Hyperspectral Remote Sensing

Basic Principles

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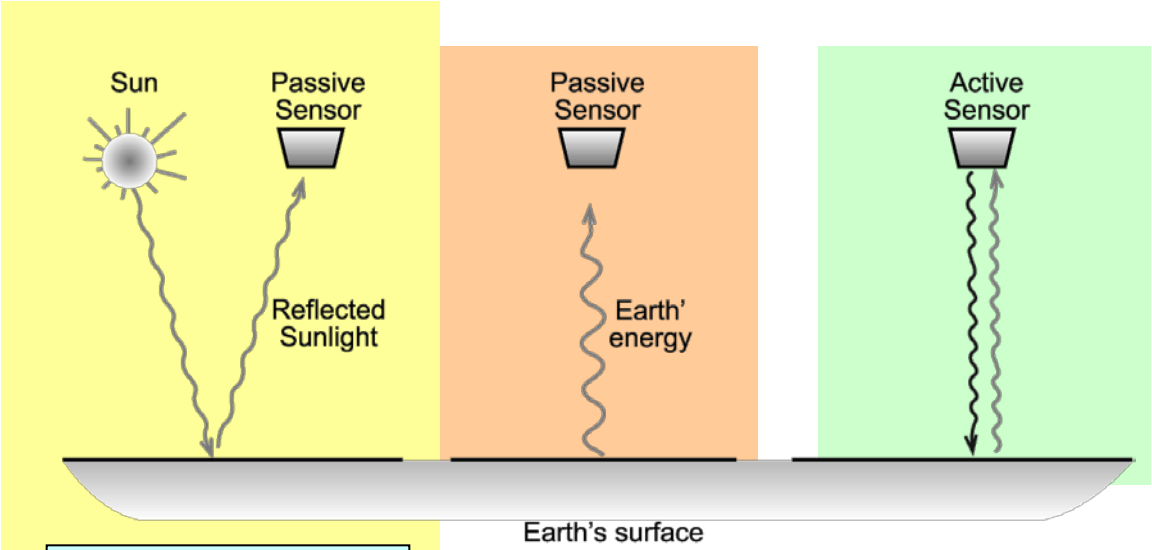
Sensors in Remote Sensing



Panchromatic

Multispectral

Hyperspectral

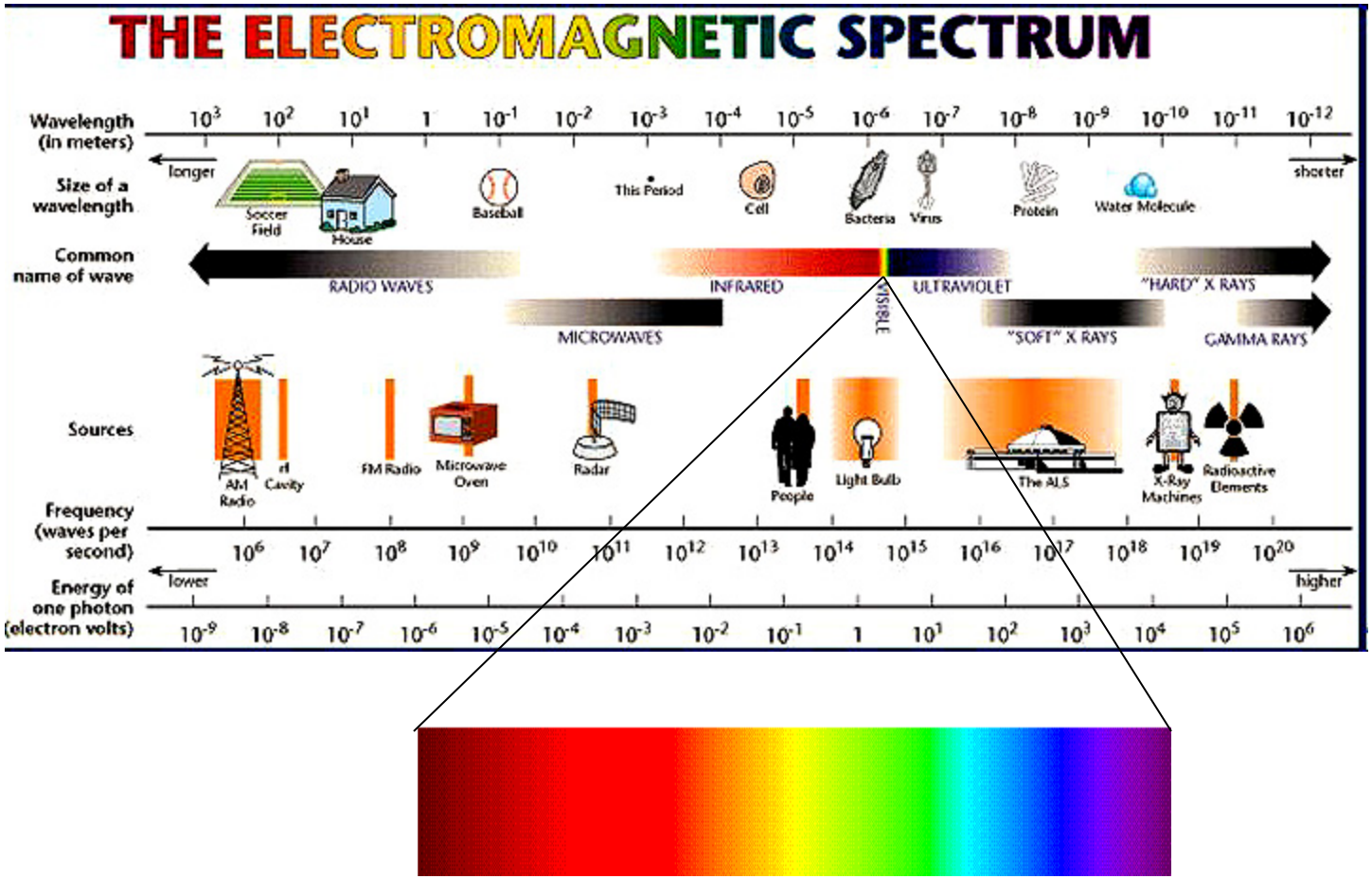
Thermal

Radar (SAR)

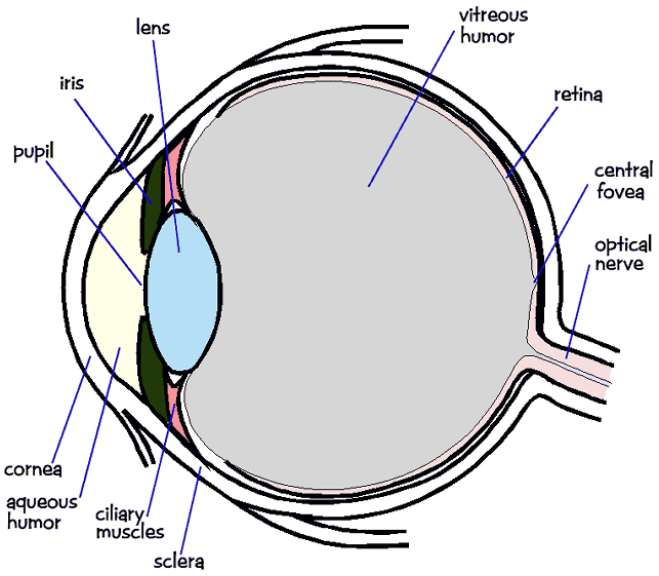
Lidar

Sonar

Electromagnetic (EM) spectrum



Human visual system

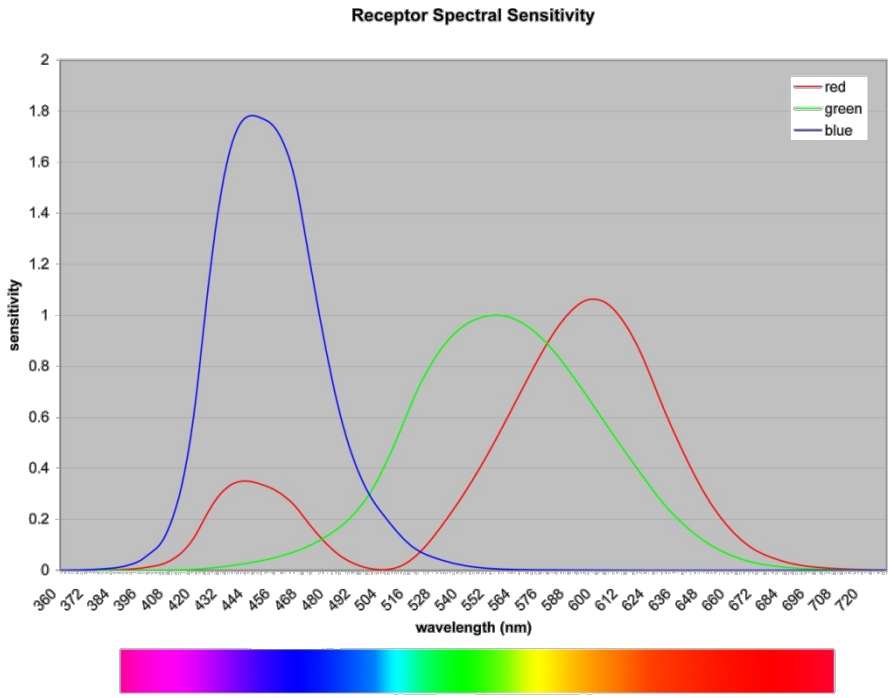


- Color perception
  - Light hits the retina, which contains photosensitive cells.
  - These cells convert the spectrum into a few discrete values.

