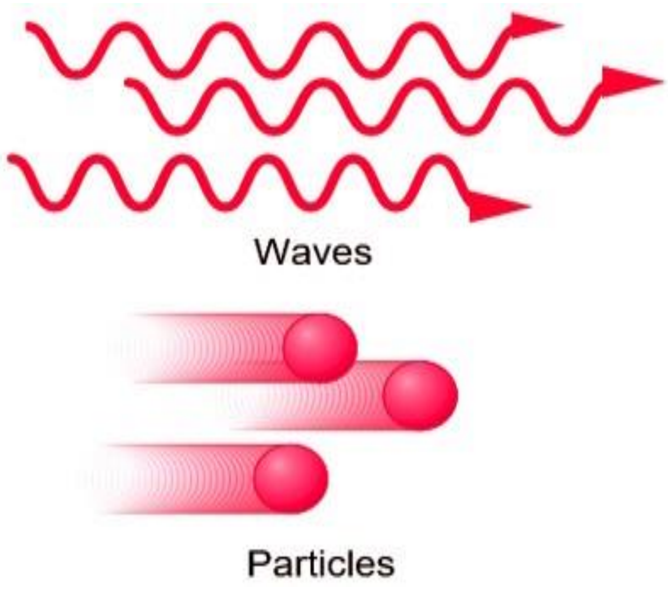


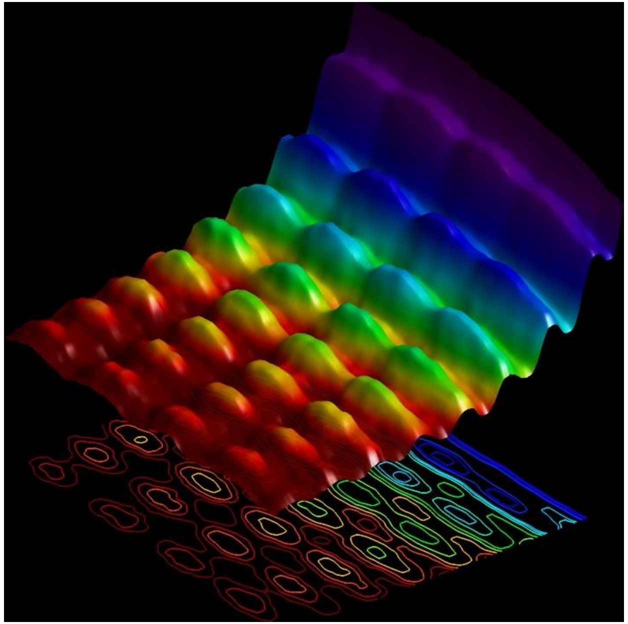
- Use an artificial source for energy
- The satellite itself can send a pulse of energy which can interact with the target
- Can be carried out during day and night and in all weather conditions

Source: https://www.earthdata.nasa.gov/learn/backgrounders/passive-sensors, https://www.earthdata.nasa.gov/learn/backgrounders/active-sensors

Properties of Electromagnetic radiation

Electromagnetic radiation has properties of **waves** but also can be thought of as a **stream of particles (quantum).**





Source: https://m.sciencecalculators.org/optics/light/, https://conciencia2.es/la-doble-naturaleza-de-la-luz/

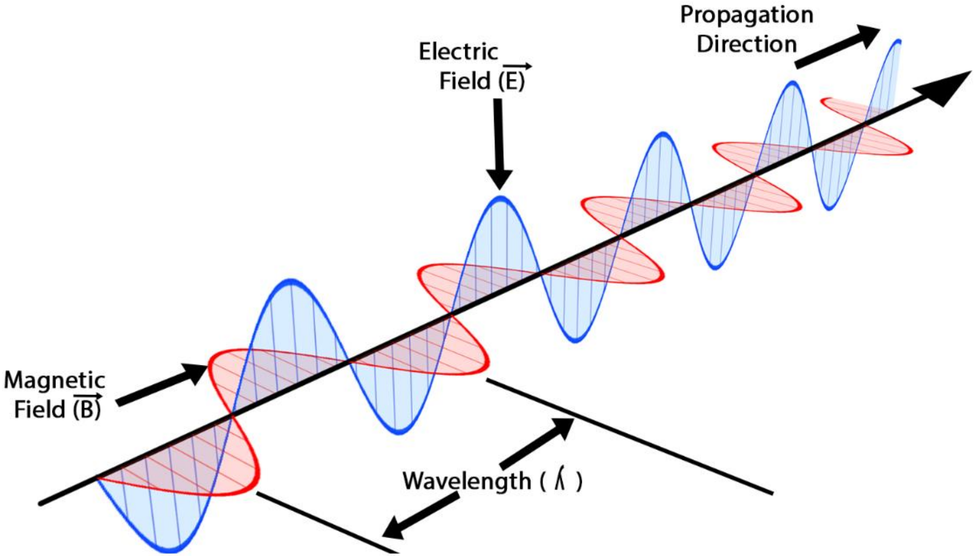
Electromagnetic wave

According to Maxwell's EM wave theory, light waves are related to changing electric fields and magnetic fields. The change within the electrical and magnetic field leads to the propagation of electromagnetic waves or light waves (c = 299 792 458 m.s^{-1})

