

# Multispectral Imaging

From astronomy to microscopy

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# Photonics

FALL TERM 1	FALL TERM 2	SPRING TERM 1	SPRING TERM 2
► ENGINEERING			
Optics & optical design 7.5 ECTS FAFF01	Lasers 7.5 ECTS FAFN01	Photonics & optical communication 7.5 ECTS FAF095 Light-matter interaction 7.5 ECTS FAFN05	Advanced optics & lasers 7.5 ECTS FAFN10
► COMMUNICATION			
Electromagnetic wave propagation 7.5 ECTS ETE071	Microwave theory 7.5 ECTS ETE091 Radio 6 ECTS ETI030	Antenna technology 6 ECTS ETE100	Optoelectronics 7.5 ECTS
► DIAGNOSTICS			
Atomic & molecular spectroscopy 7.5 ECTS FAF080	Multispectral imaging 7.5 ECTS FAF141	Laser-based combustion diagnostics 7.5 ECTS FBR024 Light matter interaction 7.5 ECTS FAFN05	Medical optics 7.5 ECTS FAF150

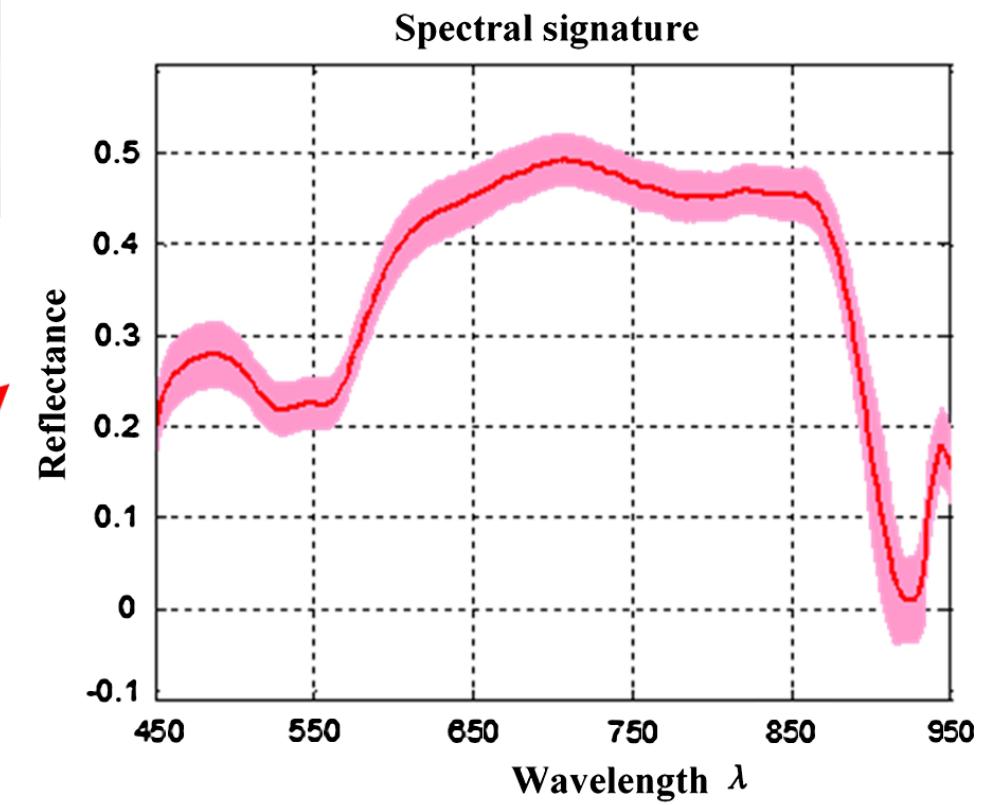
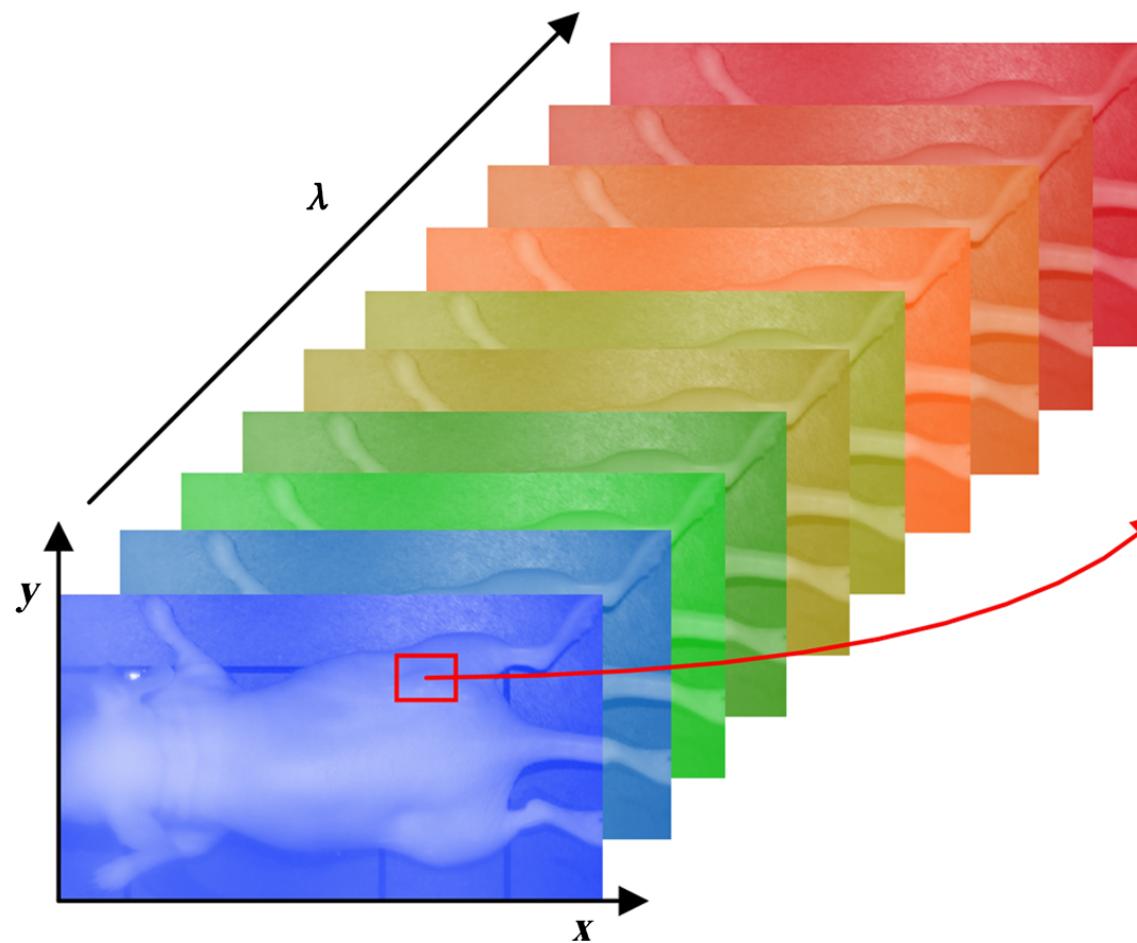
# Multispectral imaging



## Lectures:

- Fundamentals of Spectroscopy
- Instrumentations
- Molecular Spectroscopy
- Image analysis
- Multivariate analysis
- Astronomical imaging
- Satellite imaging
- Atmosphere remote sensing/imaging
- Combustion Imaging
- Medical Imaging
- Visual science
- Magnetic resonance imaging
- Microscopy
- Nuclear imaging

# Multispectral = many spectral bands

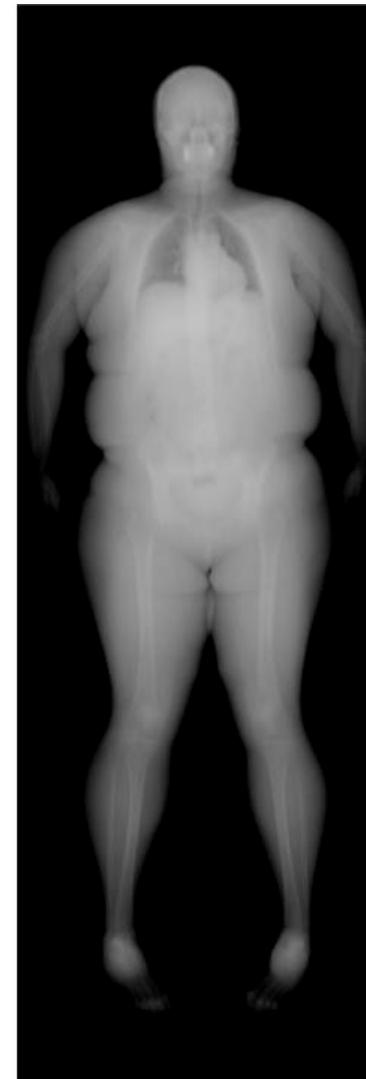


"Each pixel contains a spectrum"

Multispectral = many spectral bands



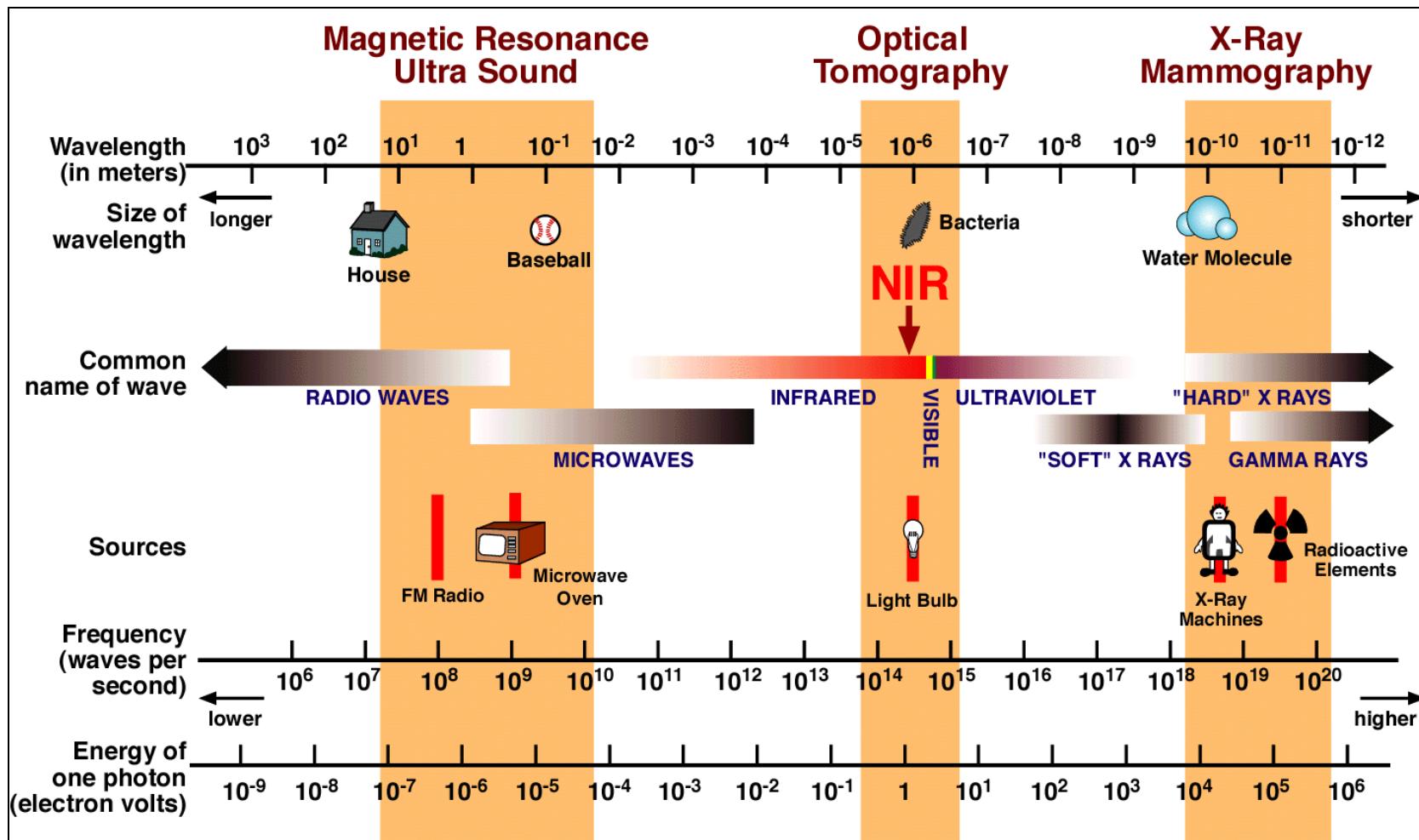
Optical microscopy



X-ray imaging



# Spectral bands from the electromagnetic spectrum

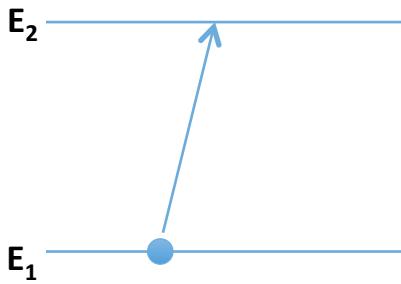
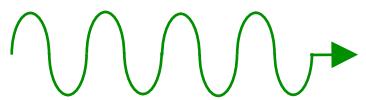


# Interactions between electromagnetic radiation and sample

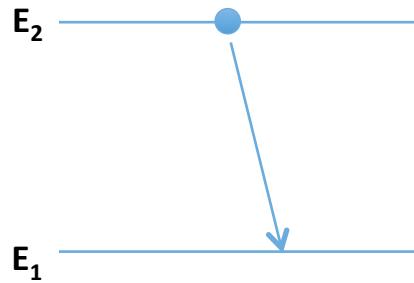
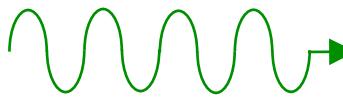
- Sample is composed of atoms, molecules
- Electromagnetic radiation transfers energy
- By examining the resulting electromagnetic radiation after it has interacted with the sample - conclusions can be drawn about the object under study

# Interactions between energy levels

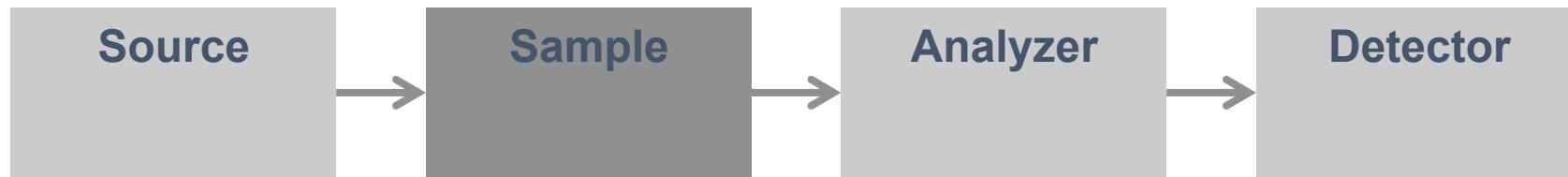
**Absorption**



**Emission**



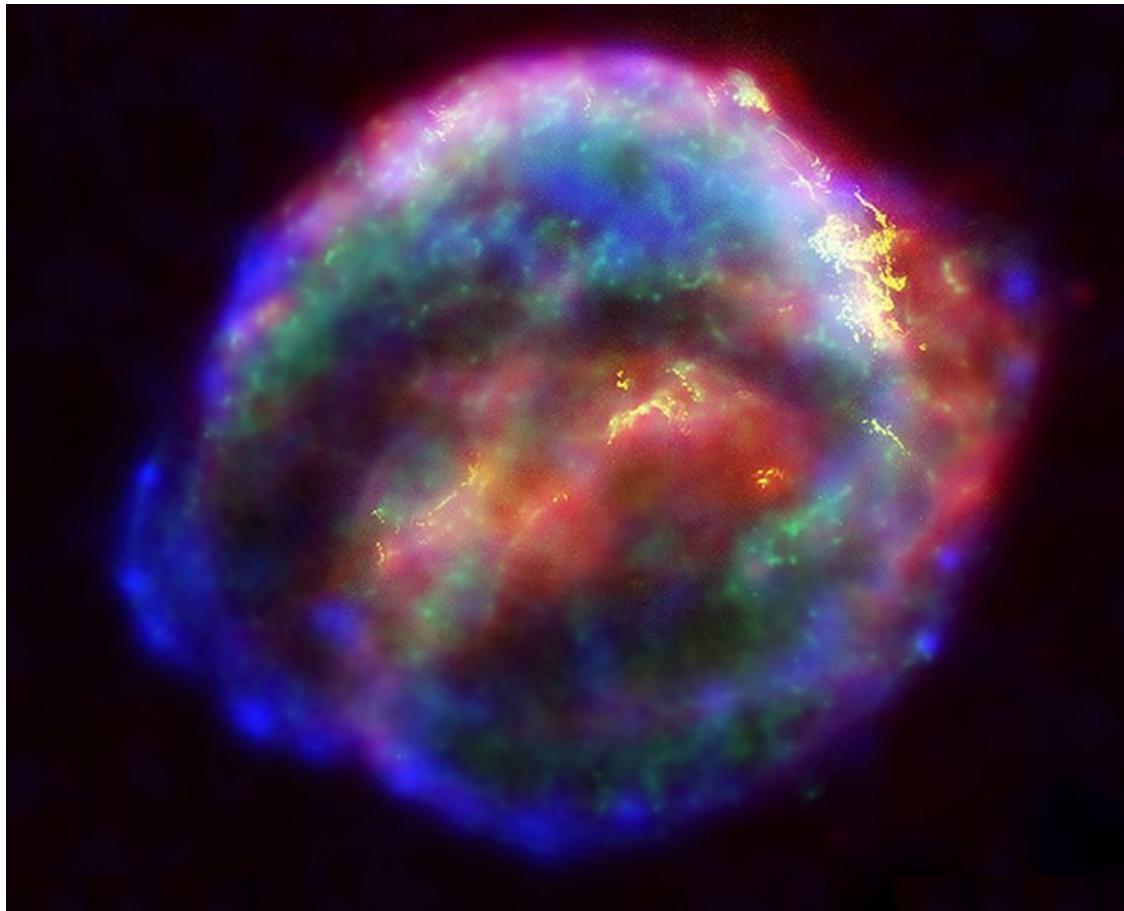
# Basic arrangement for Multispectral imaging



Sun	Plants	Filters	Photodiodes
Lamps	Forests	Spectrometers	Photomultiplier tubes
Lasers	Tissue	Monochromators	CCD cameras
LEDs	Cells		CMOS cameras
Synchrotron	Flames		Image intensifiers
X-ray tube	Chemical compounds		
	etc.		
	etc.		

# Astronomy

# Supernova 1604



Multispectral (X-ray, optical and infrared) representation of the last supervova and the Milky Way in 1604

Coronal temperature diagnostics derived from  
multilayer observations with the multi-spectral solar  
telescope array