Adapted from Steve Seitz, U of Washington

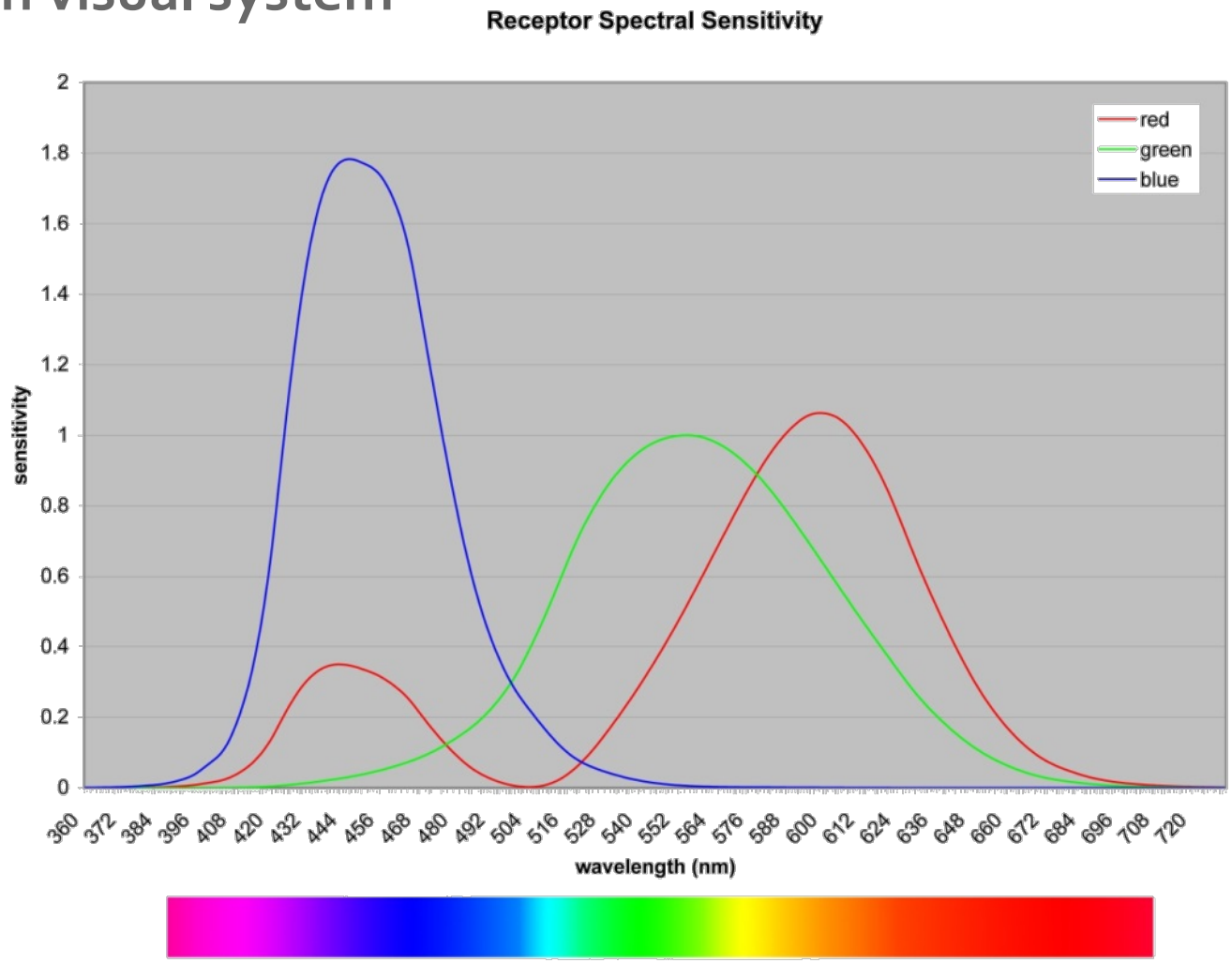
Human visual system

- Two types of photosensitive cells:
  - Cones
    - Sensitive to colored light, but not very sensitive to dim light
  - Rods
    - Sensitive to achromatic light
- We perceive color using three different types of cones.
  - Each one is sensitive in a different region of the spectrum.
    - 440 nm (BLUE)
    - 545 nm (GREEN)
    - 580 nm (RED)
  - They have different sensitivities



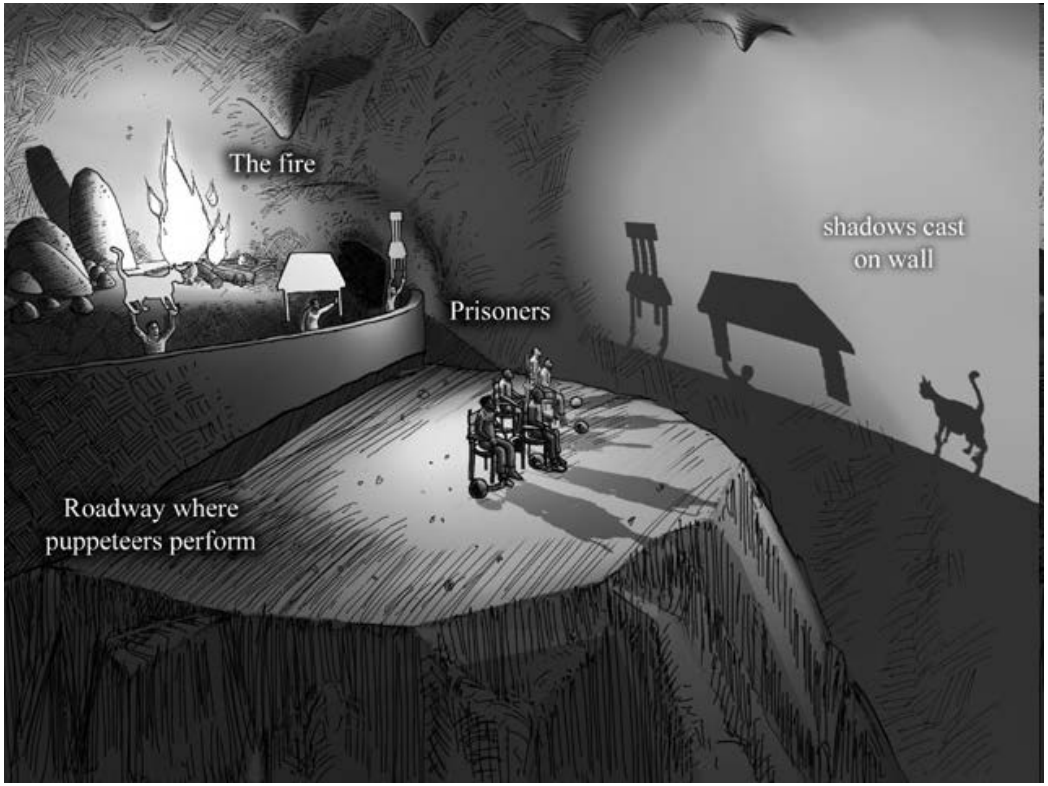
Adapted from Gonzalez & Woods

Human visual system



Adapted from Gonzalez & Woods

Can you trust your senses?

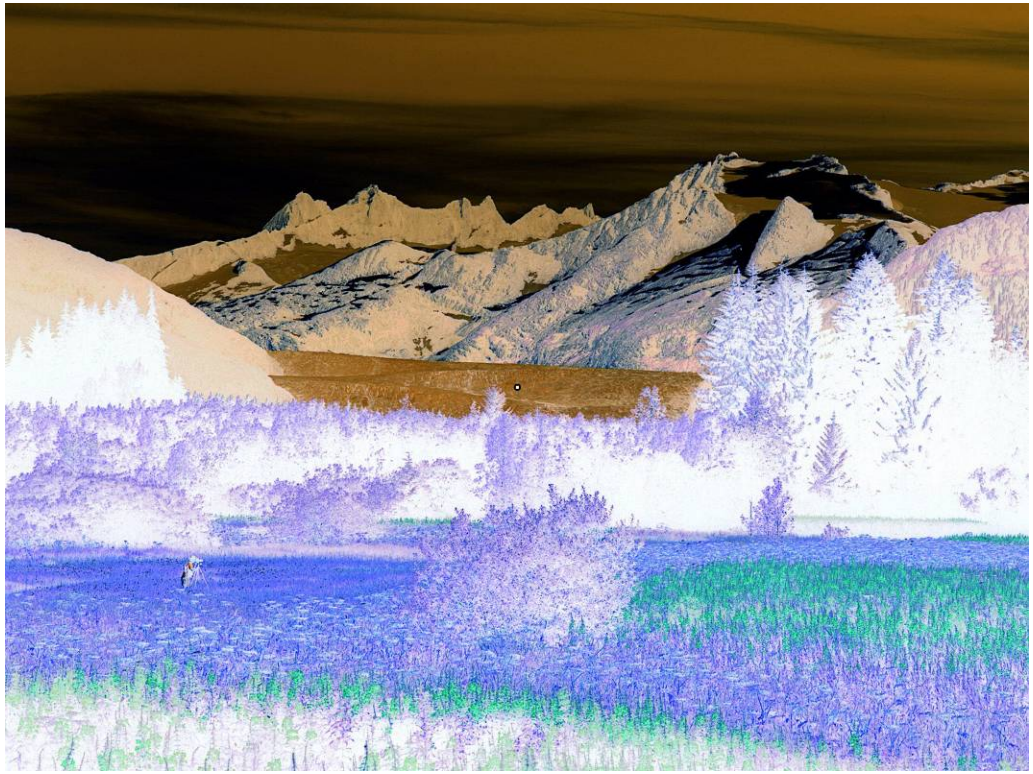


– Plato´s Myth of the Cave

– What we see with our eyes is our „perception" of reality

Can you trust your senses?