$$c = \lambda \cdot f$$

$$f = \frac{c}{\lambda}$$

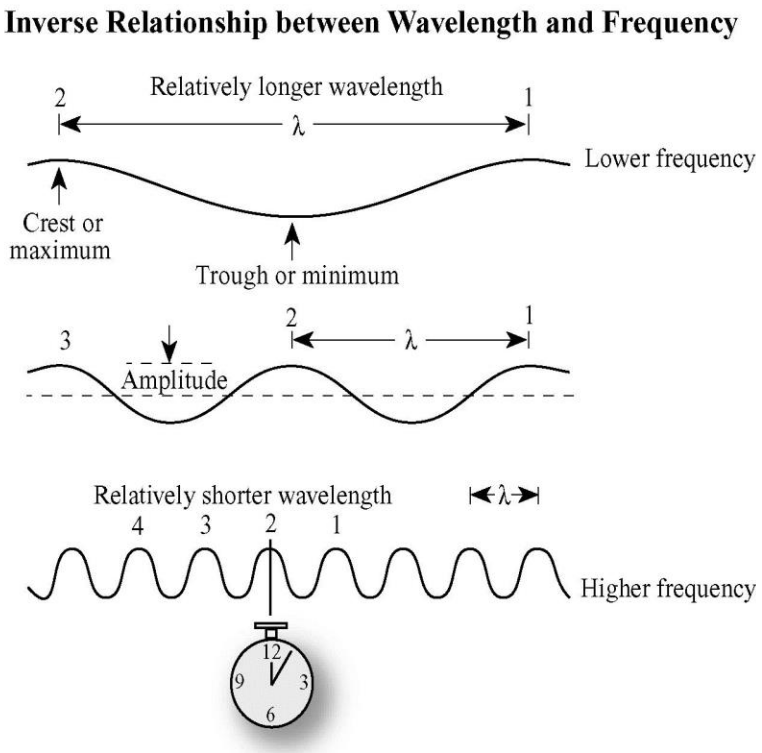
$$\lambda = \frac{f}{c}$$



Source: https://www.mdpi.com/2075-5309/13/7/1729/

Relationship between Wavelenght and Frequency

- Wavelength and frequency have an inverse relationship, as indicated by the equation. If wavelength increases, then frequency decreases and vice versa.
- Wavelength is the distance between identical points (adjacent crests) in the adjacent cycles of a waveform signal propagated in space or along a wire.
- The amplitude of an electromagnetic wave is the height of the wave crest above the undisturbed position. This frequency is measured in cycles per second, or hertz

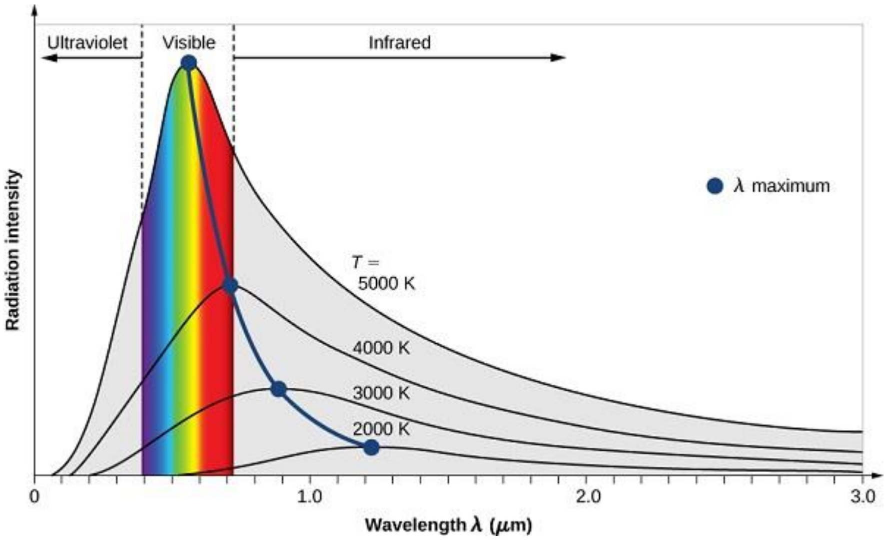


Source: Jensen (2008)