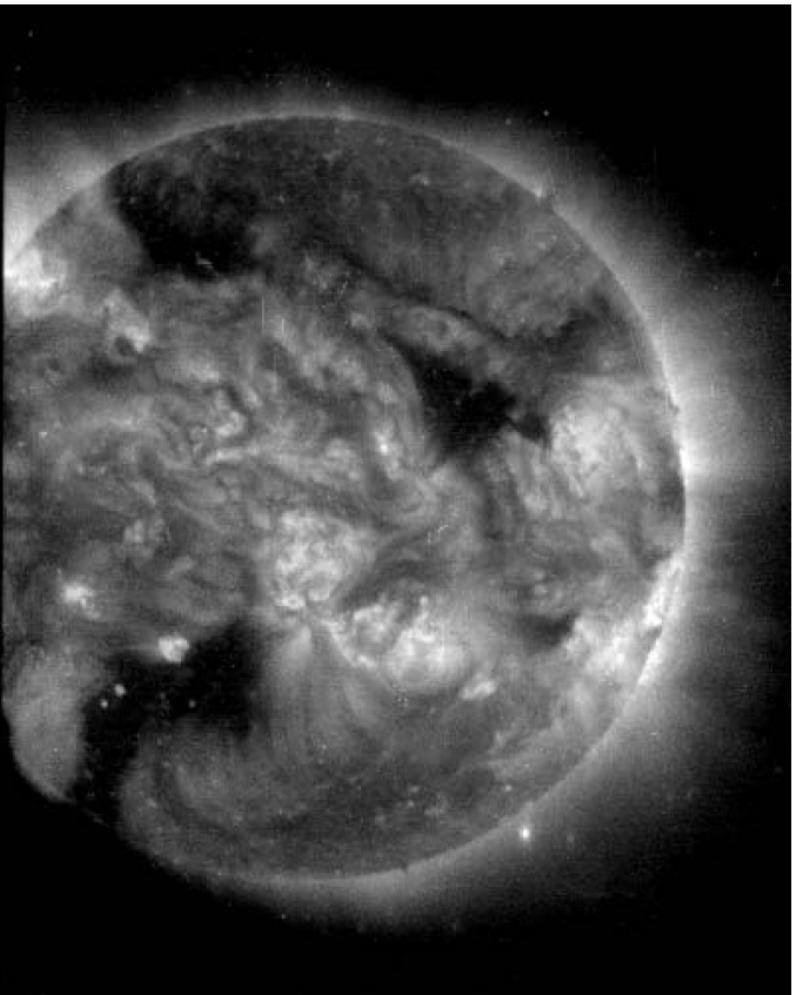


Image from the 211 Å Ritchey-Chrétien telescope

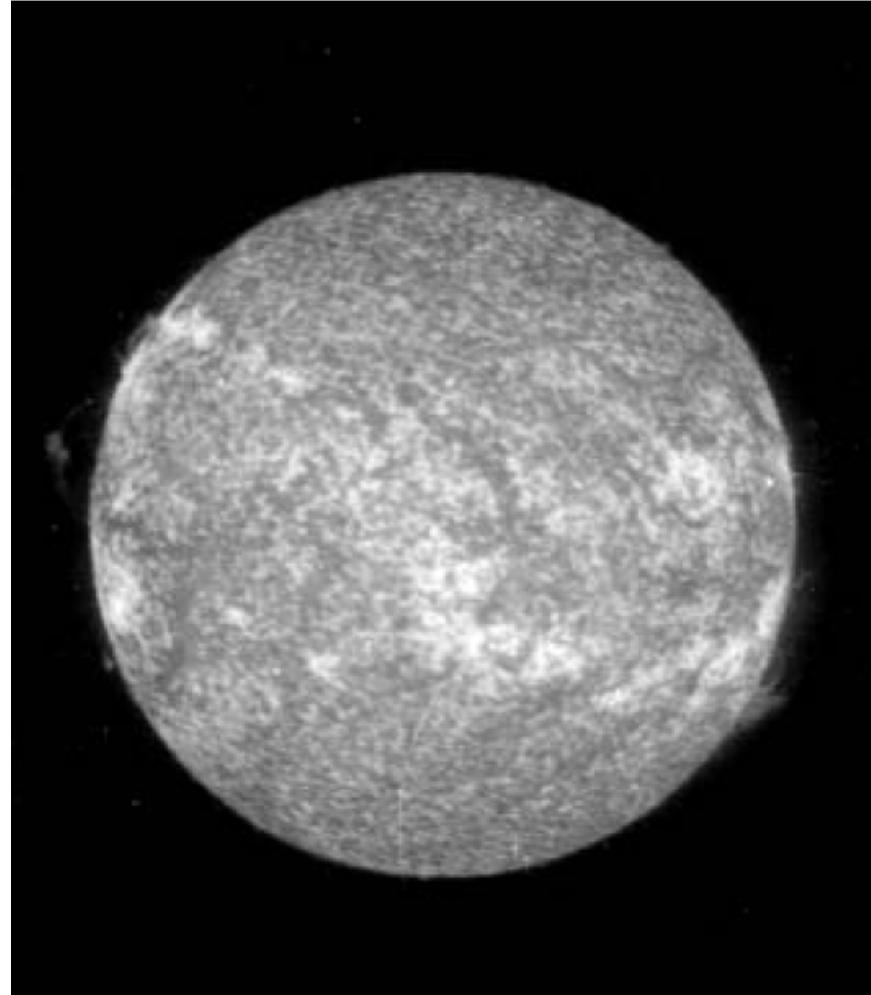
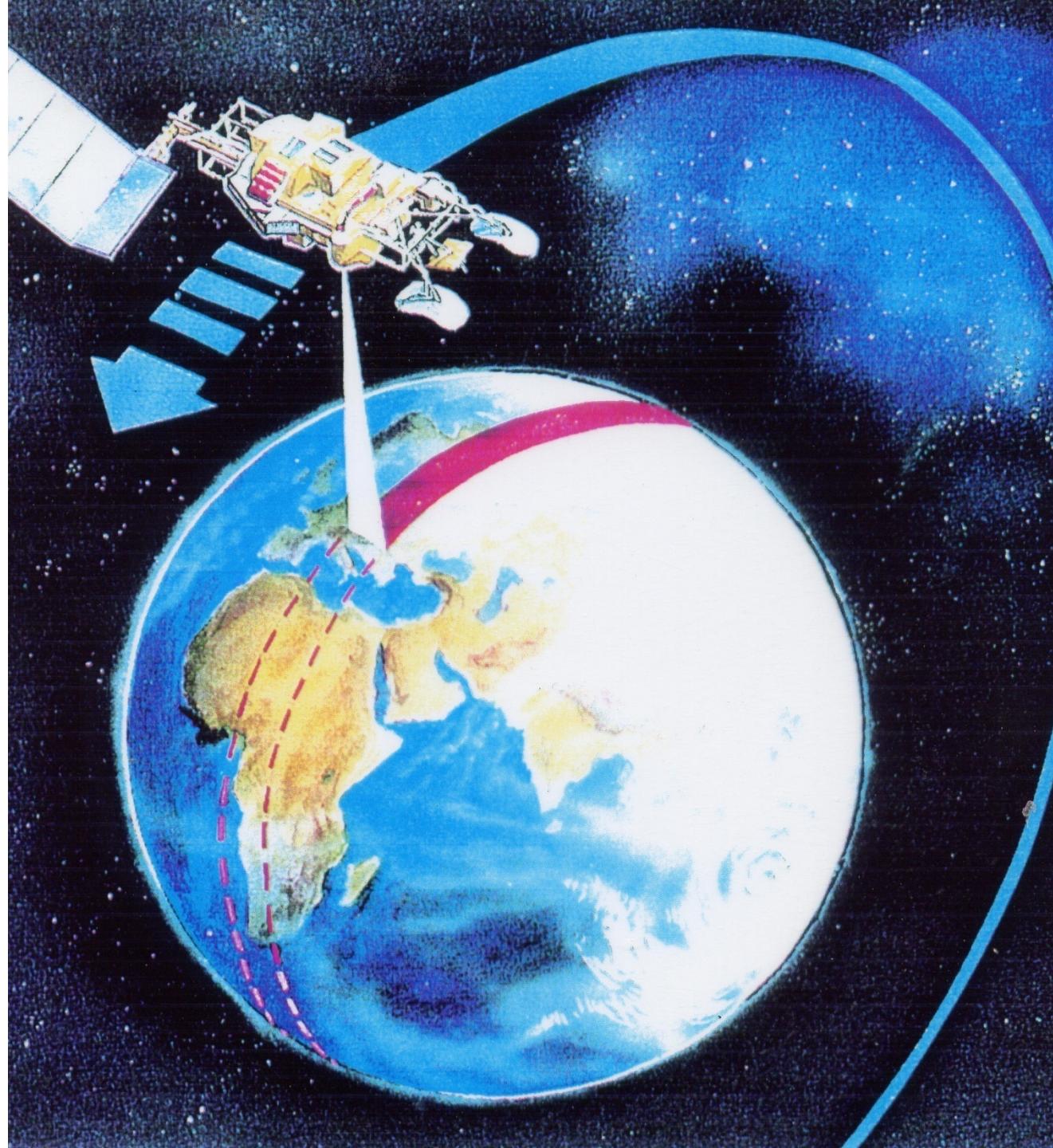
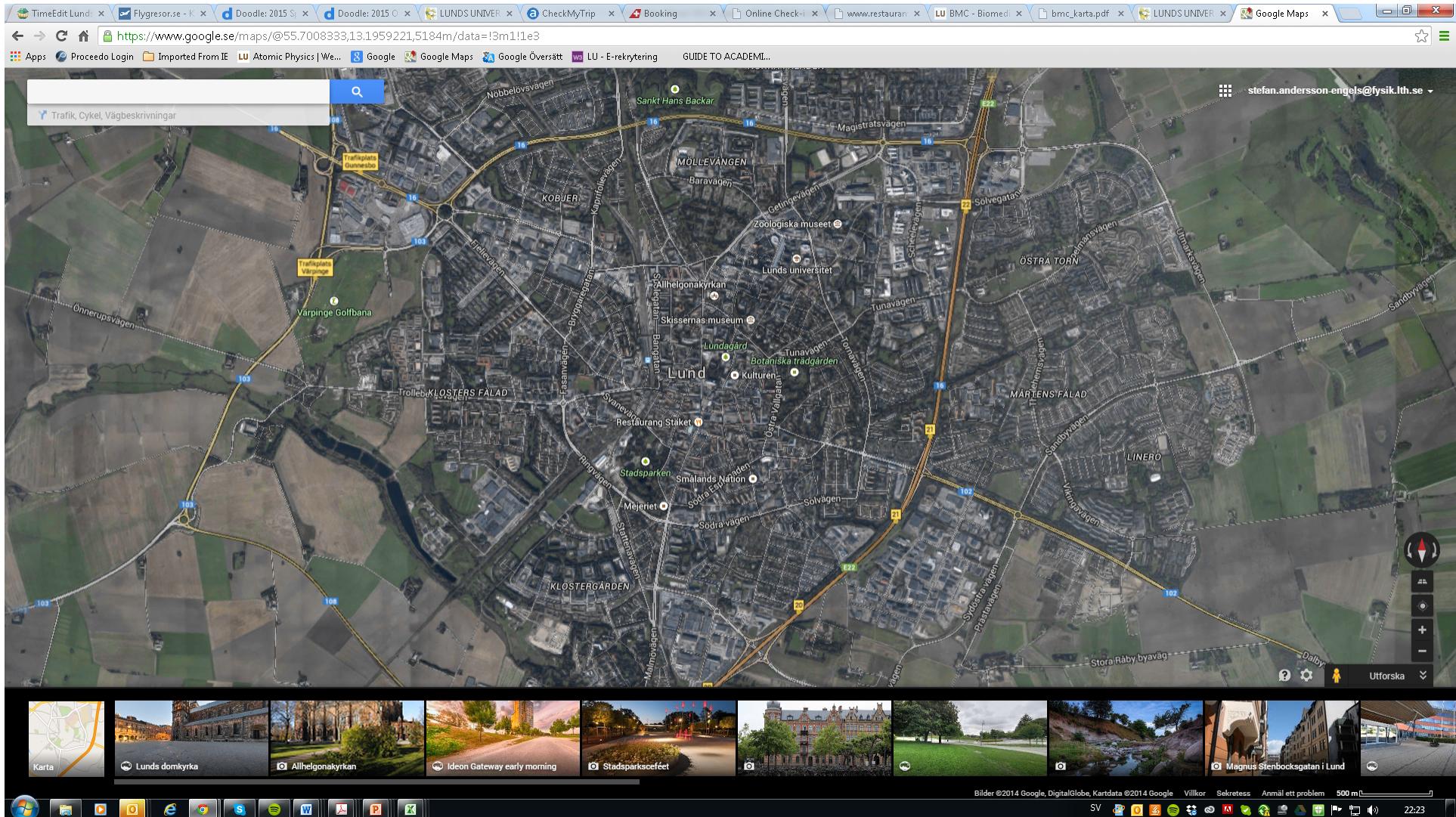


Image from the 1216 Å Ritchey-Chrétien telescope

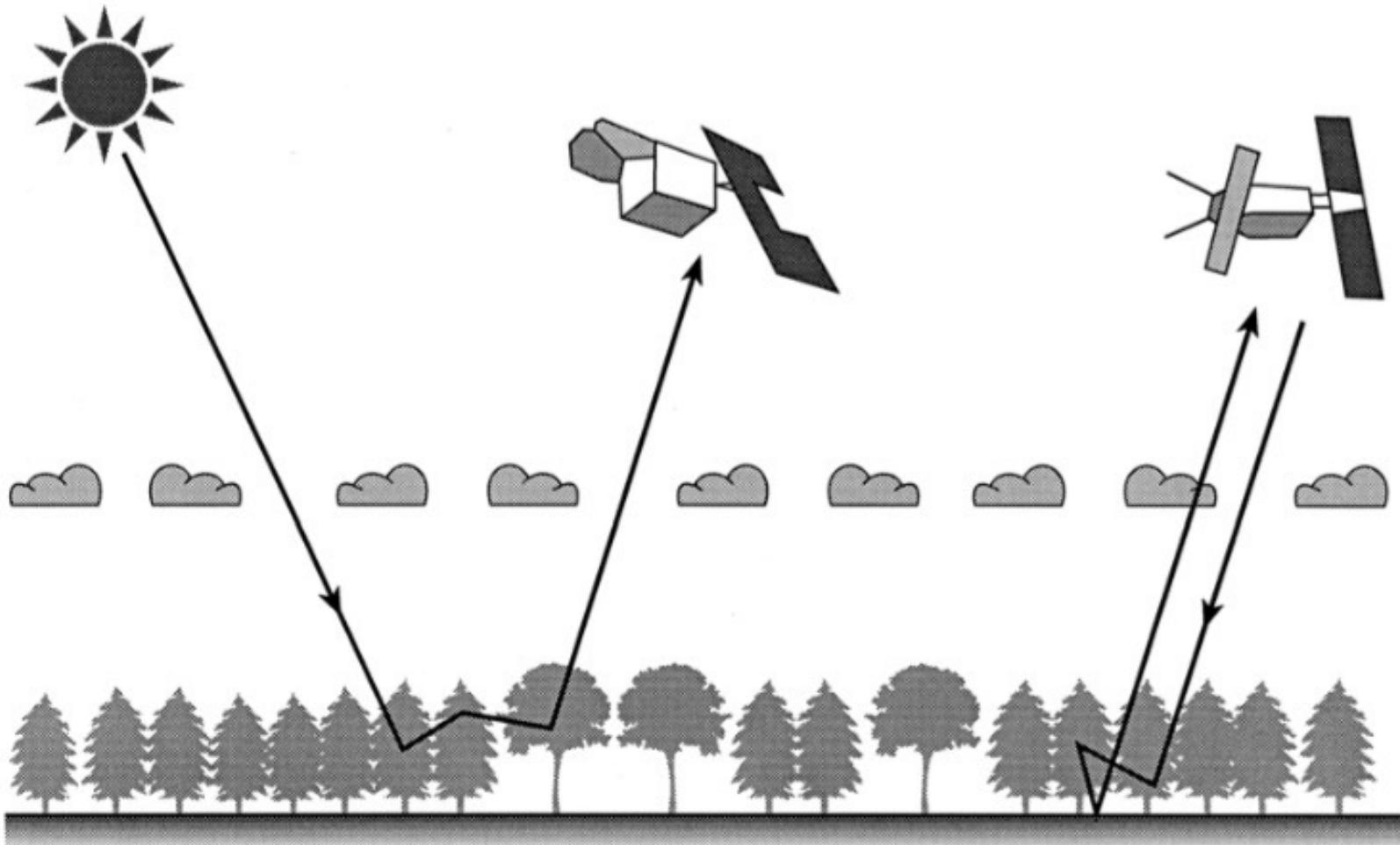
Remote sensing:  
Satellite imaging



# Google Earth



# Active or passive satellite imaging



**Sensor system:**

Optical (passive)

SAR (active)

