NC STATE UNIVERSITY

FOR 353: Air Photo Interpretation and Photogrammetry

Lecture 2

Electromagnetic Energy/Camera and Film characteristics

Center for Earth Observation

Lecture Outline

- Electromagnetic Radiation Theory
- Digital vs. Analog (i.e. ‘film’) Systems

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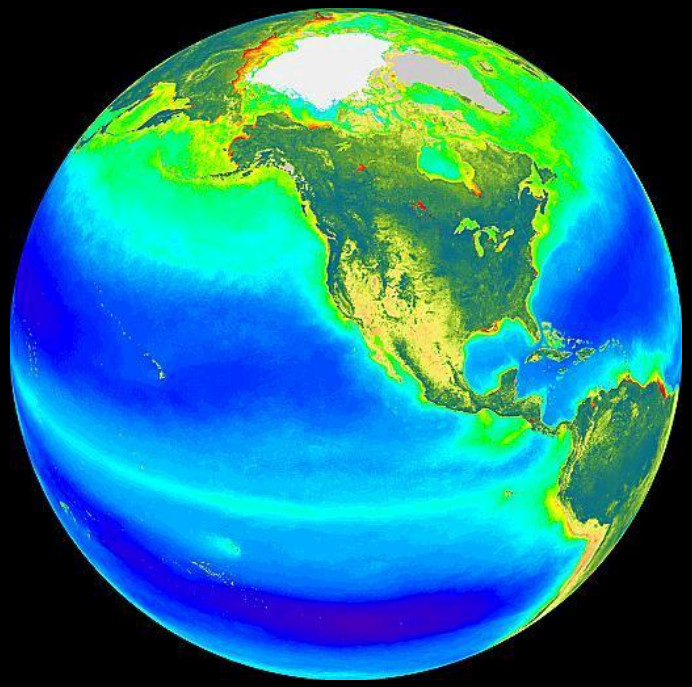
- Electromagnetic Radiation Theory
- Digital vs. Analog (i.e. ‘film’) Systems

Electromagnetic Spectrum

"EMR is energy propagated through space in the form of tiny energy packets called photons that exhibit both wave-like and particle-like properties."



Electromagnetic Spectrum

Fundamental Interactions

Sun energy:

- is radiated by atomic particles at the source (the Sun)
- propagates through the vacuum of space at the speed of light
- interacts with the Earth's atmosphere
- interacts with the Earth's surface
- interacts with the Earth's atmosphere once again, and finally reaches the remote sensor, where it interacts with various optical systems, filters, film emulsions, or detectors

Electromagnetic Radiation

Energy Source and Measurement Units

- The Sun is the most common energy source
  - Sunlight travels at a speed of 186,000 m/s

- Wavelength (λ) is used to describe the spectrum of light.
  - Micrometer (μm) (1/1000 of a millimeter)
  - Nanometer (nm) (1 billionth of a meter)

example: light in the visible portion of the spectrum ranges from 0.4 – 0.7 μm. In nanometers this would read: 400 – 700 nm

Electromagnetic Radiation

Energy Source and Measurement Units

•Different sensors are required to capture and record the different wavelengths

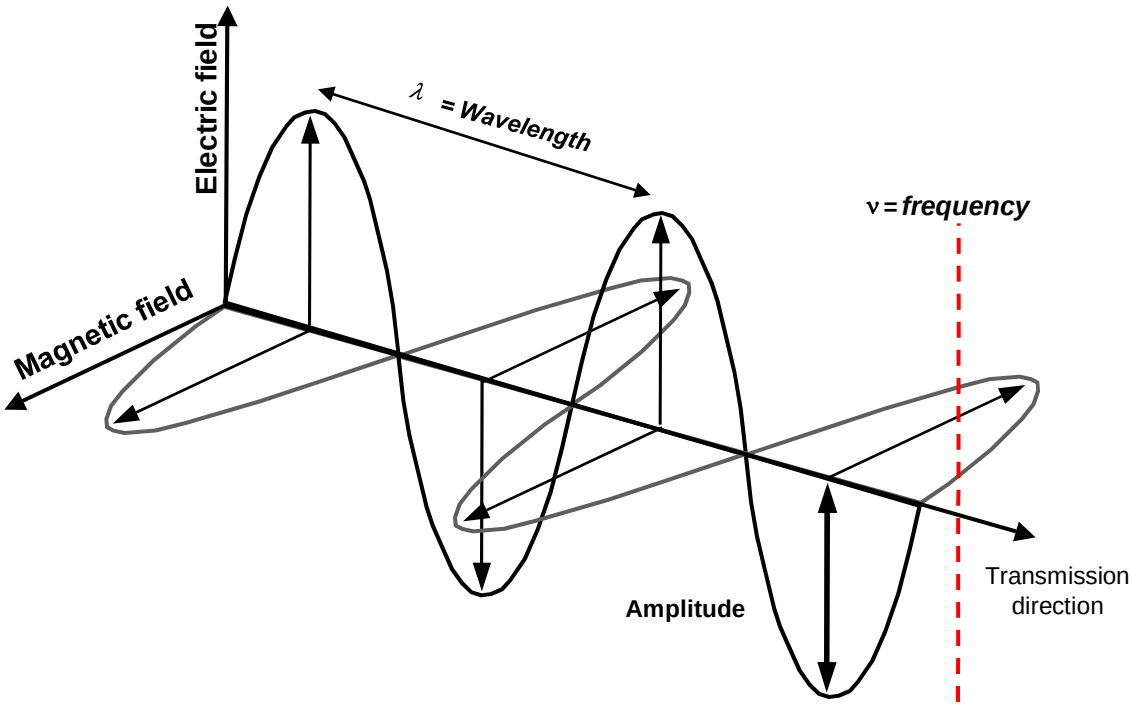
Photographic film (0.4-0.9 μm)

Landsat satellite (0.45–2.35 μm optical; 10.4–12.5 μm thermal)

MODIS satellite (0.62-14.38 μm)

Human Eye (0.4-0.7 μm)

Wavelength and Frequency



Units of wavelength:

Nanometers: 1 nm = 10^{-9} m

Micrometers: 1 μm = 10^{-6} m

Angstroms: 1 Åm = 10^{-10} m

$c = \lambda v$

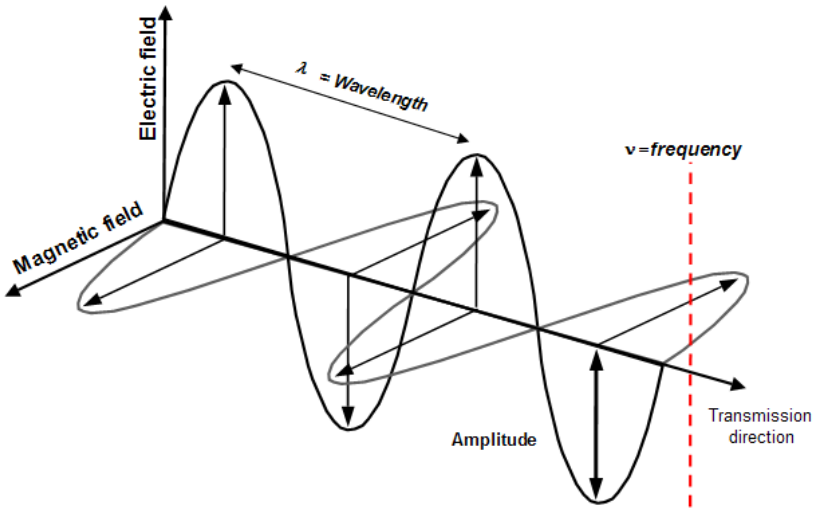
where:

λ = wavelength (m)

V = frequency (cycles/second, Hz)

c = speed of light (3×10^{8} m/s)