Relationship between Wavelenght and Frequency

Blackbody radiation

- Object or system which absorbs all radiation incident upon it and re-radiates energy
- All matter with a temperature above absolute zero (k) radiates energy in the form of EM waves of various wavelenghts
- By measuring the blackbody emission curves at different temperatures, it was able to construct two phenomenological Laws: Stefan-Boltzmann's Law and Wien's Displacement Law



Source: Jensen (2008)

Relationship between Wavelenght and Frequency

Blackbody radiation

Energy of a photon

We can measure the energy of a photon using Einstein´s equation:

$$E = hf = \frac{hc}{\lambda}$$

$h = 6.63 \times 10^{-34}$ Js → Planck constant

f = frequency of photon/electromagnetic radiation

$c = 3 \times 10^{8}$ m/s → speed of light in a vacuum

λ = wavelength of photon/electromagnetic radiation

Stefan–Boltzmann law

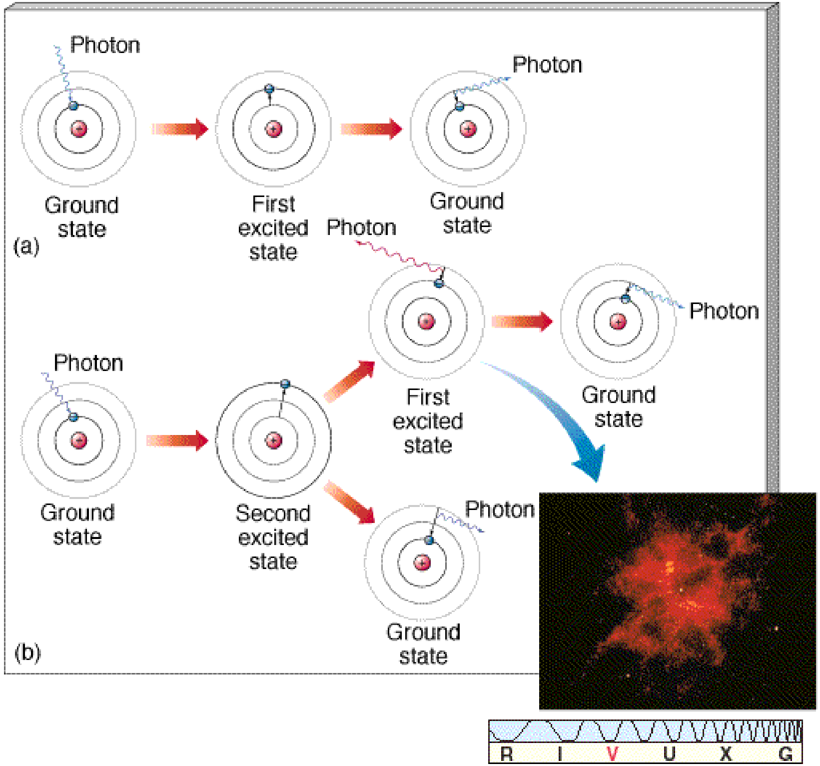
We can measure the energy of a photon using Einstein´s equation:

$$I = \sigma T^{4}$$

I is the intensity of emitted em radiation in W/m^2

σ (lower case sigma) is the Stefan-Boltzmann constant 5.67×10^{-8} W m^{-2} K^{-4}

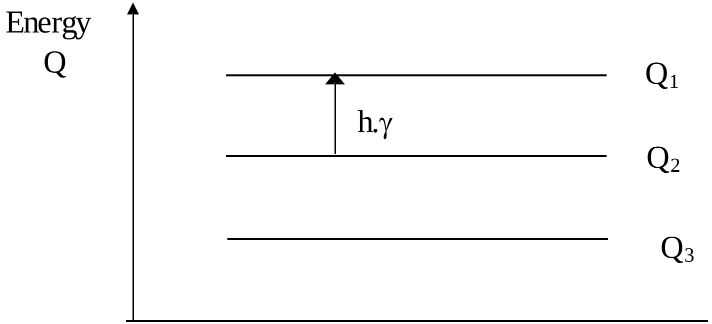
T is the temperature in kelvin, K

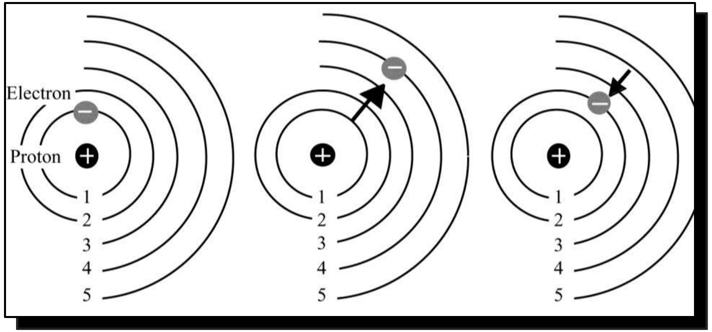


Source:http://lifeng.lamost.org/courses/astrotoday/CHAISSON/AT304/HTML/AT30402.HTMBAk