**Wavelength:**

400–3000 nm

1–100 cm

**Scattering medium:**

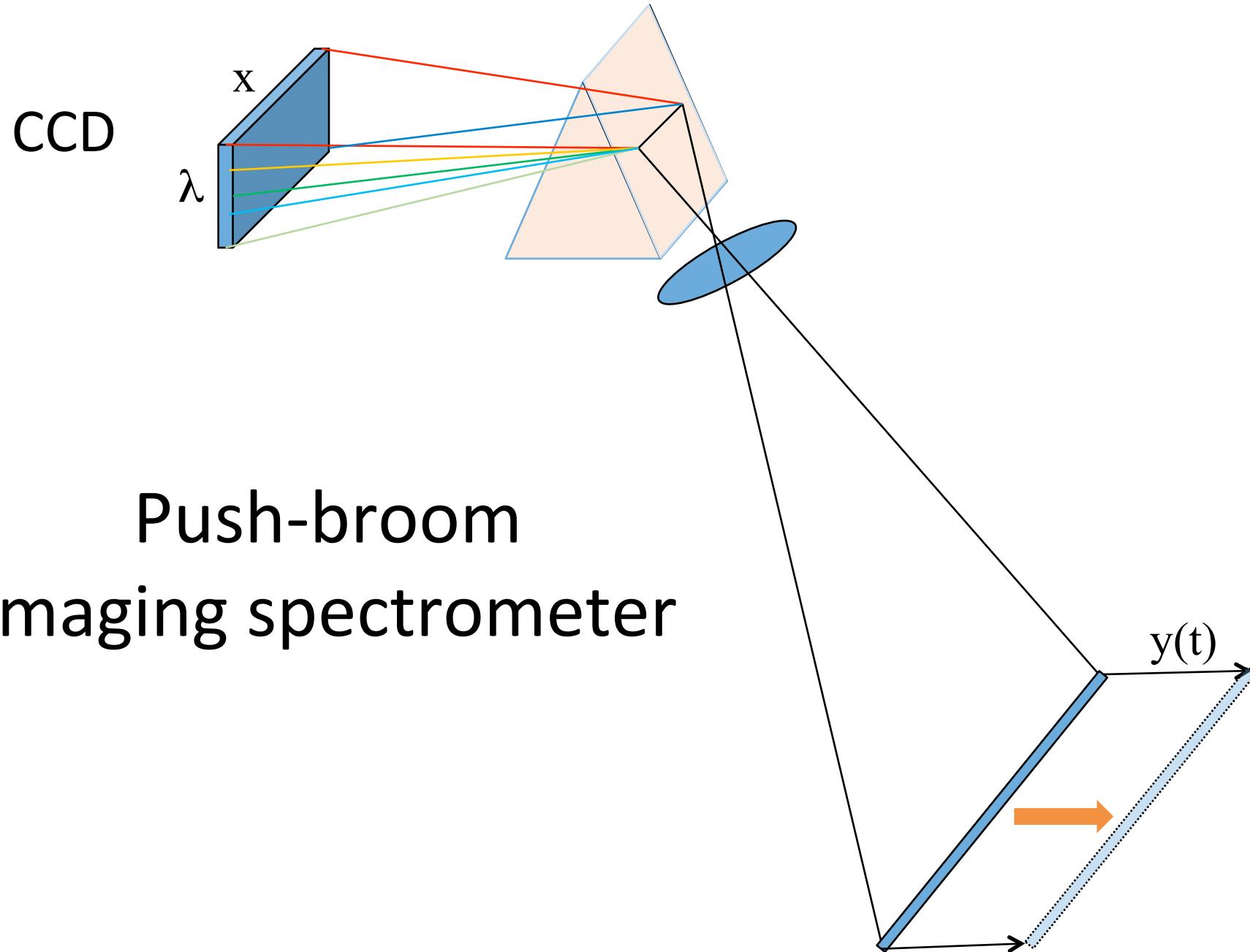
Leaf surface / interior

Branches, trunks, ground

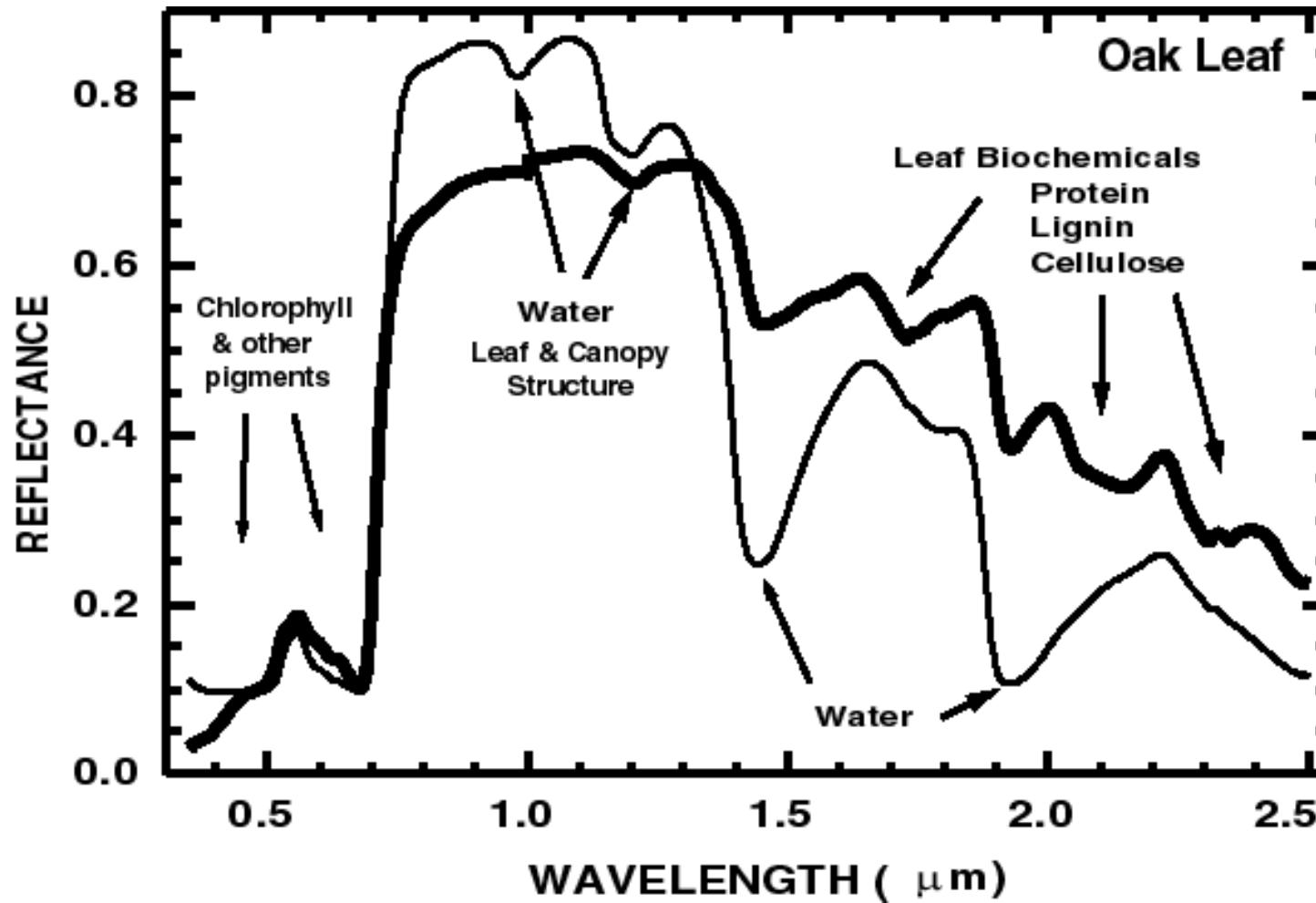
**Absorbing medium:**

Chloroplasts, cell walls and cell water

Negligible absorption

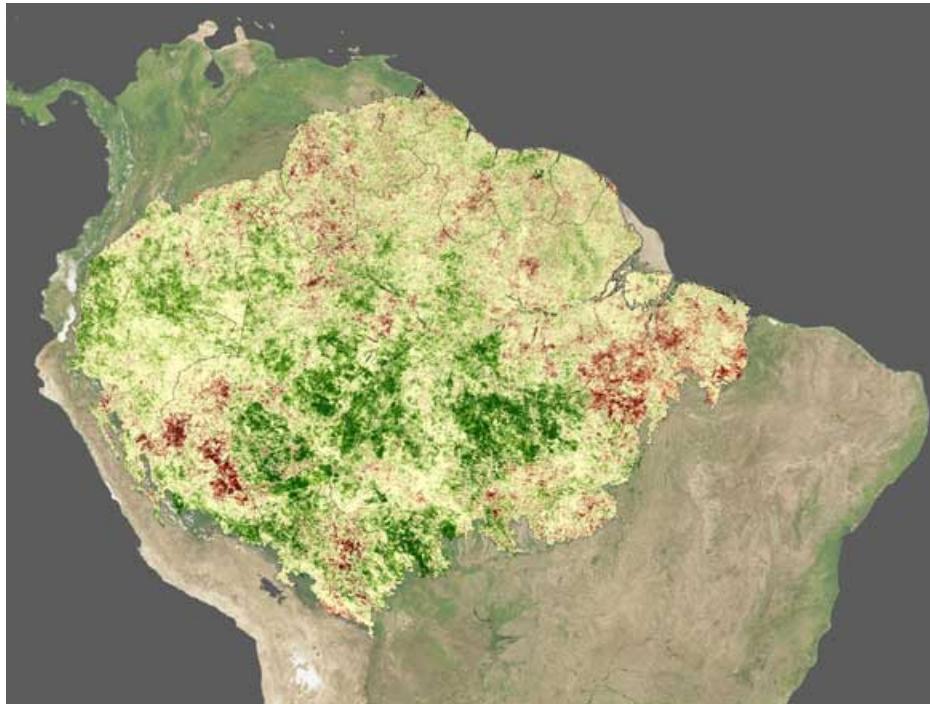


# Reflectance from fresh or dry oak leaf

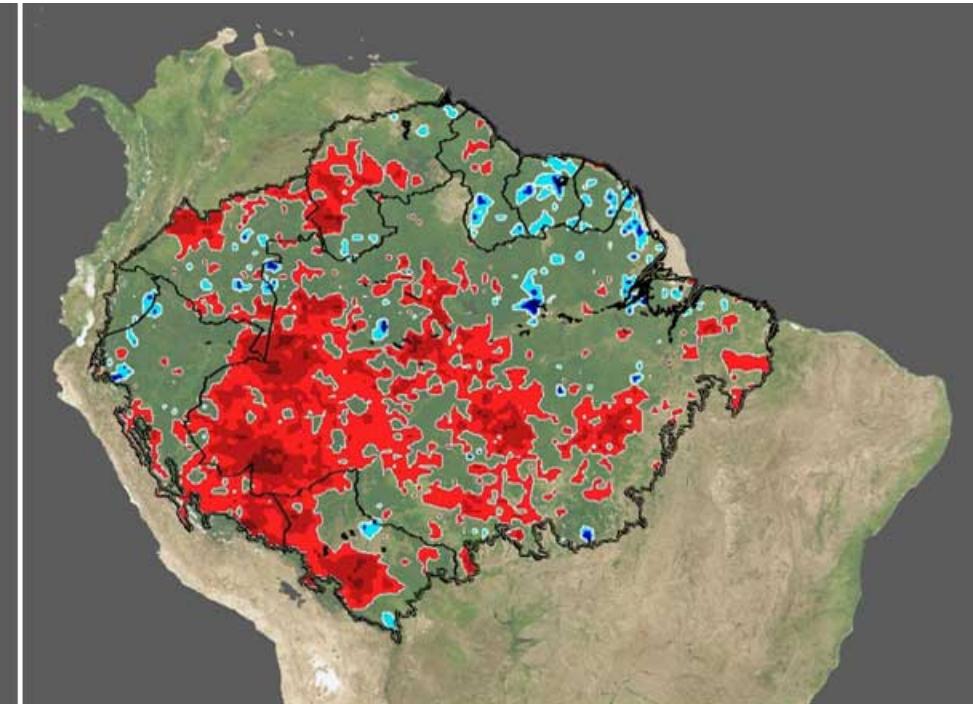


Reflectance spectra of leaves will be different dependent on its state

# Satellite imaging of forests



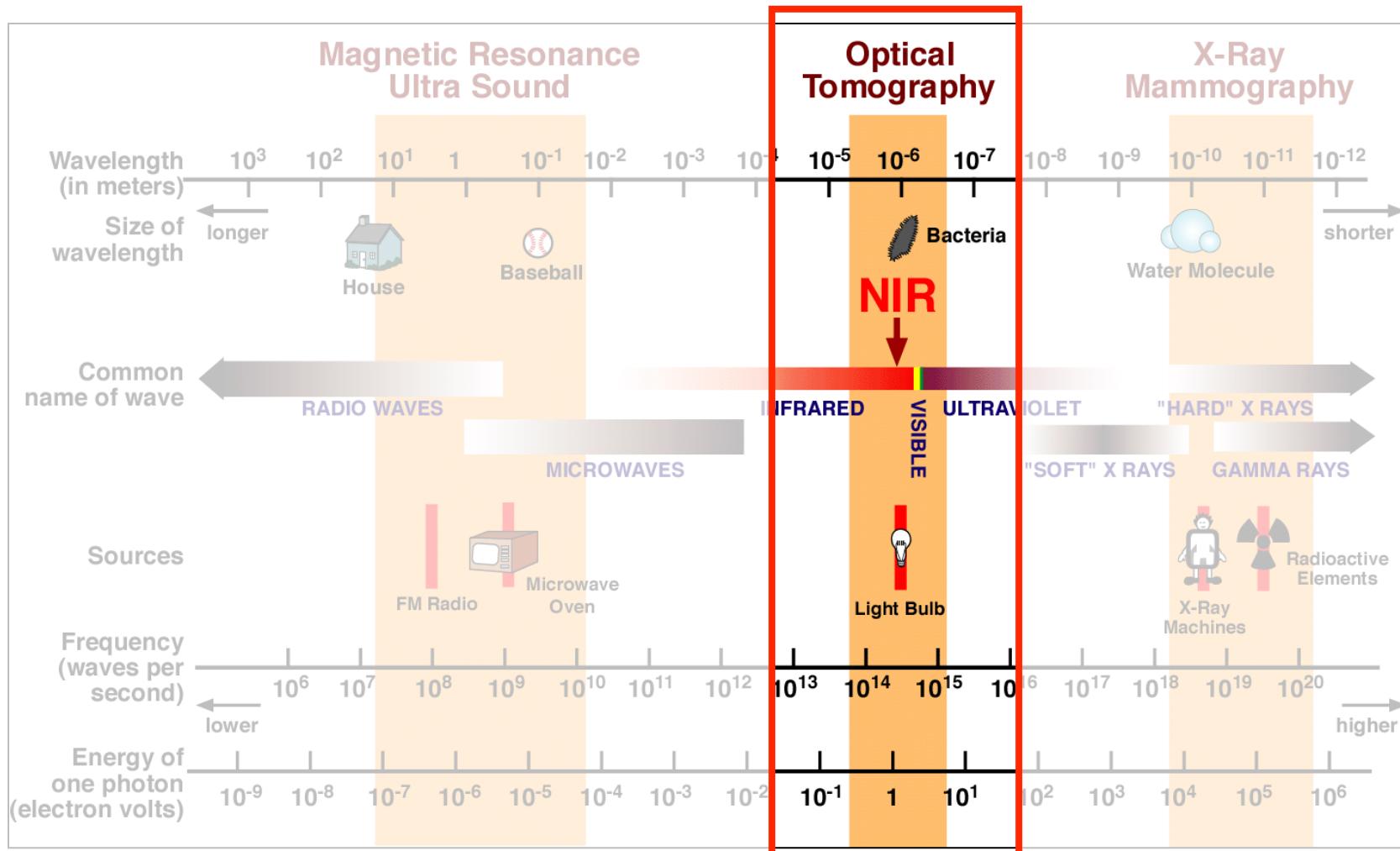
Photosynthetic activity



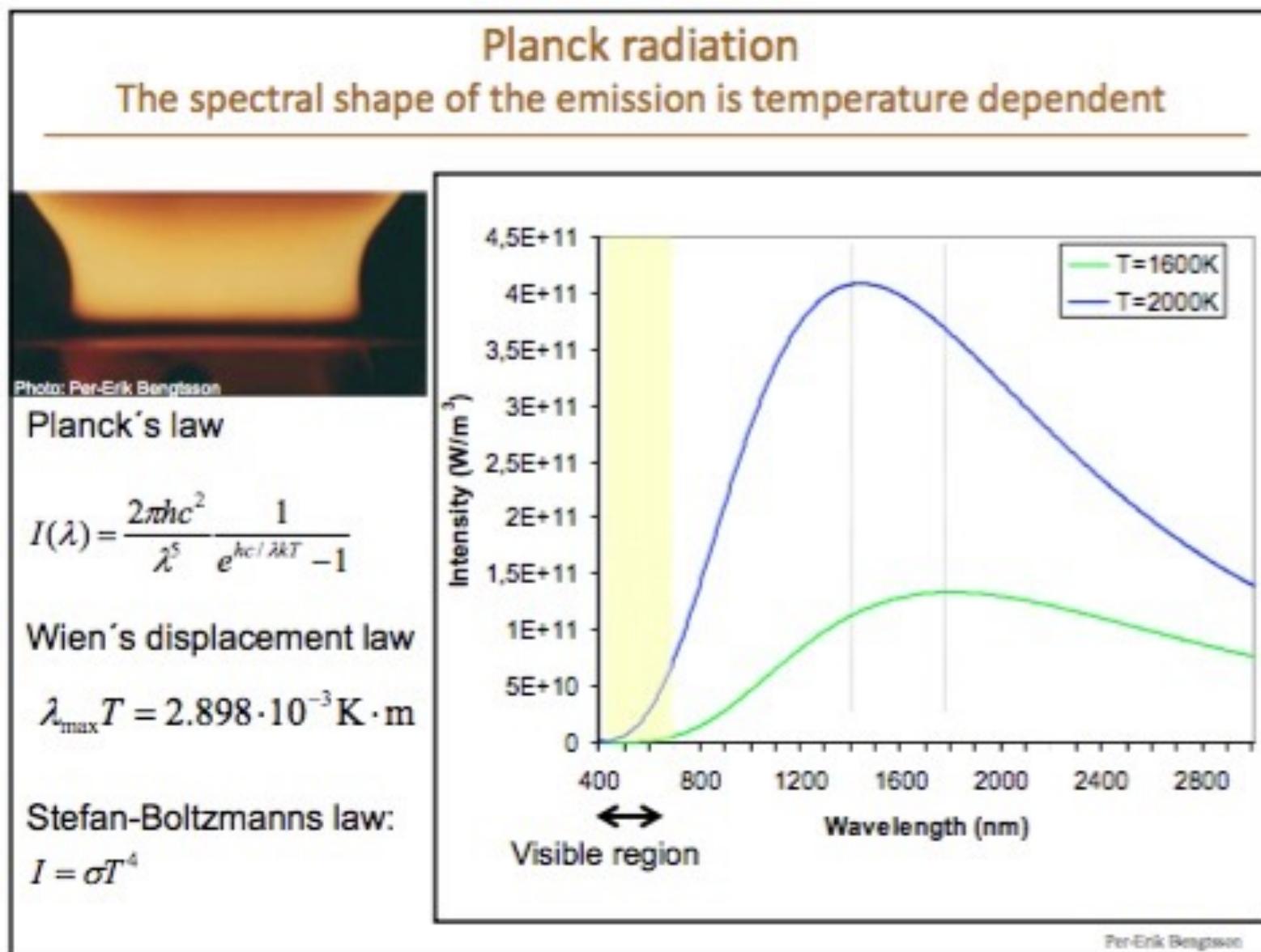
Average rainfall

# Combustion diagnostics

# Combustion diagnostics: UV-VIS-IR



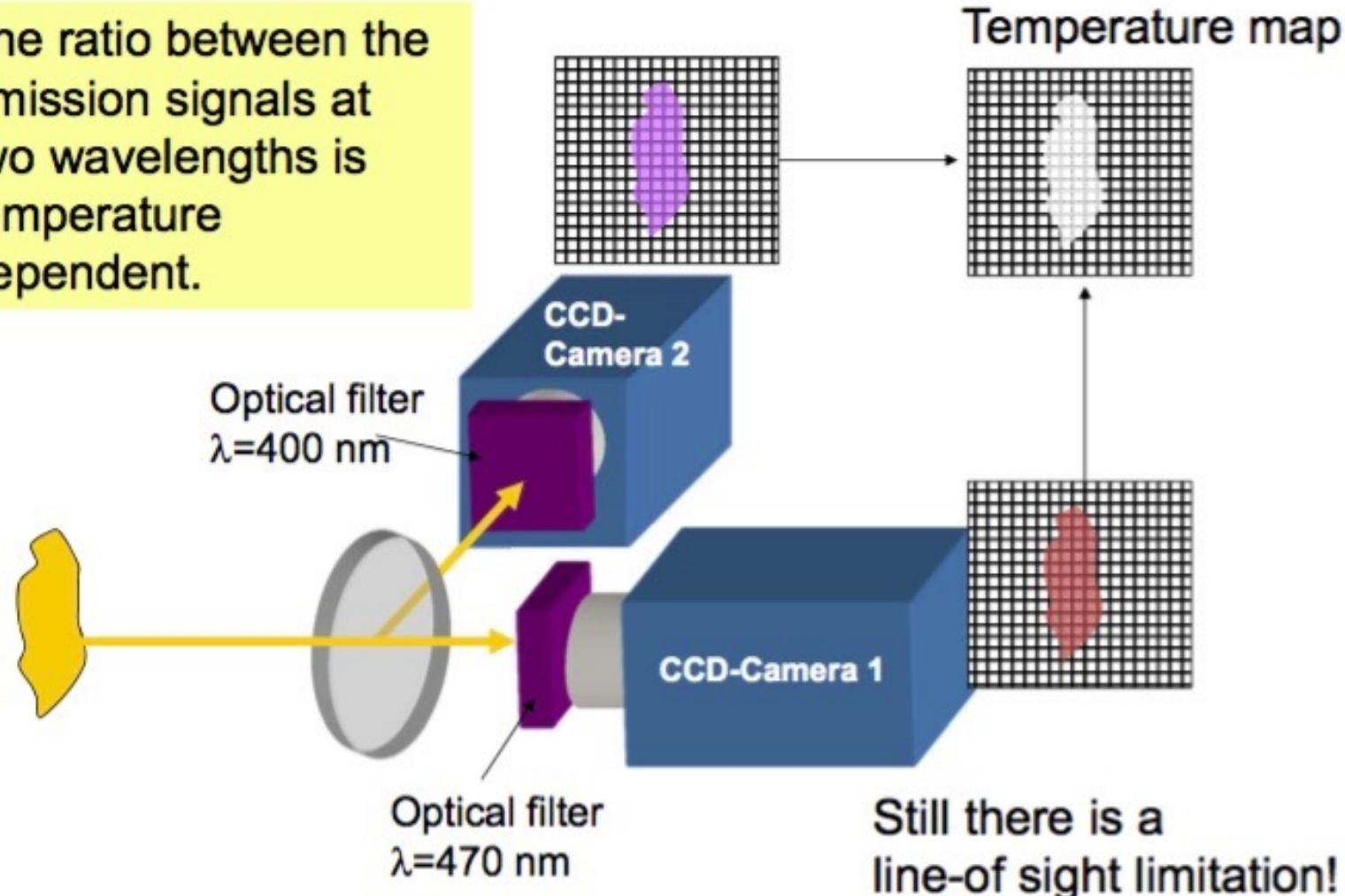
# Combustion diagnostics: Non-contact temperature measurements



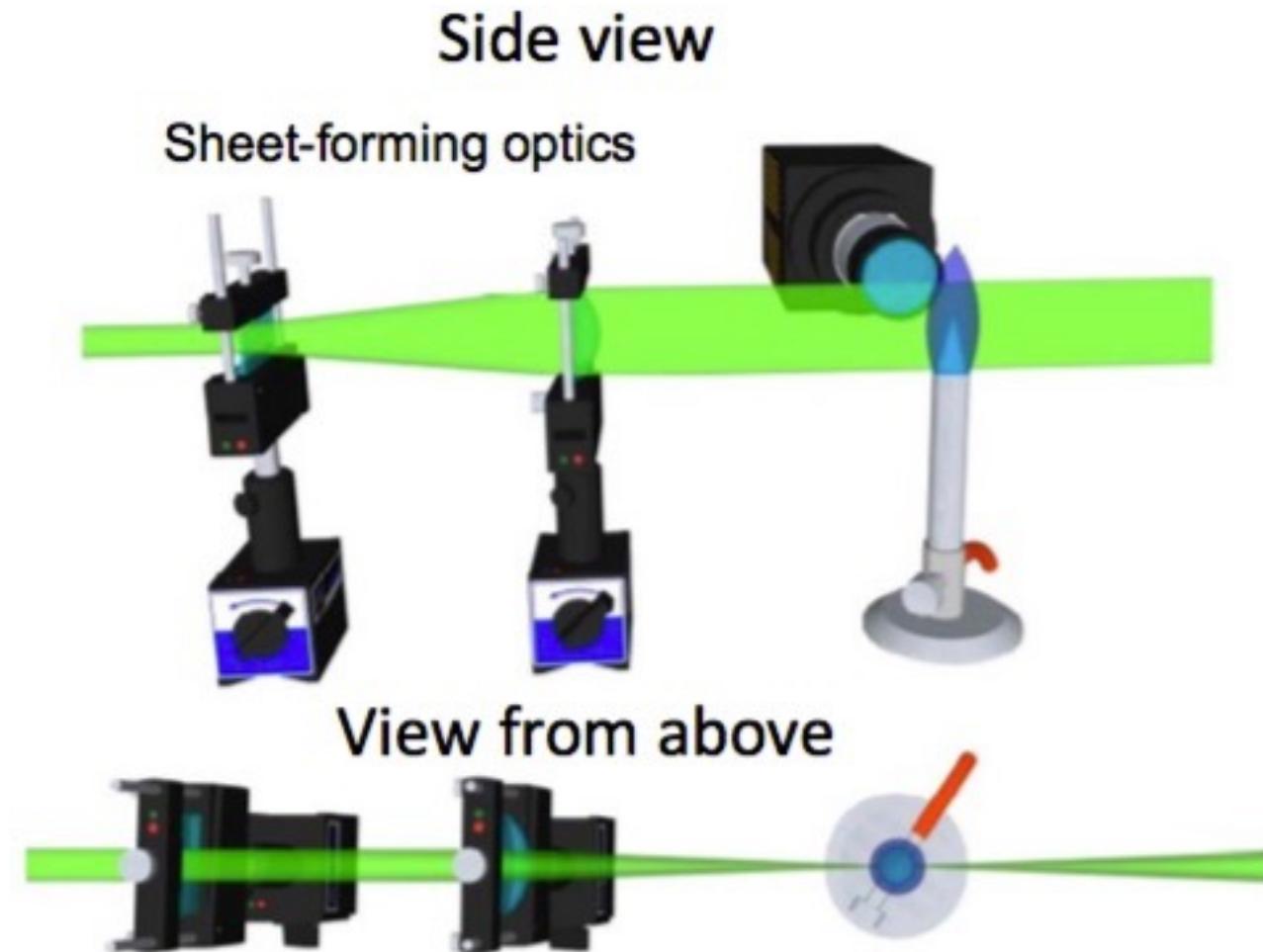
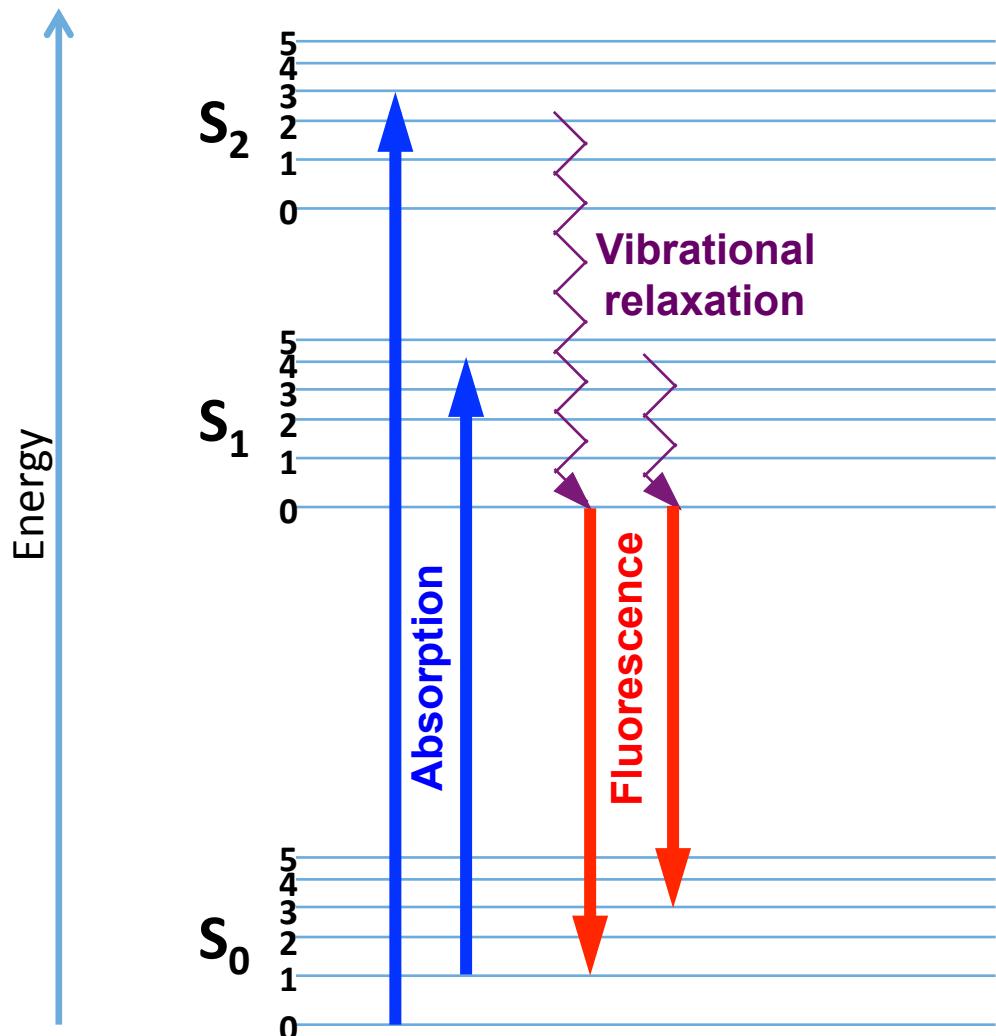
# Combustion diagnostics: Non-contact temperature measurements

## Temperature imaging using 2-D pyrometry

The ratio between the emission signals at two wavelengths is temperature dependent.