Wavelength and Frequency



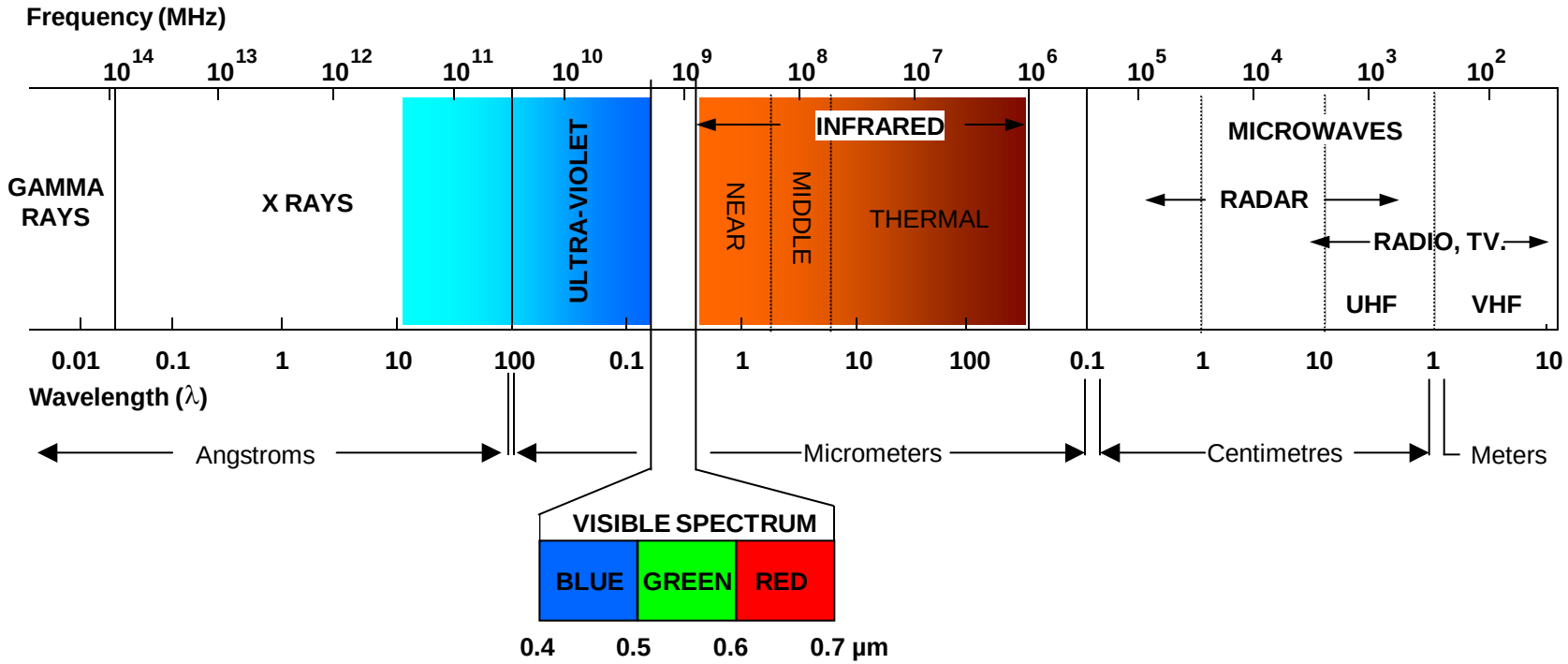
$$c = \lambda v$$

Note: frequency is inversely proportional to wavelength

def wavelength (λ) – the mean distance between maximums of roughly periodic pattern

def frequency (V) - the number of wavelengths that pass a point in time

Electromagnetic Spectrum



Electromagnetic Spectrum

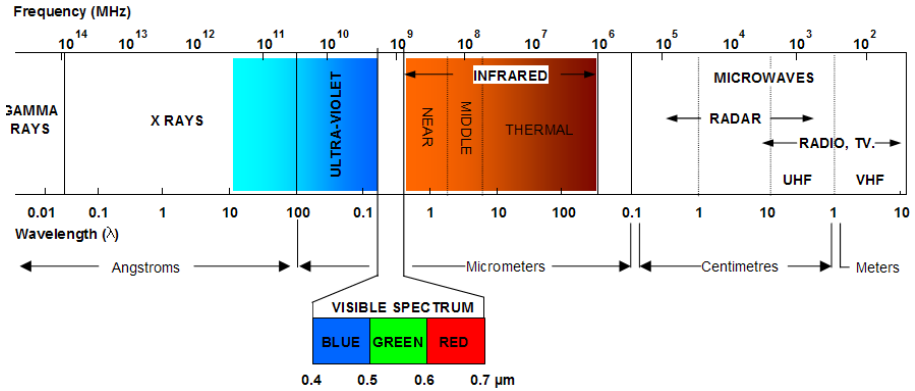
VIS – Visible region – 0.4-0.7 µm

NIR – Near-infrared (0.7 – 1.2 µm) - discriminate green vegetation

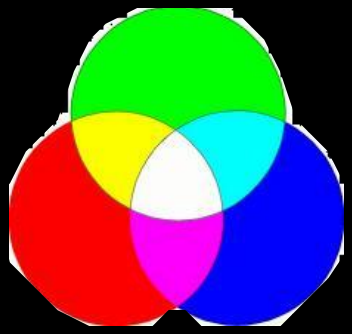
MIR – Mid-infrared (1.2 – 8 µm) [**SWIR -** Shortwave IR (1.2 – 3 µm)]
*1.3-2.5 µm used for soil and vegetation moisture contents,
*3-5 µm used for detecting high-temperature sources

TIR – Thermal infrared (8 – 14 µm) Helps to map surface temperatures, useful in detecting vegetation stress and clouds, and in assessments of environmental condition

Microwave region (>1 mm)



Color

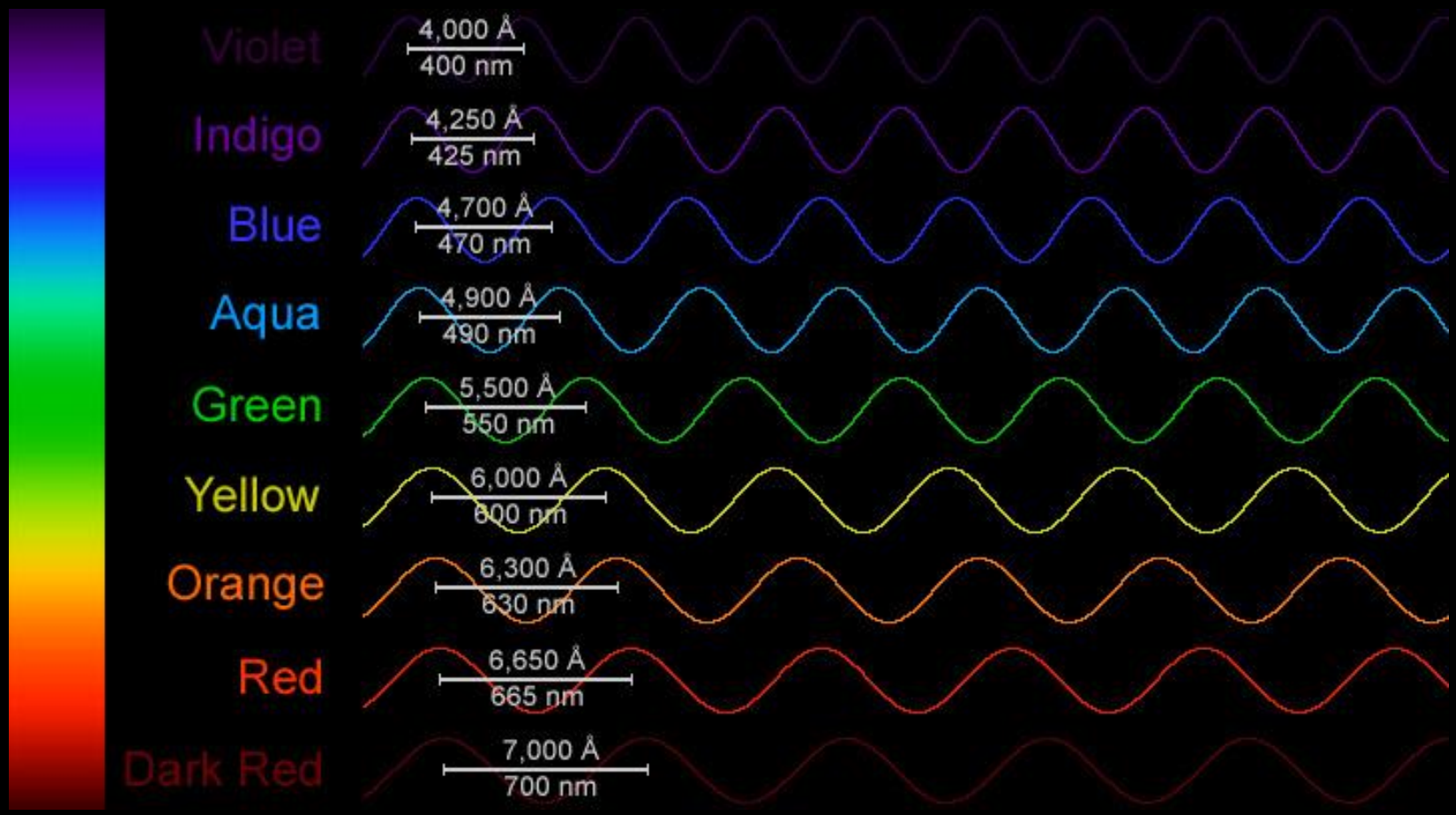


White Light

- Composed of three primary additive colors: red, green, blue
  These colors can't be created by adding other colors together (Additive color model)

- Composed of three primary subtractive colors: cyan, magenta, yellow
  These are created by adding together two primary additives (Subtractive color model)

- Adding all three primary additive colors of light produces the color white


Violet
4,000 Å
400 nm
Indigo
4,250 Å
425 nm
Blue
4,700 Å
470 nm
Aqua
4,900 Å
490 nm
Green
5,500 Å
550 nm
Yellow
6,000 Å
600 nm
Orange
6,300 Å
630 nm
Red
6,650 Å
665 nm
Dark Red
7,000 Å
700 nm

Electromagnetic Radiation

Electromagnetic Energy

- EM energy only detected when it interacts with matter
- EM energy generally travels in a straight line from its source
- Once EM energy interacts with a medium, it may be altered

(Reflection, Transmission, Absorption)

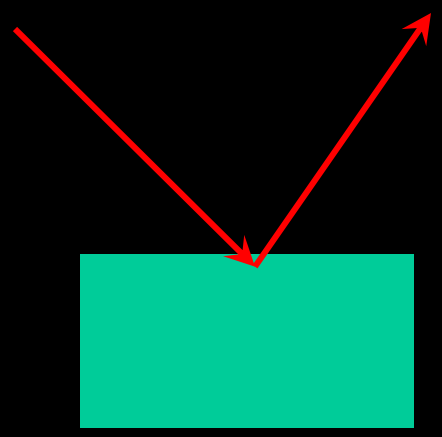
Electromagnetic Radiation

Electromagnetic Energy: Reflection

The ratio of energy reflected from an object to the energy incident upon the object

Two types:

1. Specular
2. Diffuse



Reflection

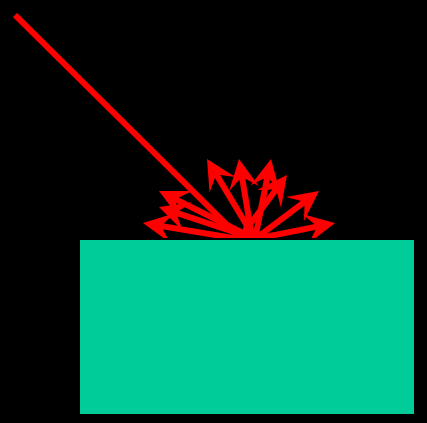
Electromagnetic Radiation

Electromagnetic Energy: Reflection

The ratio of energy reflected from an object to the energy incident upon the object

Two types:

1. Specular
2. Diffuse

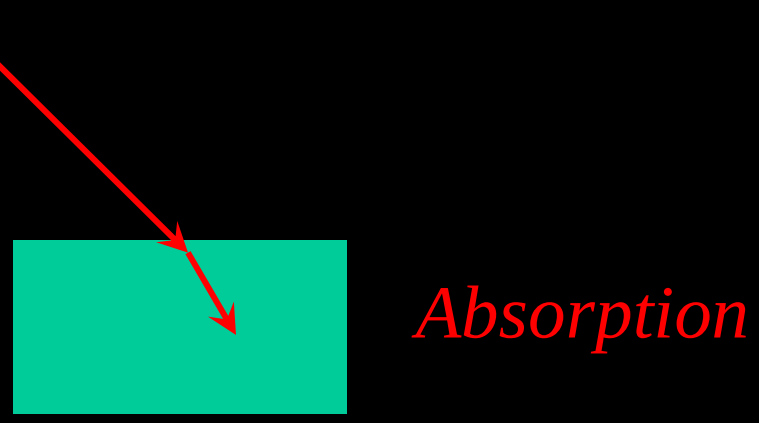


Scattering

Electromagnetic Radiation

Electromagnetic Energy: Absorption

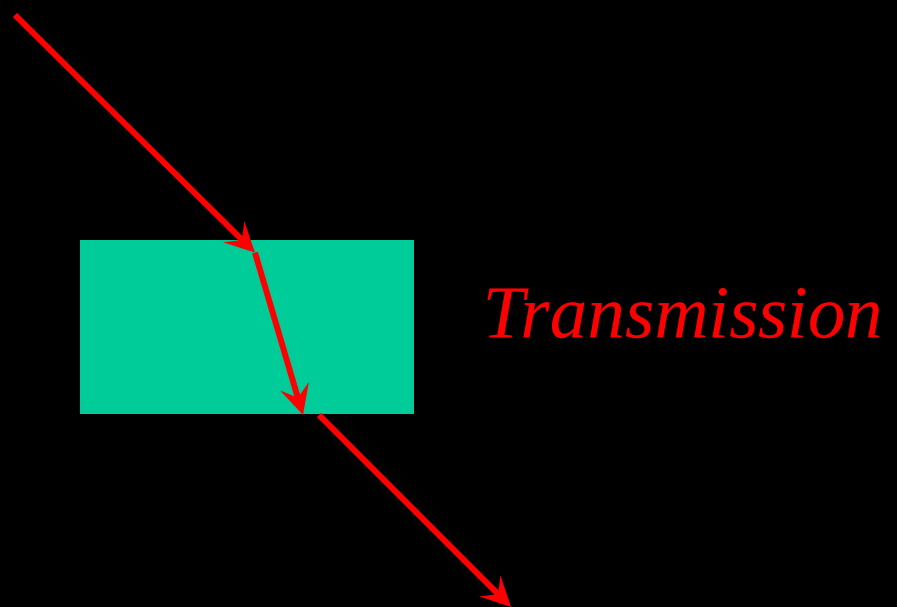
Incident energy does not bounce off an object, nor pass through it.
Energy is converted to some other form, such as heat.
Differences in absorptive qualities of objects result in “color”



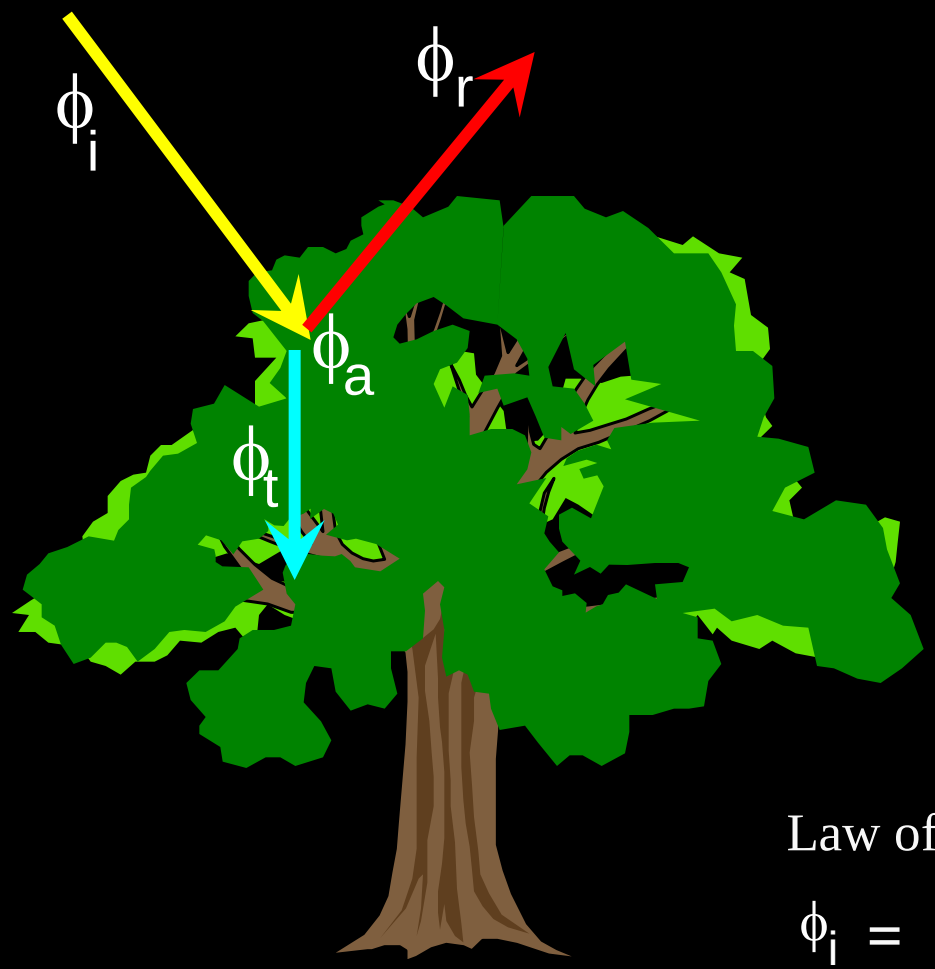
Electromagnetic Radiation

Electromagnetic Energy: Transmission

The propagation of energy through a medium. The wavelengths are refracted when entering or leaving a medium (such as a glass window). Short wavelengths are refracted more than longer wavelengths.