Relationship between Wavelenght and Frequency

Blackbody radiation



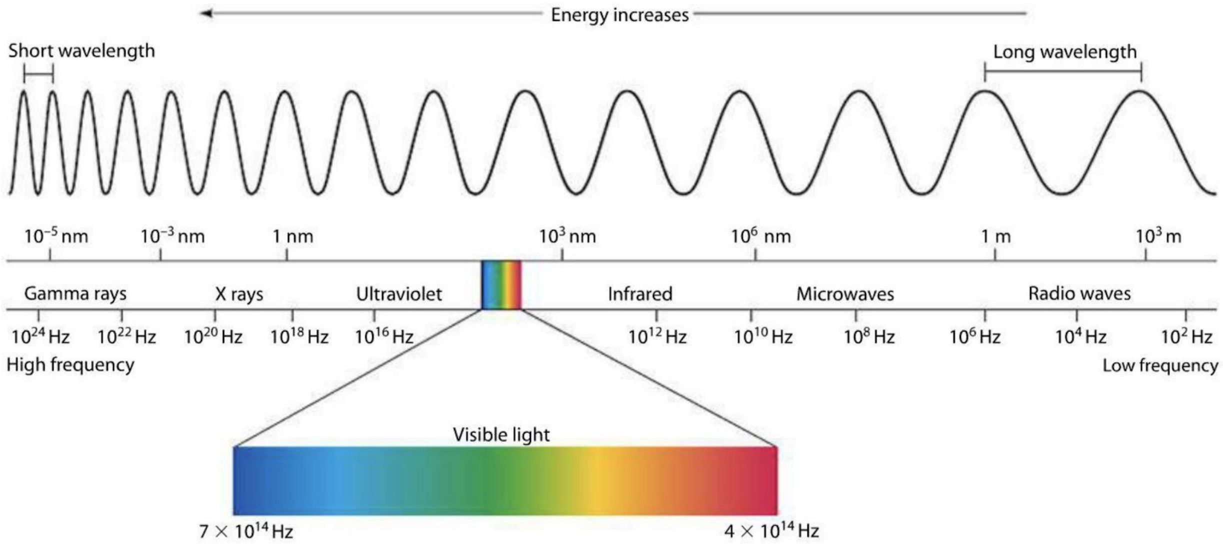


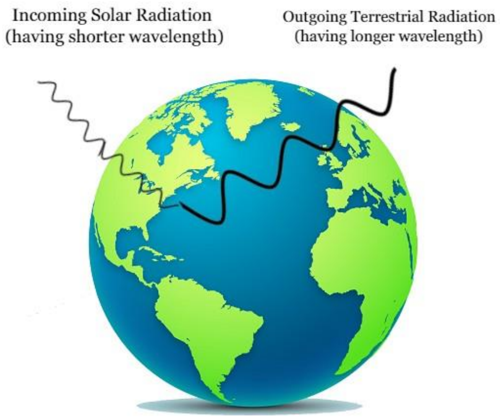
$$\Delta Q = Q_m - Q_n = h.\gamma \qquad \gamma - frequency(ní)$$

Planck constant h=6,625.10^{-34}J.s

Source: Jensen (2005)