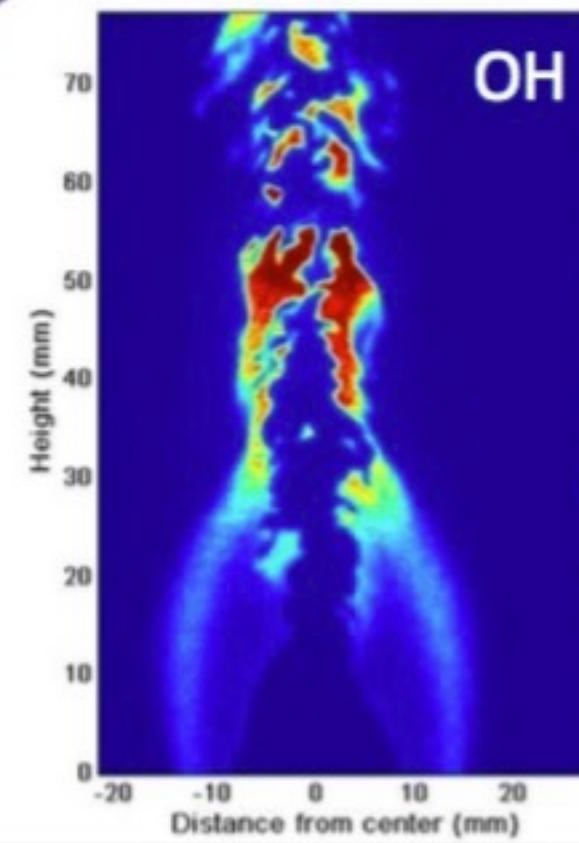
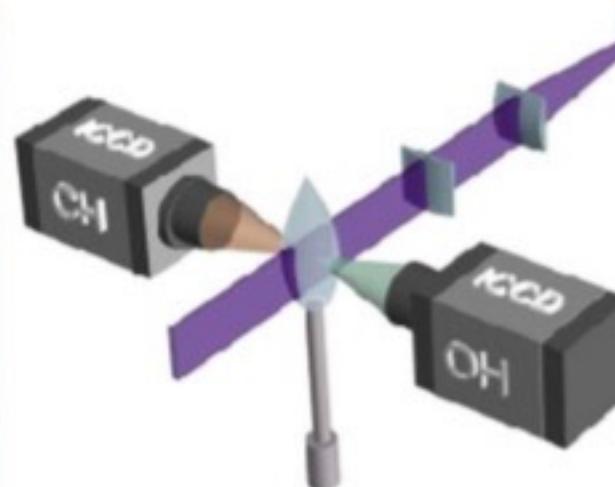
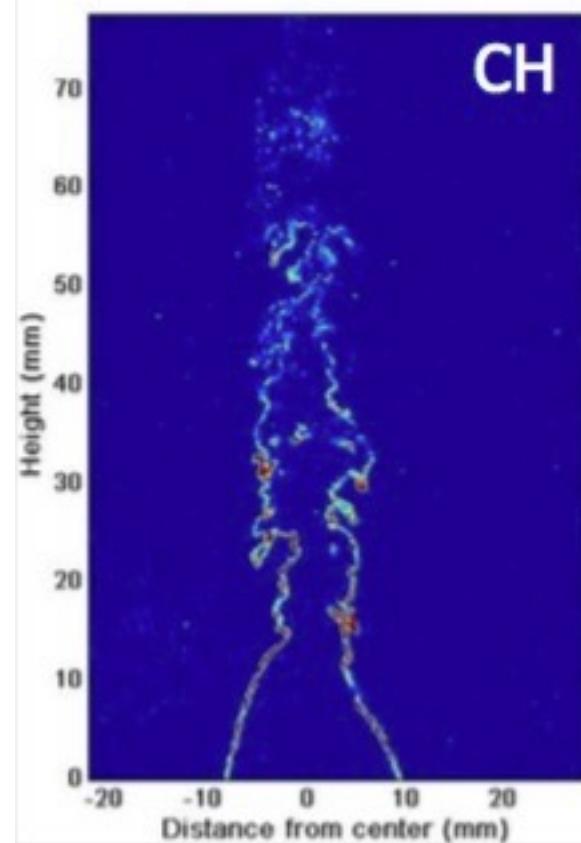
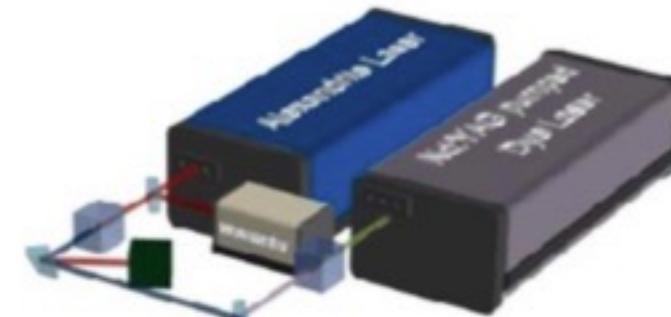


# Combustion diagnostics: Laser-induced fluorescence



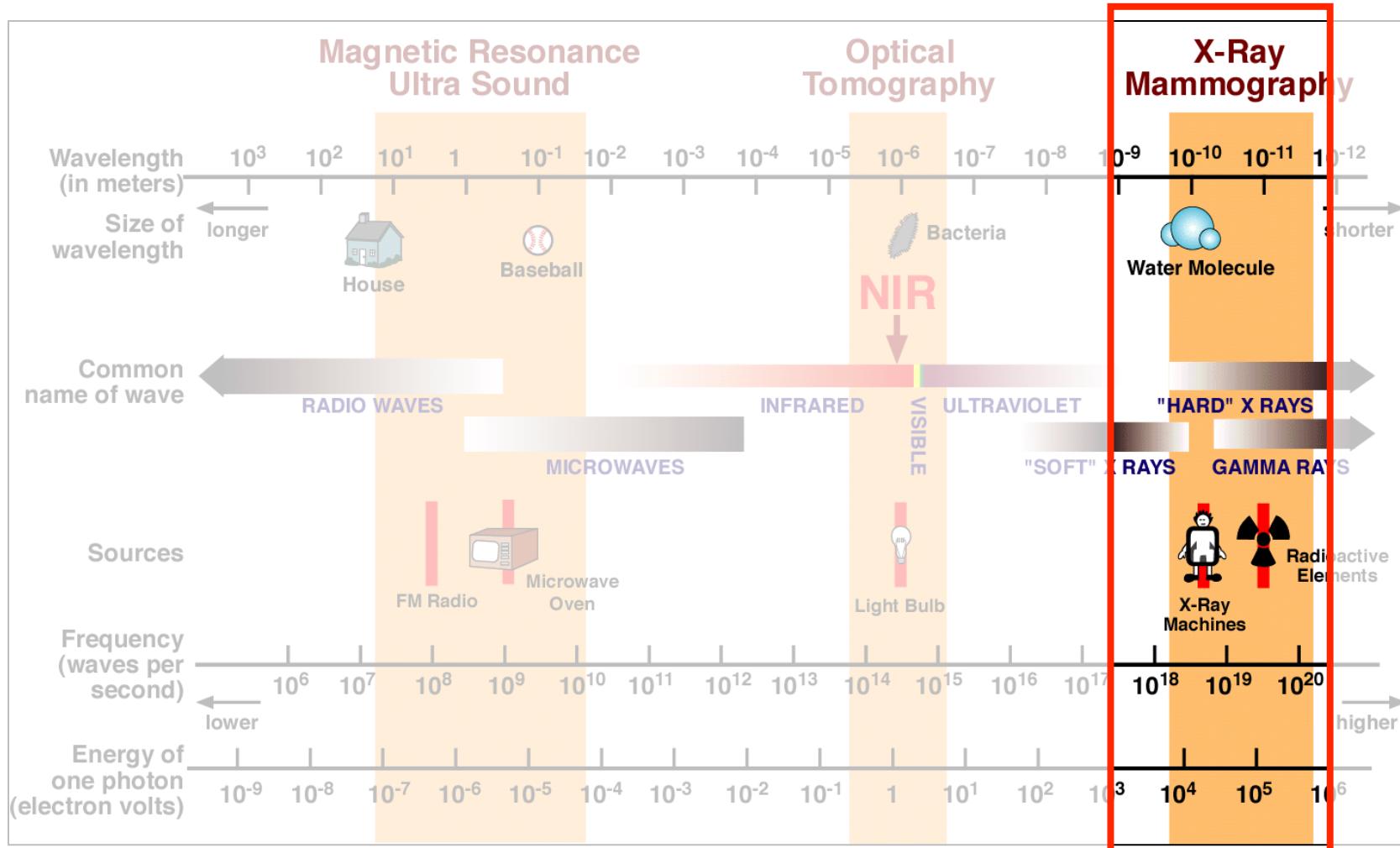
# Combustion diagnostics: Laser-induced fluorescence

