Basics of remote sensing

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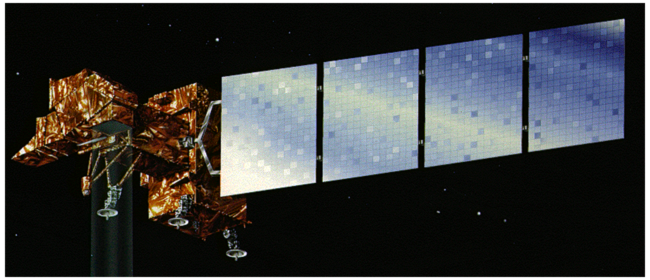
How to collect scientific data?

In situ



Remotely

What is Remote Sensing?

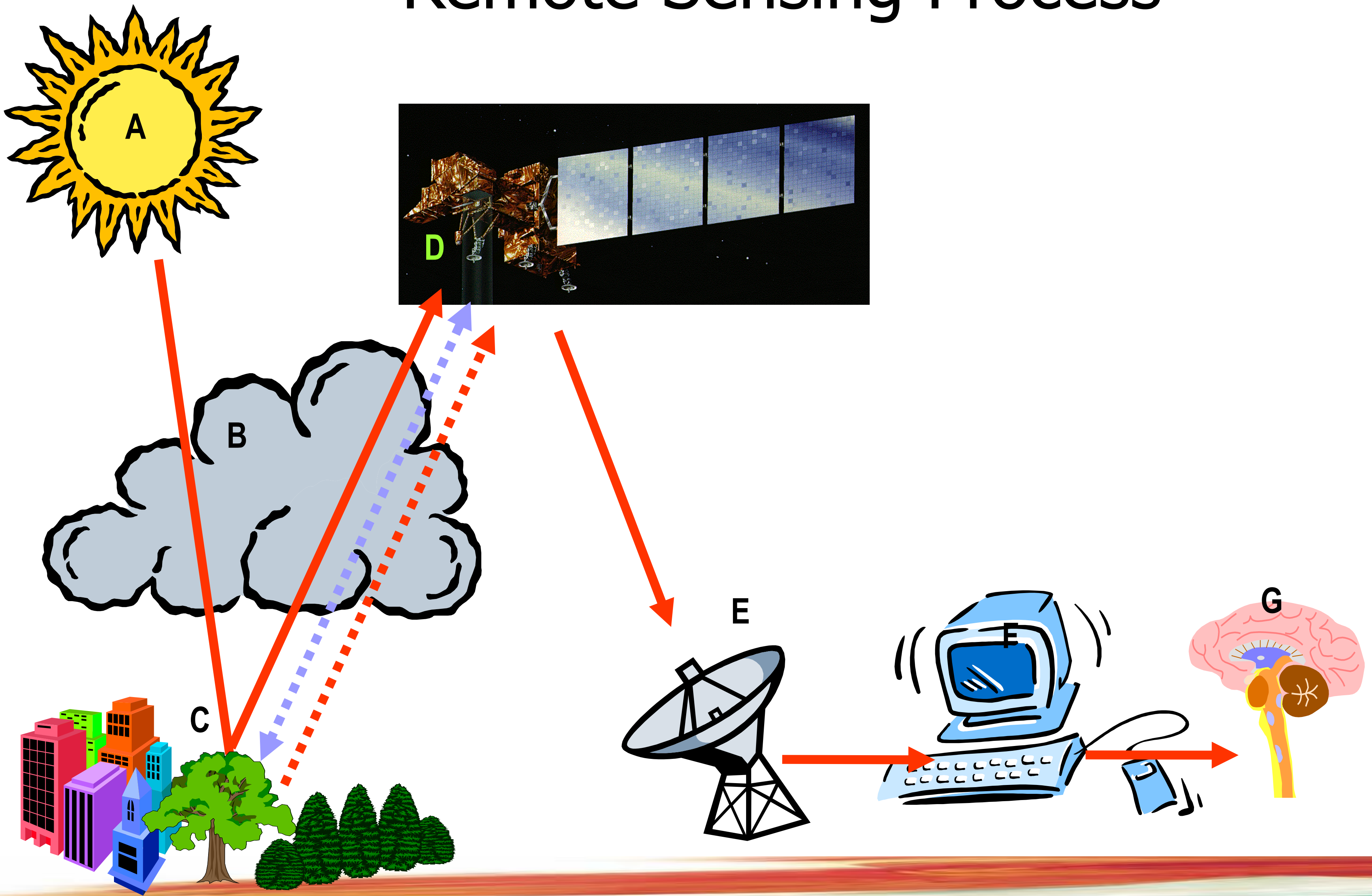
"The science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area, or phenomenon under investigation".(L&K,1994)

Why Remote Sensing?

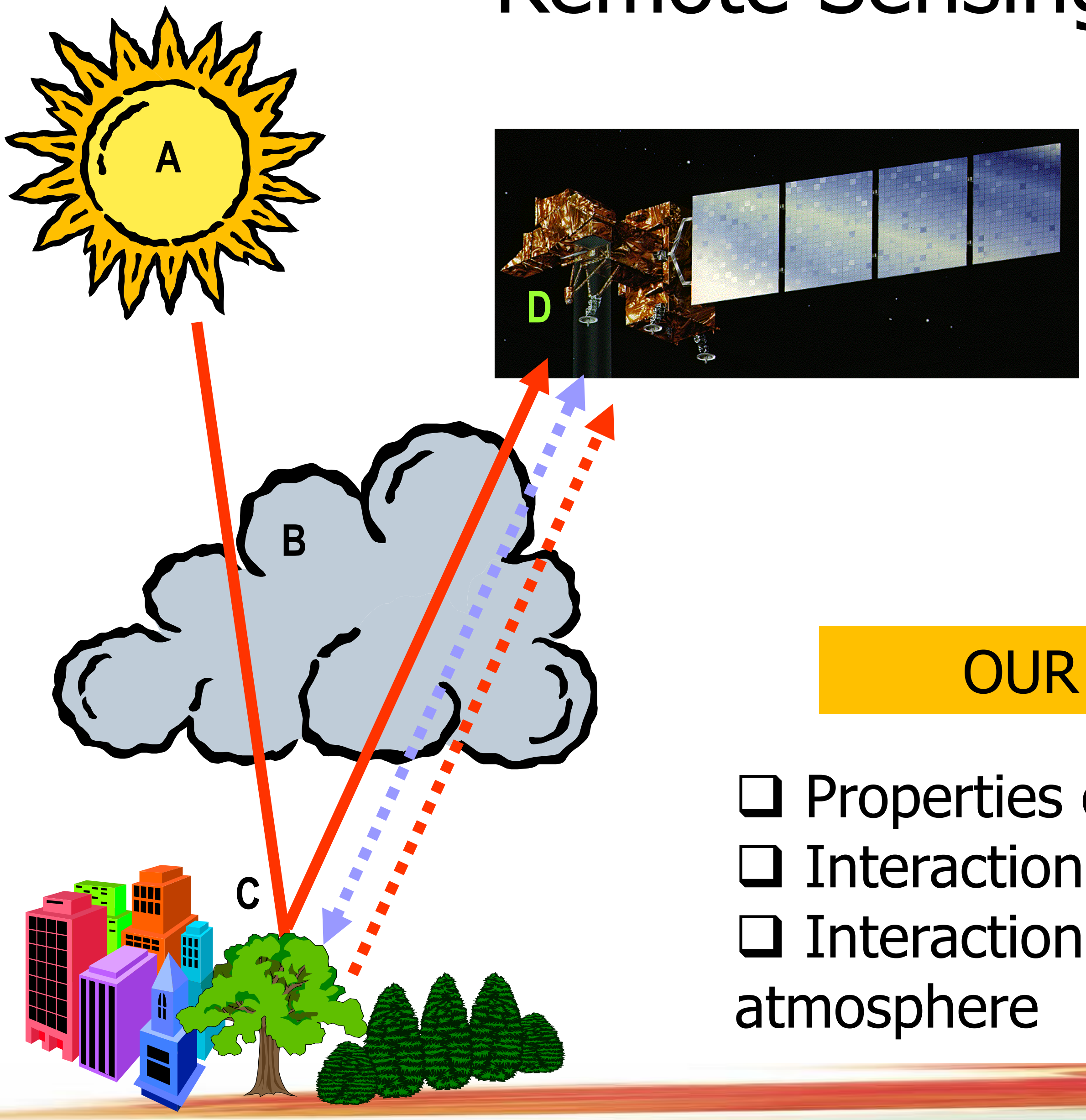
- Systematic data collection
- Information about three dimensions of real objects
- Repeatability
- Global coverage
- The only solution sometimes for the otherwise inaccessible areas
- Multipurpose information

Is it all…???