Color Perception: The Afterimage Effect



Stare at the dot in the center of the image

Color Perception: The Afterimage Effect

1. The color "negatives" saturate the local receptors
2. When the color is removed these receptors are "mute"
3. The gray tones only have contributions from the agonist (opposite) colors
   - Like the recoil after a gunshot

What is "real" is NOT only what we can see with our eyes!

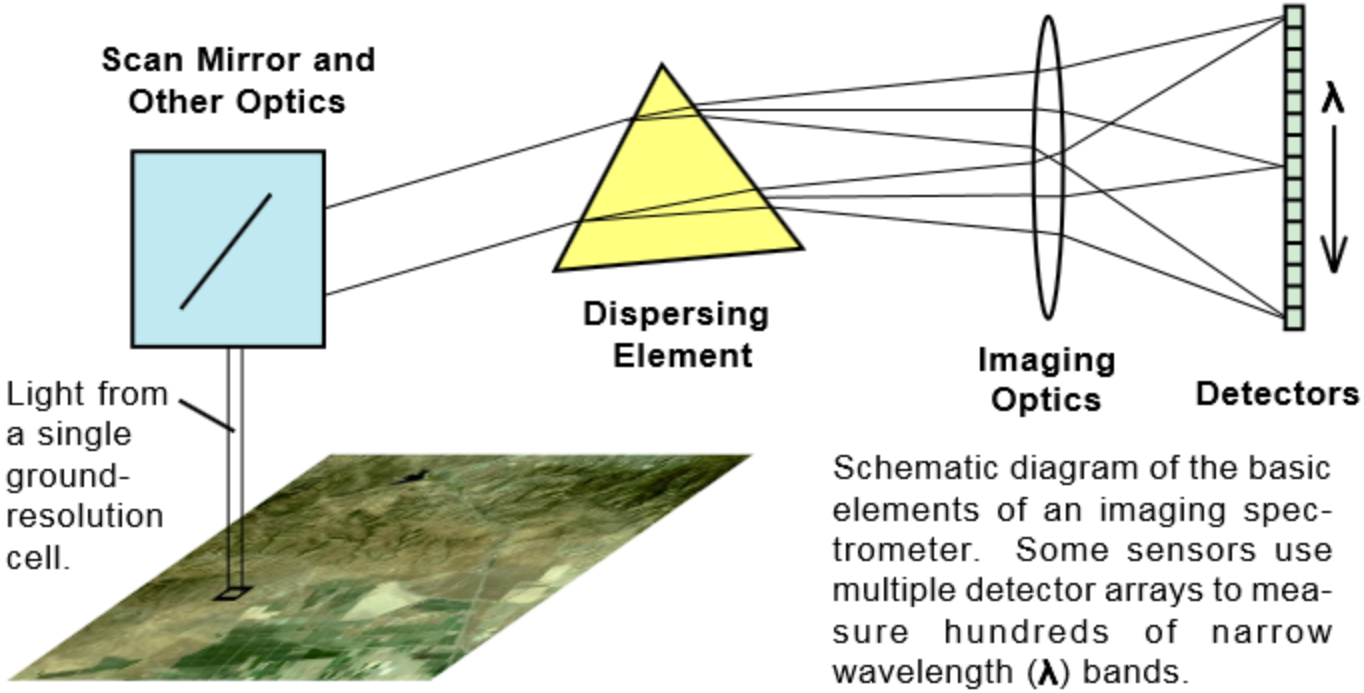
Hyperspectral

Buddingtonite

Alunite

Chalcedony

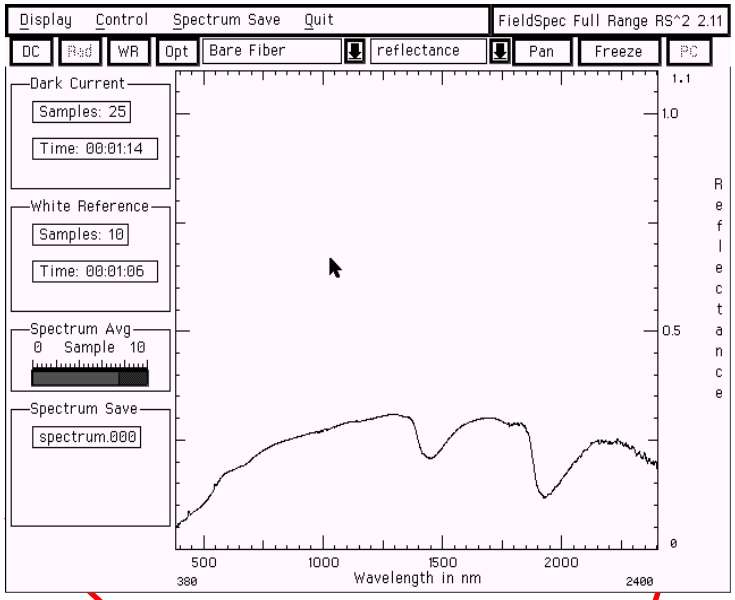
Basic Principle



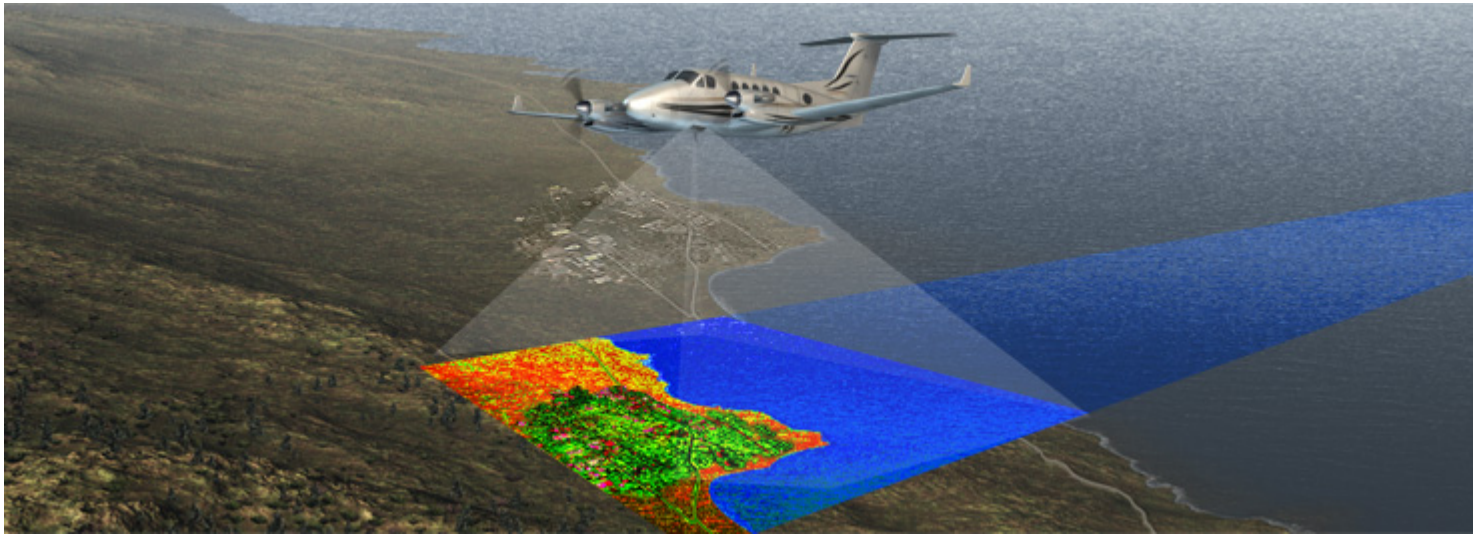
Schematic diagram of the basic elements of an imaging spectrometer. Some sensors use multiple detector arrays to measure hundreds of narrow wavelength (λ) bands.