	CH	OH
Excitation (nm)	~387	~283
Detection (nm)	~430	~310

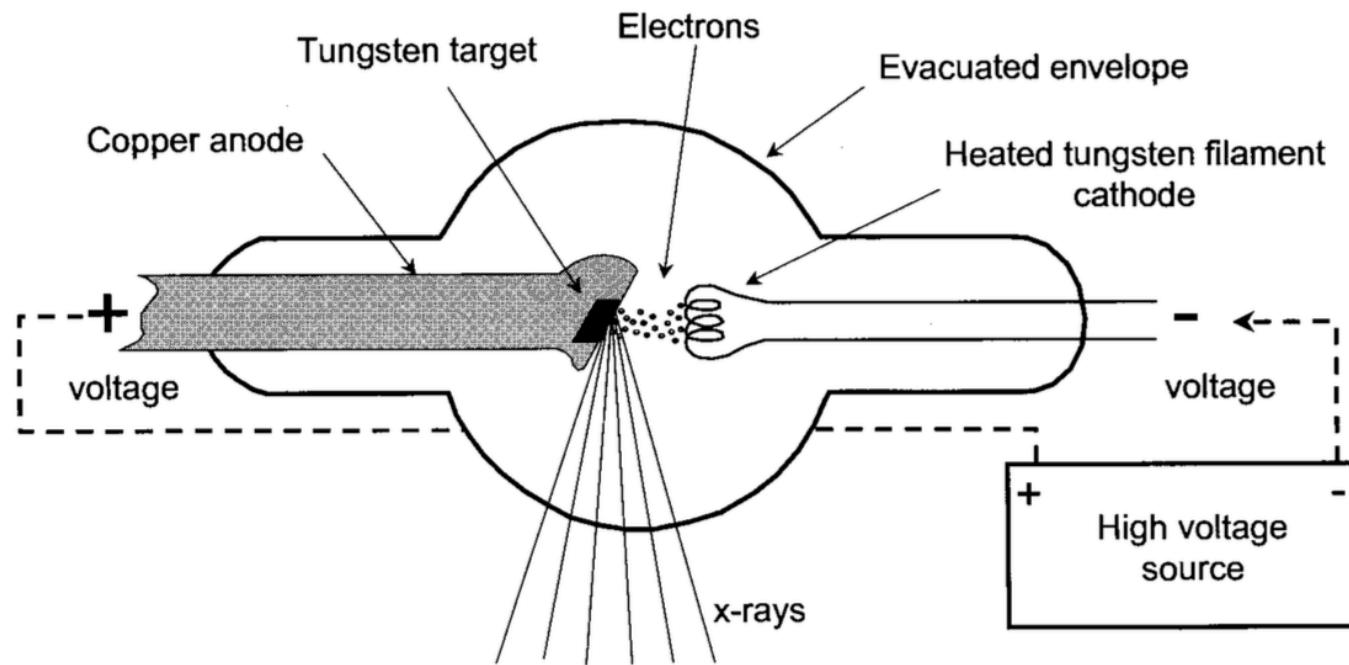


# Medical Imaging

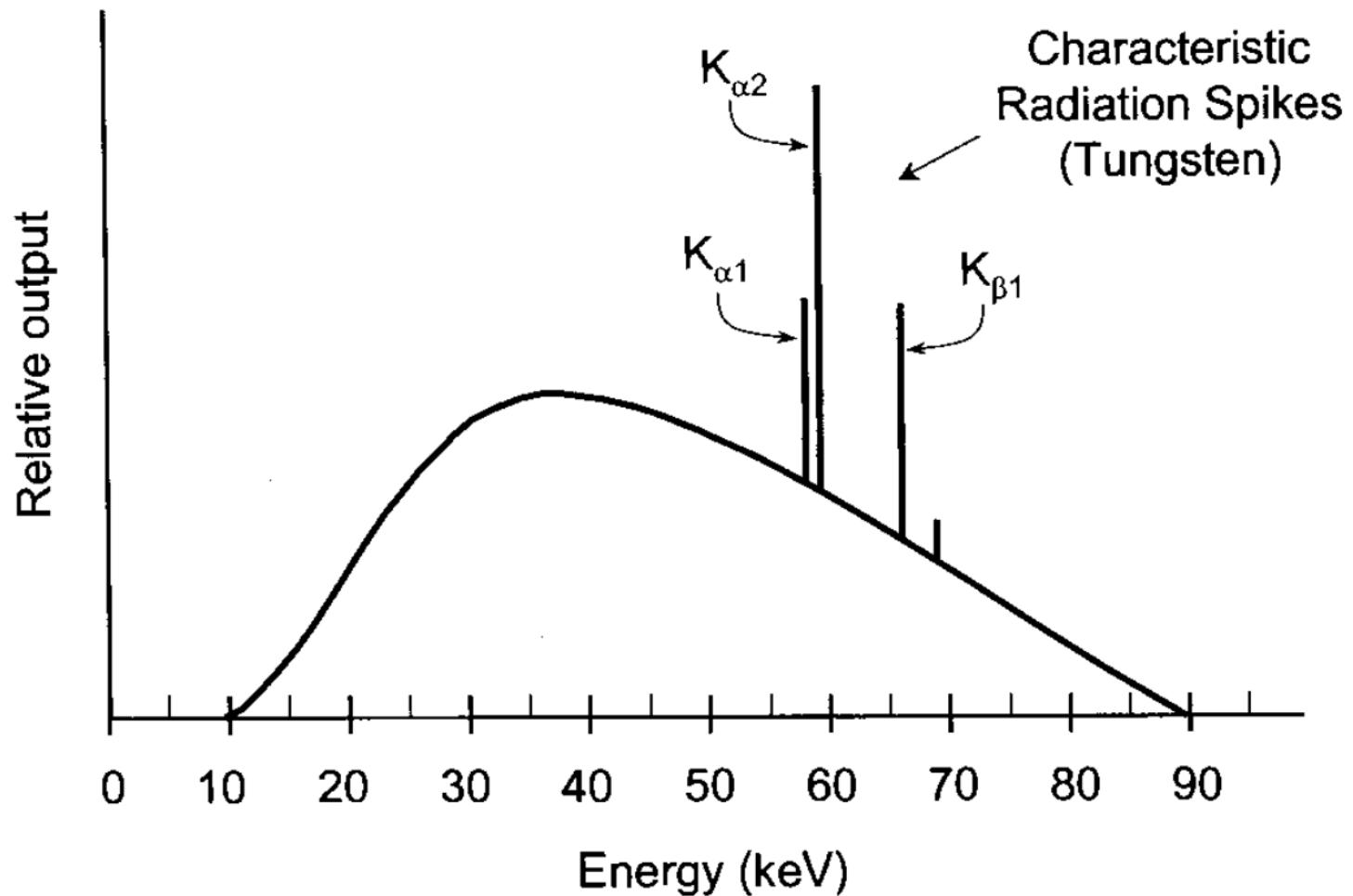
# Medical imaging: X-ray



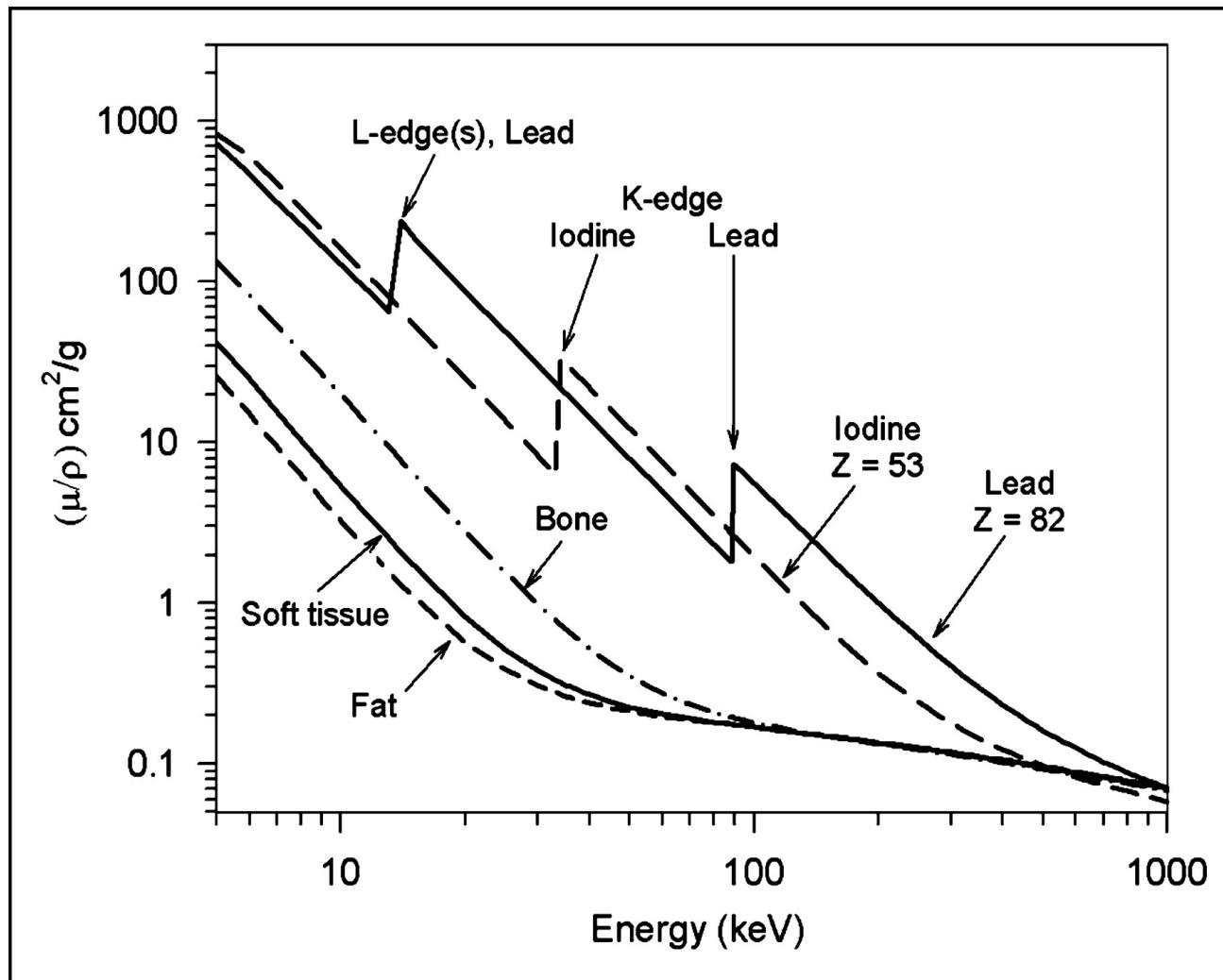
# X-ray production



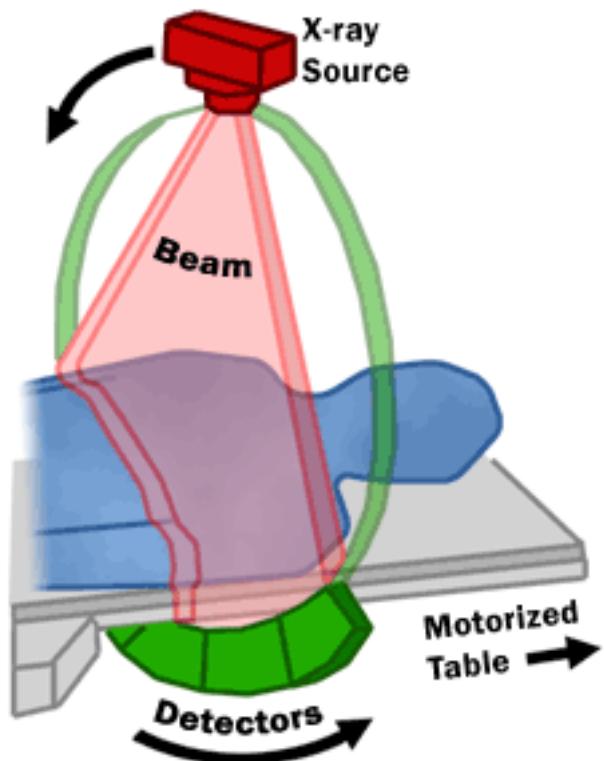
# X-ray spectrum



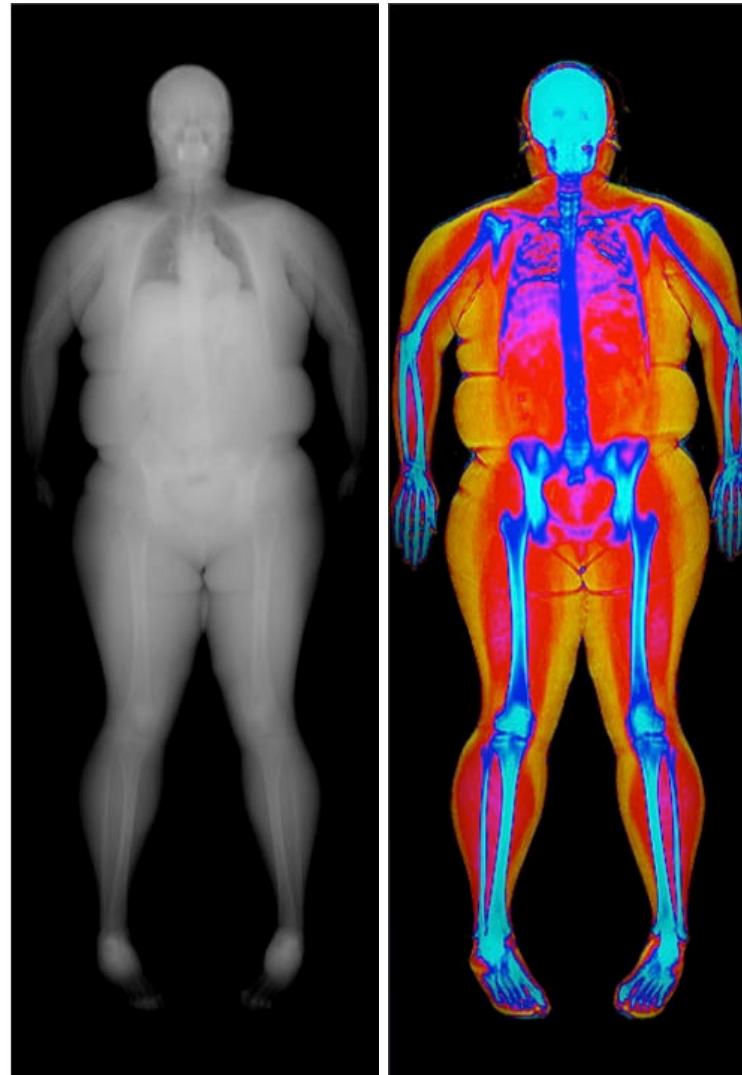
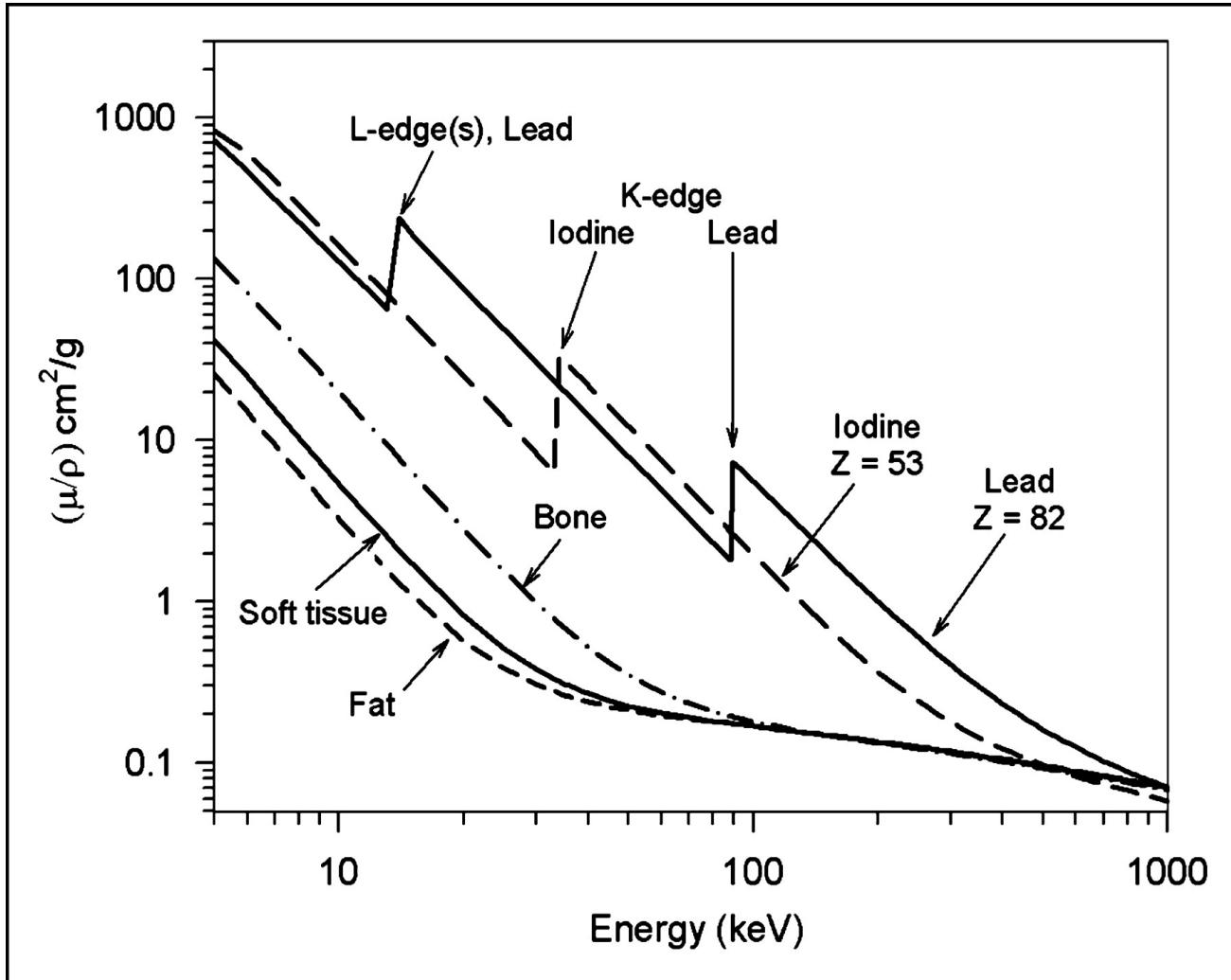
# Contrast in X-ray images



# X-ray computed tomography



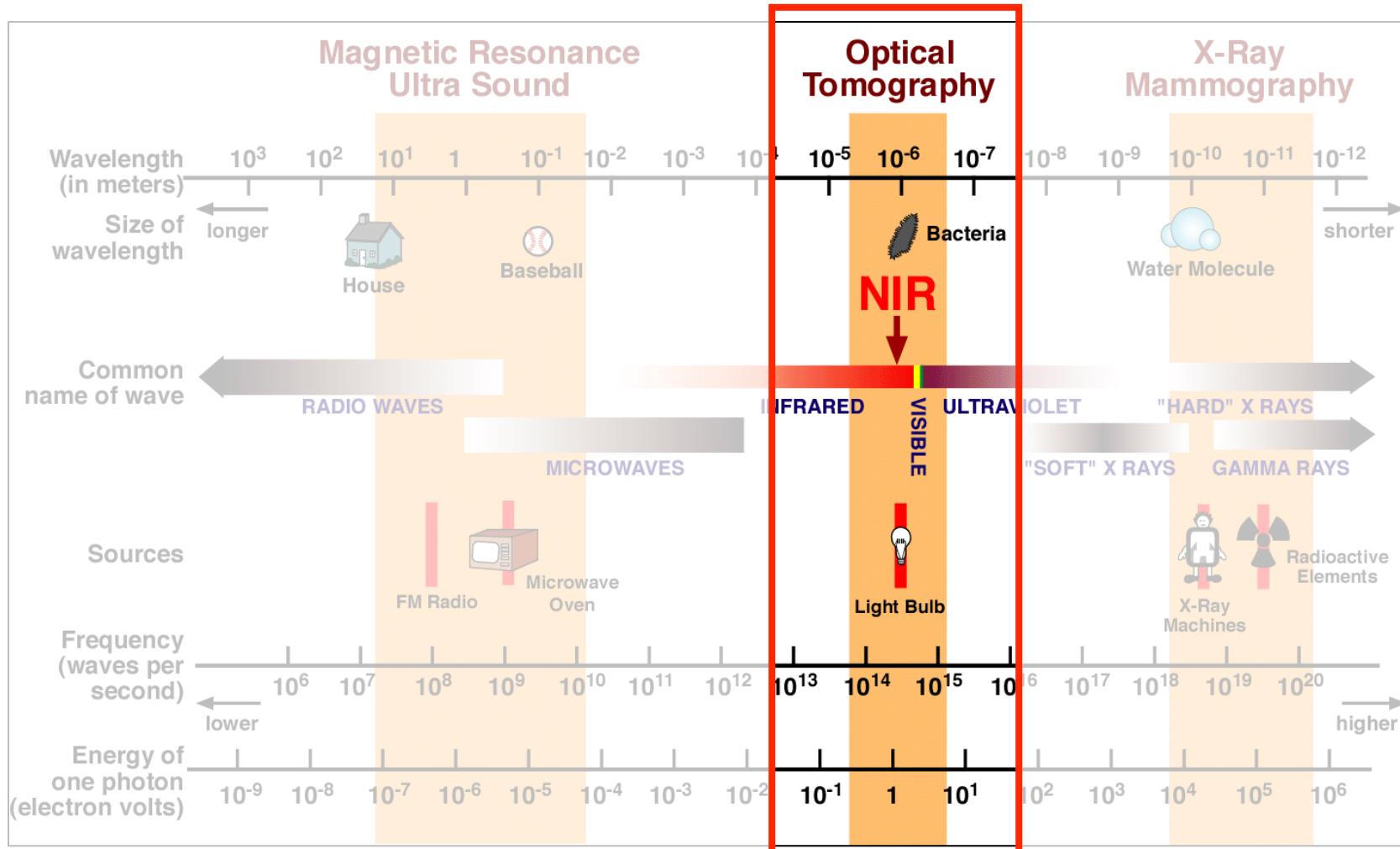
# Multispectral X-ray



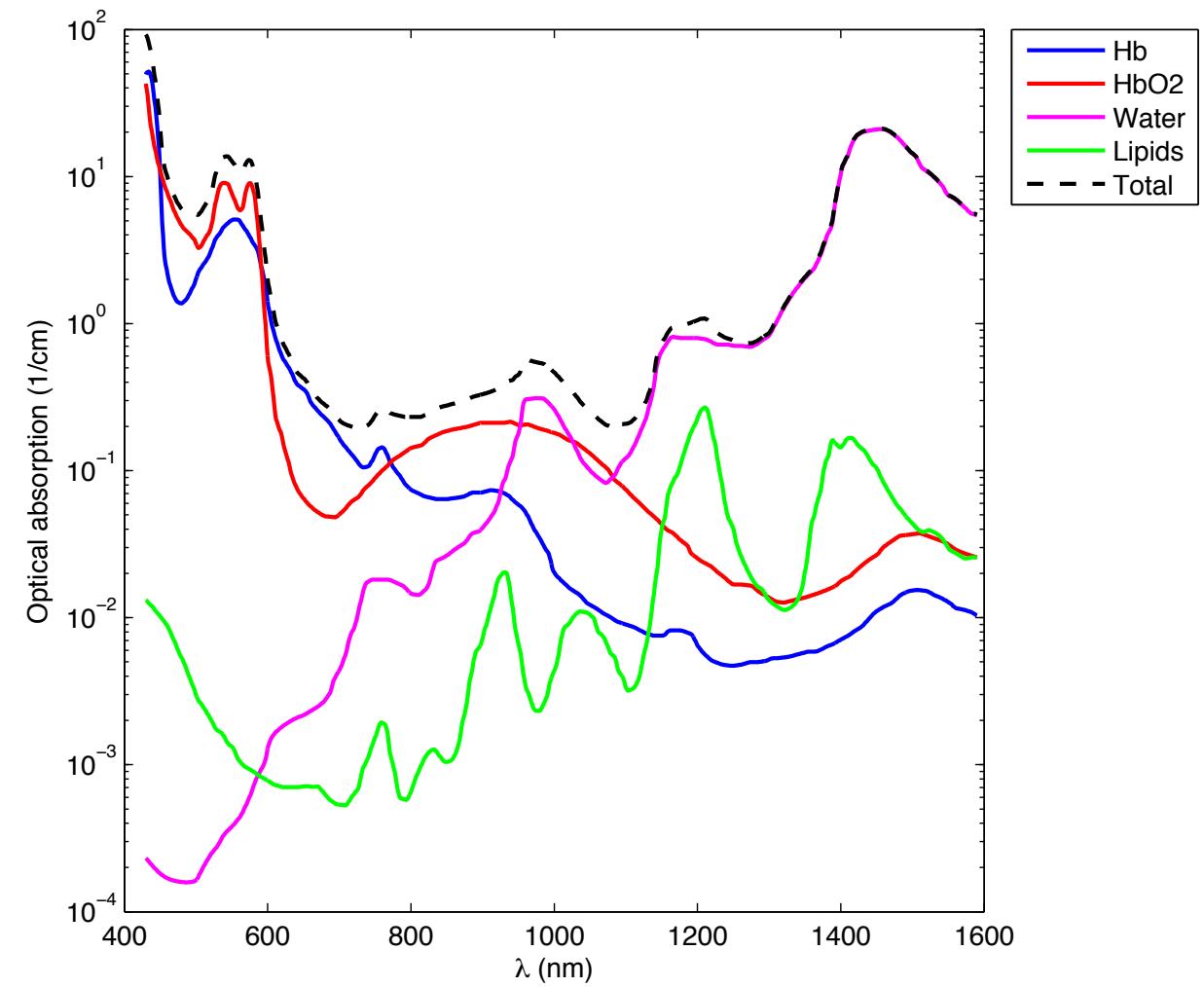
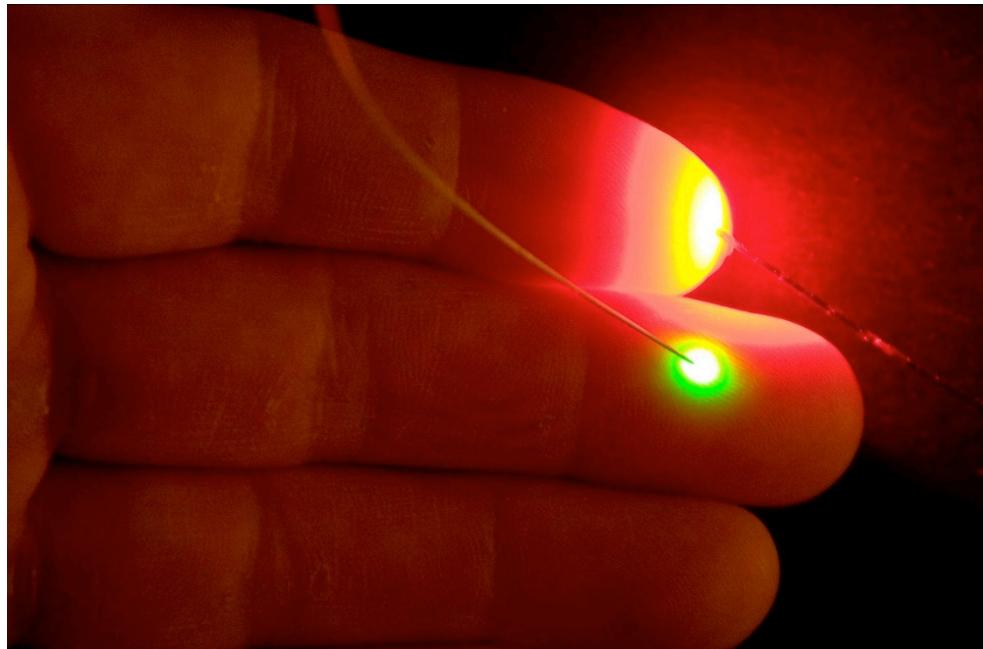
# Medical imaging: Optical imaging

- Why?
  - Non-ionizing
  - Energy carried by the visible/NIR radiation matches transitions in the outer electron shells in many molecular compounds > **multiple sources of contrast**
  - Characterize the tissue composition based on reflectance, transmission, fluorescence and scattering properties of the object under study

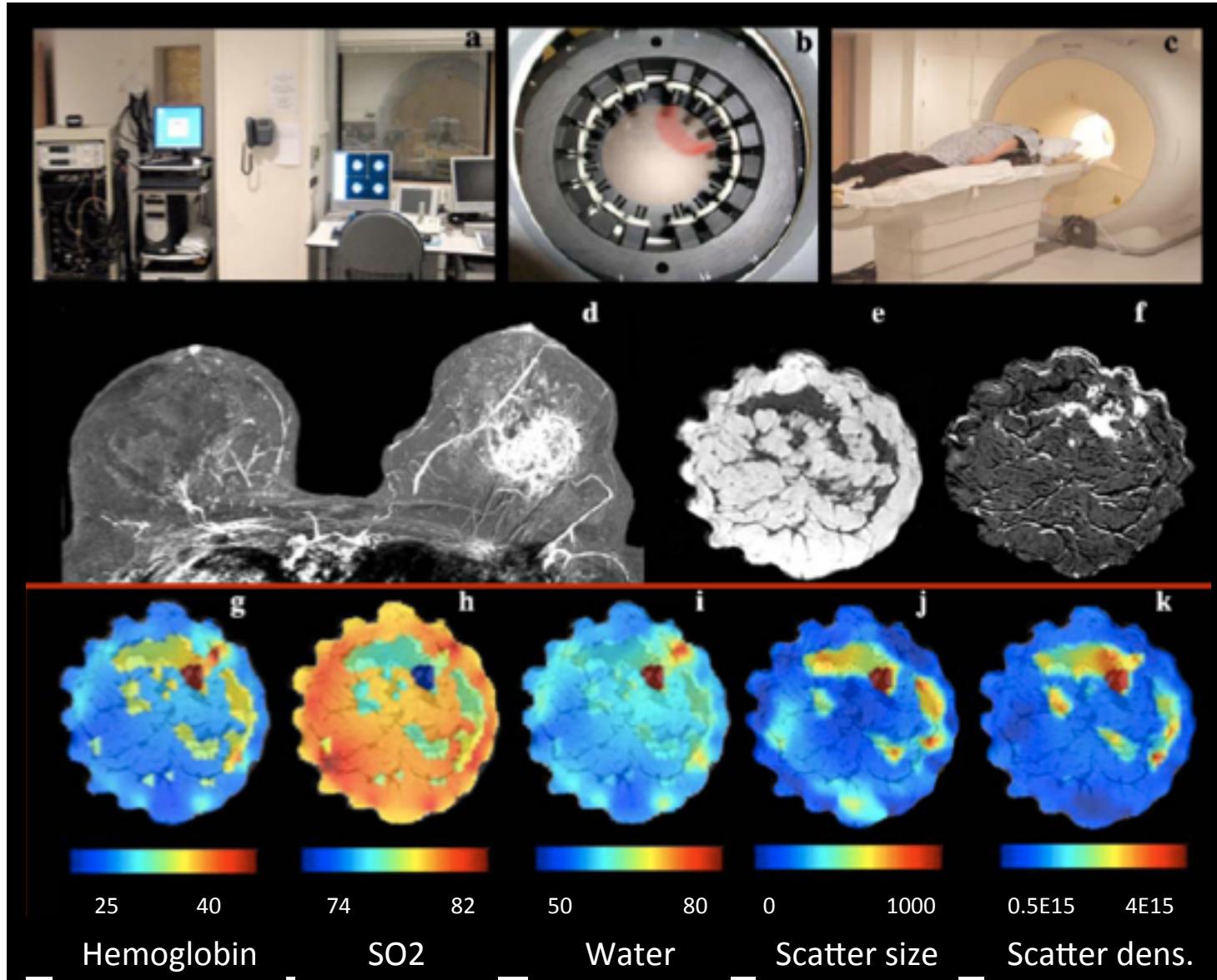
# Medical optical imaging: UV-VIS-IR



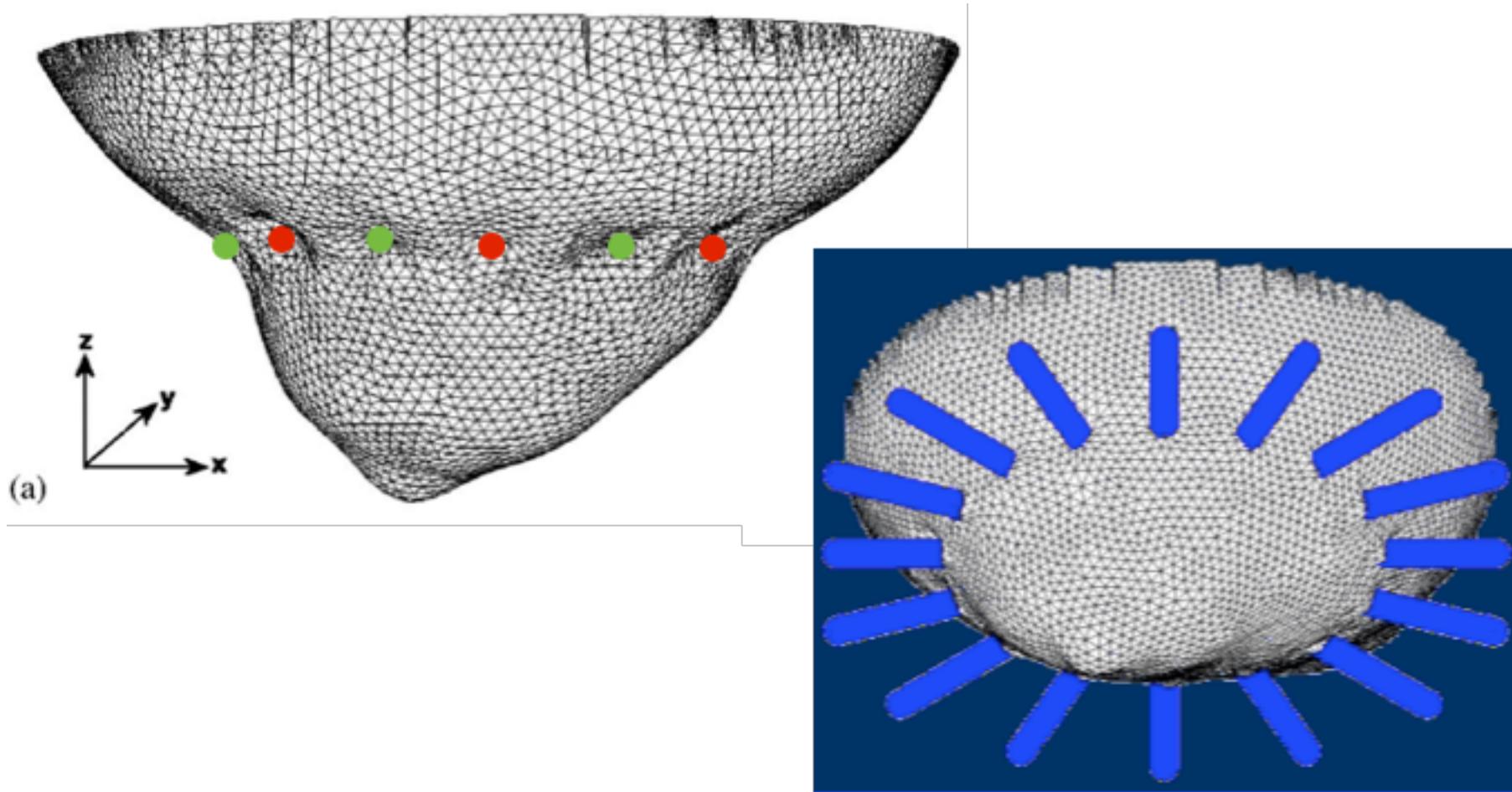
# Medical imaging: Optical imaging – absorption of light