Remote Sensing Process



Remote Sensing Process



OUR FOCUS

- ❑ Properties of EMR
- ❑ Interaction of radiation with target
- ❑ Interaction of radiation with atmosphere

❑ Properties of EMR

Time for some Physics

- -Wave Nature
- -Particle nature
- -Wave Particle duality
- -EM spectrum
- -Radiometery
- -Black Body Radiation – Laws, Spectral Emissivity

❑ Interaction of radiation with target

❑ Interaction of radiation with atmosphere

What is Electromagnetic Radiation??

There are 2 theories:

Wave theory

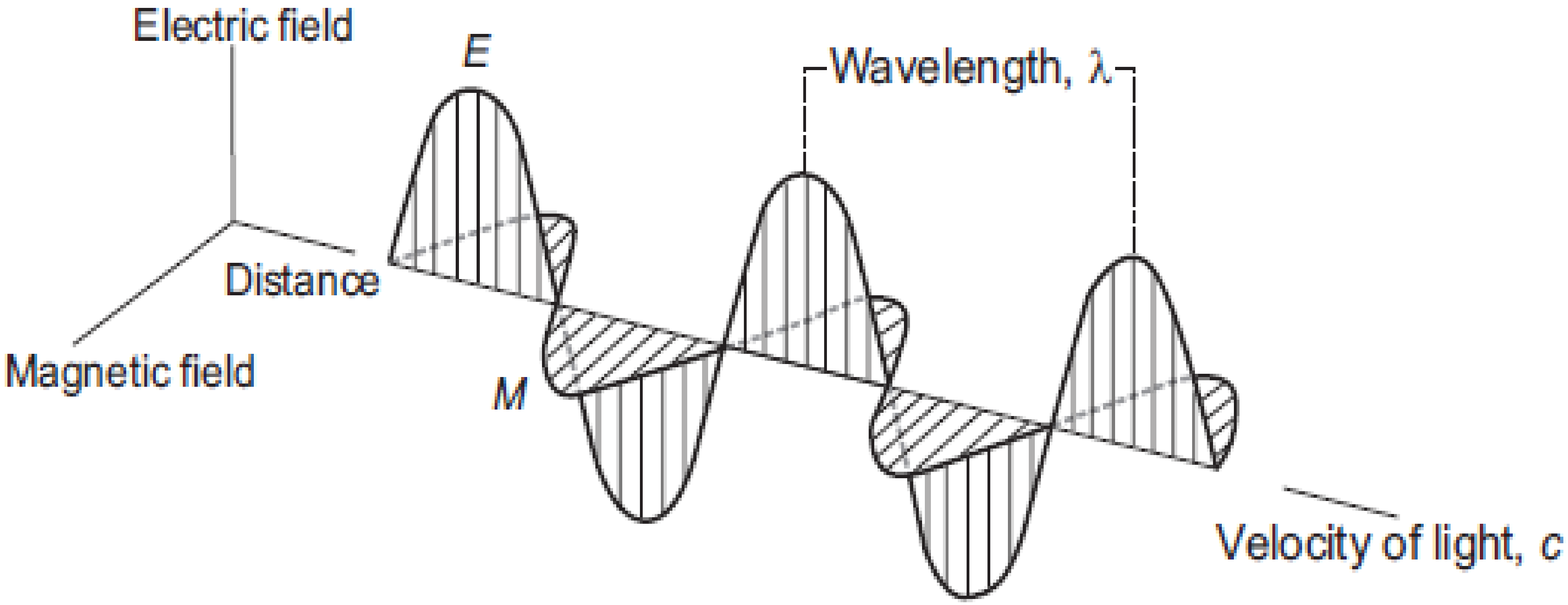
Considers electromagnetic energy as a harmonic, sinusoidal wave

Particle theory

Considers electromagnetic radiation as consisting of many discreet units - **photons**

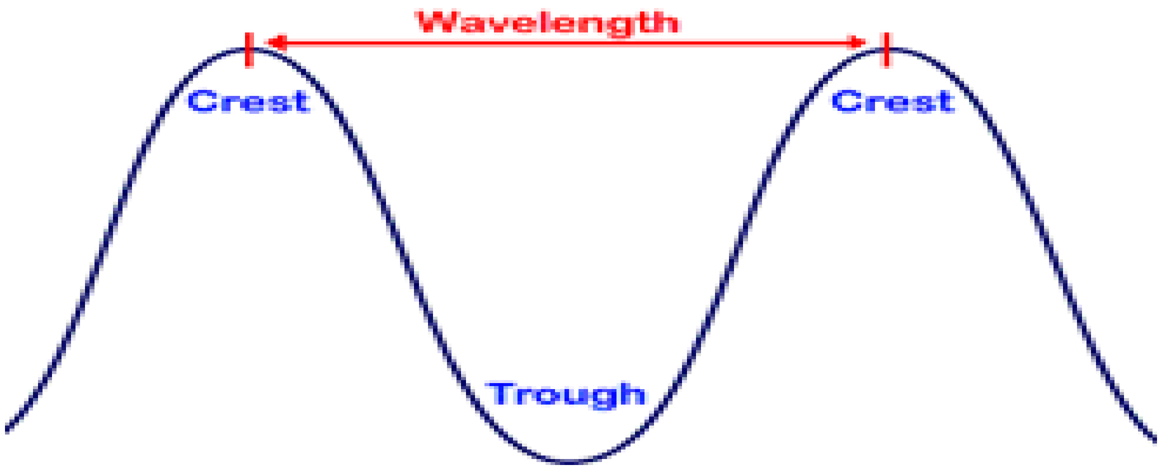
EMR propagation as wave

An electromagnetic wave is a transverse wave in that the electric field and the magnetic field at any point and time in the wave are perpendicular to each other as well as to the direction of propagation



Terms associated with wave theory

- Crest : The highest point of the wave.
- Trough : The lowest point of the wave.
- Wavelength : The distance between two identical points on the wave. .
- Frequency : The number of wavelengths that pass a point in a set period of time.



Speed of light

$c = \lambda v$

where λ is wavelength (m)
is frequency (cycles per second, Hz)
c is speed of light (3×10^8 m/s)

Light does not require a material medium for its propagation!!