Electromagnetic bands used in Remote Sensing

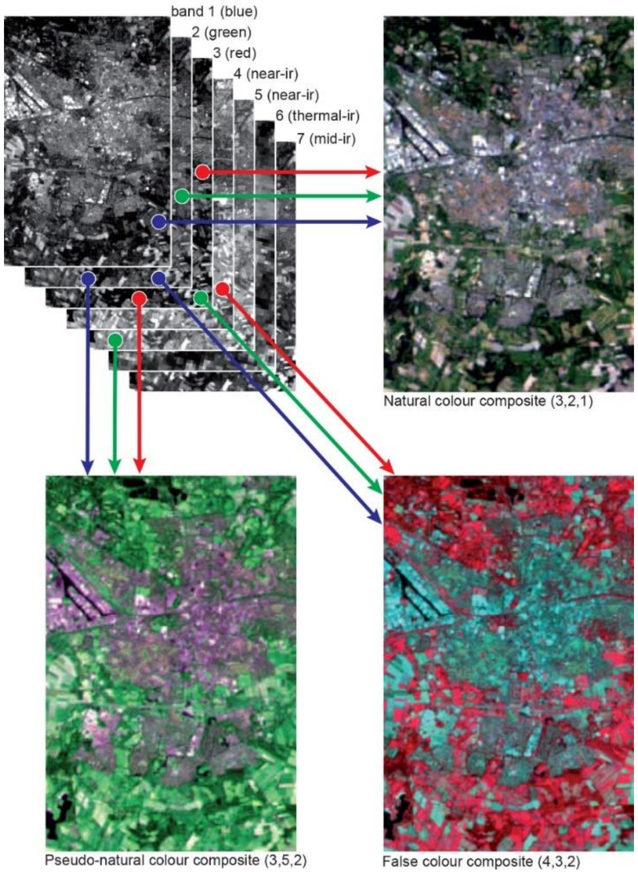


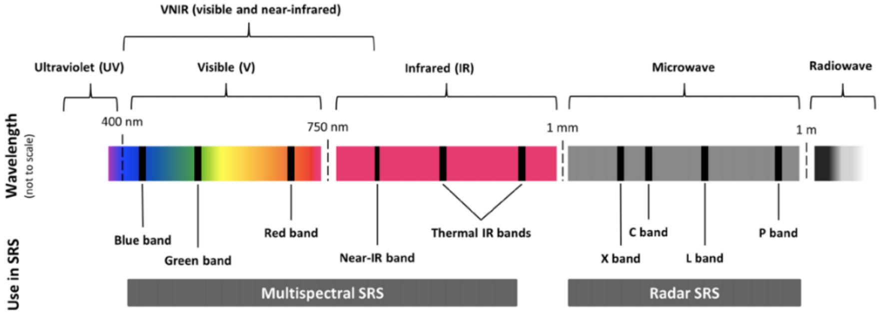


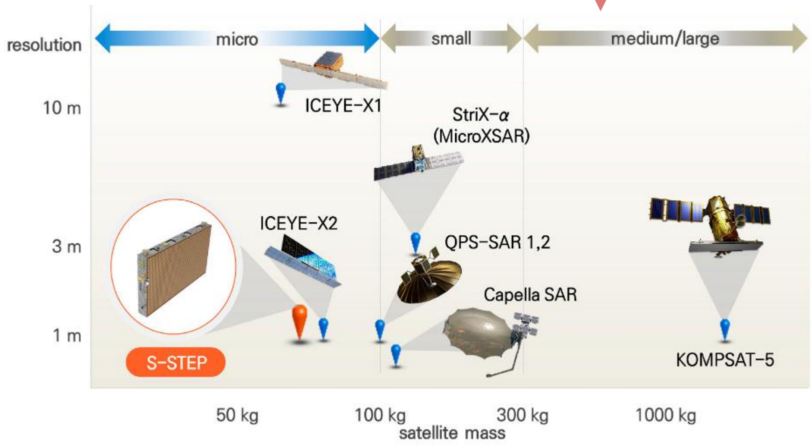
- The Sun produces a *continuous spectrum* of energy from gamma rays to radio waves that continually bathe the Earth in energy.
- The portion of the spectrum may be measured using wavelength, frequency or electron volts (eV). All units are interchangeable.

Source: https://www.researchgate.net/publication/326025281_Review_on_Material_Processing_Through_Microwave_Energy, https://www.iasnotes.in/2022/10/insolation-and-heat-budget-vision-ias-notes-upsc-classnotes.html

Electromagnetic bands used in Remote Sensing







Source: https://ltb.itc.utw ente.nl/498/concept/81525, https://rpubs.com/GeospatialEcologist/RS, https://www.mdpi.com/2226-4310/9/4/213

Electromagnetic bands used in Remote Sensing

Commonly used bands in remote sensing

- **Visible (400-700 nm)** — Commonly used in satellite and aerial imaging, to provide detailed information about land cover, vegetation health, urban development, etc.

- **Near-infrared (700-1300 nm)** — One of the most powerful ways to classify healthy vegetation and water. This is because, healthy plants reflect more energy in the NIR, while water absorbs it.

- **Mid-infrared (1300-3000 nm)** — Used for vegetation monitoring, geological mapping, fire detection, urban heat island detection, and atmospheric studies.

- **Thermal infrared (3000-14000 nm)** — Useful in understanding surface temperature, environmental monitoring, fire detection, and volcanic activity monitoring.

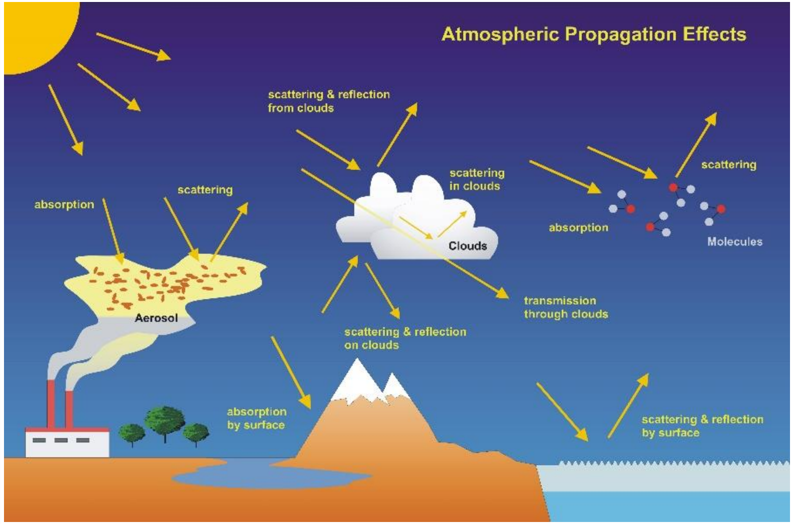
- **Microwave (1 mm-1m)** — The microwave band is used for penetrating clouds and vegetation, monitoring soil moisture, studying oceans and ice, radar imaging, atmospheric studies.