Interactions of Solar energy with the Earth's surface



ϕ_i Incident energy

ϕ_r Reflected energy

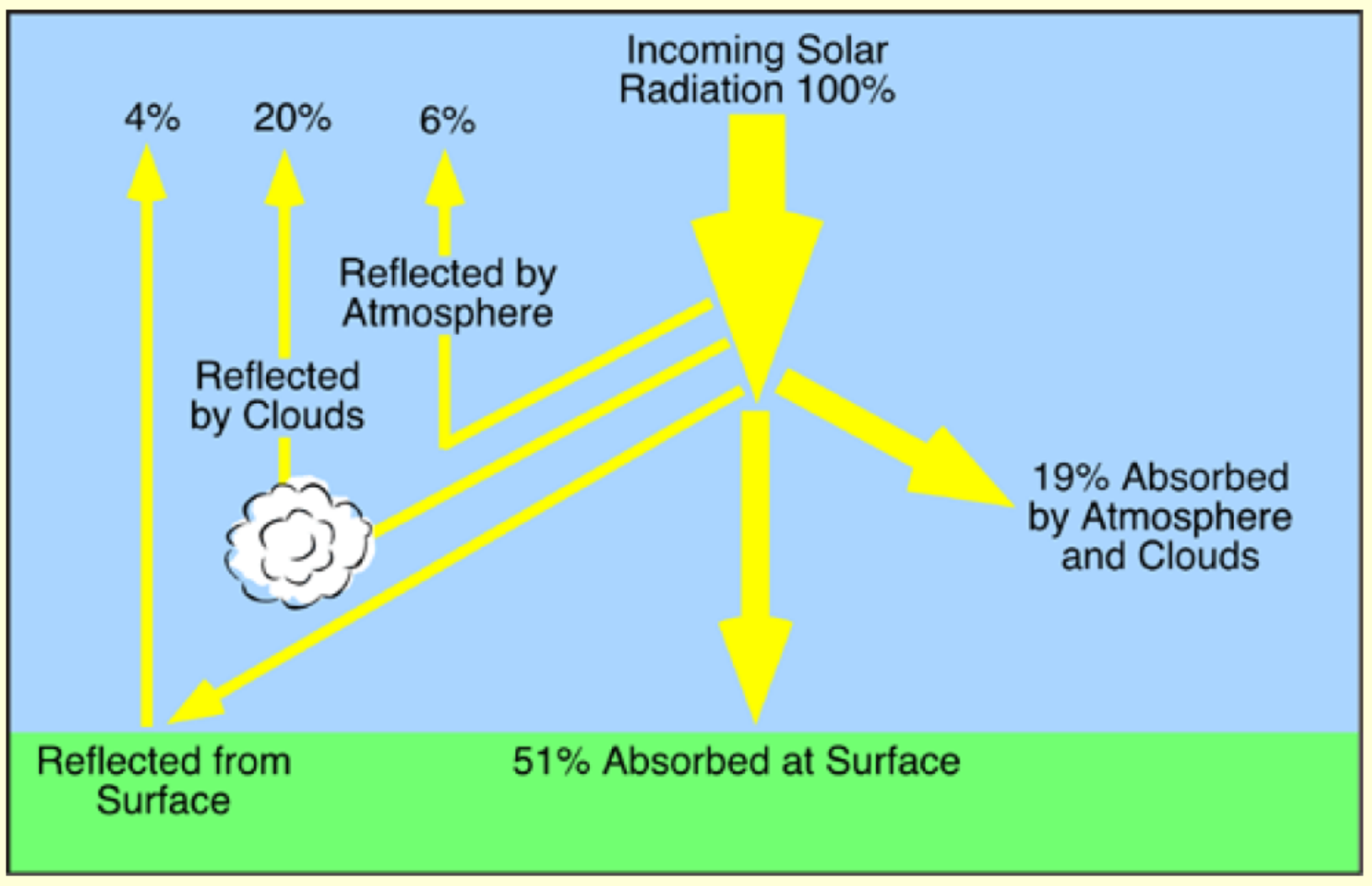
ϕ_t Transmitted energy

ϕ_a Absorbed energy

Law of the Conservation of Energy

$$\phi_i = \phi_r + \phi_t + \phi_a$$

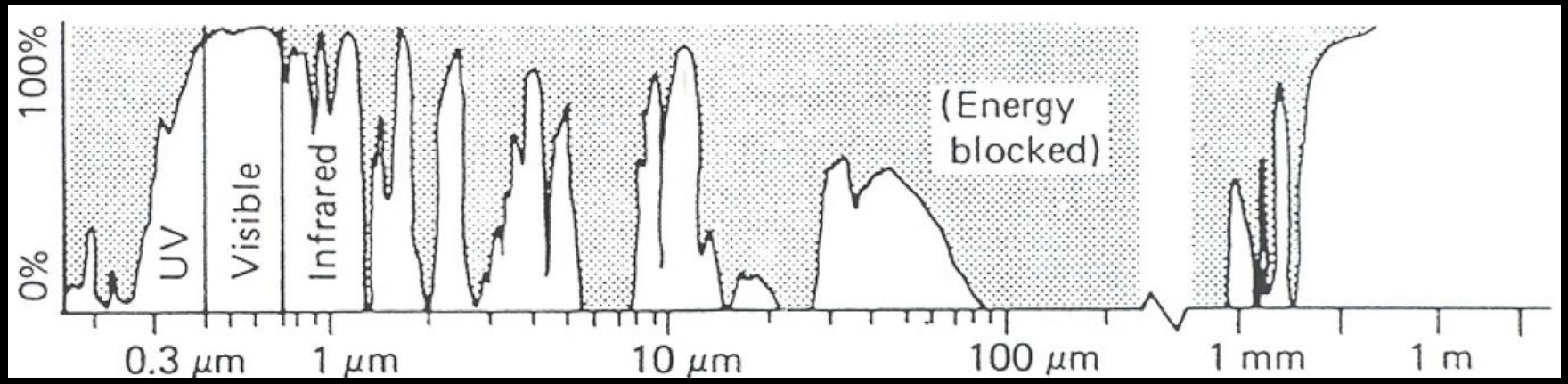
EMR Energy Budget



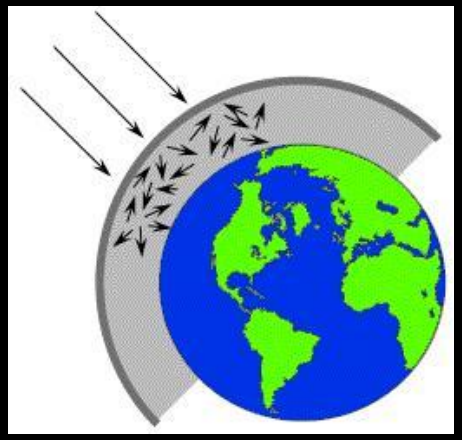
Electromagnetic Spectrum

Atmospheric Windows

- Gamma and UV radiation filtered out by the atmosphere
- Human eye can resolve wavelengths between 0.4 and 0.7 μm, nearly 100% transmission through the atmosphere
- Photographic film records EM energy within the 0.4 - 0.9 μm range



Atmospheric Scattering



- ***Rayleigh*** (air molecule scattering)
  - -Blue Sky
  - -Blue and Violet wavelengths scattered
  - -Haze
  - -Scattering by smaller particles

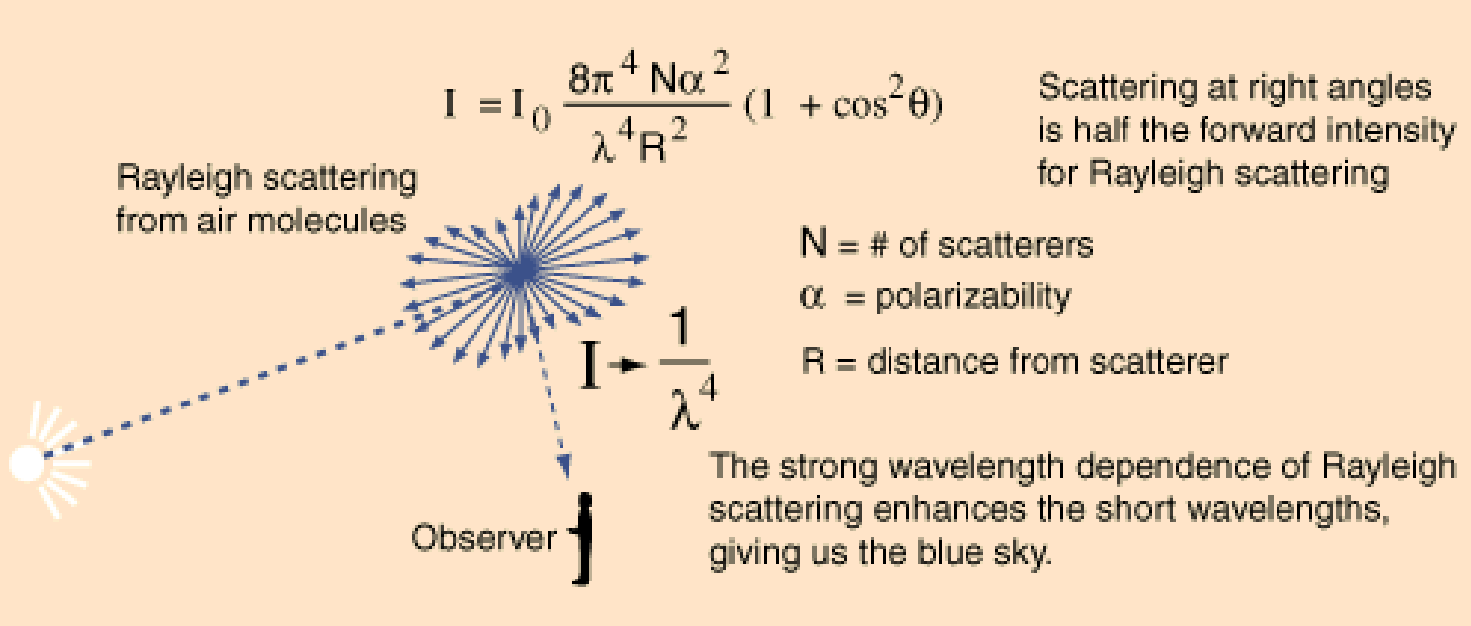
- ***Mie*** (aerosol scattering)
  - -Scattering by larger particles
  - -Red and orange wavelengths scattered
  - -Reds and oranges in sunsets

- ***Non-selective***
  - - Atmospheric and particulate molecule scattering
  - - Larger diameter than the wavelength striking them
  - -Water droplets
  - -Visible to IR equally scattered

Atmospheric Scattering

- ***Rayleigh*** (air molecule scattering)

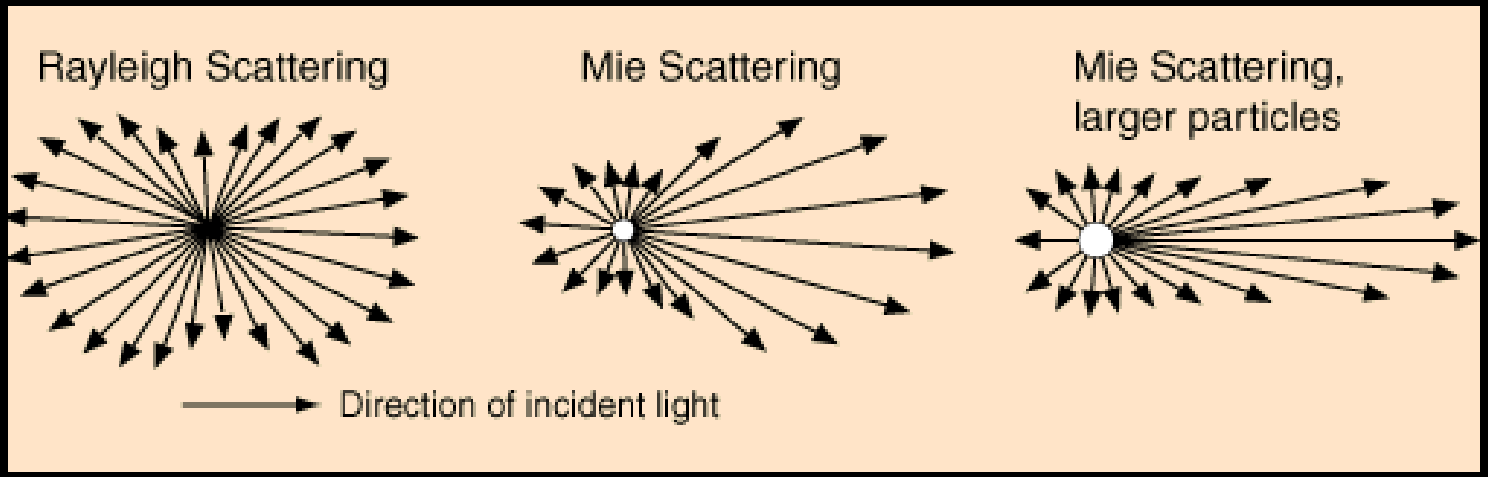
Rayleigh scattering refers to the scattering of light off of the molecules of the air, and can be extended to scattering from particles up to about a tenth of the wavelength of the light.