EMR : particle nature

The energy of a photon is given by :

$E = hv$

$= hc/\lambda$

where c, v and λ are the velocity, frequency and wavelength respectively and h is Plank's constant

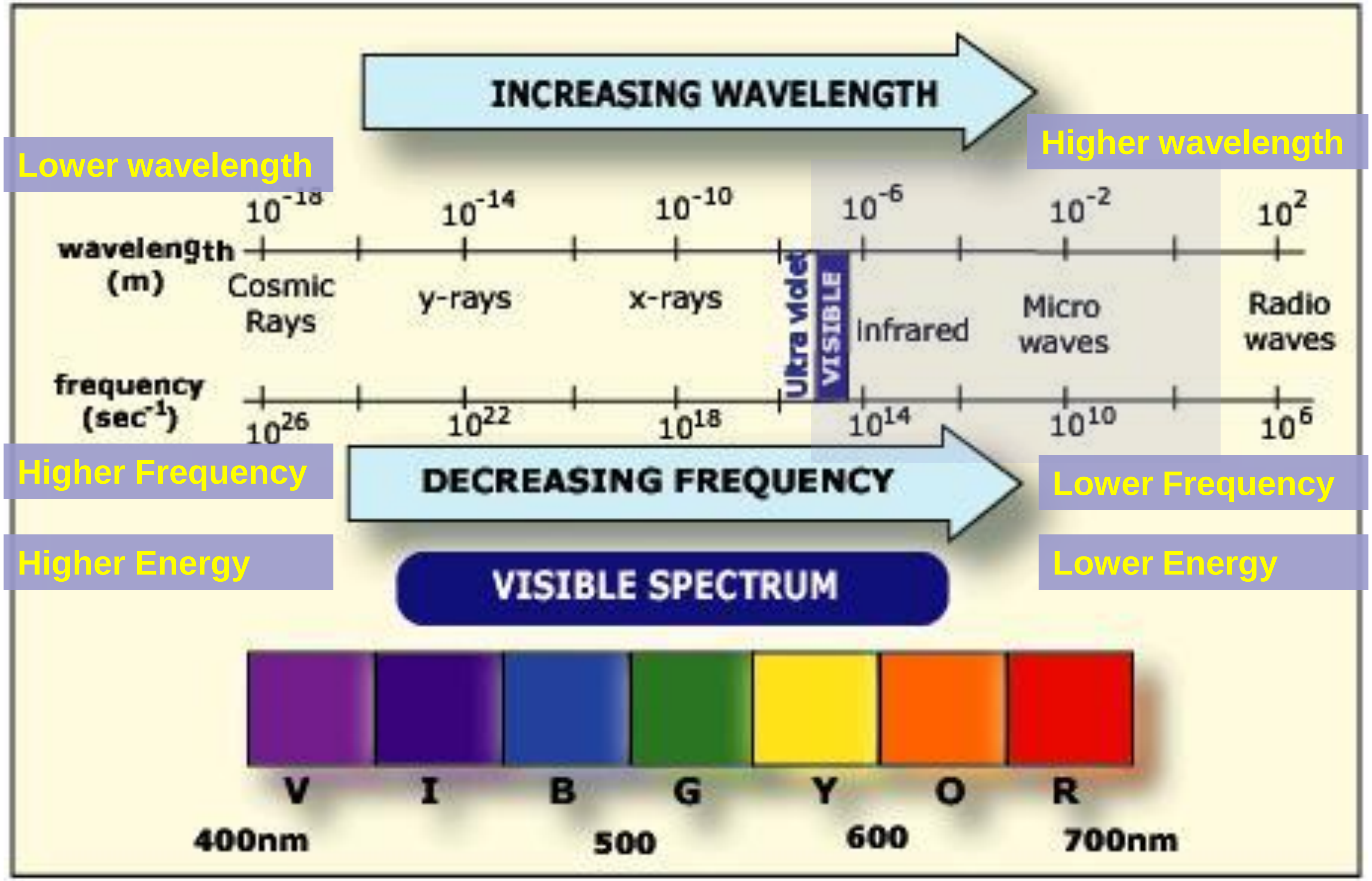
$h = 6.6260... \times 10^{-34}$ Joules-sec

Wave-particle duality

In 1924, Louis-Victor de Broglie formulated the de Broglie hypothesis, claiming that *all* matter, not just light, has a wave-like nature; and related wavelength (denoted as λ), and momentum (denoted as *p*):

$$\lambda = h/p$$

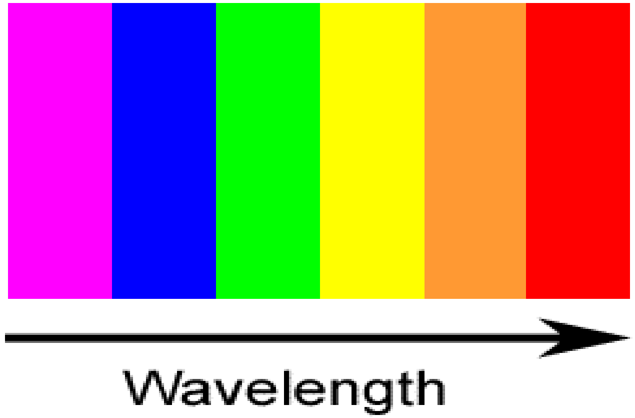
h is Plank’s constant


INCREASING WAVELENGTH
Lower wavelength
Higher wavelength
wavelength (m)
10-18
10-14
10-10
10-6
10-2
10^2
Cosmic Rays
γ-rays
x-rays
Ultra violet
VISIBLE
Infrared
Micro waves
Radio waves
frequency (sec-1)
10^26
10^22
10^18
10^14
10^10
10^6
Higher Frequency
DECREASING FREQUENCY
Lower Frequency
Higher Energy
Lower Energy
VISIBLE SPECTRUM
V
I
B
G
Y
O
R
400nm
500
600
700nm

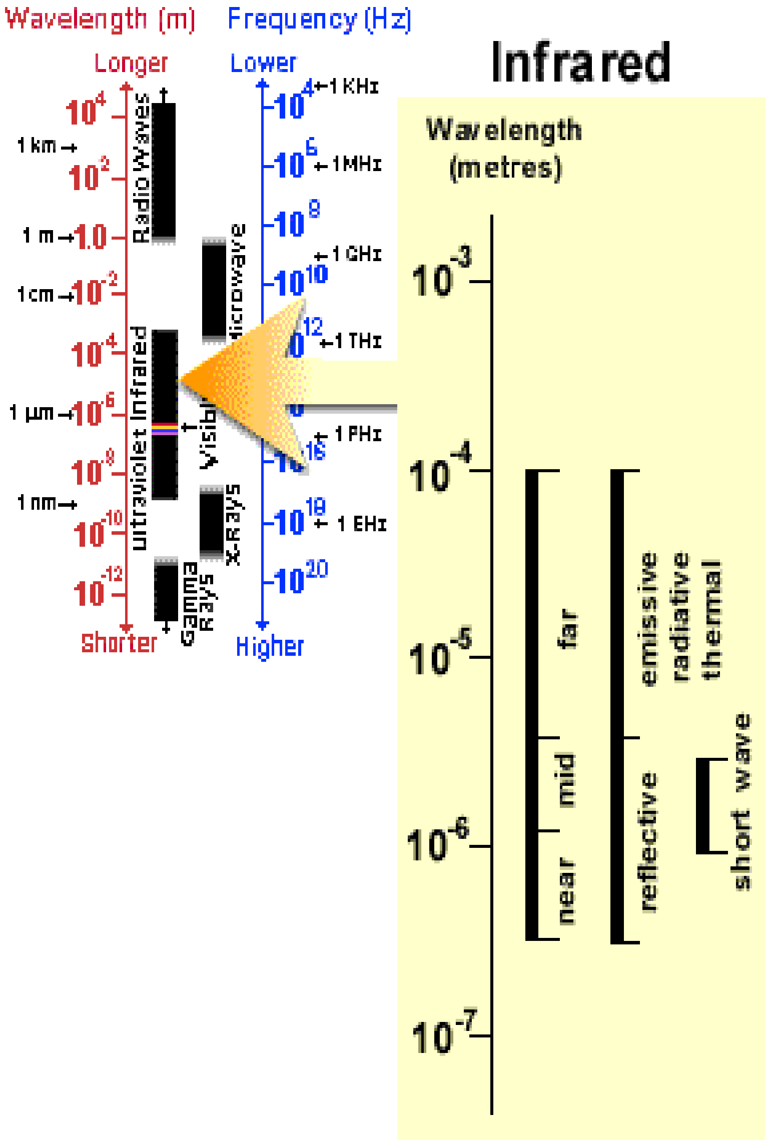
Visible range

The light which our eyes - our "**remote sensors**" - can detect is part of the visible spectrum.