Image by TNTmips

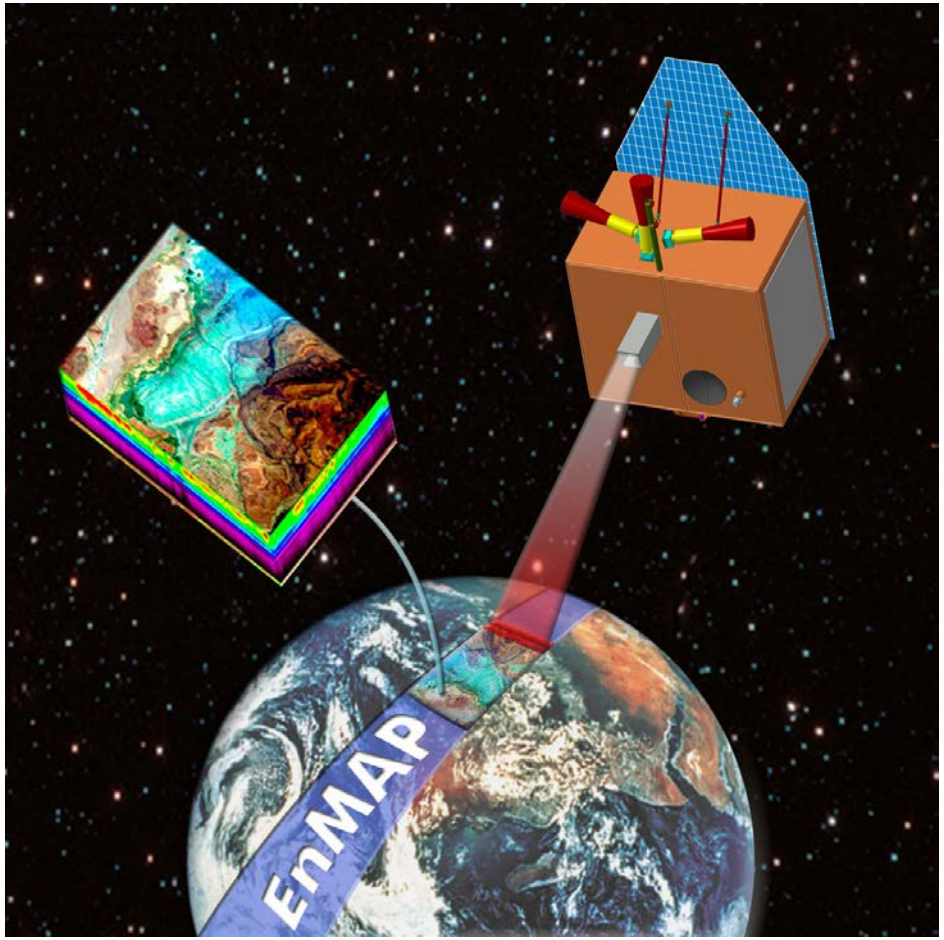
Acquisition Systems



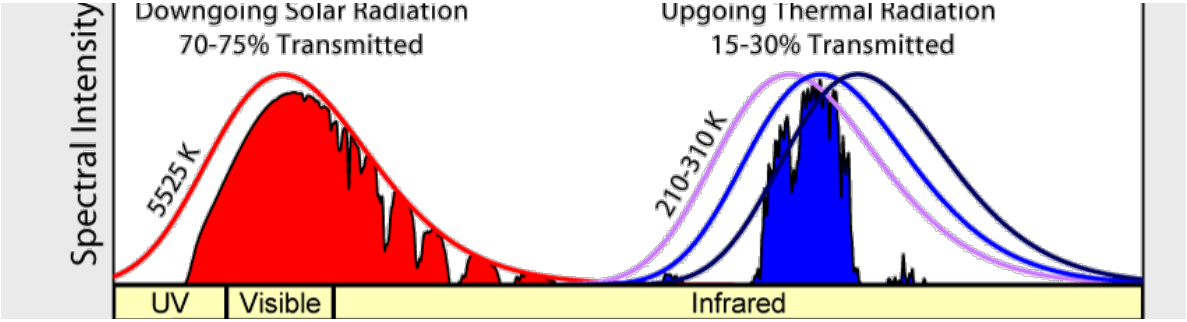
Acquisition Systems



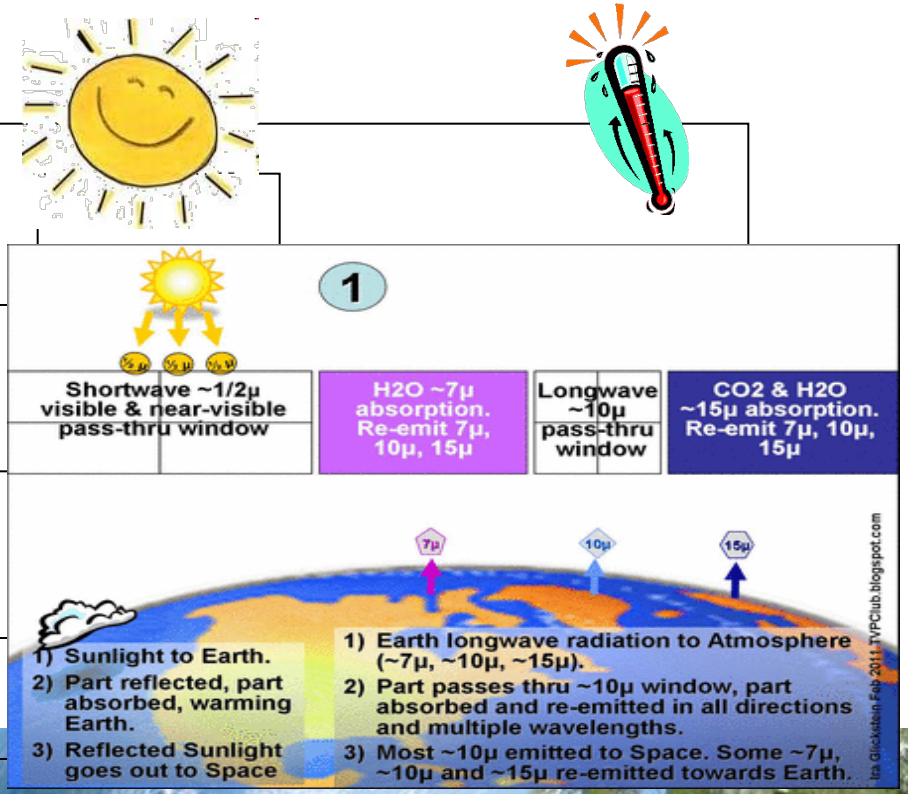
Acquisition Systems



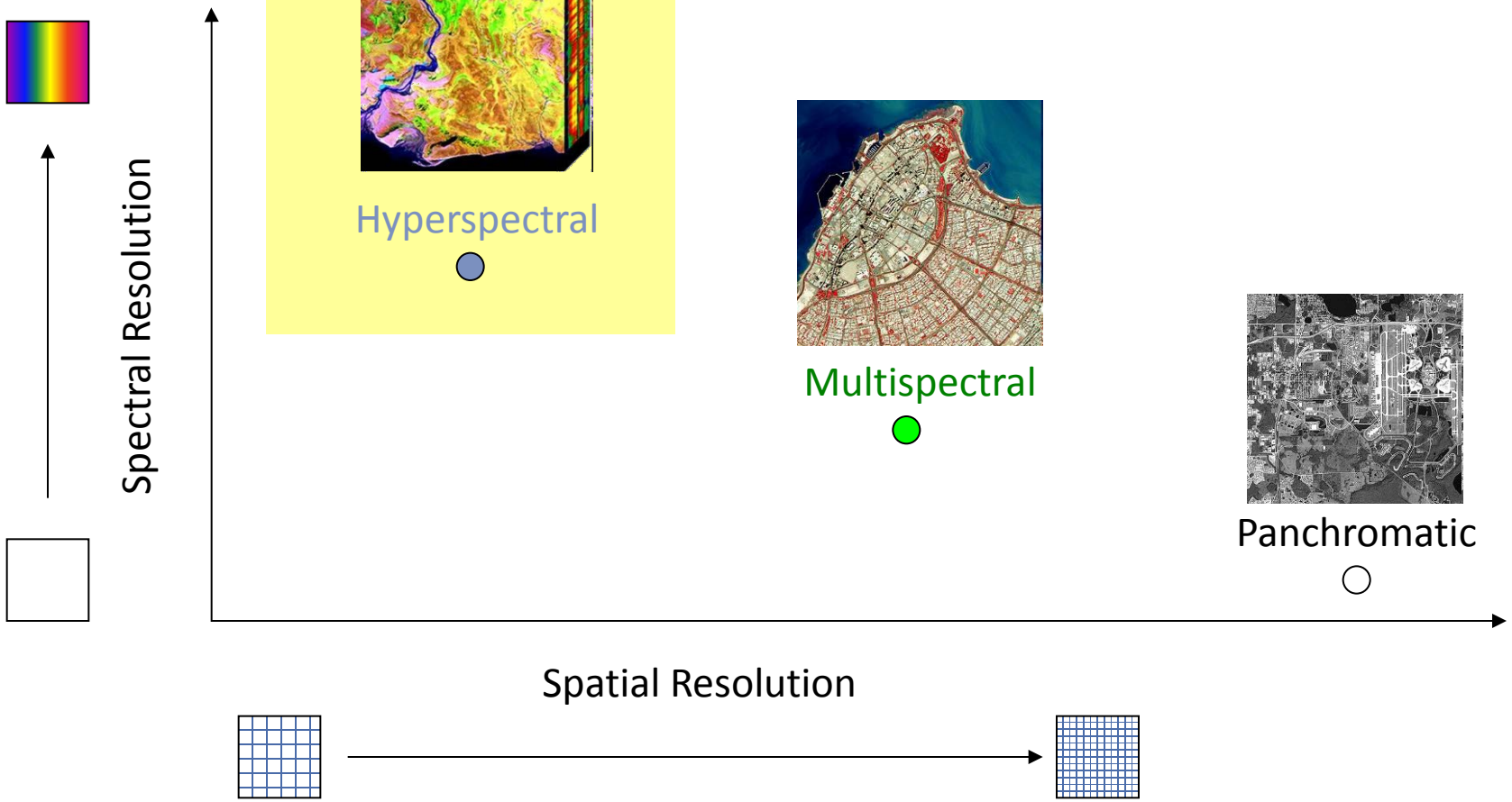
Radiation transmitted by the atmosphere



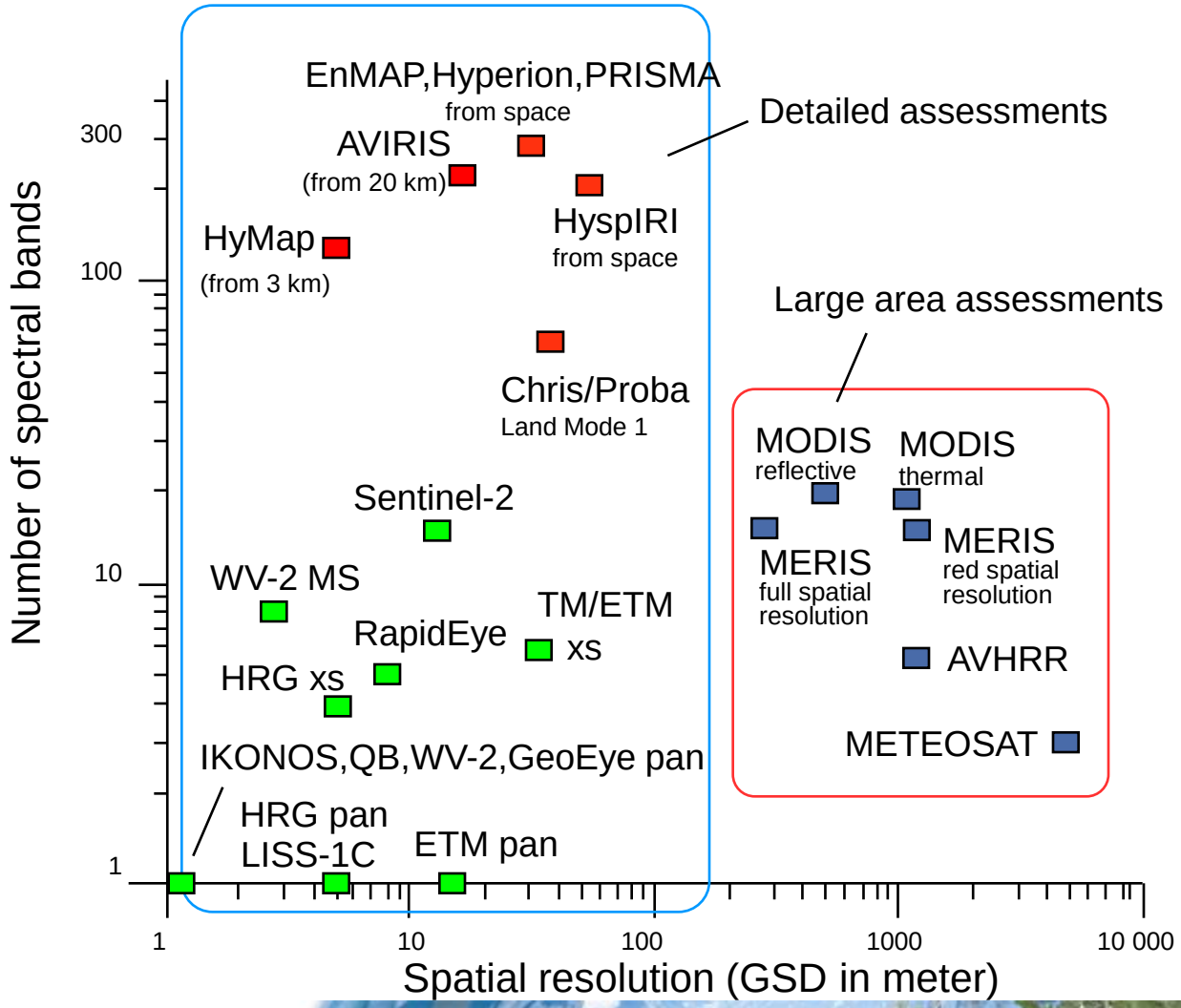
Sensor Type
Panchromatic
Multispectral
Hyperspectral
Thermal (HS)



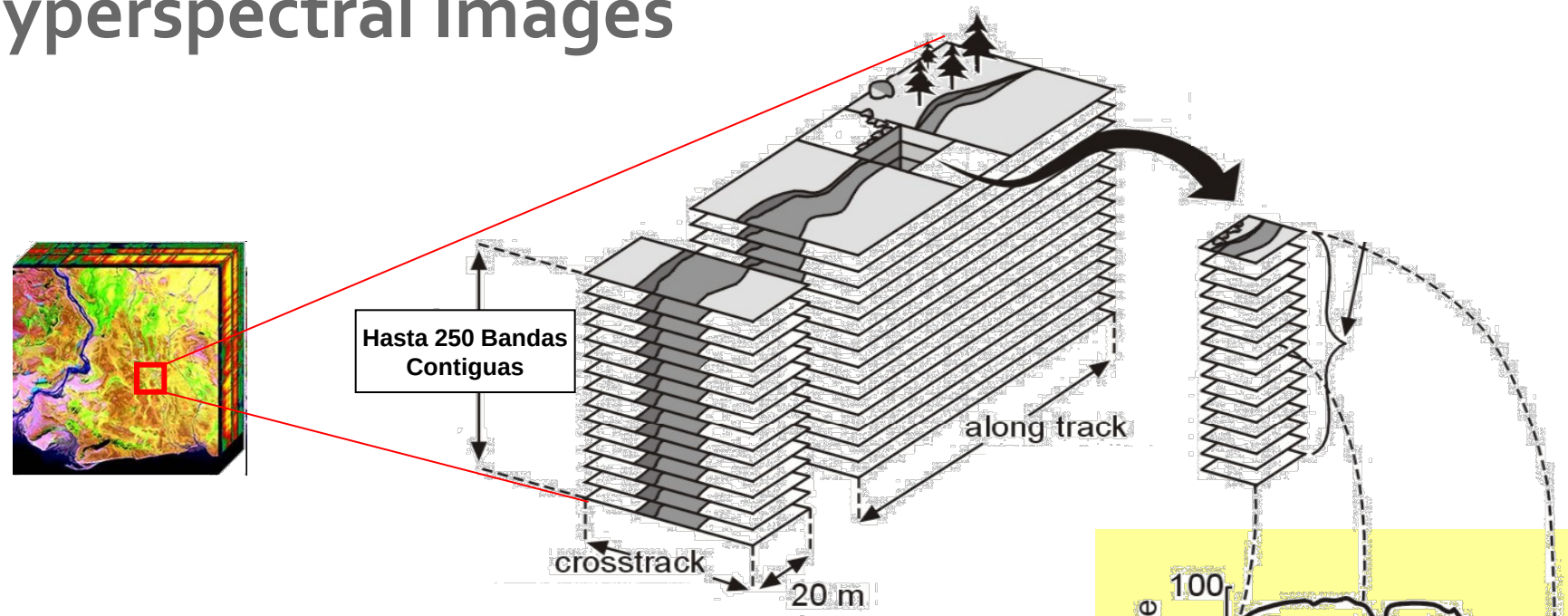
Optical Passive Sensors in Remote Sensing



Context of Optical EO Systems



Hyperspectral Images