Atmospheric Scattering

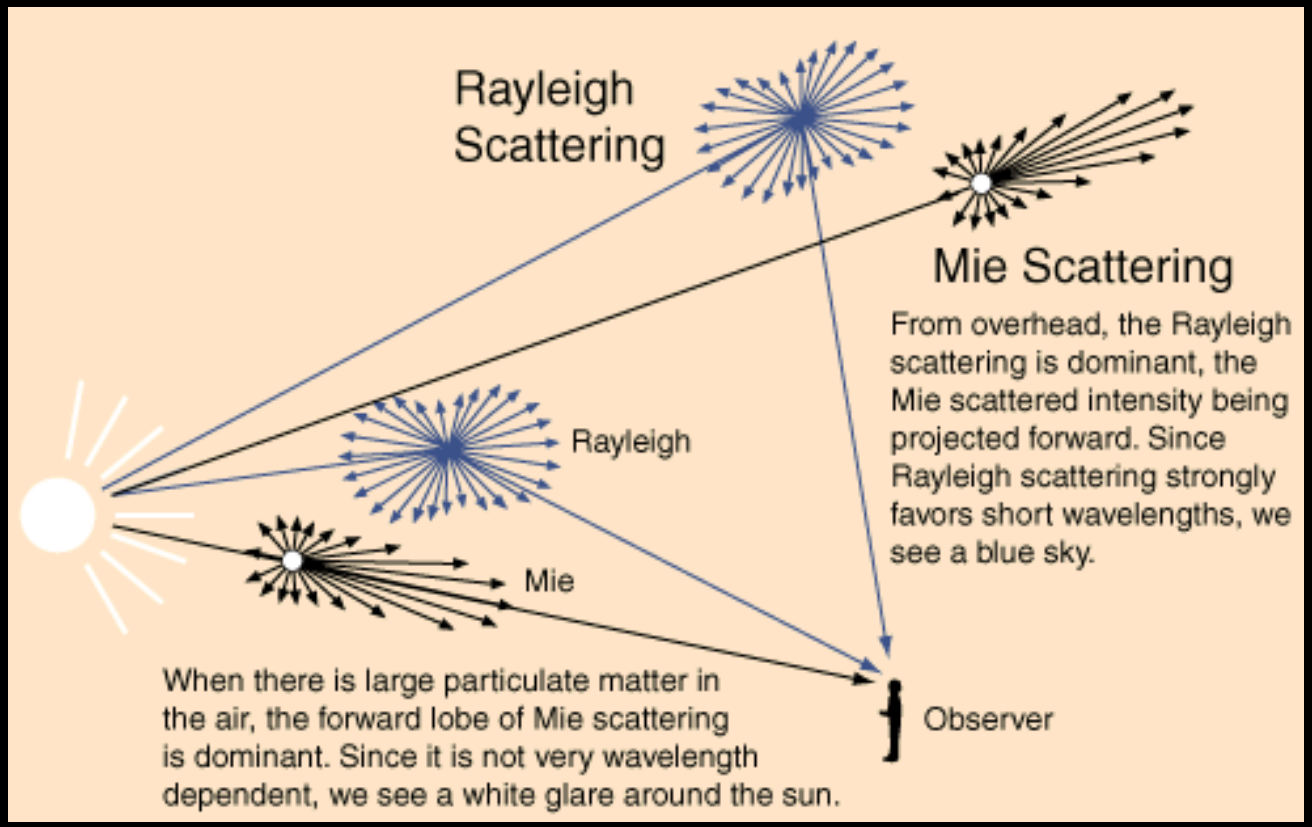
- ***Mie*** (aerosol scattering)

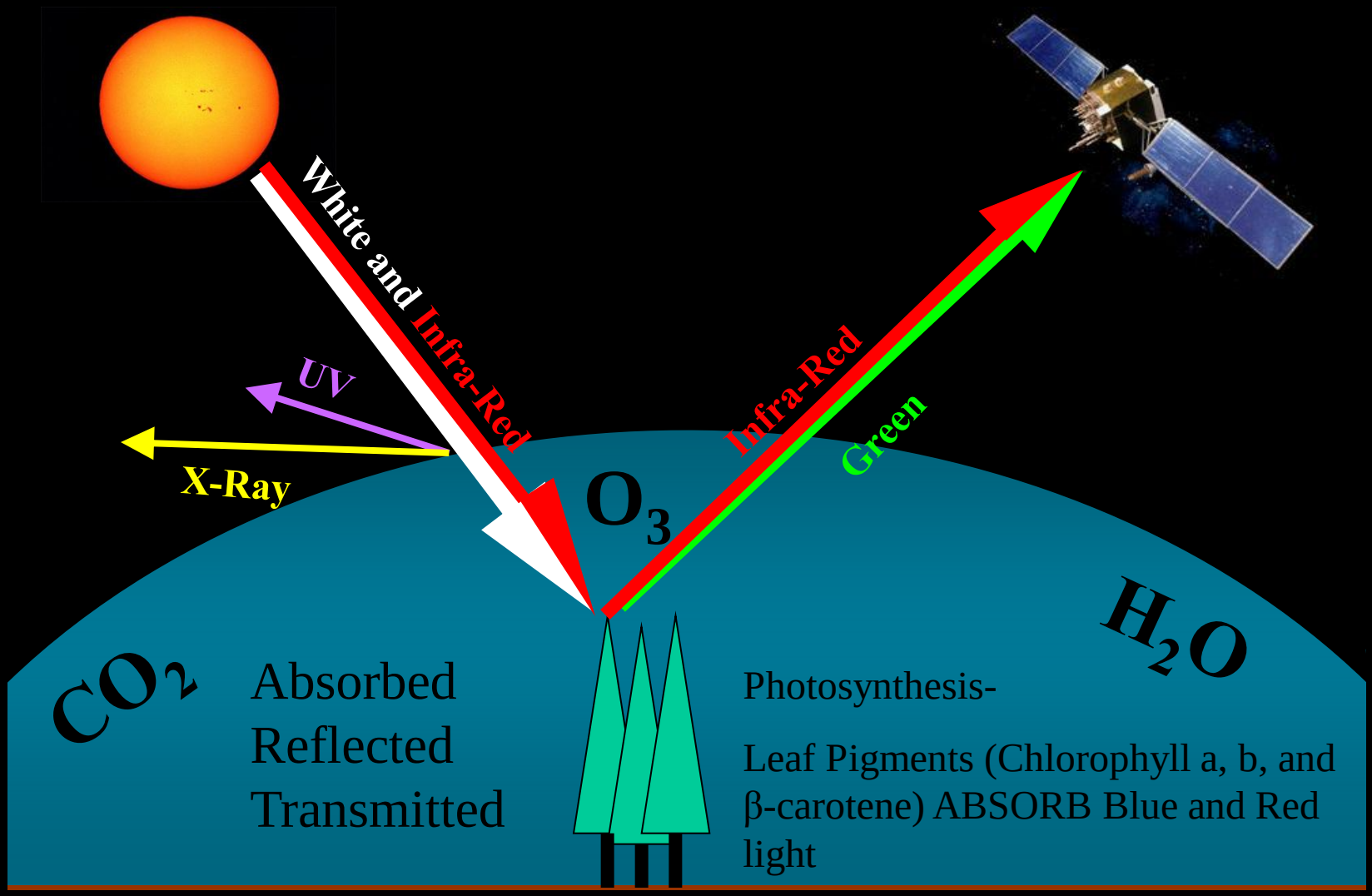
For particle sizes larger than a wavelength, Mie scattering predominates. This scattering produces a pattern like an antenna lobe, with a sharper and more intense forward lobe for larger particles.