Violet: 0.4 - 0.446 μm
Blue: 0.446 - 0.500 μm
Green: 0.500 - 0.578 μm
Yellow: 0.578 - 0.592 μm
Orange: 0.592 - 0.620 μm
Red: 0.620 - 0.7 μm



Infra-Red range

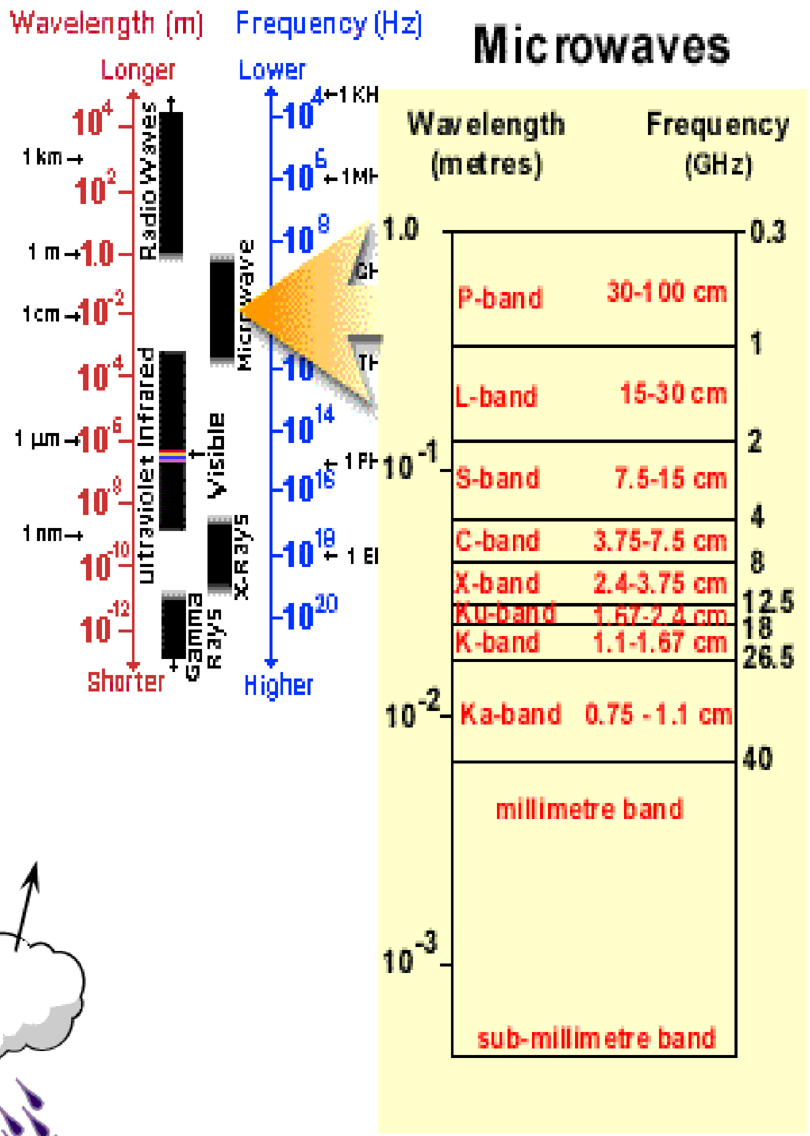


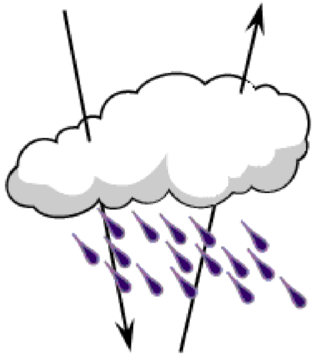
The infrared region can be divided into two categories based on their radiation properties - the **reflected IR**, and the emitted or **thermal IR**.

The reflected IR covers wavelengths from approximately 0.7 µm to 3.0 µm. The thermal IR covers wavelengths from approximately 3.0 µm to 100 µm.

Microwave range

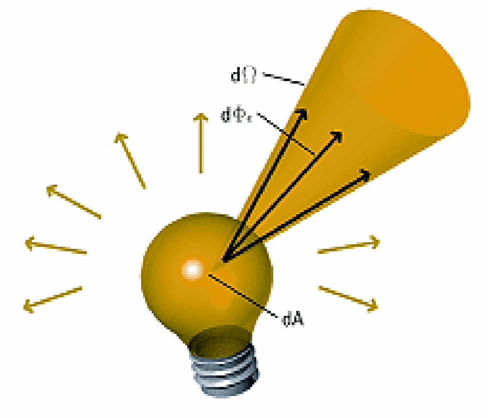
The portion of the spectrum of more recent interest to remote sensing is the microwave region from about 1 mm to 1 m. This covers the longest wavelengths used for remote sensing.