- A Hyperspectral image is adquired by a sensor with a high number of narrow and contiguous bands
- Spatial resolution
  - ≈ 1 to 4 meters (airborne sensors, state of the art)
  - ≈ 30 meters (satellites, sperimental, future missions)
- Spectral range: usually 0.4 – 2.5 micrometers (μm)
- Each pixel has a characteristic spectrum
  - In this example it is related to a mineral (kaolinite) →

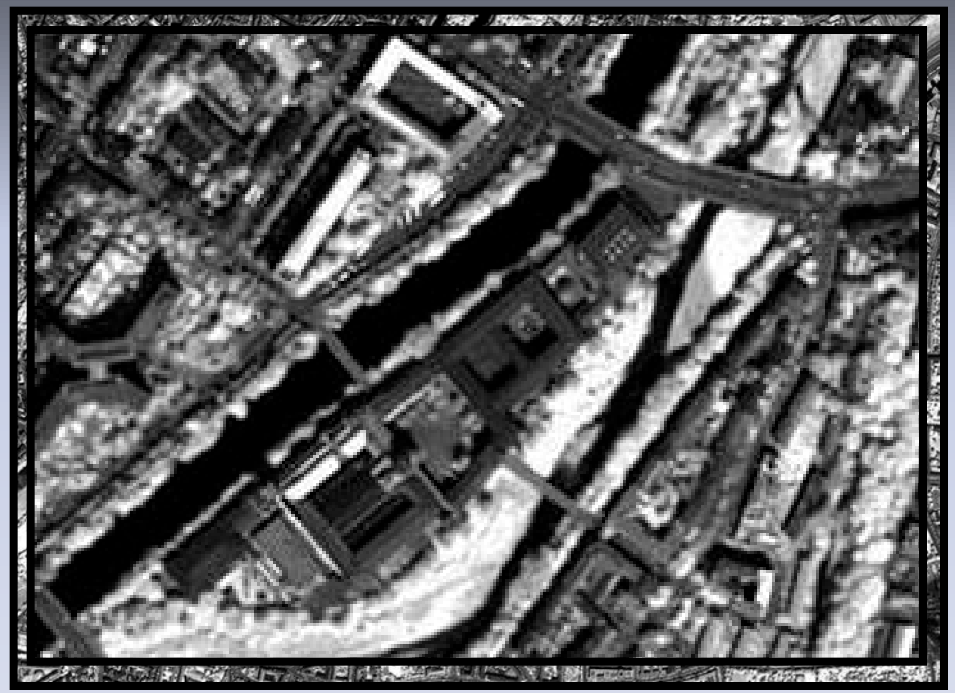
The spectrum of a pixel is represented by its values across all bands

Why are spatial and spectral resolution inversely proportional?