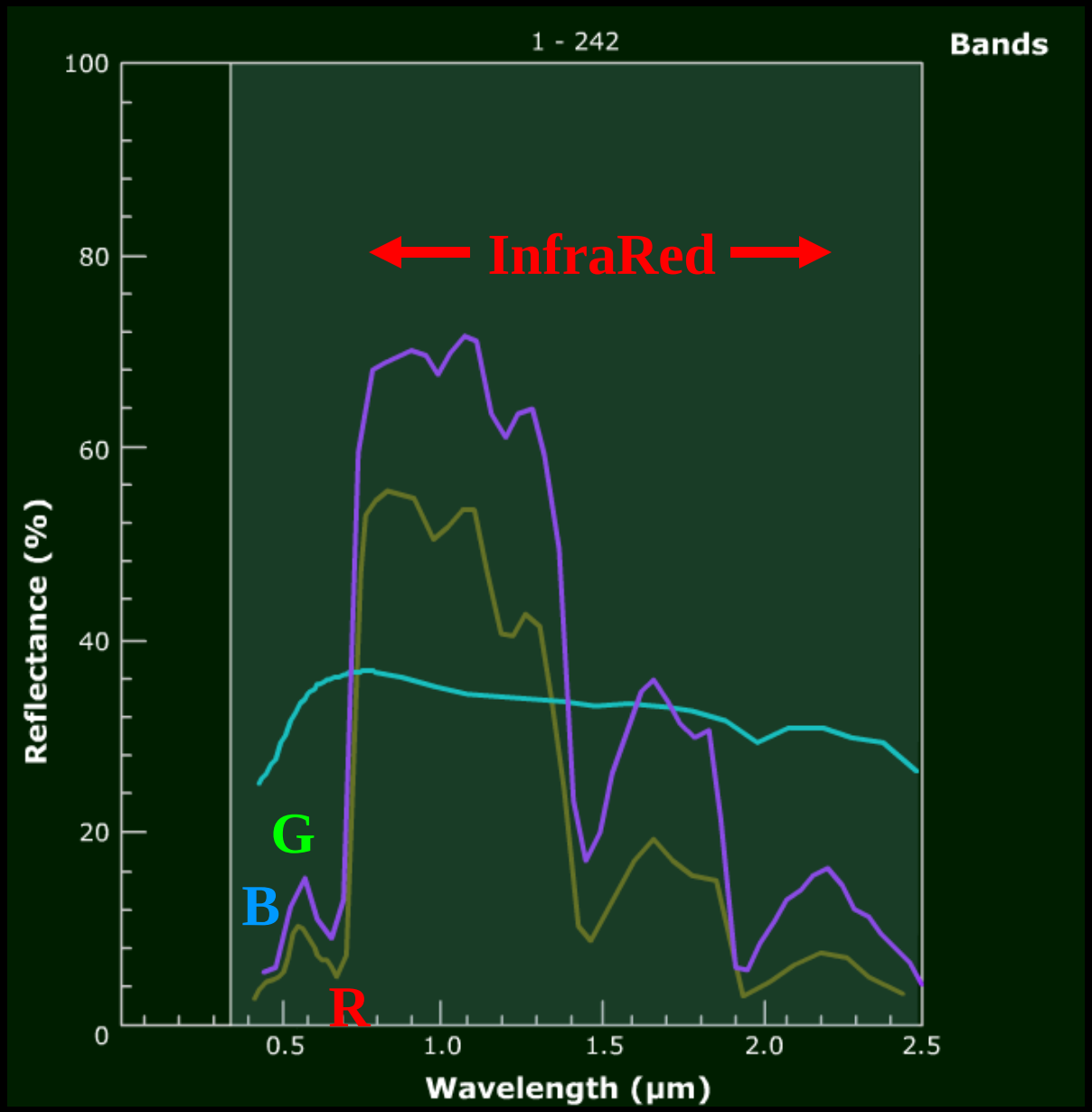


Atmospheric Scattering

- ***Rayleigh and Mie Scattering***




White and Infra-Red
UV
X-Ray
Infra-Red
Green
O_3
H_2O
CO_2
Absorbed
Reflected
Transmitted
Photosynthesis-
Leaf Pigments (Chlorophyll a, b, and β-carotene) ABSORB Blue and Red light