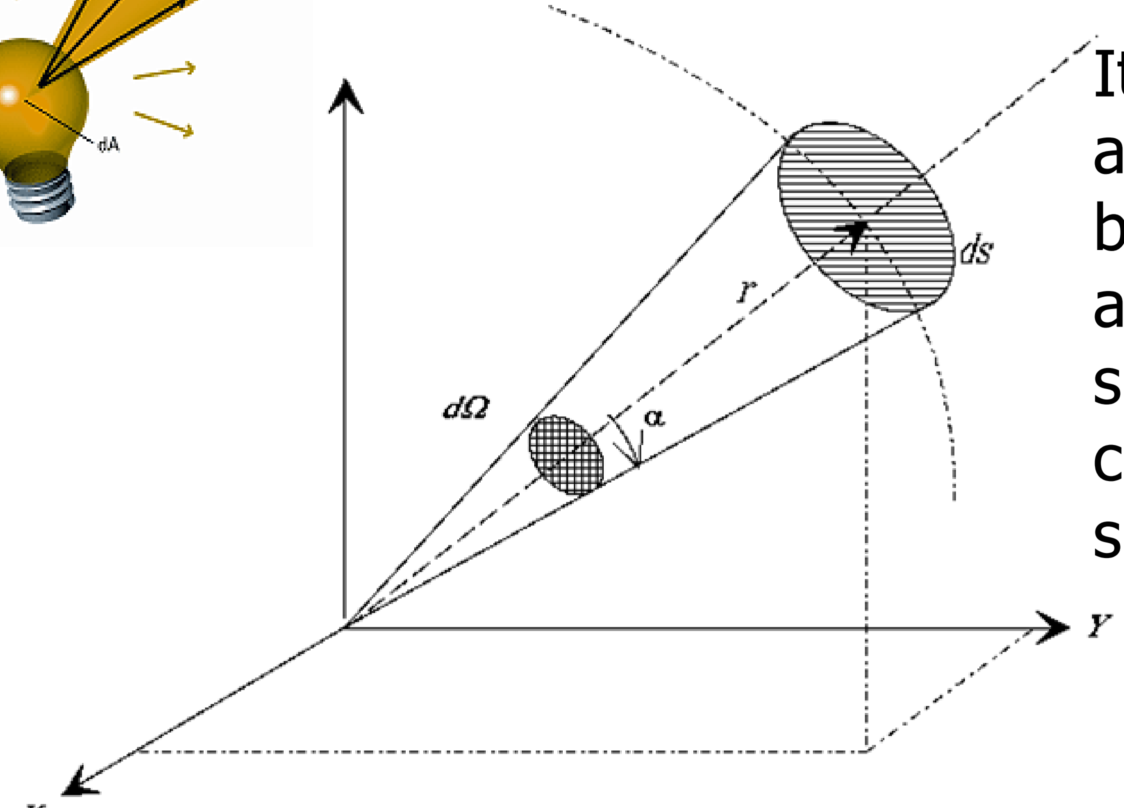




RADIOMETRY

Solid angle





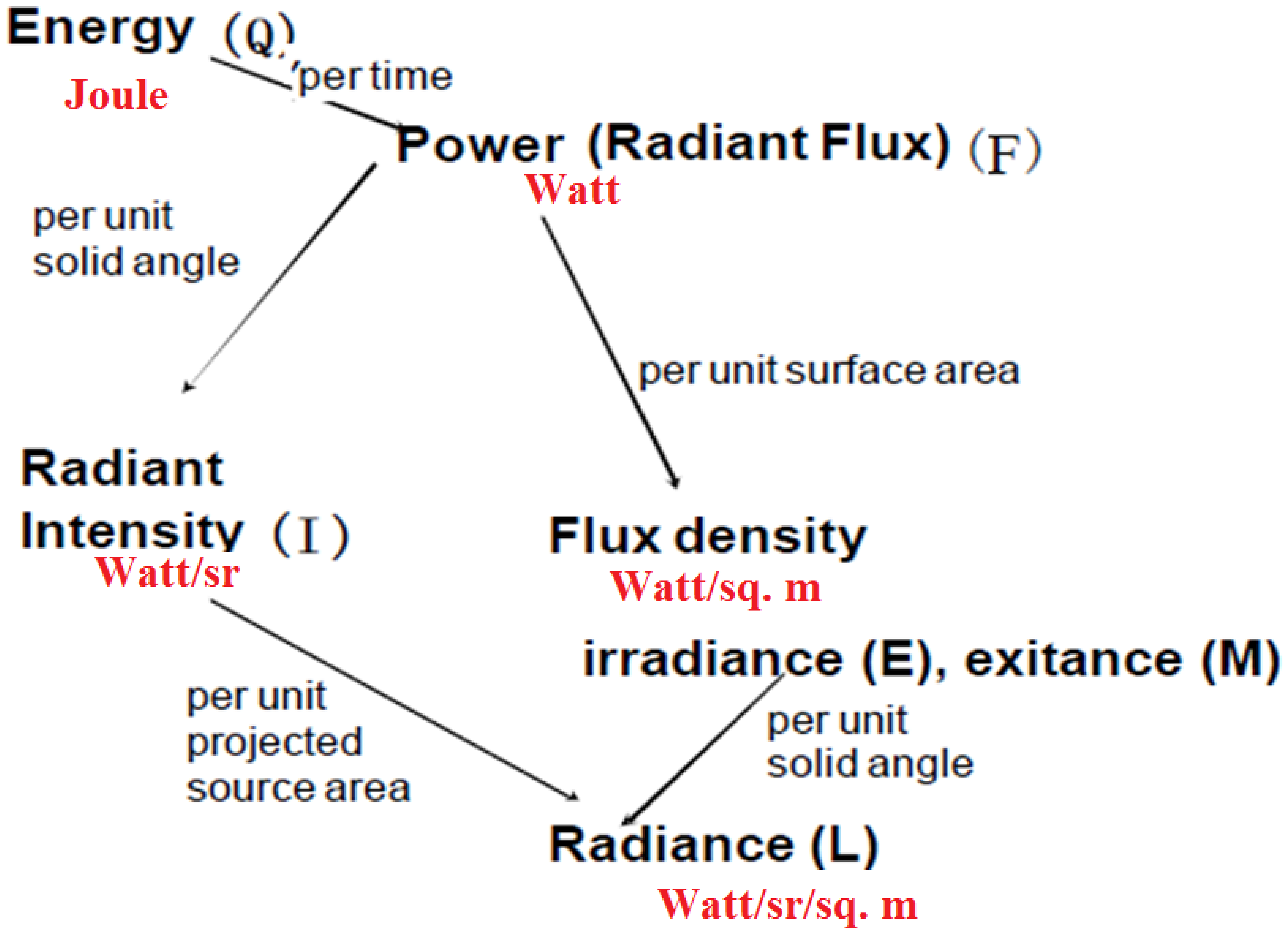
Solid angle notion.

It is the cone angle subtended by the portion of a spherical surface at the center of the sphere.

$$d\Omega = dS / r^2 \text{ (in steradians, Sr)}$$

TIME

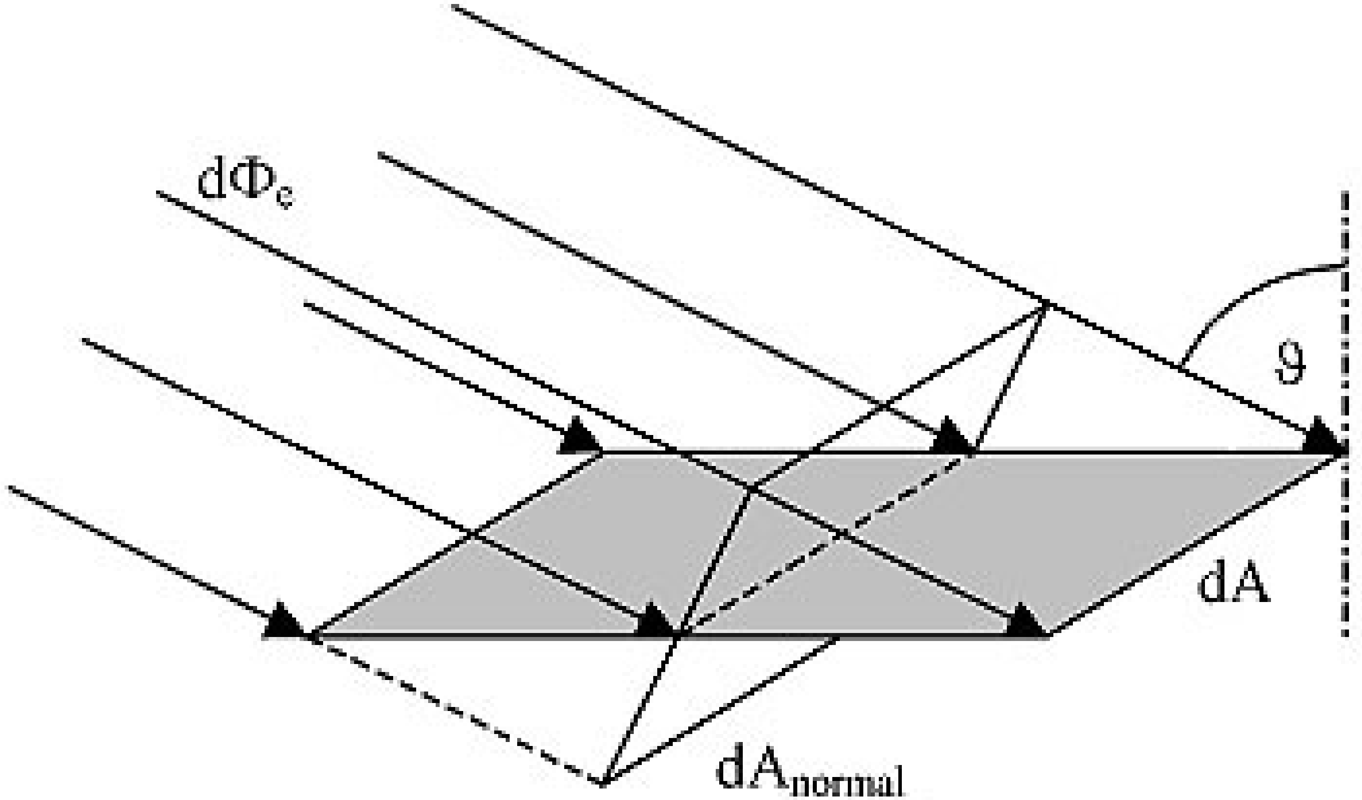
TIME
SOLID
ANGLE



TIME
AREA

TIME
SOLID ANGLE
AREA

Projected area



QUIZ TIME

1. Is our eye a remote sensor?

A) YES B)NO

2. What are the units of spectral radiance ?

A) W/m sq. B)W/m sq./Sr C)W/m sq/Sr/micron

3. Which radiometric quantity would be most suitable to measure for

a) sun's incoming energy ?

b) At-sensor ?