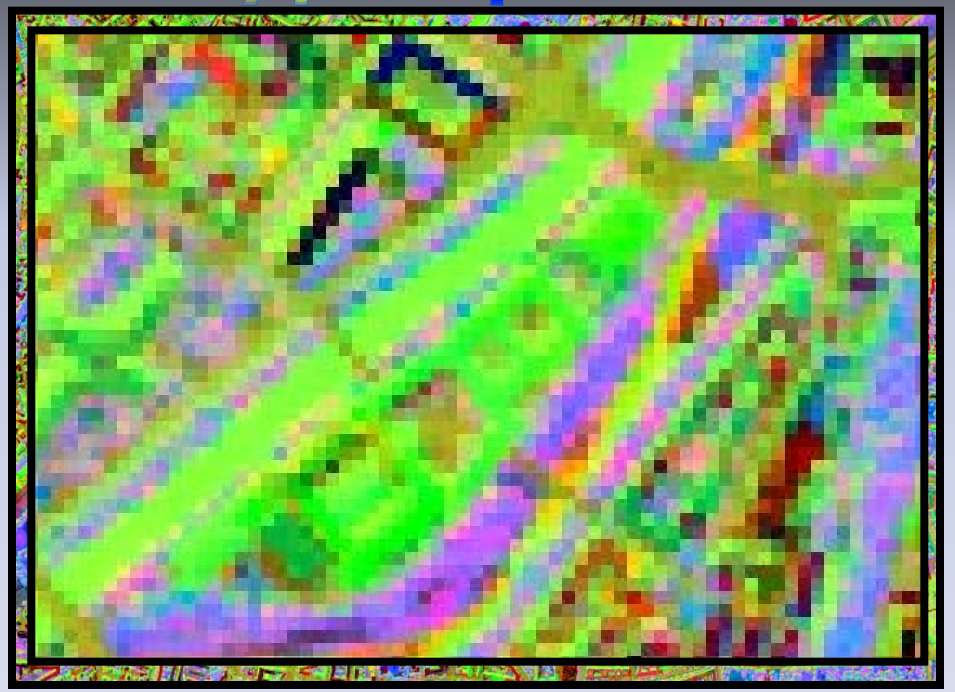
In the city..

Zoom in!

Panchromatic



Hyperspectral



Panchromatic

Hyperspectral

100 W

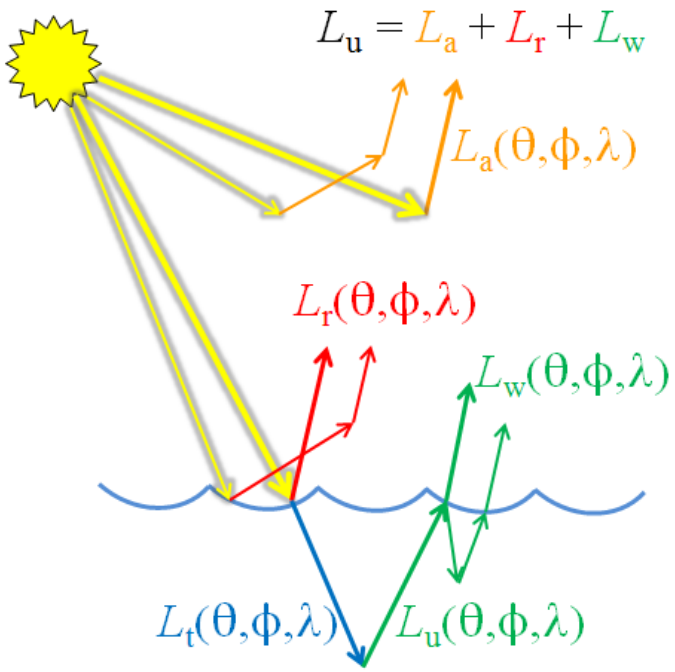
In the last episode..

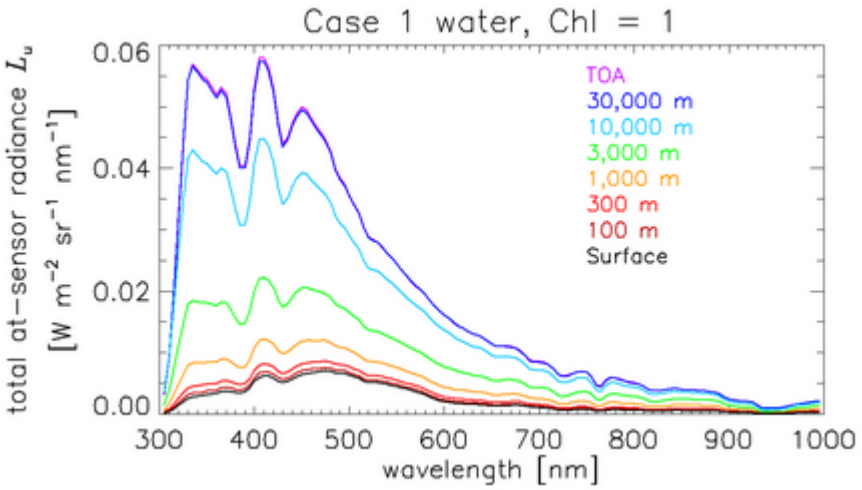
– Once our raw data are corrected, the image is formed and usually undergoes other correction steps….

  – Atmospheric Correction
  – Geometric Correction / Orthorectification..

Atmospheric Correction: Why is the sky blue?

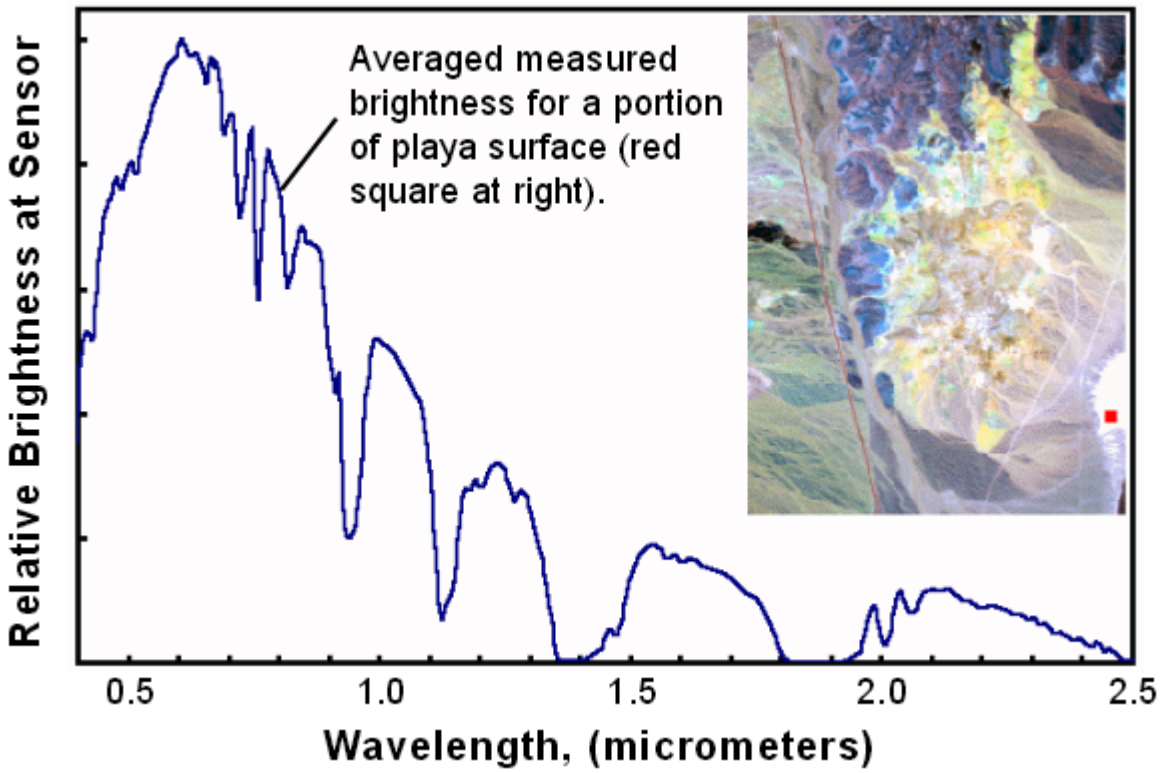
– Atmospheric path radiance → *La*





– Less important at long waves (infrared), more evident at short wavelengths

From radiance to reflectance



– If we want to know which fraction of the incoming solar energy is reflected by each band, we have to process the radiance values (amount of light/radiation measured in each band)