Source:https://gisgeography.com /spectral-signature/

Interaction of EMR with atmosphere

- Energy recorded by RS systems undergoes fundamental interactions that should be understood to properly interpret the remotely sensed data. For example, if the energy comes from the Sun, the energy:

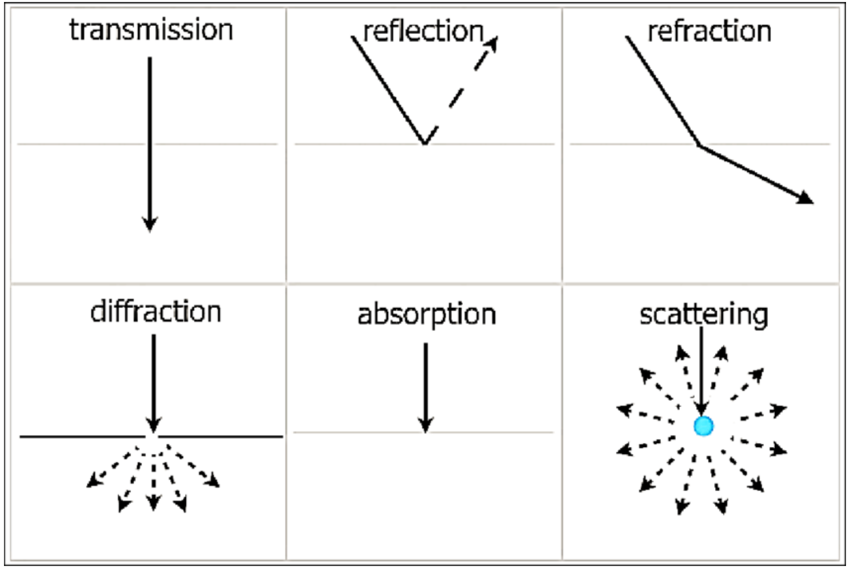
- propagates through the vacuum of space at the speed of light
- <u>interacts with the Earth's atmosphere</u>
- <u>interacts with the Earth's surface</u>
- <u>interacts with the Earth's atmosphere once again</u>
- finally reaches the remote sensor where it interacts with various optical systems, etc.

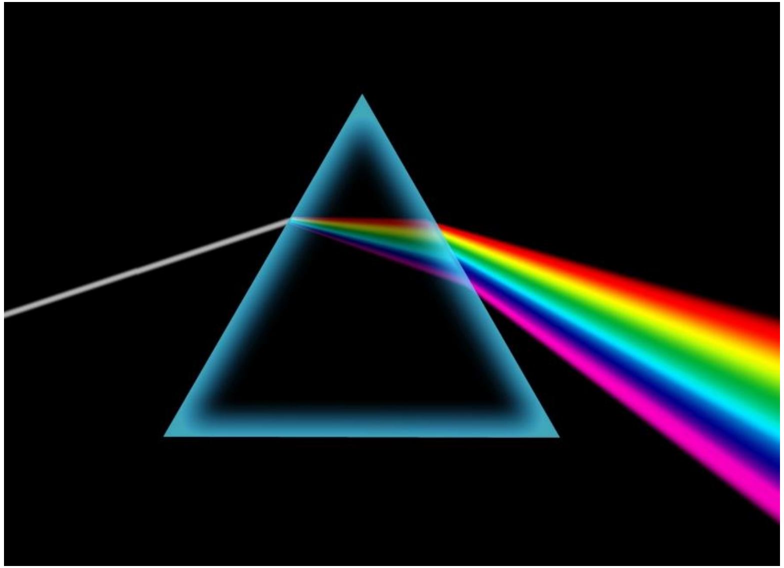


Source:https://atmos.eoc.dlr.de/projects/scops/sciamachy_book/sciamachy_book_figures_springer/chapter_7/fig_7_1.jpg

Interaction of EMR with atmosphere

- Upon interaction with matter, EMR can undergo transmission, reflection, refraction, diffraction, adsorption and scattering