A) Irradiance B)Exitance C)Radiance

4. A radiation of wavelength 4 micron falls in which portion of EM spectrum ?

A) Visible B)IR C)Microwave

Black Body

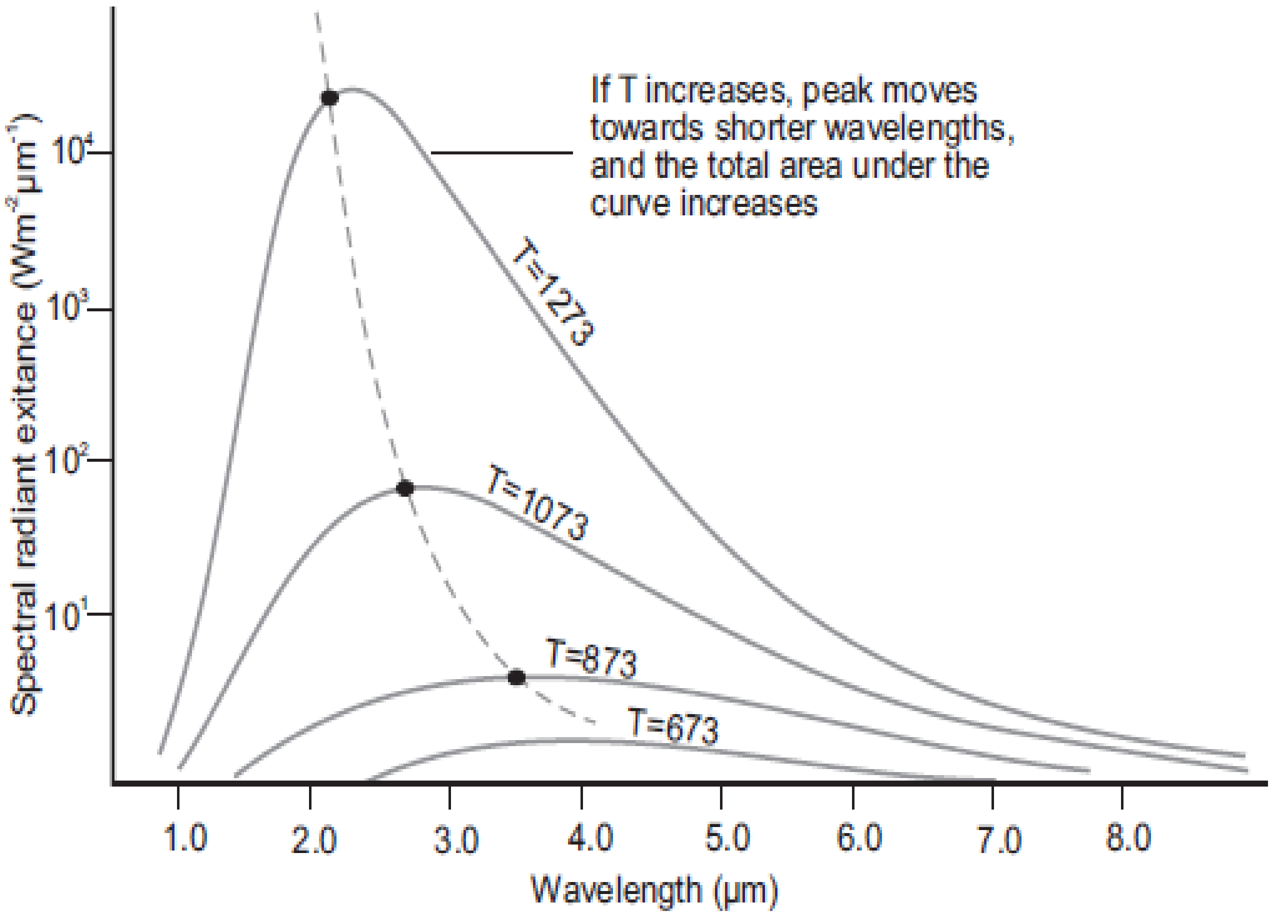
Blackbodies absorb and re-emit radiation in a characteristic, continuous spectrum. However, a black body emits a temperature-dependent spectrum of light. This thermal radiation from a black body is termed **black-body radiation**.

Plank’s Law of radiation

$$M_\lambda = C_1\lambda^{-5}\,[\exp.(C_2/\lambda T) - 1]^{-1}$$

Manifestation of quantization of energy !

M_λ is spectral exitance
$C_1 = 3.74\text{x}10^{-16}\,\text{Wm}^2$
$C_2 = 1.44\text{x}10^{-2}\,\text{m}^o\text{K}$
λ is the wavelength
T is the absolute temperature



http://csep10.phys.utk.edu/astr162/lect/light/planck.html

Plank's Law of radiation

INTEGRATE

DIFFERENTIATE

Stefan Boltzmann Law

$M = \int M(\lambda)\, d\lambda = \sigma T^4$

$M(\lambda)$ = spectral radiant exitance

T = temperature (°K),

σ = 5.67×10^{-8} W/m^{2}K^4

Wien's Displacement law

$$\lambda_{max}(\mu m) \cong \frac{2898}{T(°K)}$$

How close a real body is to a Black Body ??

Spectral Emissivity

The efficiency with which real materials emit thermal radiation at different wavelengths is determined by their emissivity 'ε'

$$\varepsilon(\lambda) = M_\lambda \text{ (material, } {}^0\text{K) / } M_\lambda \text{ (blackbody, } {}^0\text{K)}$$

$\varepsilon(\lambda)$ varies between 0 and 1

Blackbody : $\in$ = 1 at all wavelengths.
Gray body : 0 < $\in$ < 1 (does not depend upon wavelength)
Perfect reflector: $\in$ = 0
All other bodies $\in = \in(\lambda)$ is a function of wavelength

EMR interaction with matter

At boundary of two surfaces:

Reflection

Refraction

Within medium

Absorption

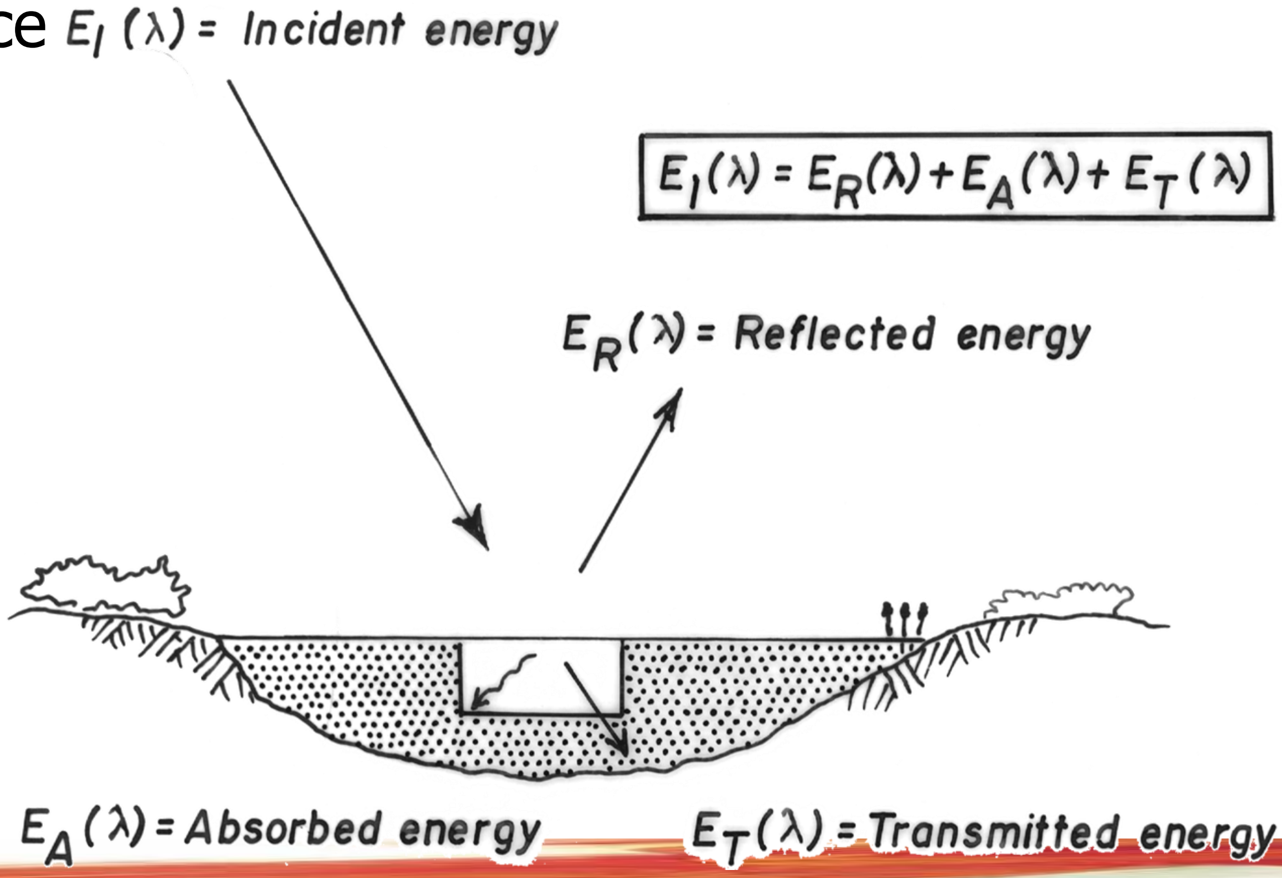
Scattering

Interaction of EMR with Earth's surface

Kirchoff's law of Radiation

$$\alpha(\lambda) + \rho(\lambda) + \tau(\lambda) = 1$$

where $\alpha(\lambda)$ is absorptivity , $\rho(\lambda)$ is reflectance and $\tau(\lambda)$ is transmittance



Interaction Processes

1. **Reflection**

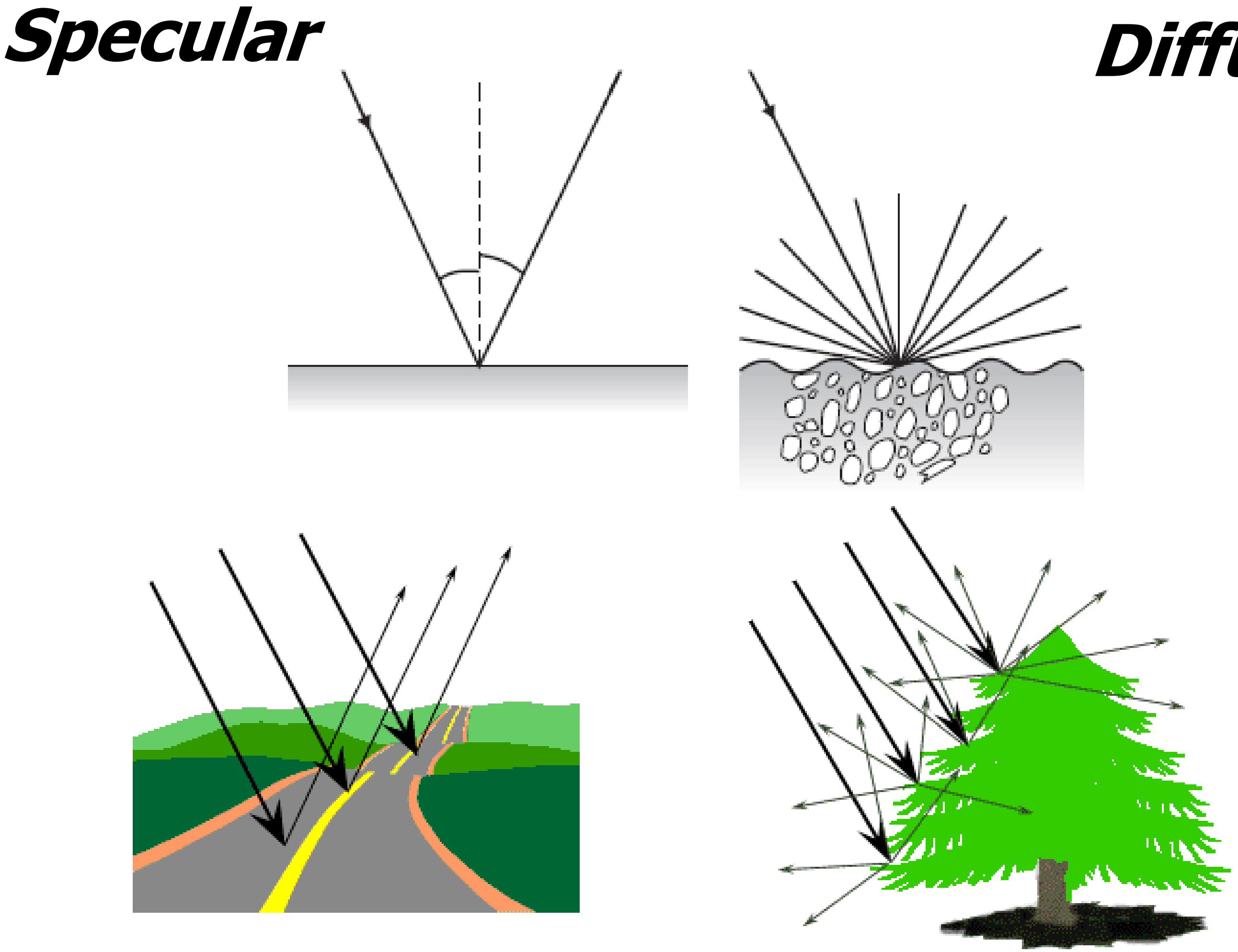
    Specular : *Snell's law*

    Diffused

    Lambertian : Lambert Cosine law

2. **Transmission**
3. **Absorption**

Reflection



Rayleigh Criteria for smooth surface

Rayleigh's criteria for a rough surface is :