Figure by TNTmips

From radiance to reflectance

– The solar energy is not constant across all the bands! We must correct this

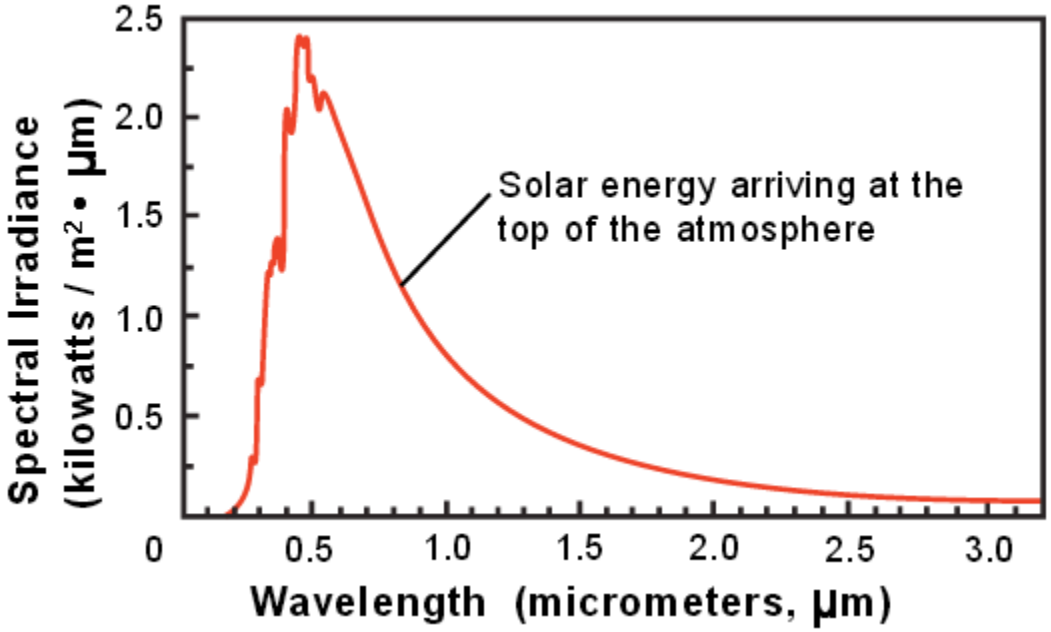
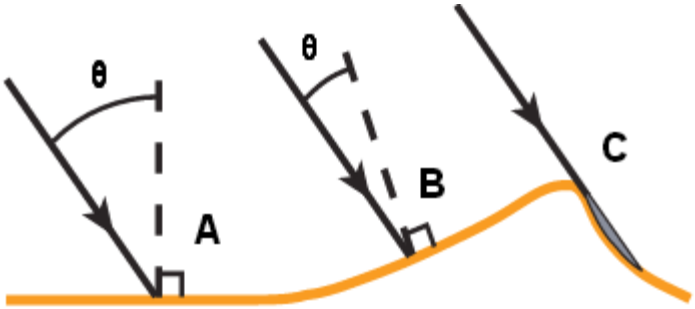


Figure by TNTmips

From radiance to reflectance

– Geometric effects / shadows

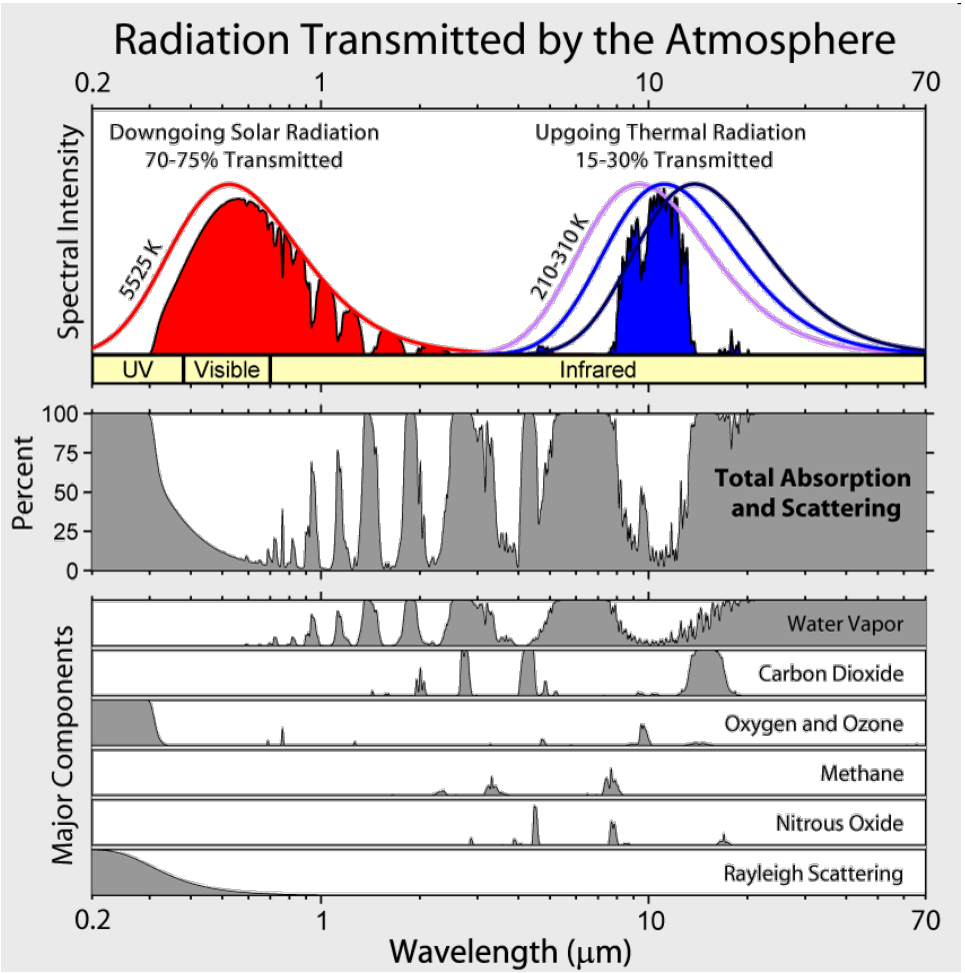


Illumination differences can arise from differing incidence angles (θ) as for **A** and **B**, or from shadowing (**C**).

Figure by TNTmips

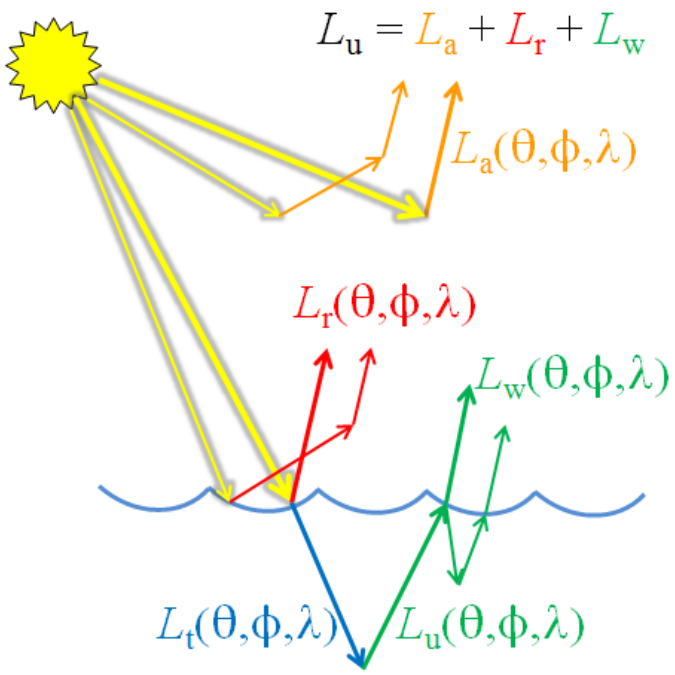
From radiance to reflectance

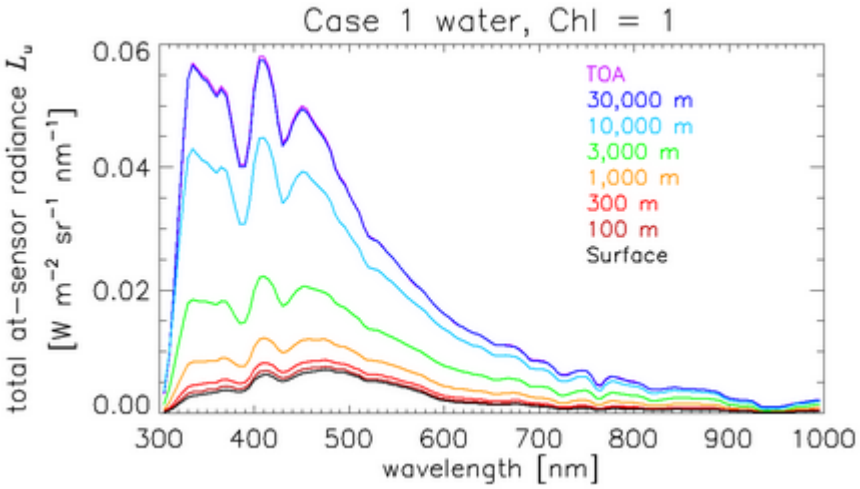
– Atmospheric effects



Why is the sky **blue**?