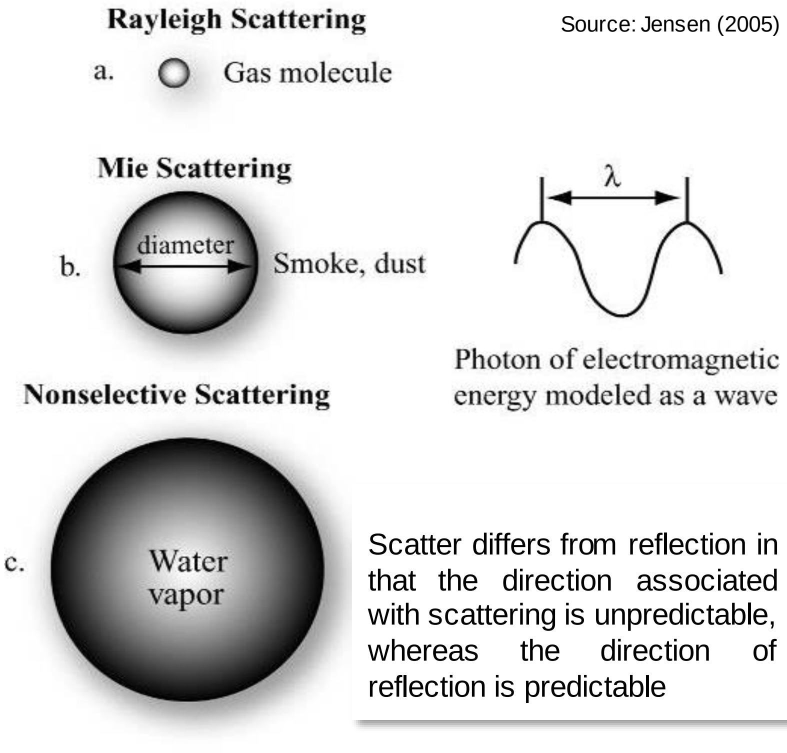
Source: Robinson and Dean, 2017, https://socratic.org/questions/how-can-refraction-make-a-rainbow-1

Interaction of EMR with atmosphere - Scattering

- **There are essentially three types of scattering:**
  - Rayleigh
  - Mie
  - Non-selective

- **Type of scattering is a function of:**
  1) the wavelength of the incident radiant energy, and
  2) the size of the gas molecule, dust particle, and/or water vapor droplet encountered

Source: Jensen (2005)



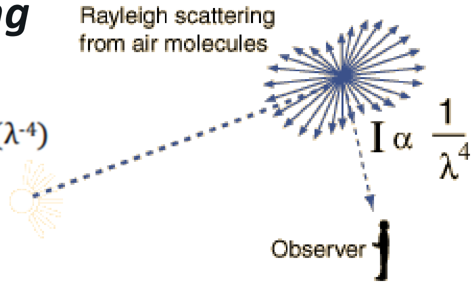
Scatter differs from reflection in that the direction associated with scattering is unpredictable, whereas the direction of reflection is predictable

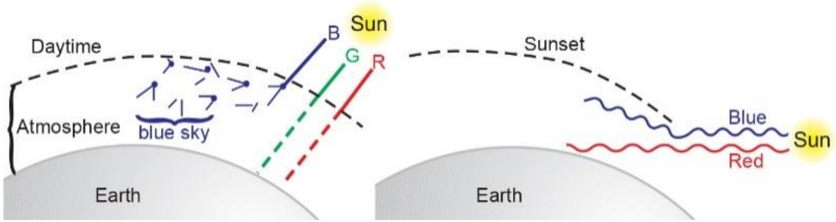
Interaction of EMR with atmosphere - Scattering

Rayleigh scattering

$\varnothing < \lambda$

Stronger effect at shorter λ (λ^{-4})