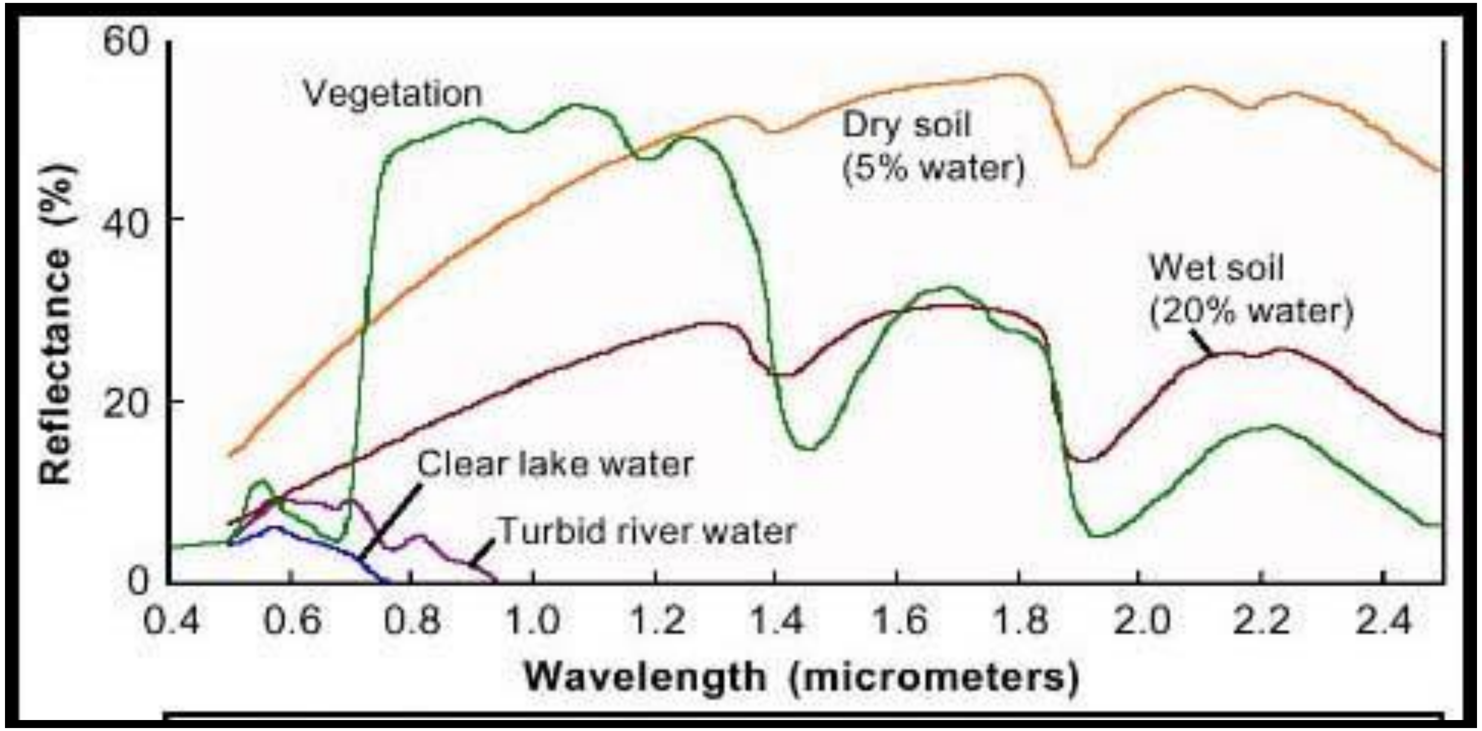
$$\mathbf{h > \lambda/8\cos\theta}$$

where h = rms height variation above a reference plane in units of λ

λ is the wavelength and θ is the angle of incidence

Spectral Signatures

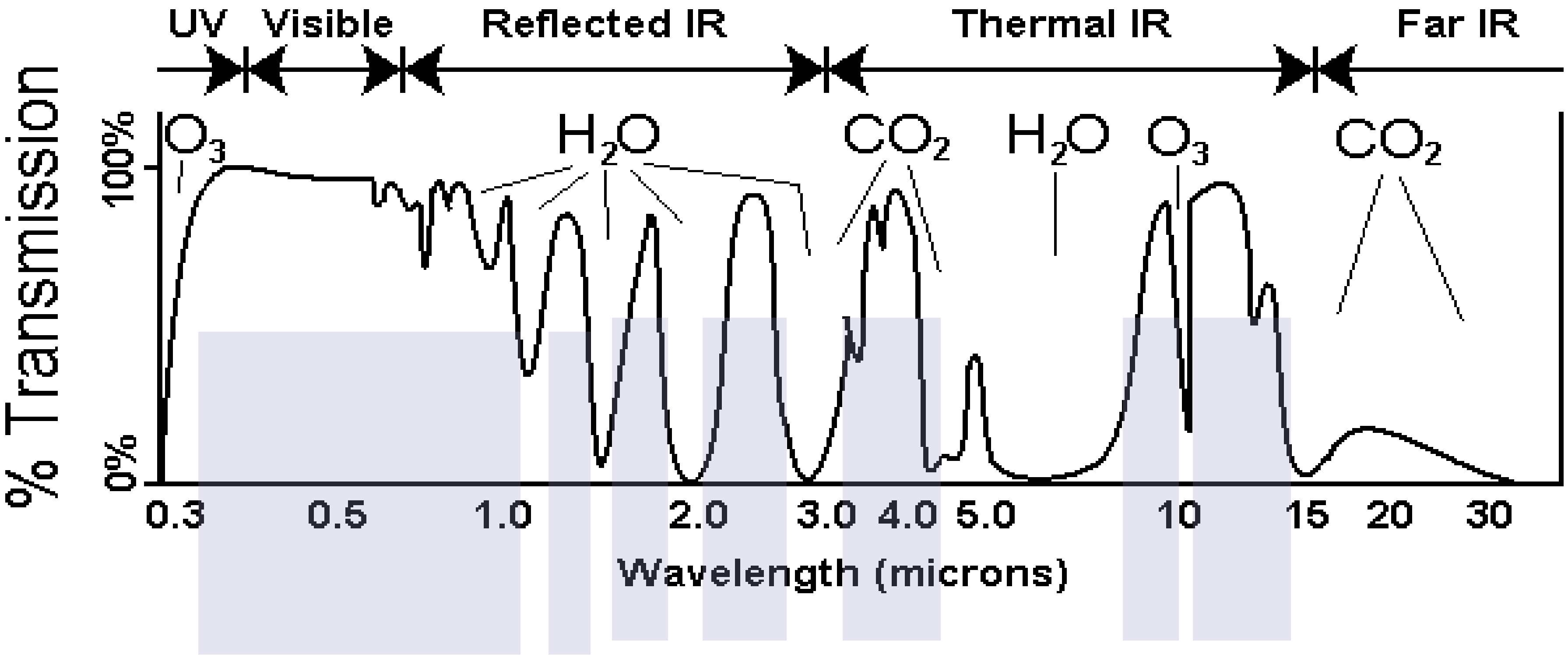
Why the name signature ??



Physical processes in atmosphere

- Absorption
- Scattering
- Refraction

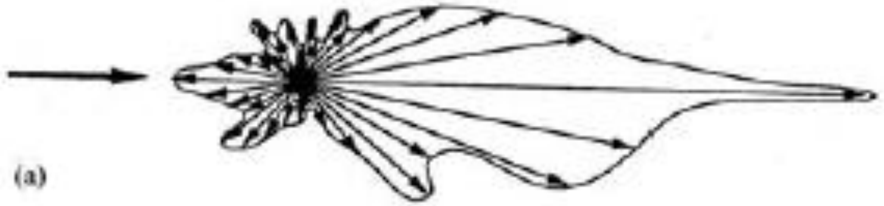
Atmospheric Windows



Atmospheric windows : Spectral regions where the EMR is passed through without much attenuation.

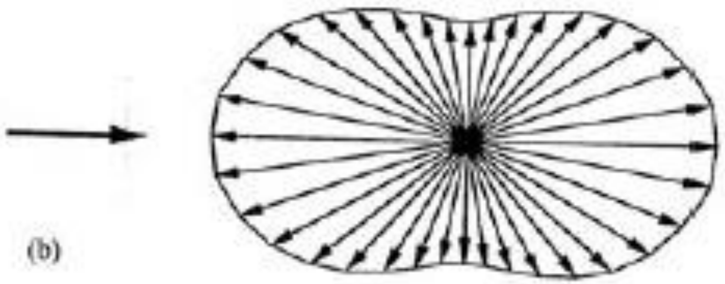
Scattering : Redirection of light

Mie Atmospheric Dust Smoke



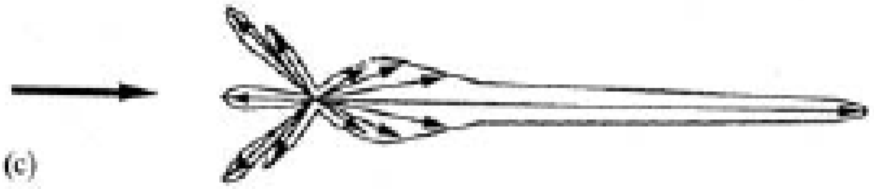
(a)

Rayleigh Atmospheric Molecules



(b)

Non-selective Large Water Droplets



(c)

Scattering

Scattering process	Wavelength dependency	Approximate dependence on particle size	Kinds of particles
Selective			
Rayleigh	λ^{-4}	< 1 µm	Air molecules
Mie	λ^0 to λ^{-4}	0.1 to 10 µm	Smoke, haze
Non-selective	λ^0	> 10 µm	Dust, fog, clouds

Effect of Atmosphere on Remote sensing

- Absorption

Only Atmospheric windows available !

- Scattering

Modification of spatial/spectral distribution of incoming and outgoing radiation !

Atmospheric turbulence limits resolution !

What have we learnt ??

- Definition and Overview of Remote Sensing History and Evolution of Remote Sensing and Remote Sensing Systems.
- Electromagnetic Radiation, Terms and Definitions, Laws of Radiation, EM Spectrum
- Interaction between EM Radiation and matter, Reflection, Absorption and Transmission.
- Interactions between EM Radiation and Atmosphere, Atmospheric windows

THANKS

For further queries and doubts :
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PS : The material used in the presentation has been compiled from various sources : book by Dr.George Joseph, RS tutorials by ccrs, NASA, ITC, other books, lecture notes, tutorials and online resources

Suggested readings

- George J. (2005) : Fundamentals of remote Sensing; Universities press (India)Pvt ltd, Hyderabad, india.
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