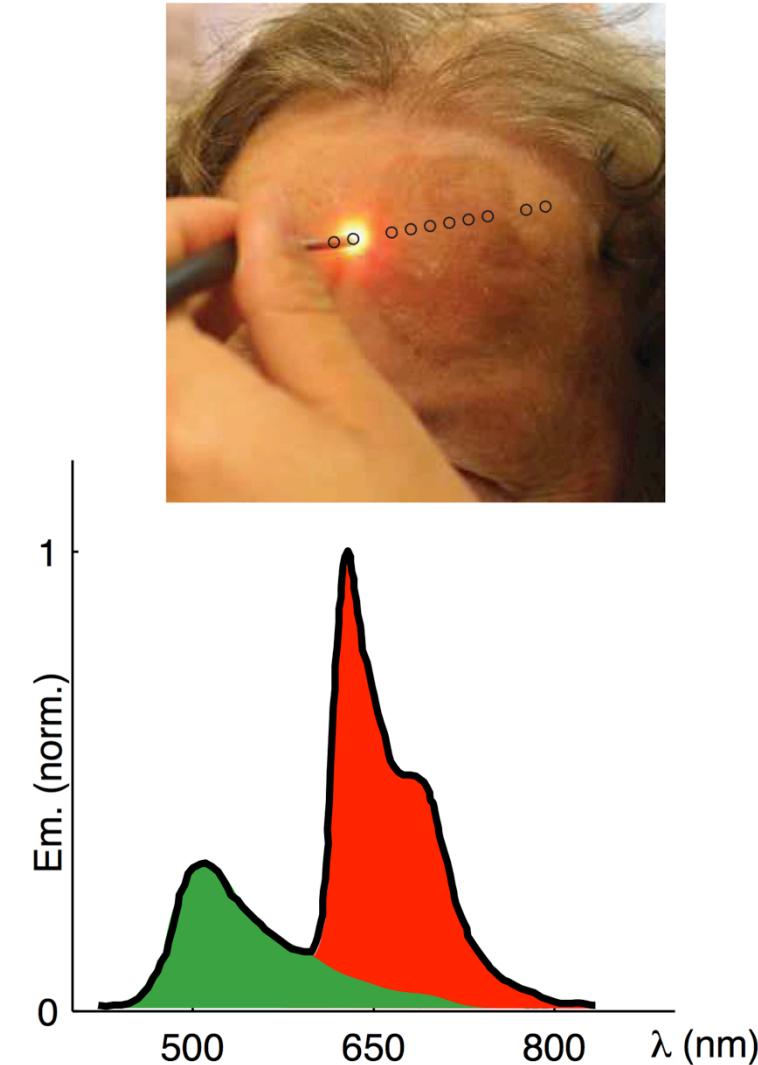
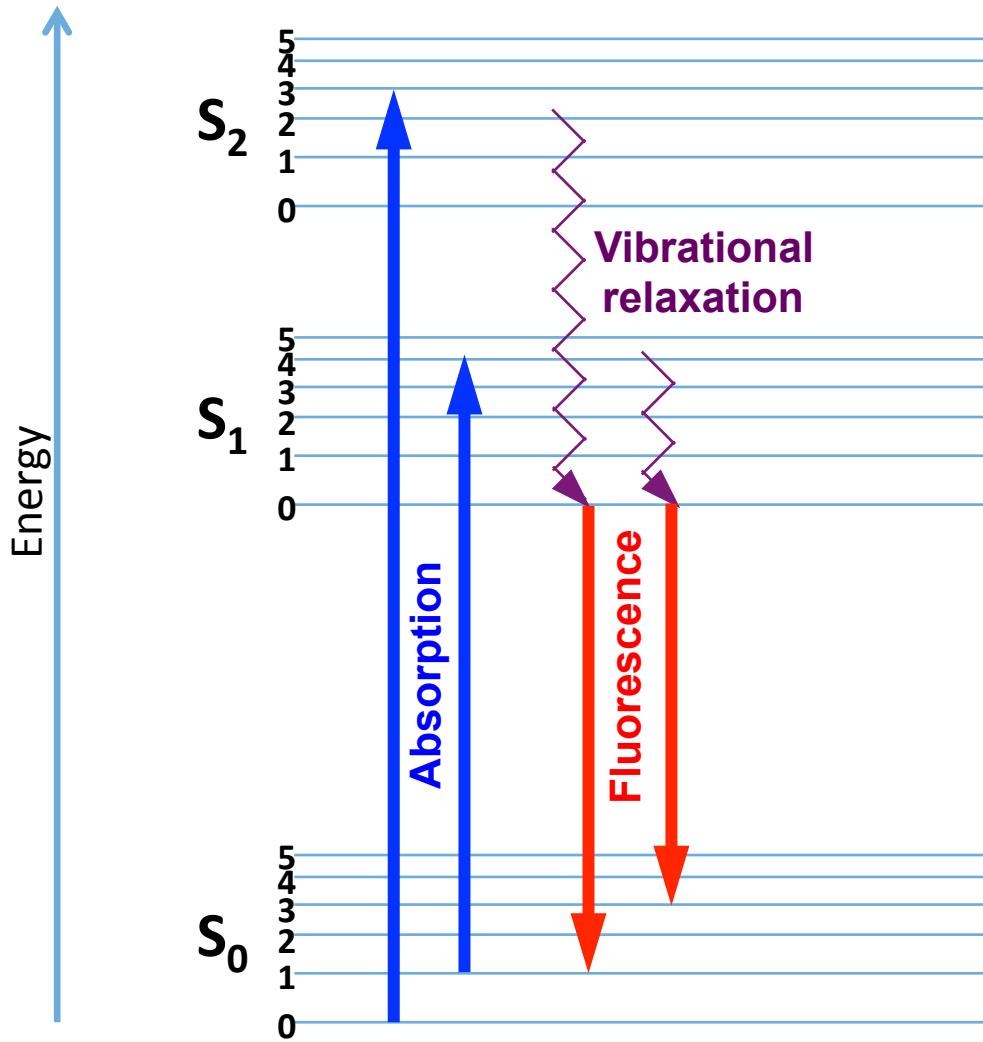
# Optical tomography of tissue chromophores



# Optical tomography of tissue chromophores

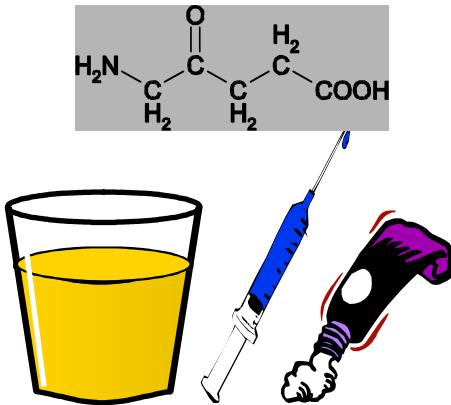


# Medical imaging: Contrast based on fluorescence

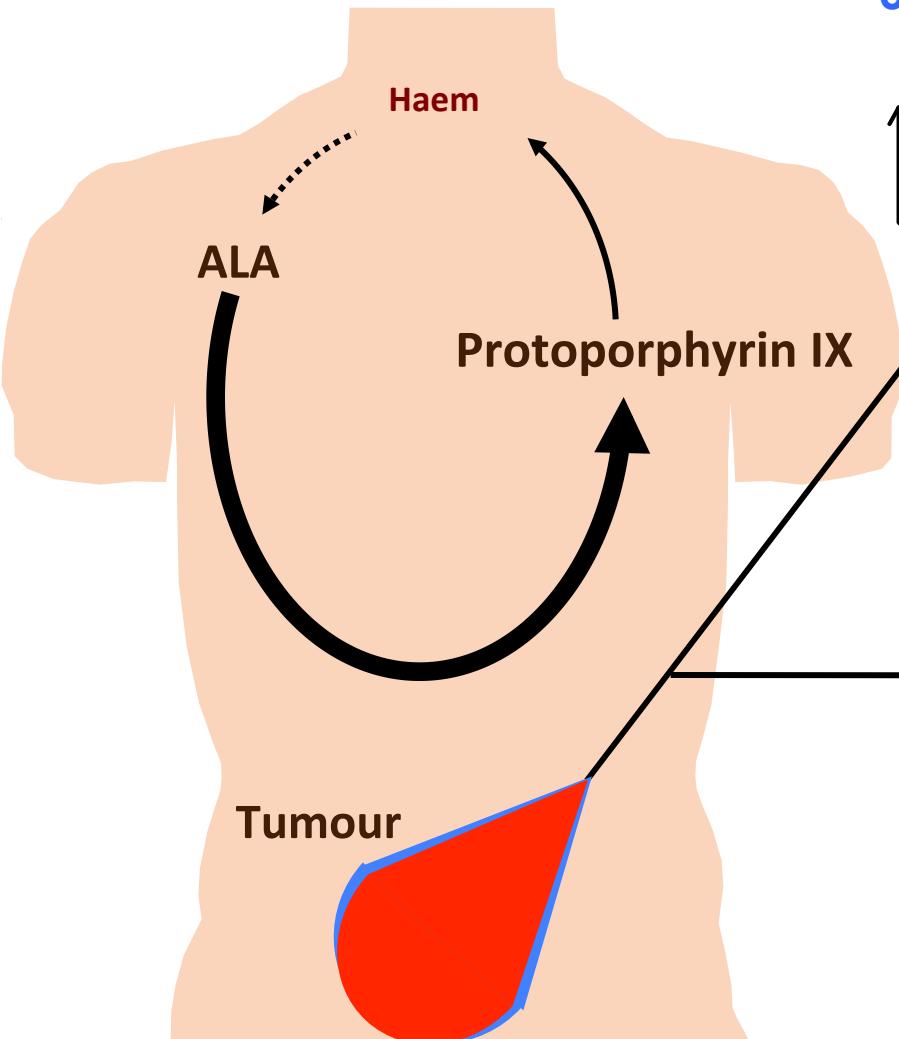


# ALA-induced Protoporphyrin IX (PpIX) production

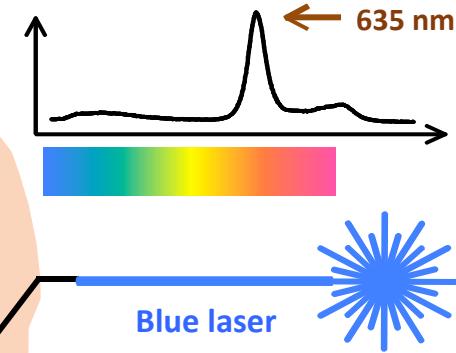
## 1. Administration of ALA or its esters



## 2. Build-up of PpIX



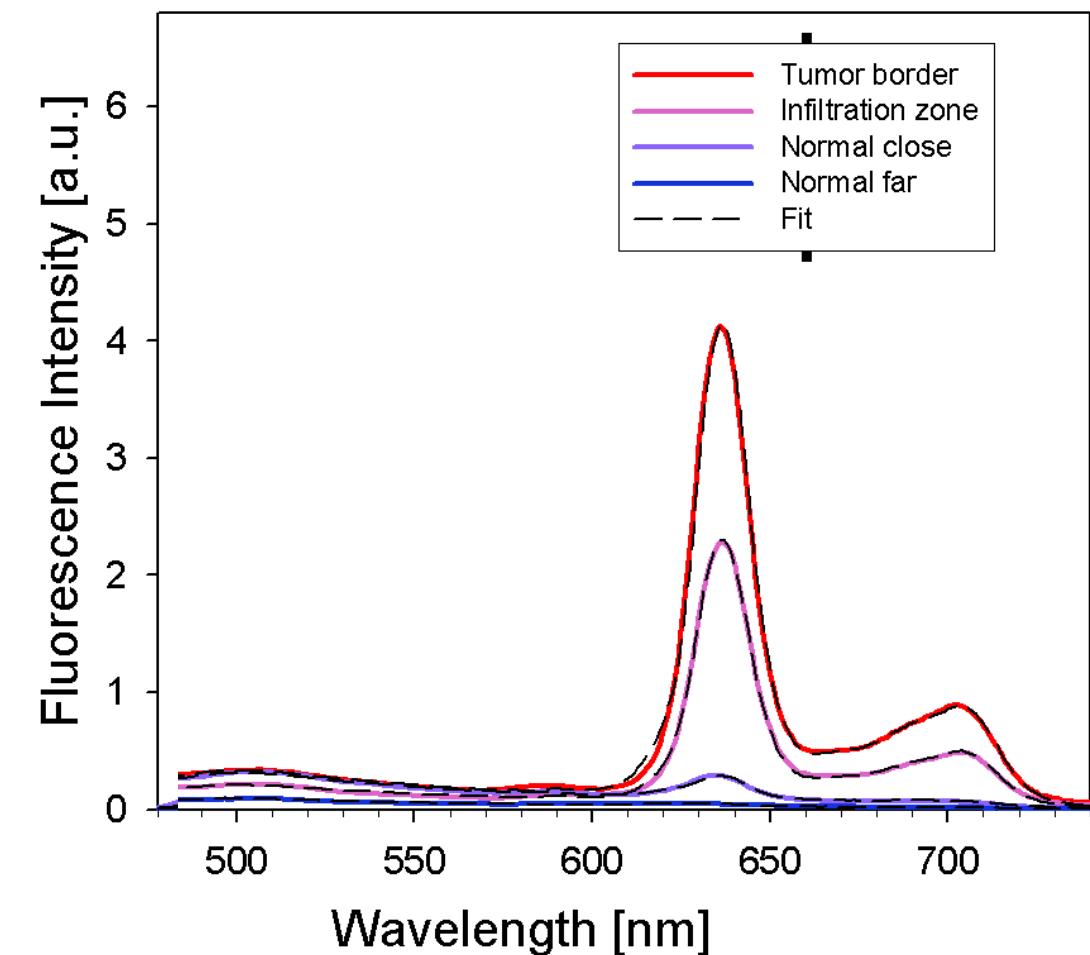
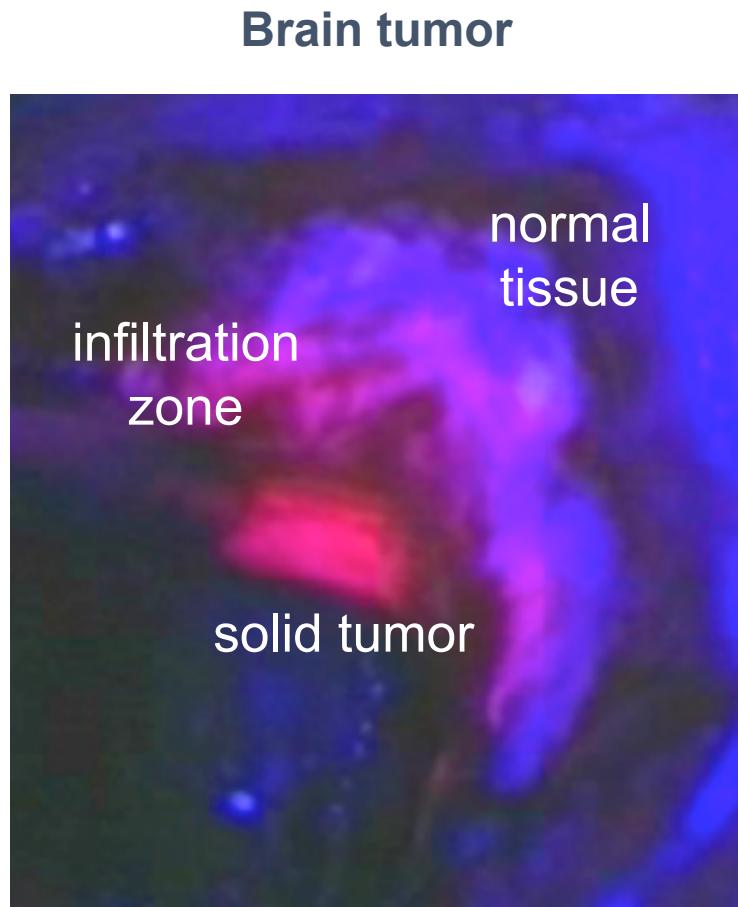
## 3. Diagnostics



## 4. Treatment



# Fluorescence guided brain tumor resection



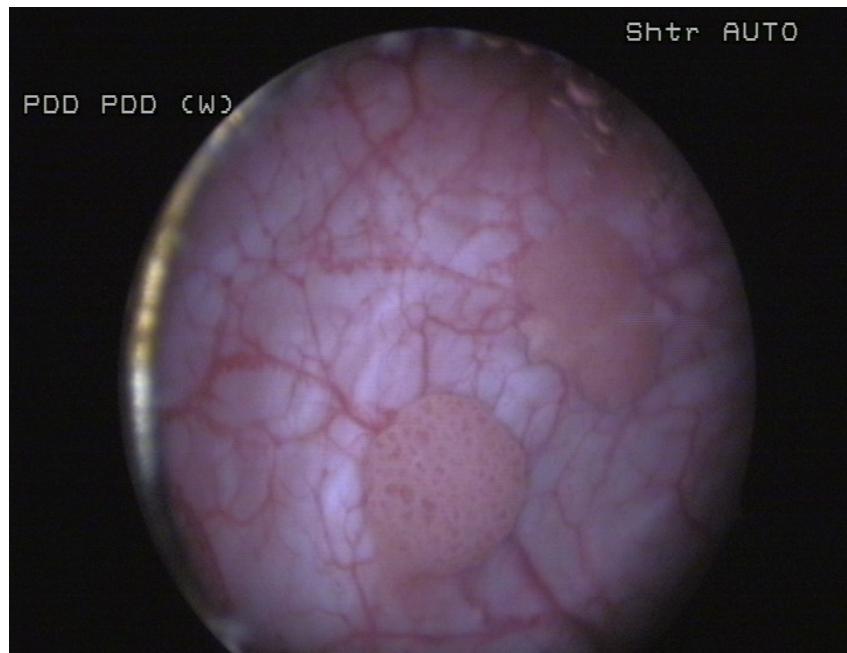
# Fluorescence guided bladder cancer delineation

Fluorescence diagnostics

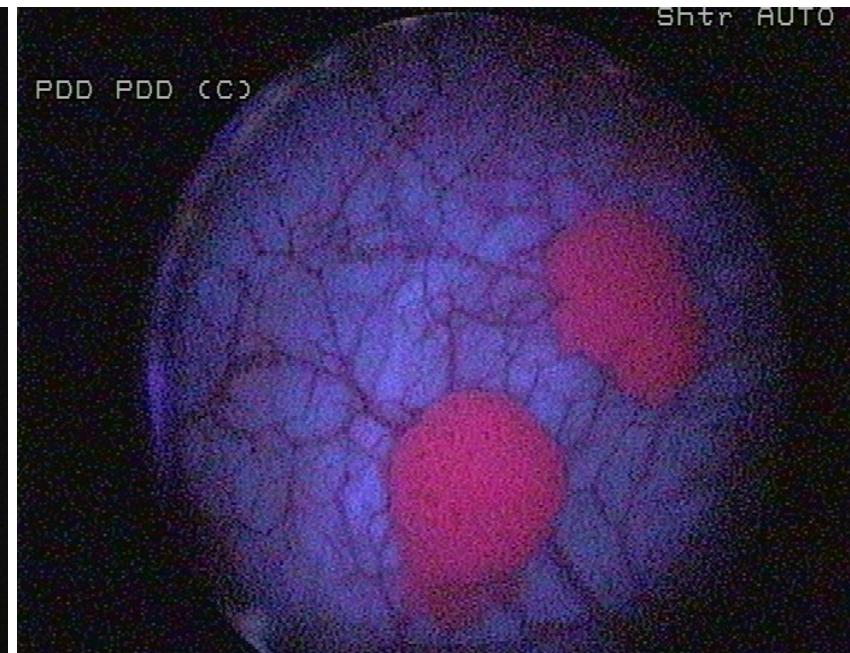
Blue Light



Fluorescent tumour marker



Normal white light examination

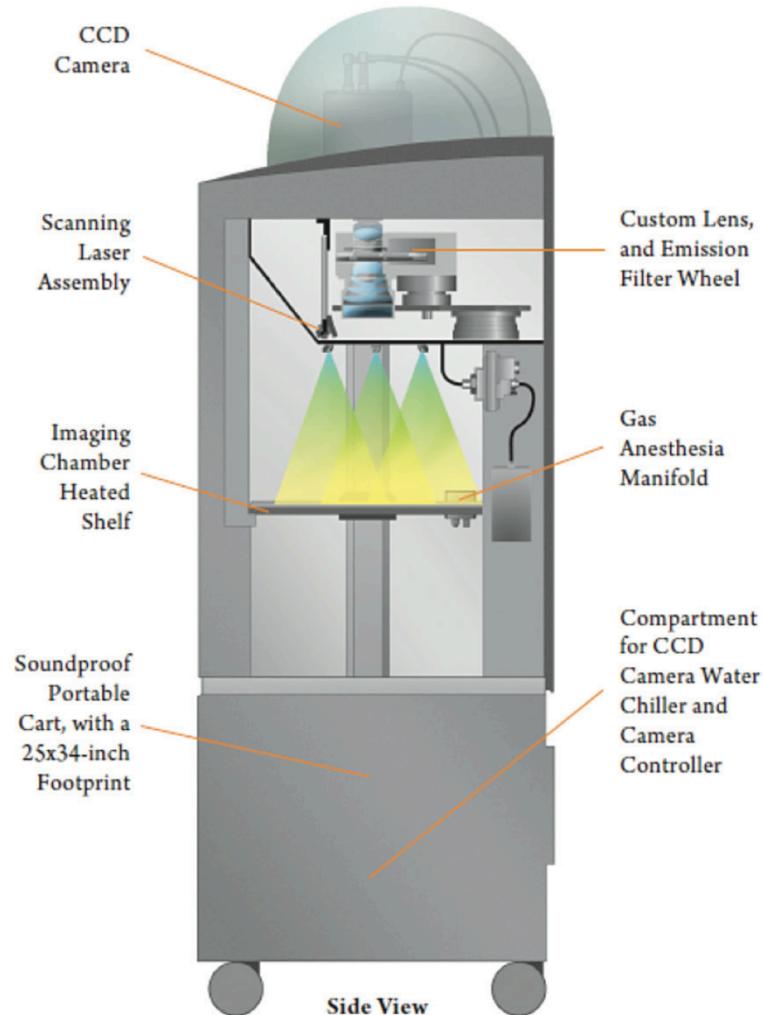


Blue light examination

# Medical imaging: Pre-clinical imaging

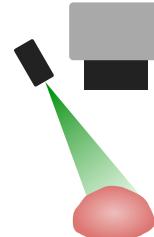
- Imaging of biological events within an experimental animal model (i.e. mice or rats)
- Relied heavily upon when investigating e.g.
  - Tumor growth
  - Pharmaceutical uptake
  - Pharmaceutical effect on tissue
  - ...