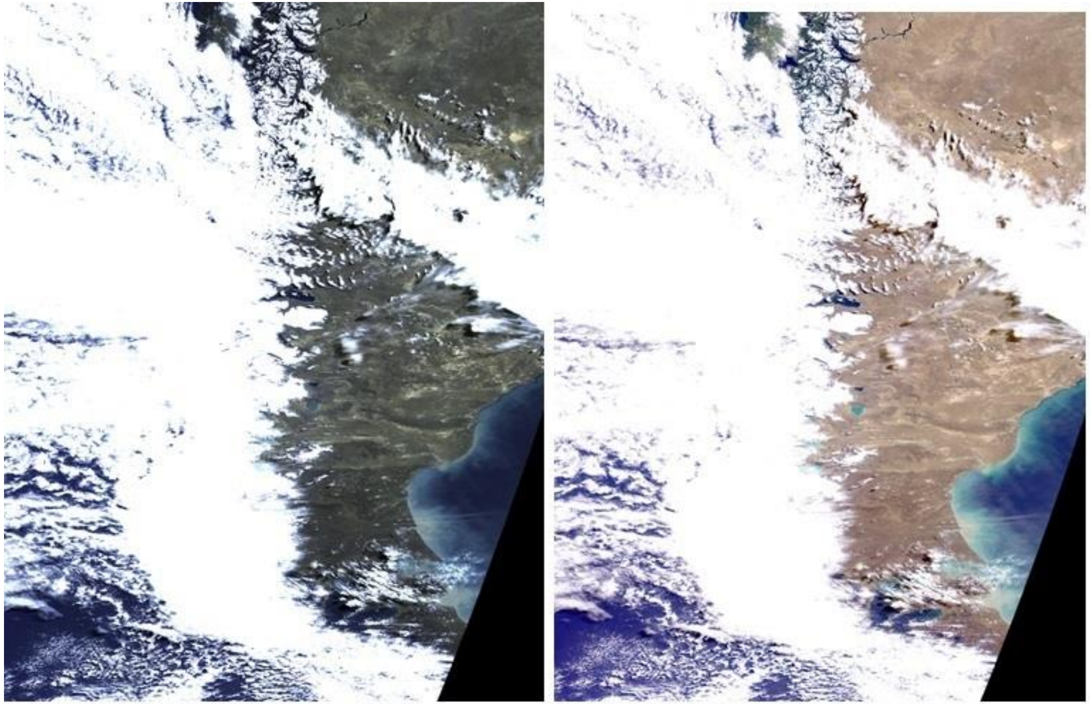


- The Rayleigh scattering effect in the atmosphere causes greater reflection of shorter wavelengths (blue color) – blue color of clear sky
- Involves particles smaller than the wavelength of incident light

Source: http://hyperphysics.phttps://www.researchgate.net/figure/Rayleigh-scattering-causes-us-to-perceive-a-blue-sky-during-daytime-and-a-red-sky-at_fig15_233793398, hy-astr.gsu.edu/hbase/atmos/blusky.html, https://fineartamerica.com/featured/red-sunset-jasna-buncic.html, https://theconversation.com/explainer-why-is-the-sky-blue-10821,

Interaction of EMR with atmosphere - Scattering

Rayleigh scattering



Before Rayleigh correction After Rayleigh correction

Source: https://forum.step.esa.int/t/still-a-strong-rayleigh-signal-after-rayleigh-correction/7006/8:

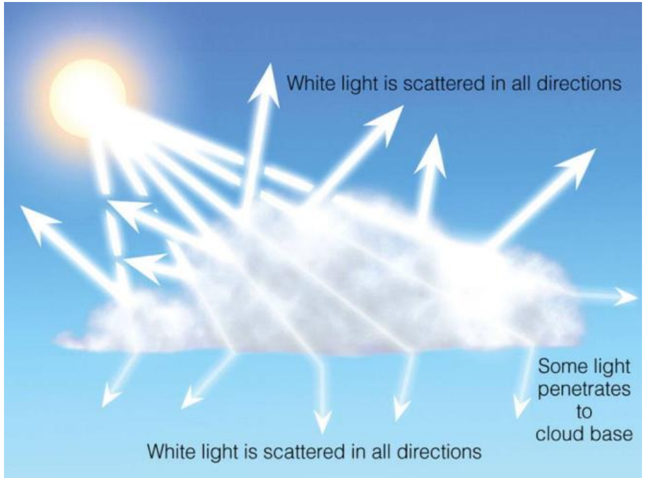
Interaction of EMR with atmosphere - Scattering

Mie scattering

$\varnothing \approx \lambda$

Clearer effect at longer λ

- Predominates for particle sizes equal or larger than a wavelength (0.1 - 10 times the wavelength)
- Occurs below 4.5 km in the atmosphere - more spherical particles with diameters approx. equal to the size of the wavelength of the incident energy (aerosols, pollution, dust particles, etc.)
- Produces almost white glare around the sun when a lot of particulate material is present in the air
- White light from mist and fog
- Contributes to the reddish sunsets



Source: http://www.china.org.cn/travel/2017-07/06/content_41165327.htm, https://medium.com/@elif_erkk/the-color-of-clouds-and-the-color-of-the-sky-a-dance-of-light-and-scattering-acbf2e66fe22

Interaction of EMR with atmosphere - Scattering

Non-selective scattering

$\varnothing > \lambda$

Similar at different λ: clouds.

- Takes place in the lower parts of the atmosphere where the particles are larger than 10 times the wavelength of the incident radiation
- Here, any wavelength can be scattered equally effectively, hence the clouds appear white, for example

Source: https://depositphotos.com/cz/photos/poprad-tatry.html, https://backcountrymagazine.com/stories/hillary-nelson-and-james-morrison-make-first-full-descent-of-27940-foot-lhotse/

Thank you for the attention