– Atmospheric path radiance → La

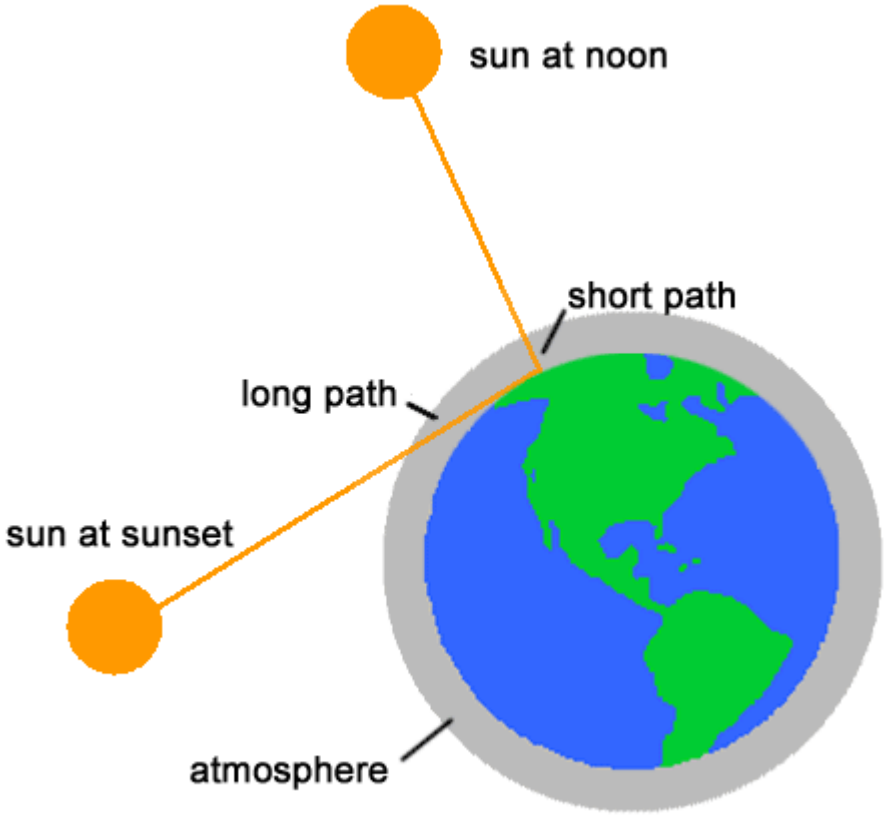




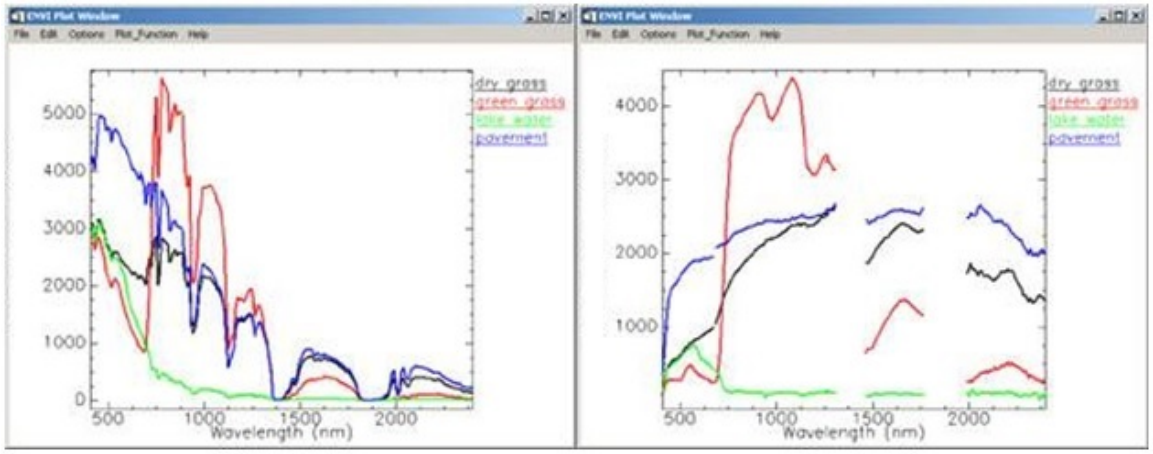
– Less important at long waves (infrared), more evident at short wavelengths

Figure by Ocean Optics

...and why is it red at sunset?



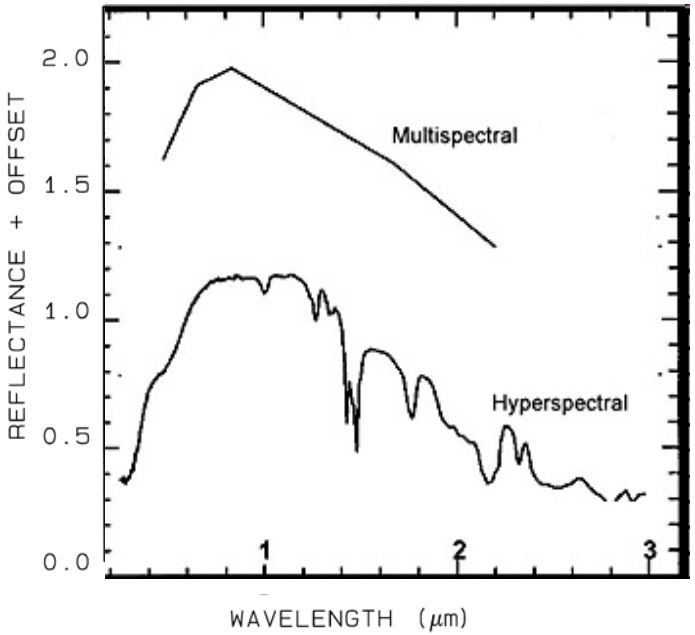
From radiance to reflectance



- After correcting all these aspects, we can convert each pixel value into the fraction of reflected energy for each band (from 0 to 1).
- To do this there are a lot of different methods
  - We are not going to see them in detail
- It is not mandatory to do this (only if we need to work with physical values)
- For statistical operations we can also use the data in radiance

Figure courtesy of Exelis VIS

What we cannot see in Multispectral images

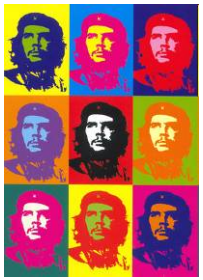


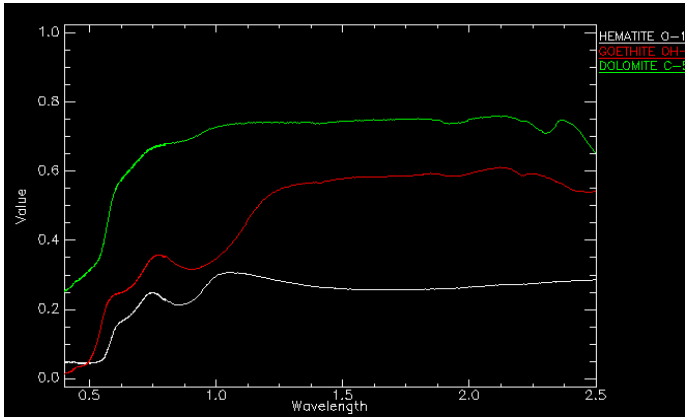
Landsat (7 bands)

- Laboratory (up to 1000 bands)
- Hyperspectral images (up to 250 bands)

- The main characteristic of hyperspectral sensors: their bands are contiguous
  - It is not just the number of bands they contain!
  - We are going to see an application with a sensor having only 15 bands!
  - The important thing is to represent a material with a continuous curve in a given area of the spectrum

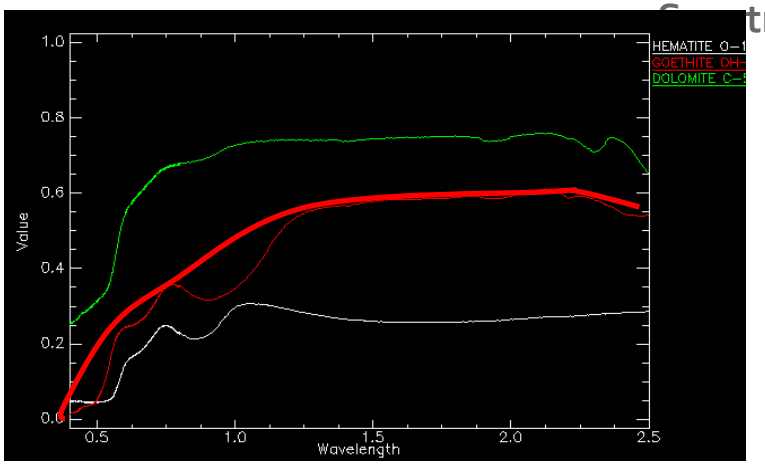
Spectral Signatures





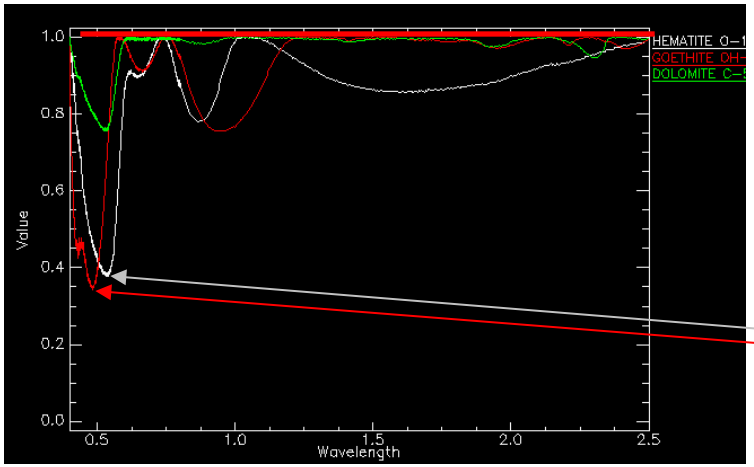
Each material can be identified through its characteristic spectral signature

- In this example 3 spectra of minerals adquired in laboratory
- Different members in each class (in this case different kinds of rocks):
  - Cannot always be identified by the "level" of the curves
    - In an image these depend on illumination conditions
  - They are usually identified by small variations in frequency of the maxima and minima of the slope (derivative) of the curve



Spectra and Spectral Signatures

- Most of the information is in the absorbing bands (less reflected energy)
- Spectra can be represented in an alternative way to highlight this
- Continuum removal: the general shape of the spectra is subtracted
- Absorbing bands become more evident
- This helps in distinguishing the classes of interest for some applications



After Continuum Removal