# Fluorescence imaging instruments



PerkinElmer IVIS Spectrum

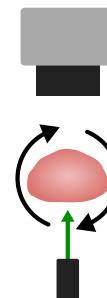
Epi-illumination



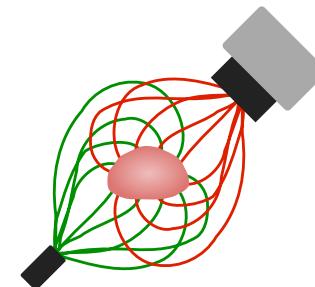
Transillumination



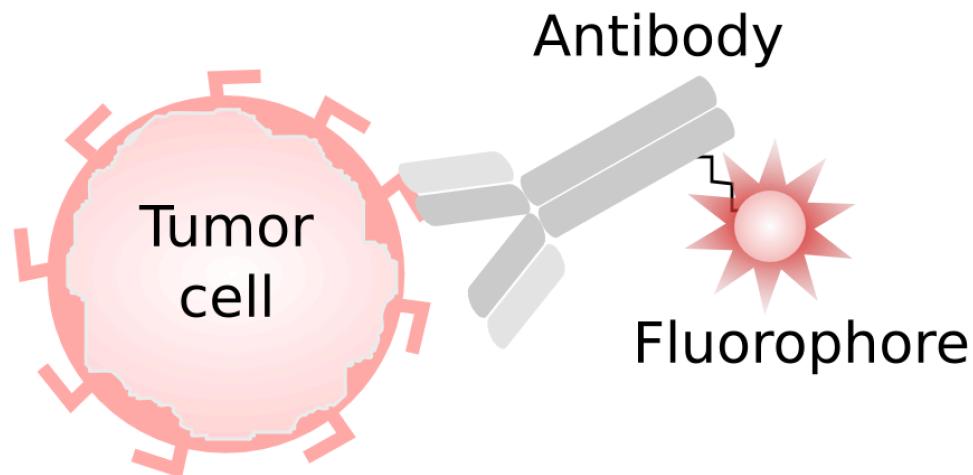
Rotational illumination



Fiber-optic illumination



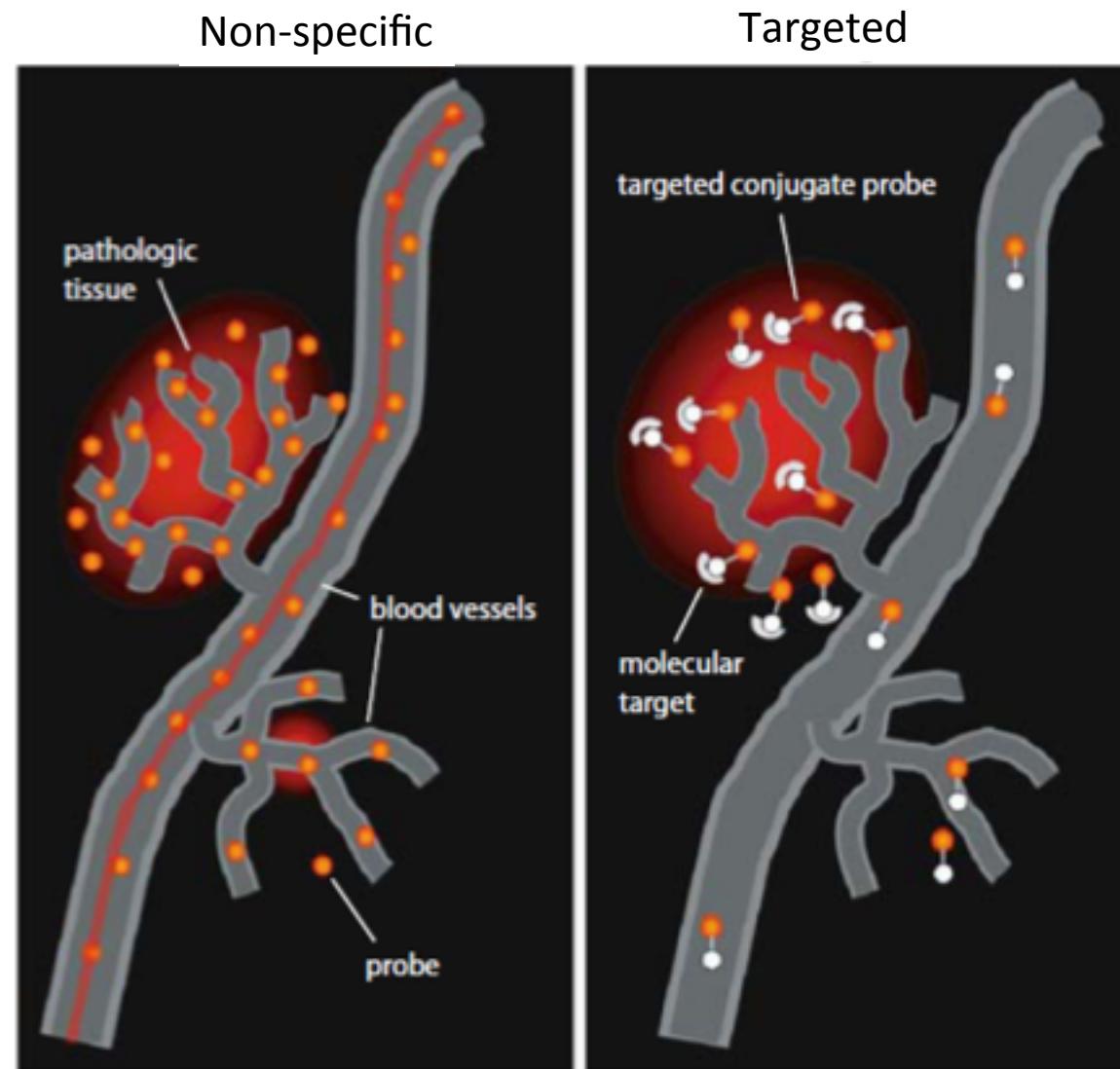
# Fluorescence imaging: Targeting fluorophores



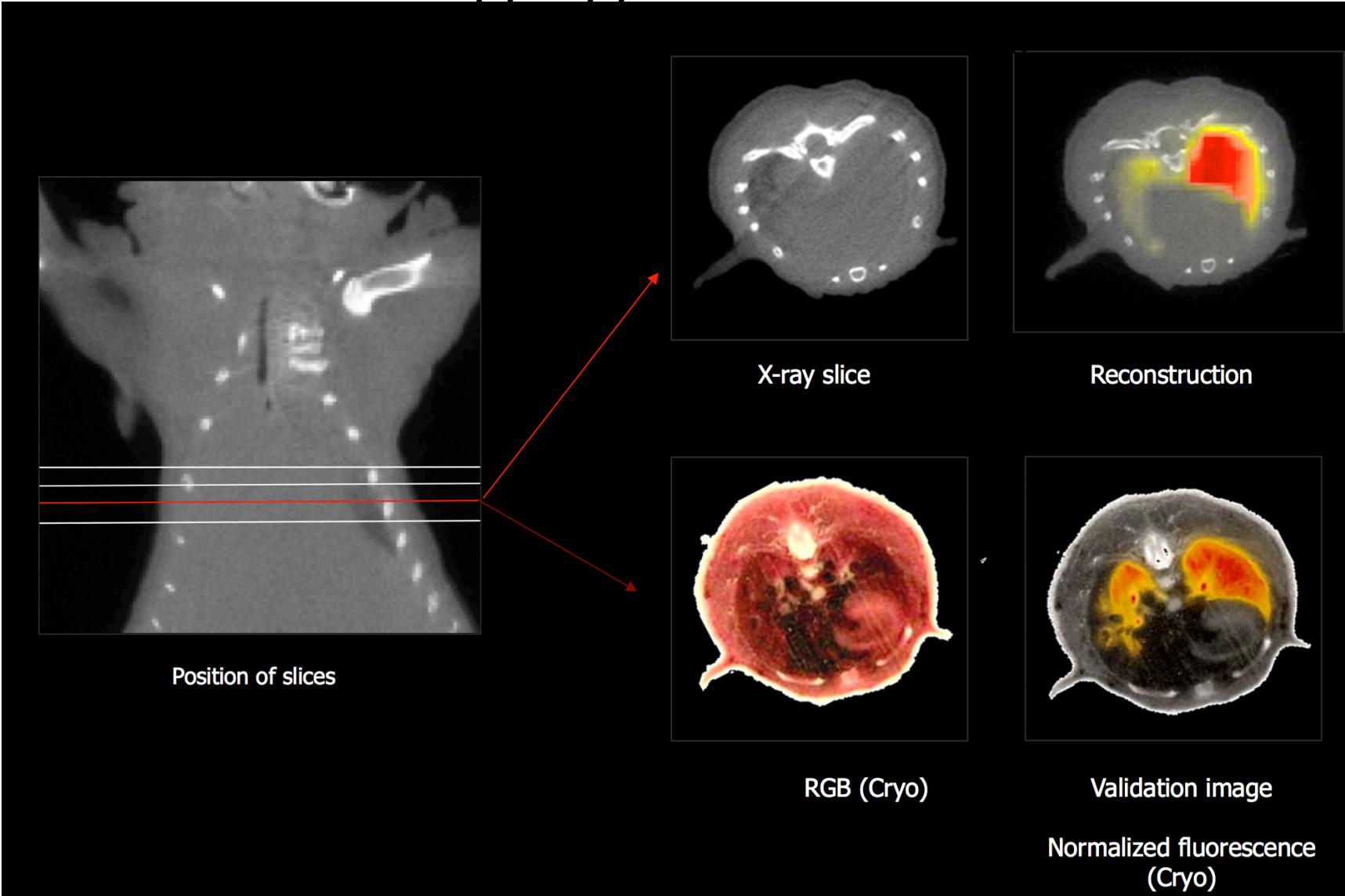
Targets a certain antigen on/  
in the cell

Over time the concentration  
will be higher in tissues  
where the antigen is over-  
expressed

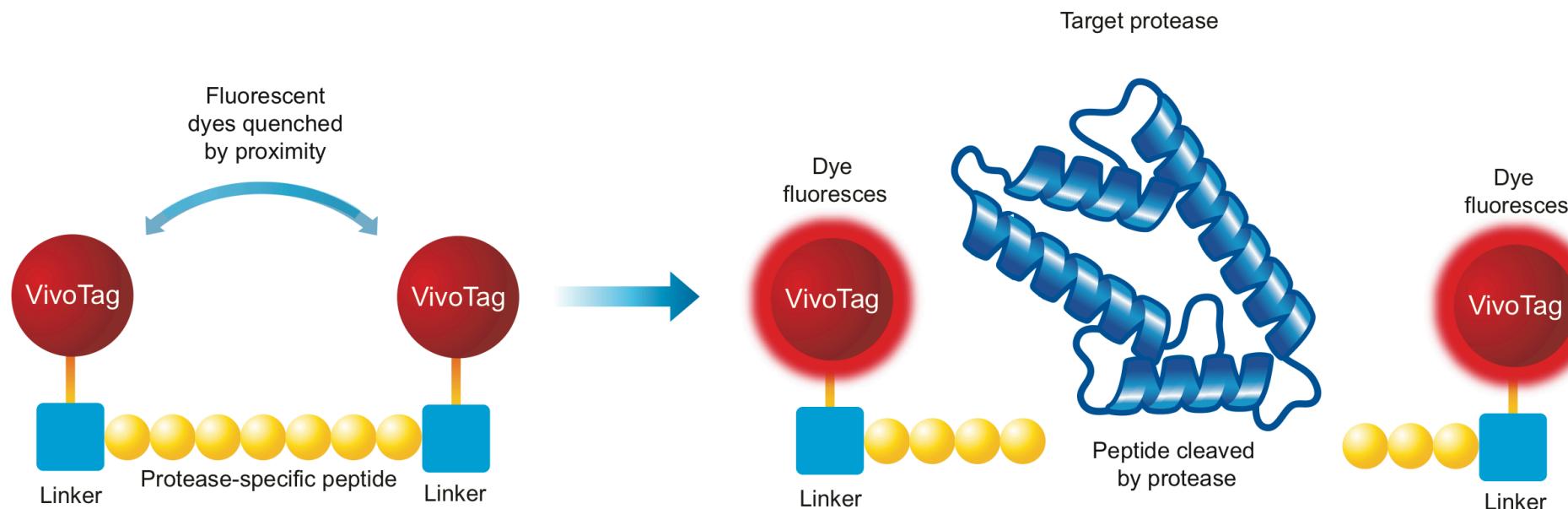
# Fluorescence imaging: Targeted fluorophores



# Fluorescence imaging in 3D

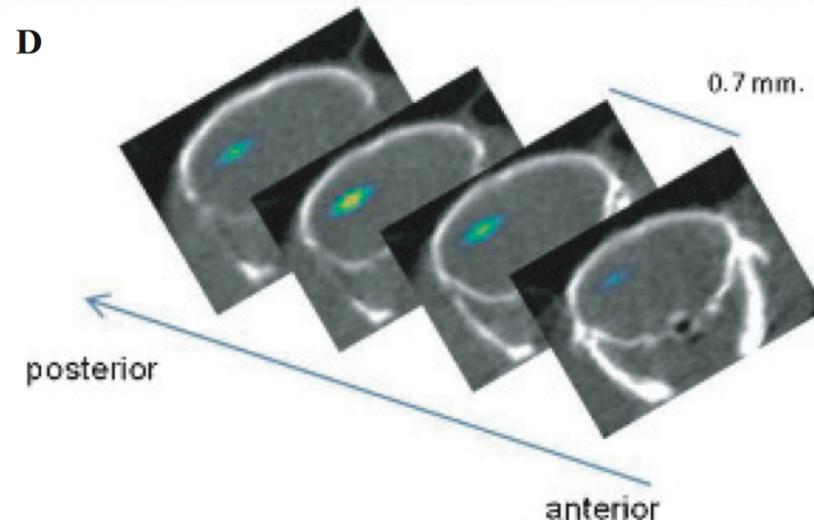
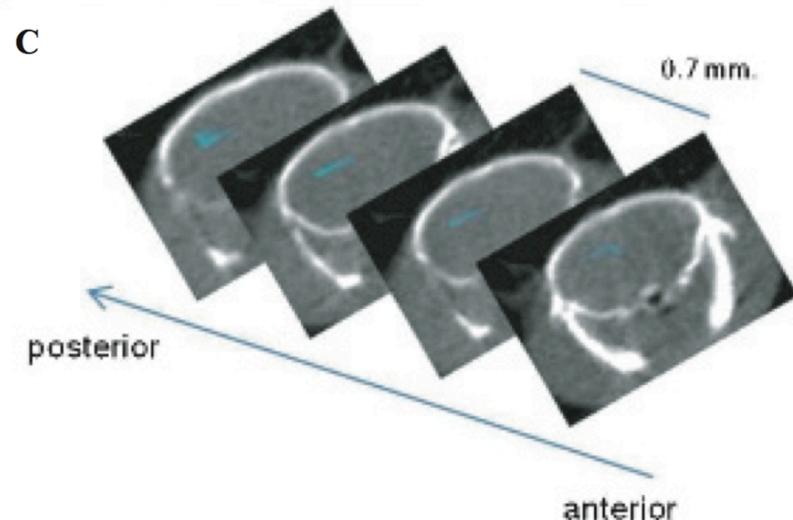
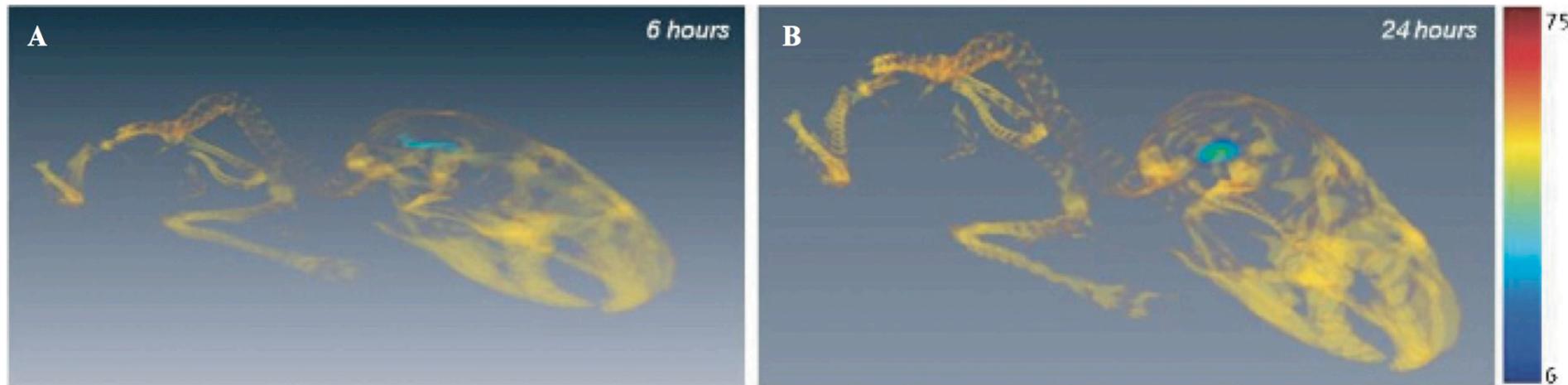


# Fluorescence imaging: Activatable fluorophores



# Fluorescence imaging: Activatable fluorophores

Imaging of MMP-activation after induction of cerebral ischemia



# Bioluminescence imaging

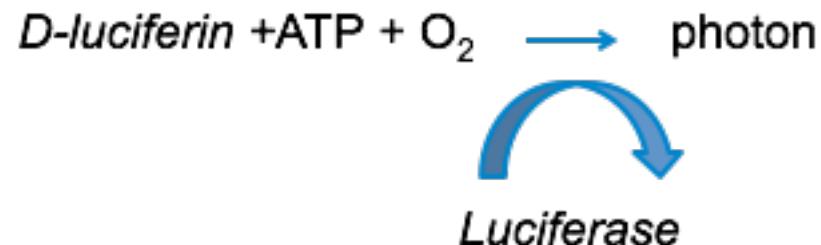


The firefly gene that encodes the ***Luciferase*** enzyme is infected into mice genome

***Luciferase*** is an enzyme catalysing a reaction between ***D-luciferin***, oxygen and ATP that yields light.



The expression of ***Luciferase*** can be tracked by imaging the green luminescence after administration of ***D-luciferin***

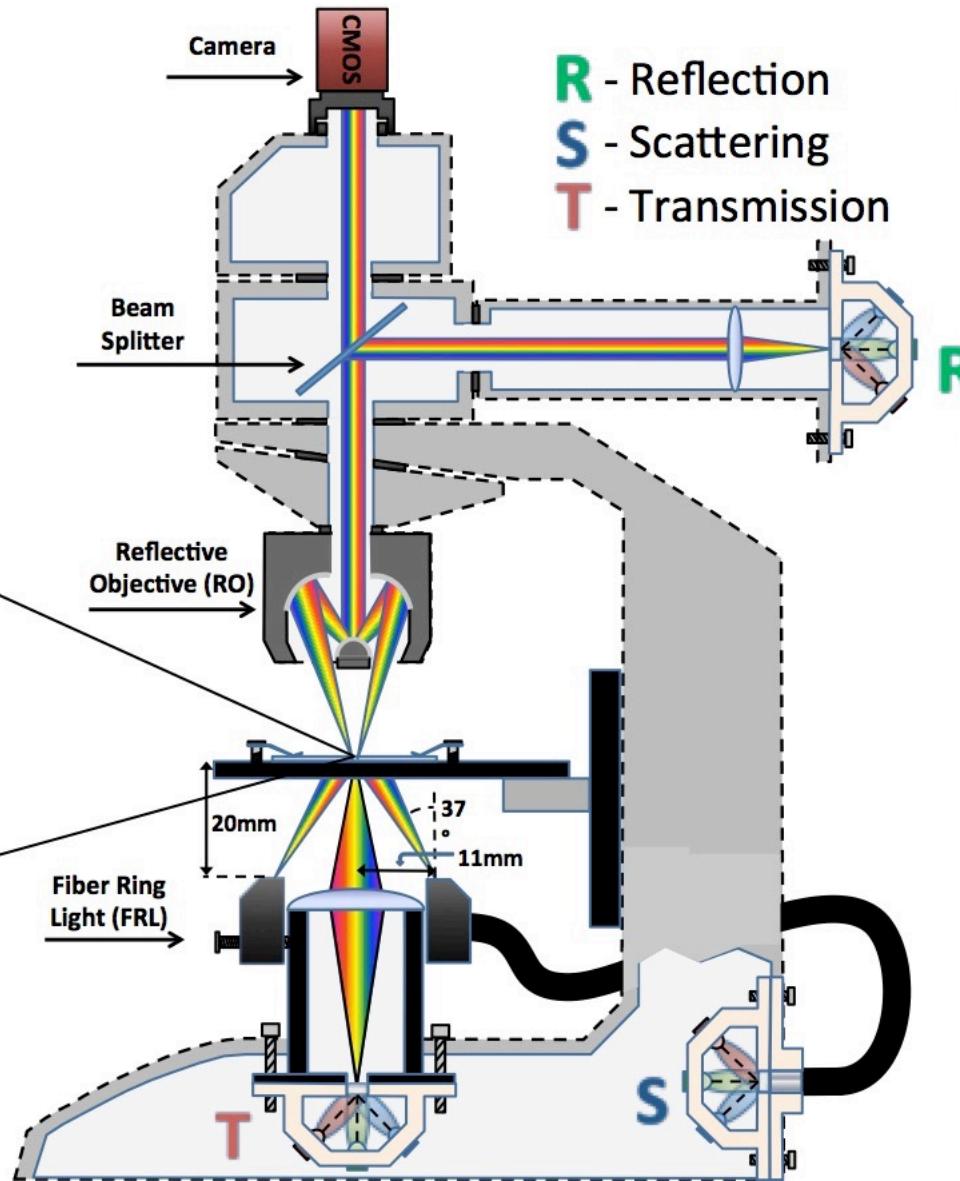
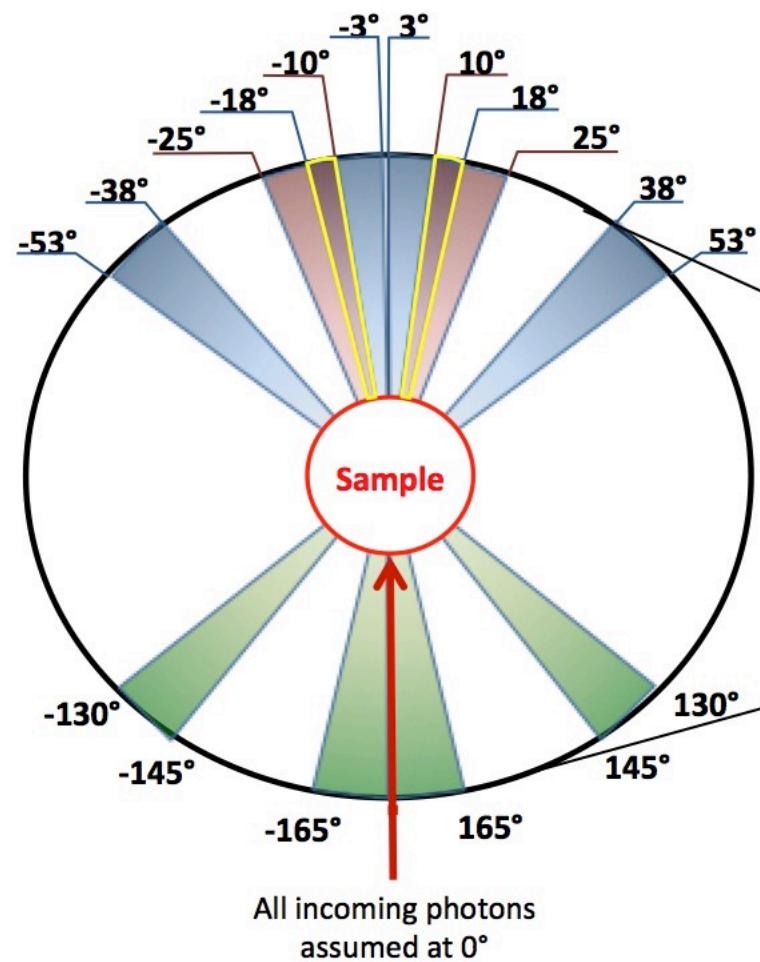


The oxidation of ***D-luciferin*** produces light at 500-560 nm.