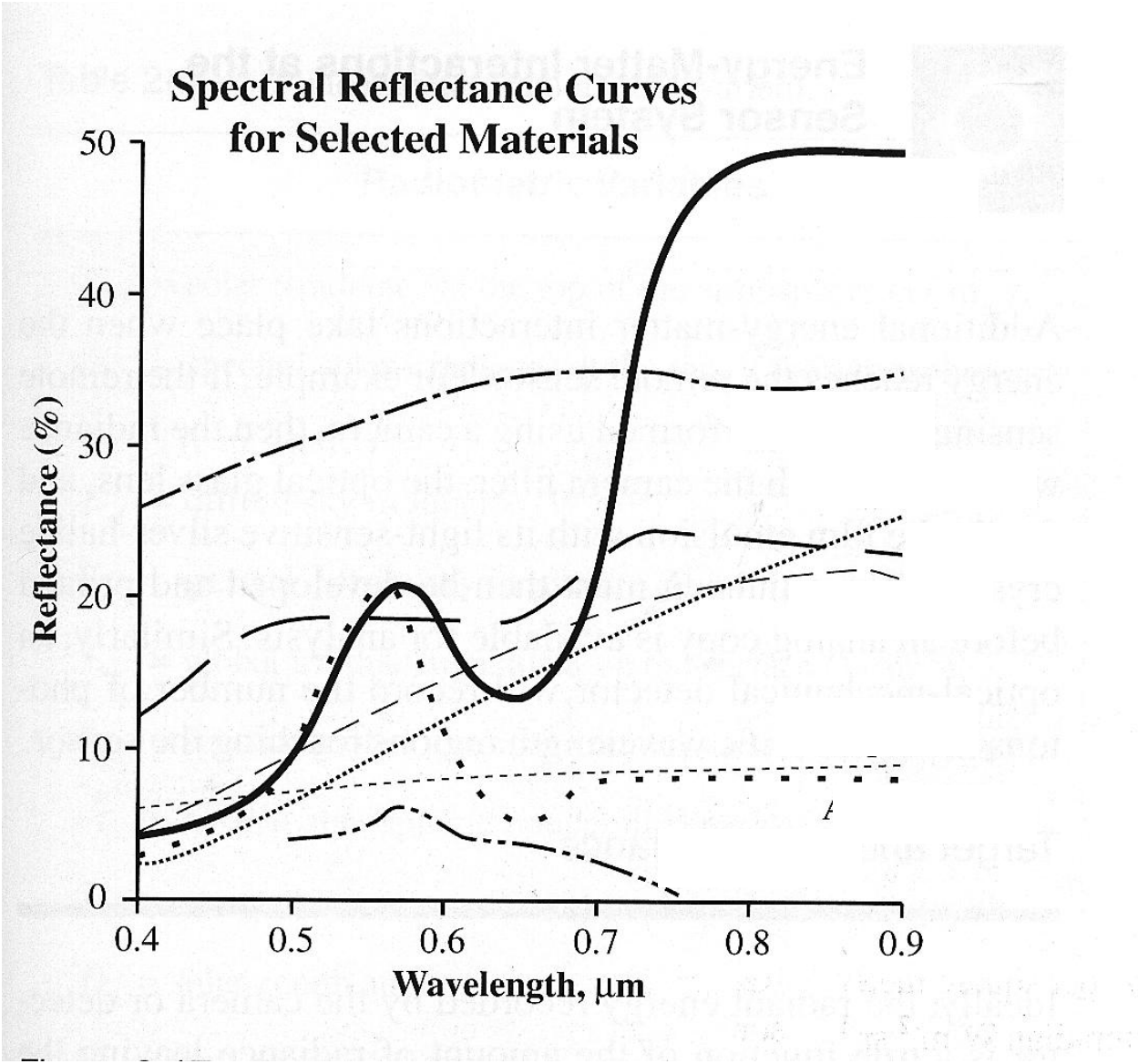


Oak

Pine

Concrete

Identify the Spectral Curves



Grass

Clear Water

Fallow Field

Sandy Loam Soil

Shingles

Concrete

Artificial Turf

Asphalt

Rank these colors from shortest to longest wavelength

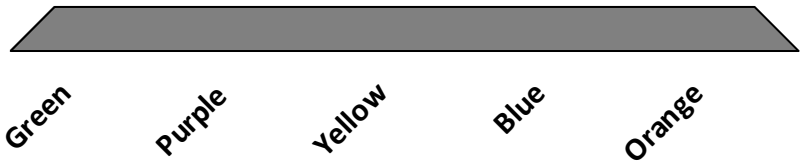
A. Green

B. Purple

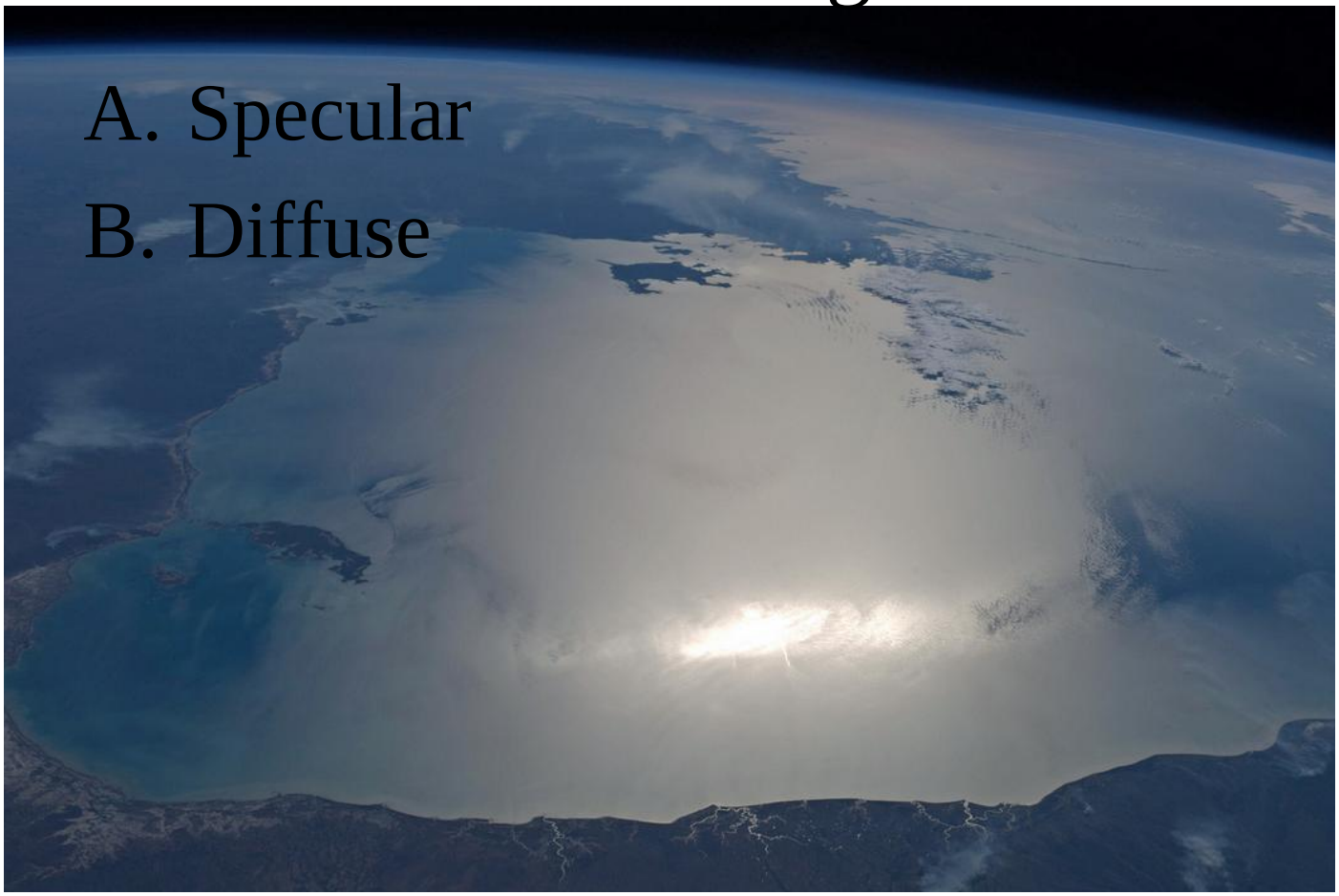
C. Yellow

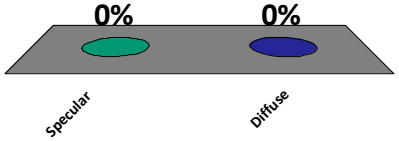
D. Blue

E. Orange

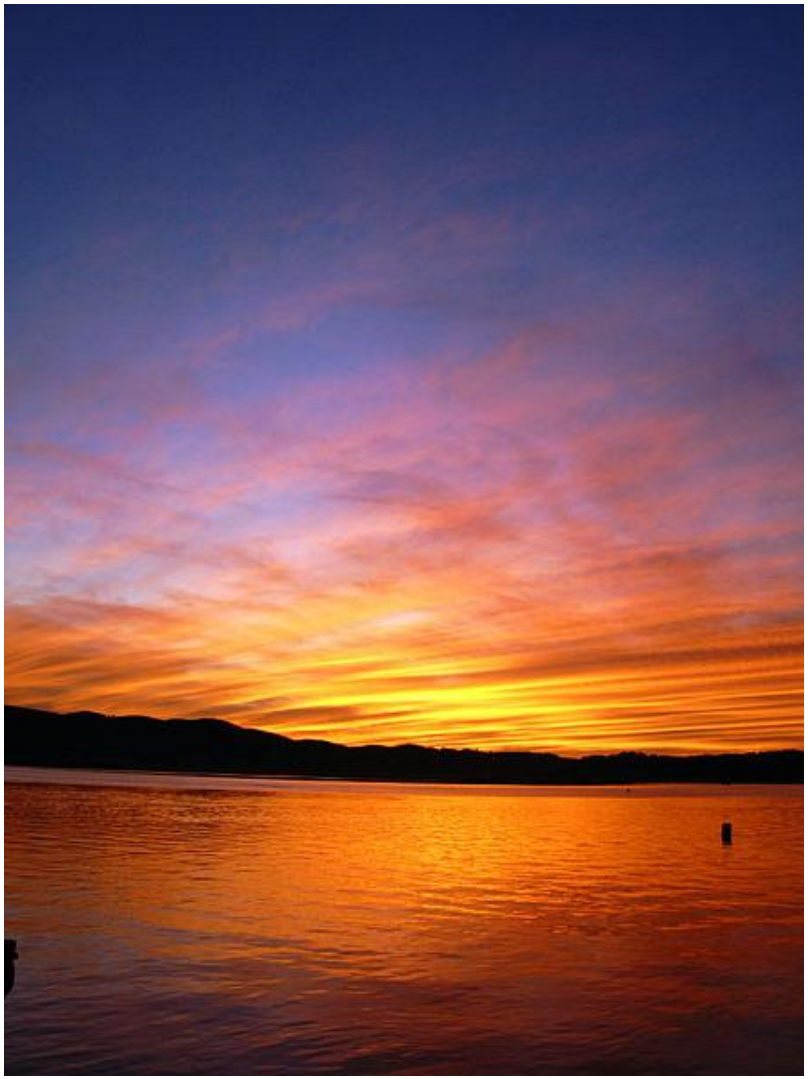


What reflection-type is seen in this oblique satellite image of Australia?





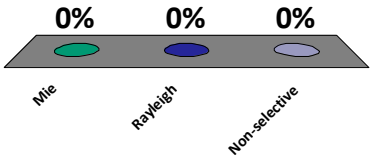
What type of scattering is seen closest to the horizon?



A. Mie

B. Rayleigh

C. Non-selective



Lecture Outline

- Electromagnetic Radiation Theory
- Digital vs. Analog (i.e. ‘film’) Systems

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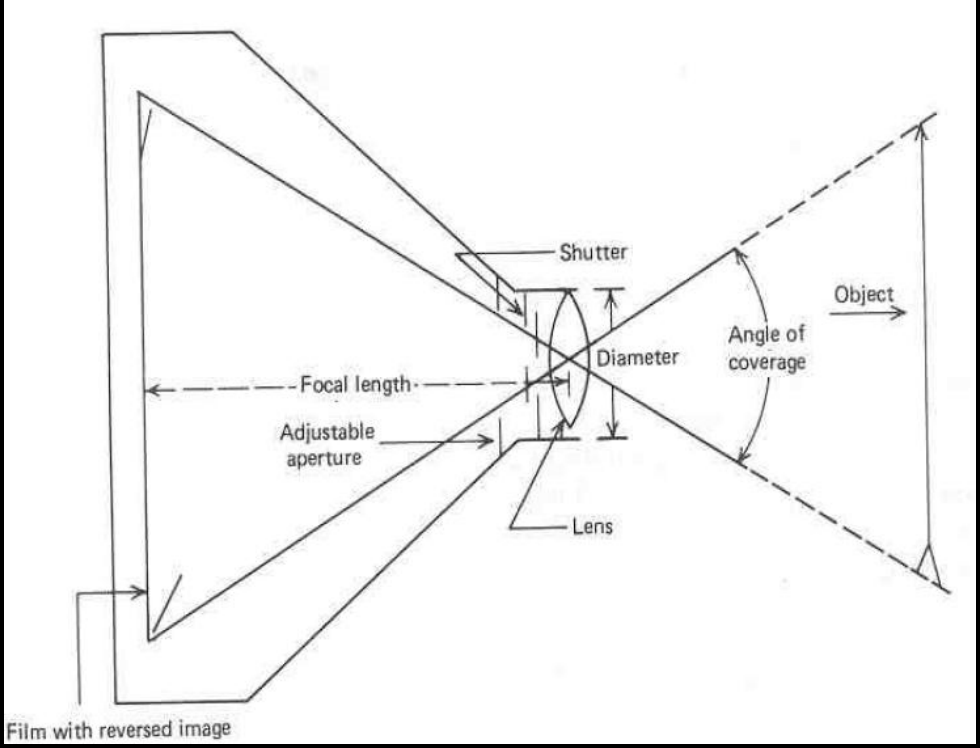
Camera Components

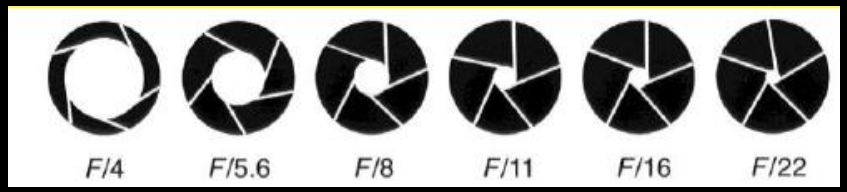
A film camera is made of three basic elements:

1. Optical (the lens)
2. Chemical (the film)
3. Mechanical (the camera body)

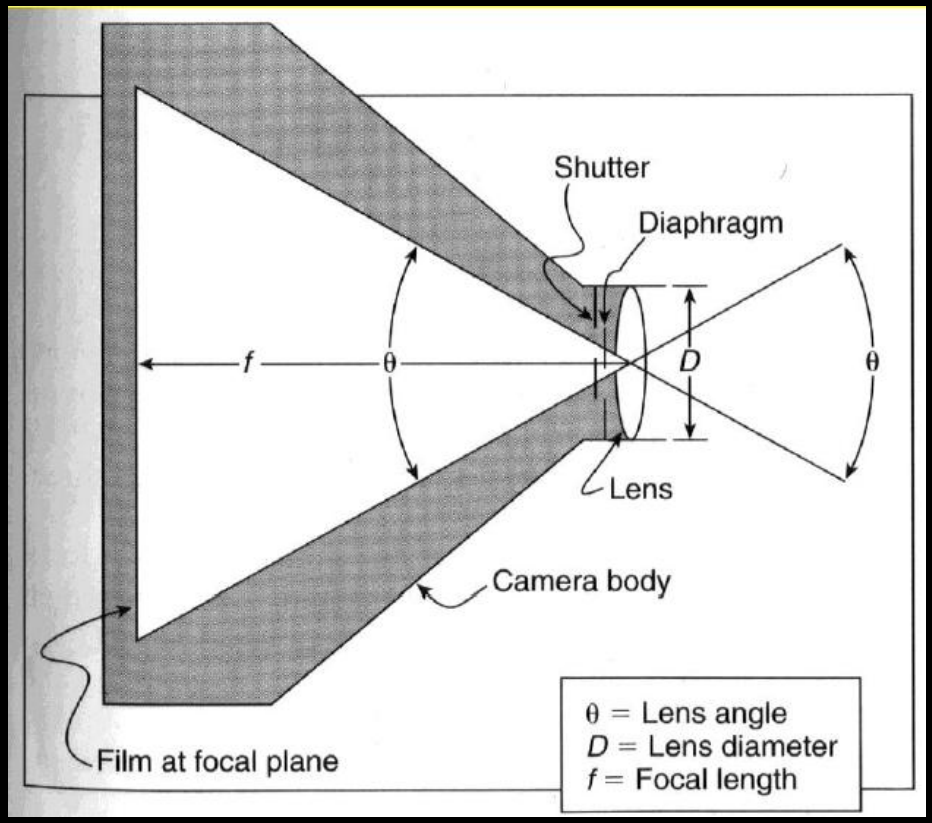


Camera Components

Exposure of film (amount of light that reaches film) is controlled by the f/stop and shutter speed



f/stop = f / D



shutter speeds:

slow speeds — fast speeds

1/1 1/2 1/4 1/8 1/16 1/32 1/64 1/128 1/256 1/528

Analog Systems (i.e. 'film')

Energy Source and Measurement Units

•Different sensors are required to capture and record the different wavelengths

Photographic film is used to capture energy in the 0.4-0.9 μm range

Film Types:

1. Black and White
   - panchromatic (0.4 – 0.7 μm)
   - infrared (0.4 – 0.9 μm)

2. Color
   - normal color (0.4 – 0.7 μm)
   - color infrared (0.4 – 0.9 μm)

Energy Flow

Energy flow within the camera

- Not all energy that reaches a sensor is recorded by the sensor.

- Cameras (and other sensors) use film (or CCD's, etc.) that only allow the capture and display of certain wavelengths of energy.

- Filters can be used to absorb specific quantities and qualities of energy, and affect the type of energy that finally reaches the film.

Camera Filters

Filters

- Absorb unwanted rays of light before they reach the film

Antivignetting filters

Compensate for unequal light transmission with very wide-angle lenses. Designed to allow as much light to the corners of an image as it does the center of the image

Polarizing filters

Designed to penetrate haze and to reduce reflections from the surfaces of water

Haze-cutting filters

Designed to remove the blue light in the atmosphere that is scattered by dust, moisture, smoke, or other air pollutants

Film

Energy Source and Measurement Units

Photographic film is used to capture energy in the 0.4-0.9 μm range

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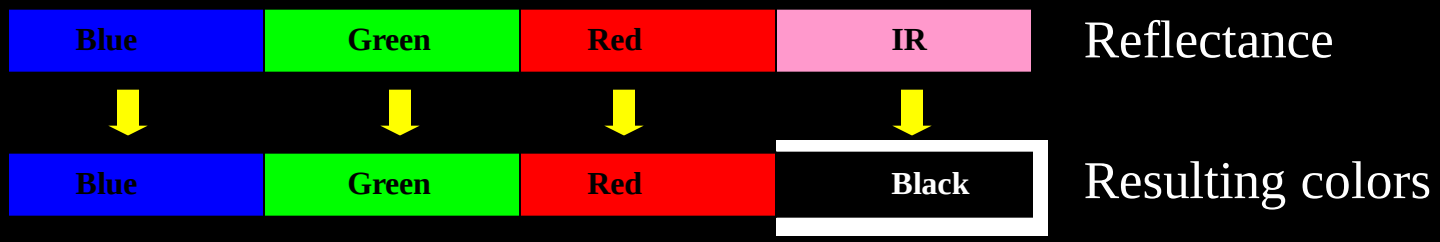

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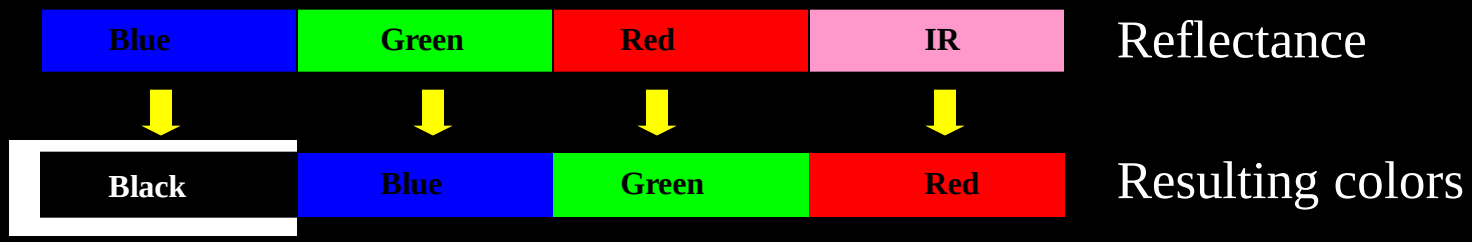


Film

Comparisons of Film Types

Advantages of panchromatic black and white and normal color over infrared:

- More natural to the eye
- Better resolution
- Better penetration of water

Advantages of infrared over panchromatic black and white and normal color:

- Better penetration of haze
- Emphasizes water and wet areas
- Good differentiation between hardwood and conifers
- Good differentiation between healthy and diseased trees

Film

Comparisons of Film Types

Advantage of normal color over panchromatic black and white:

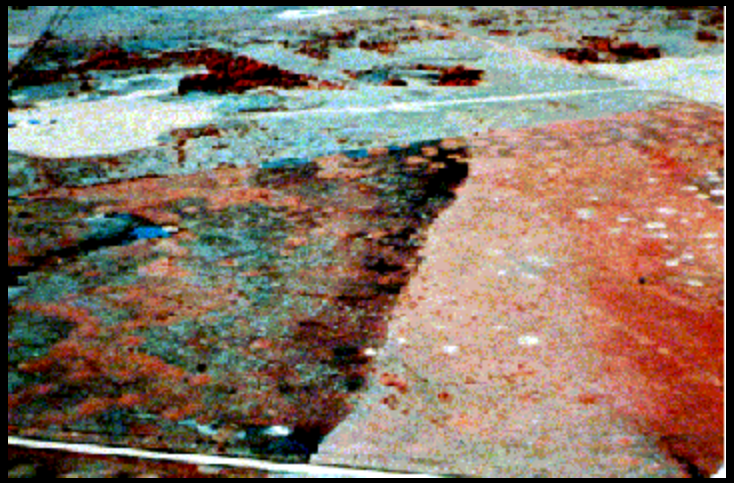
Humans can discriminate 20,000 - 5 million shades of color, but only about 200 shades of gray.

Advantages of panchromatic black and white over normal color:

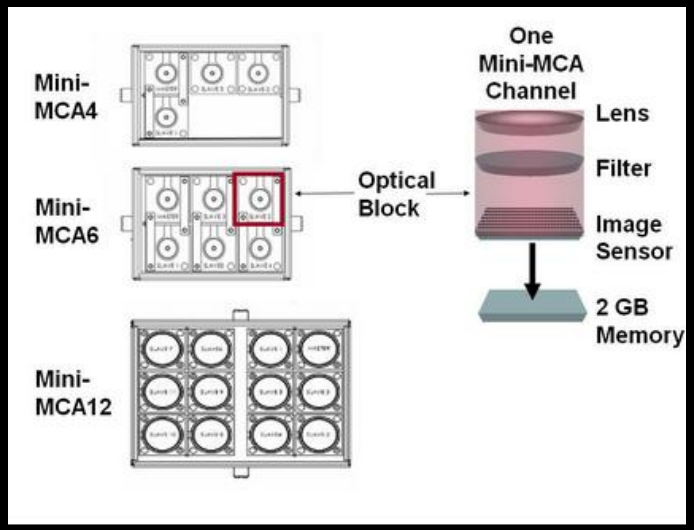
Color film is more expensive to process.
Resulting images on color prints are usually not as sharp as on B&W prints.

Advantages/Disadvantages of BW and Color Aerial Photography

	Advantage	Disadvantage
BW Pan	Best resolution Least expensive processing Familiar gray tones Detail in shadows Shallow water penetration	No color Vegetation discrimination more difficult
Normal Color	Natural color for humans Detail in shadows Shallow water penetration	Not as good as IR for vegetation
BWIR	Good distinction of hardwood and softwood Cuts through haze Good land/water definition	No color No information in shadows
Color IR	Good distinction of vegetation Types Good land/water definition Cuts through haze	No information in shadows More expensive processing Not natural colors



Digital Systems



The Mini-MCA12 System Includes:
12 channel Mini MCA camera
12 ea. 2 GB Certified CF Cards
12 ea. 9.6 mm lenses
12 ea. 1.3 MB image sensors (15.6 MB total)
12 ea. Bandpass Filter Set *
- 490FS10-25
- 520FS10-25
- 550FS10-25
- 570FS10-25
- 671FS10-25
- 680FS10-25
- 700FS10-25
- 720FS10-25
- 800FS10-25
- 840FS10-25
- 900FS20-25
- 950FS40-25

Digital Systems

Digital Cameras convert analog information (represented by a fluctuating wave) into digital information (represented by ones and zeros, or bits).

Benefits of Digital Aerial Imagery

- Low noise and graininess compared to scanned film
- Enhanced radiometric resolution, 12 bit vs. 8 bit, for great detail in shadows.
- Improved tolerance for cloudy or less than ideal weather conditions.
- No geometric degradation effects related to film warping or distortion.
- Eliminates cost of film, film development, and digital scanning.
- Rapid turnaround and delivery, imagery available minutes after landing.