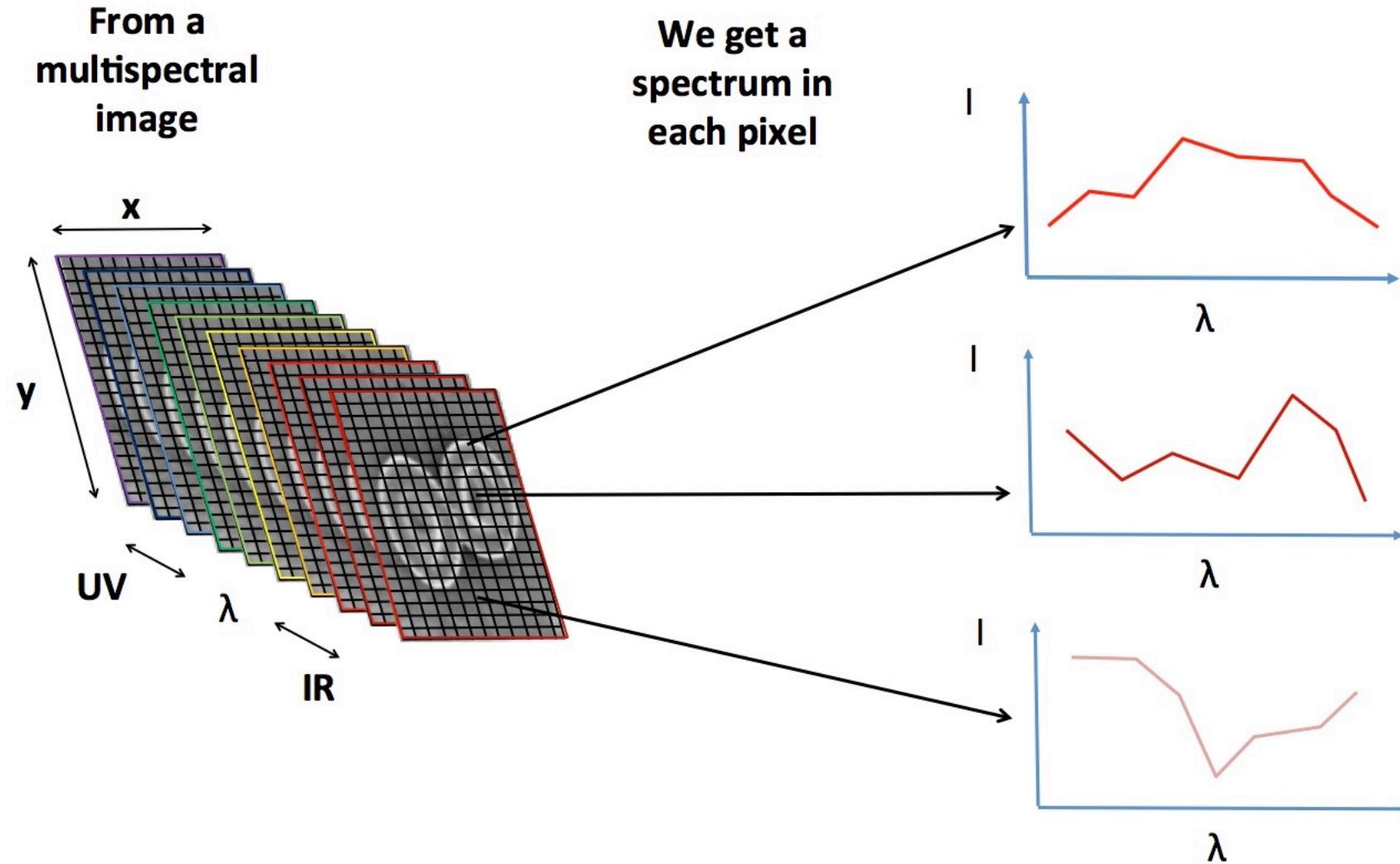
# Microscopic imaging

# Microscopic imaging

Angular Deflection Detection Regions

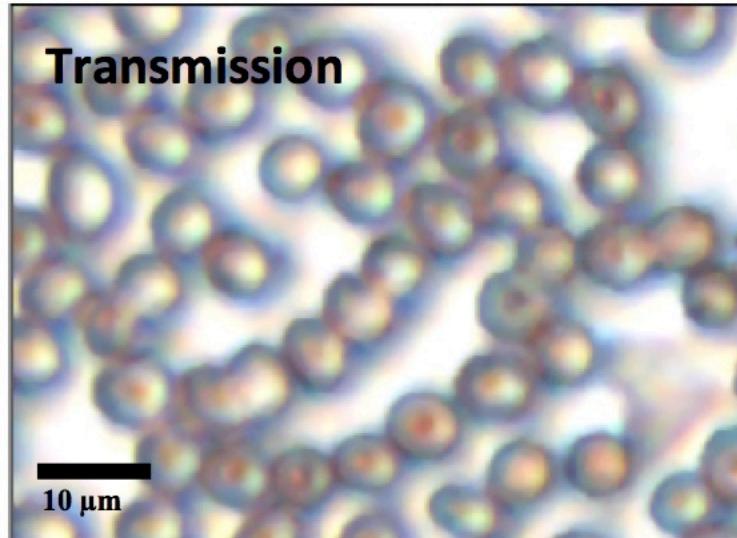
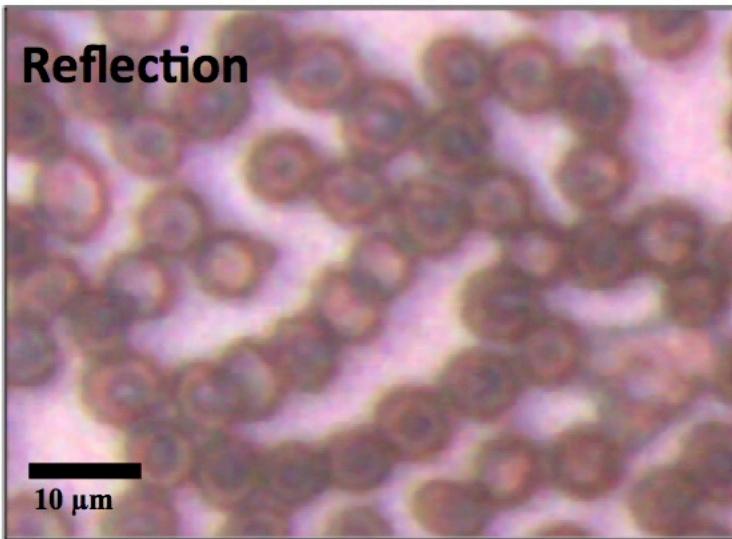
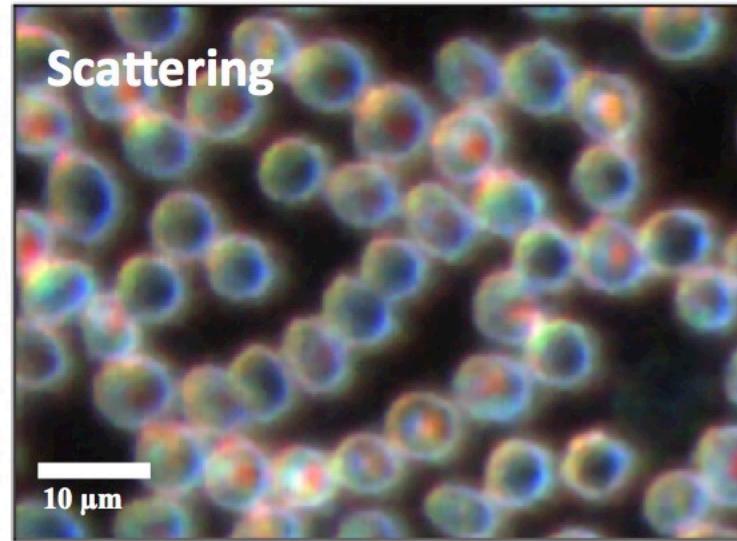


# Microscopic imaging

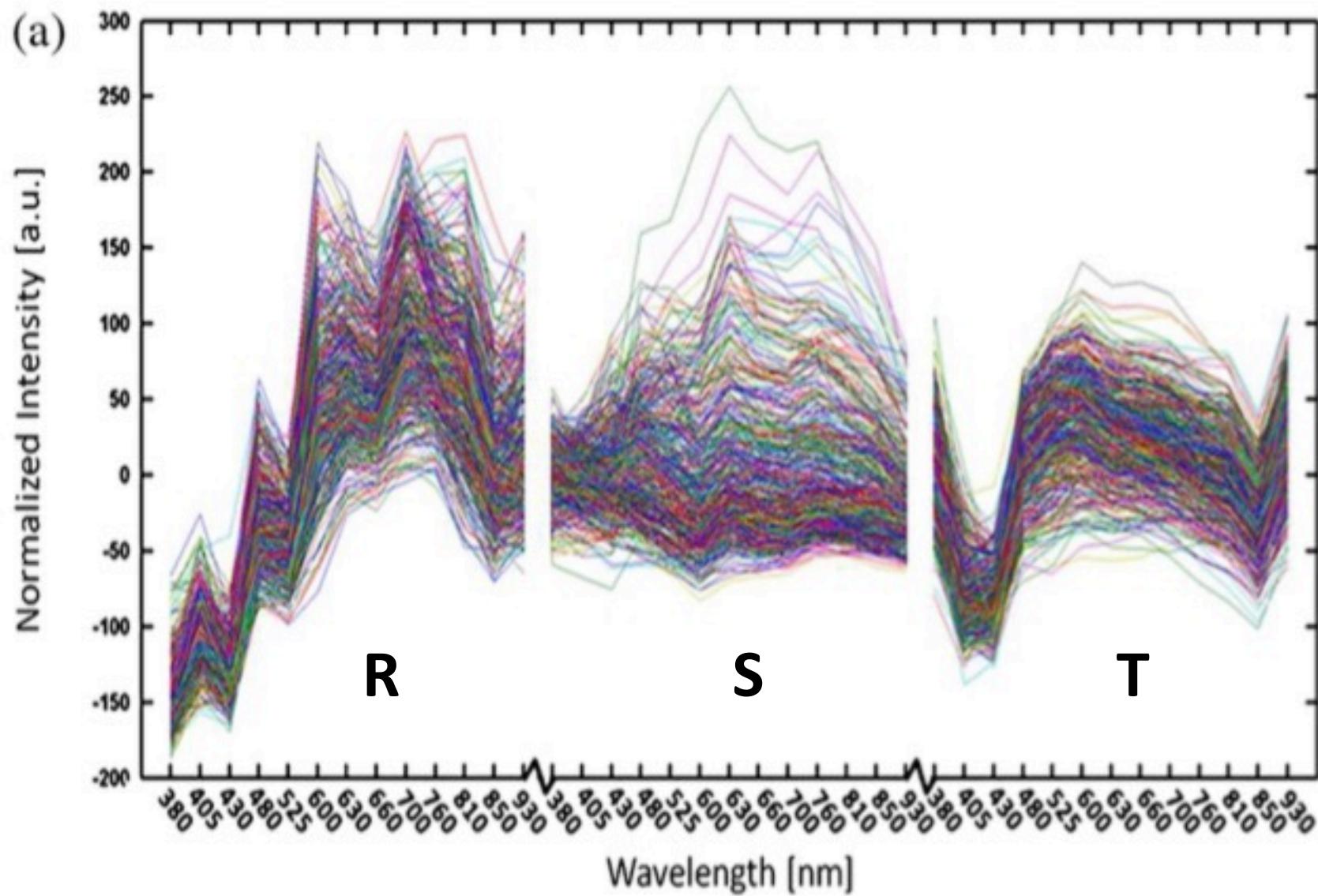


# Microscopic imaging

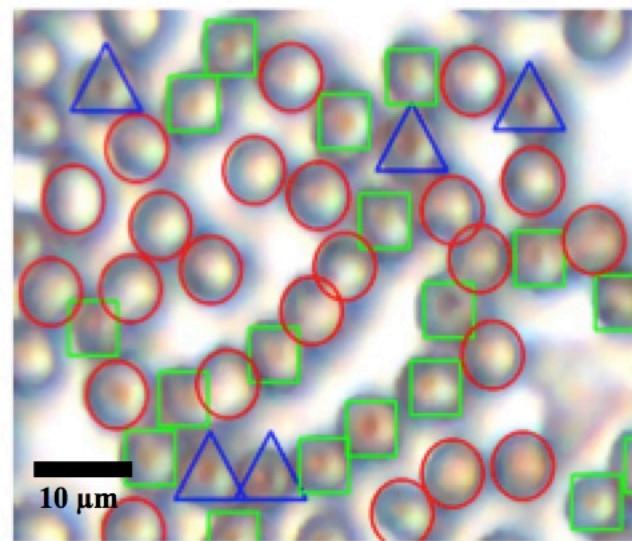
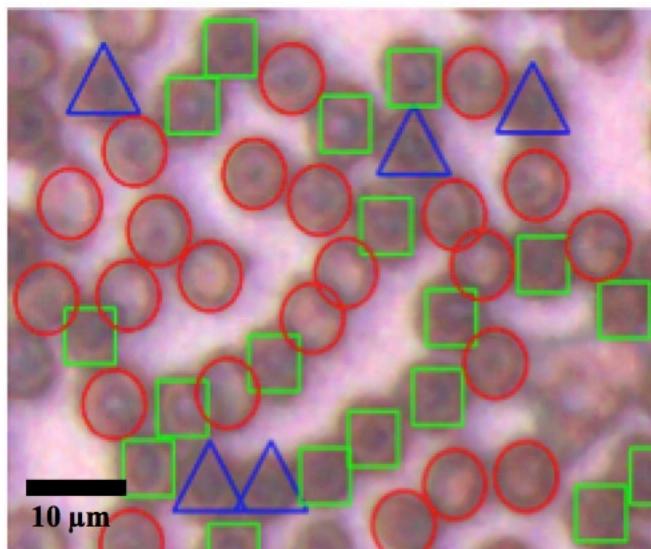
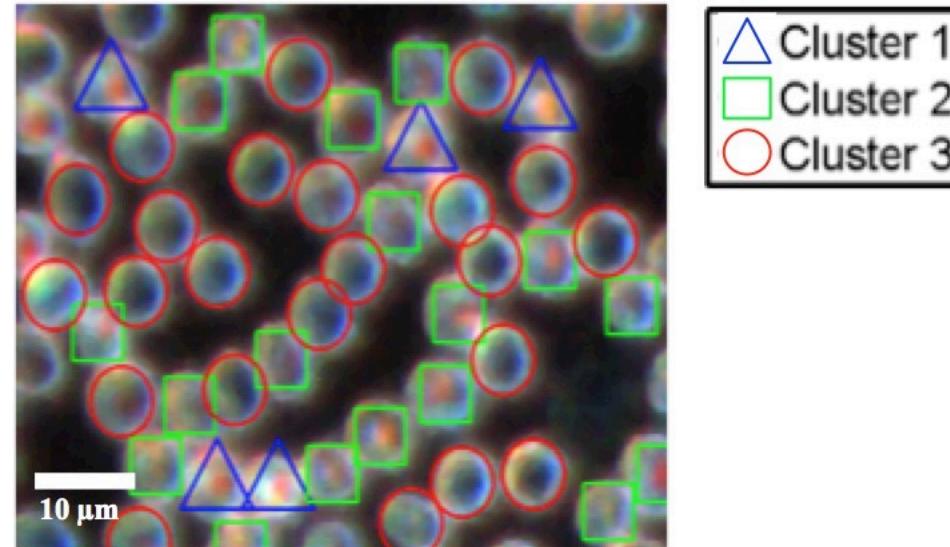
- Microscopy of red blood cells
- Find which red blood cells that are infected with the malaria parasite



# Microscopic imaging

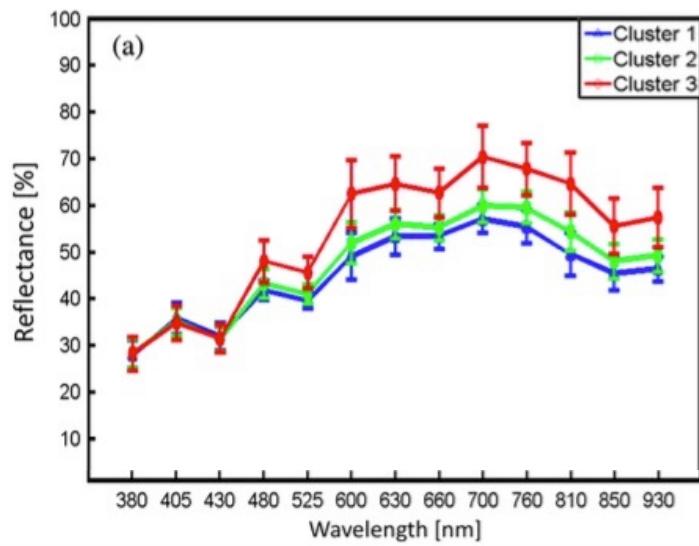


# Microscopic imaging

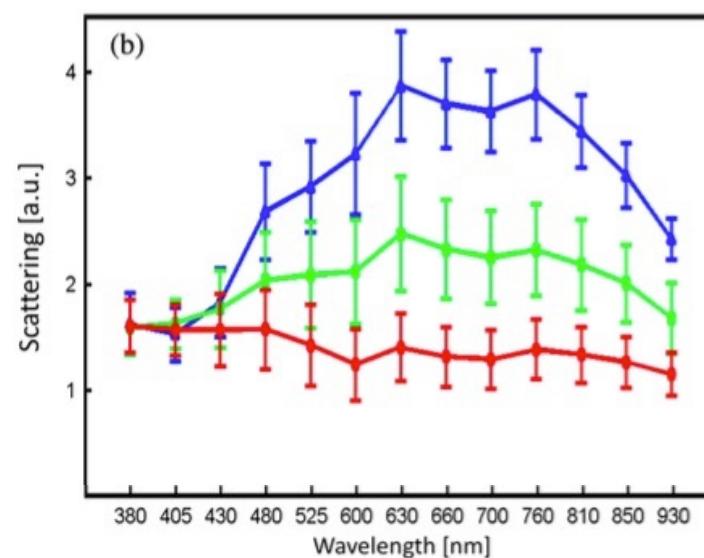


# Microscopic imaging

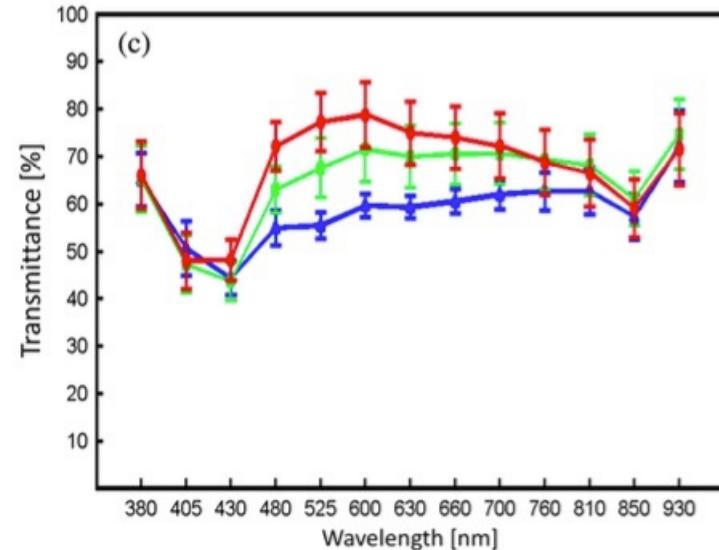
Reflectance



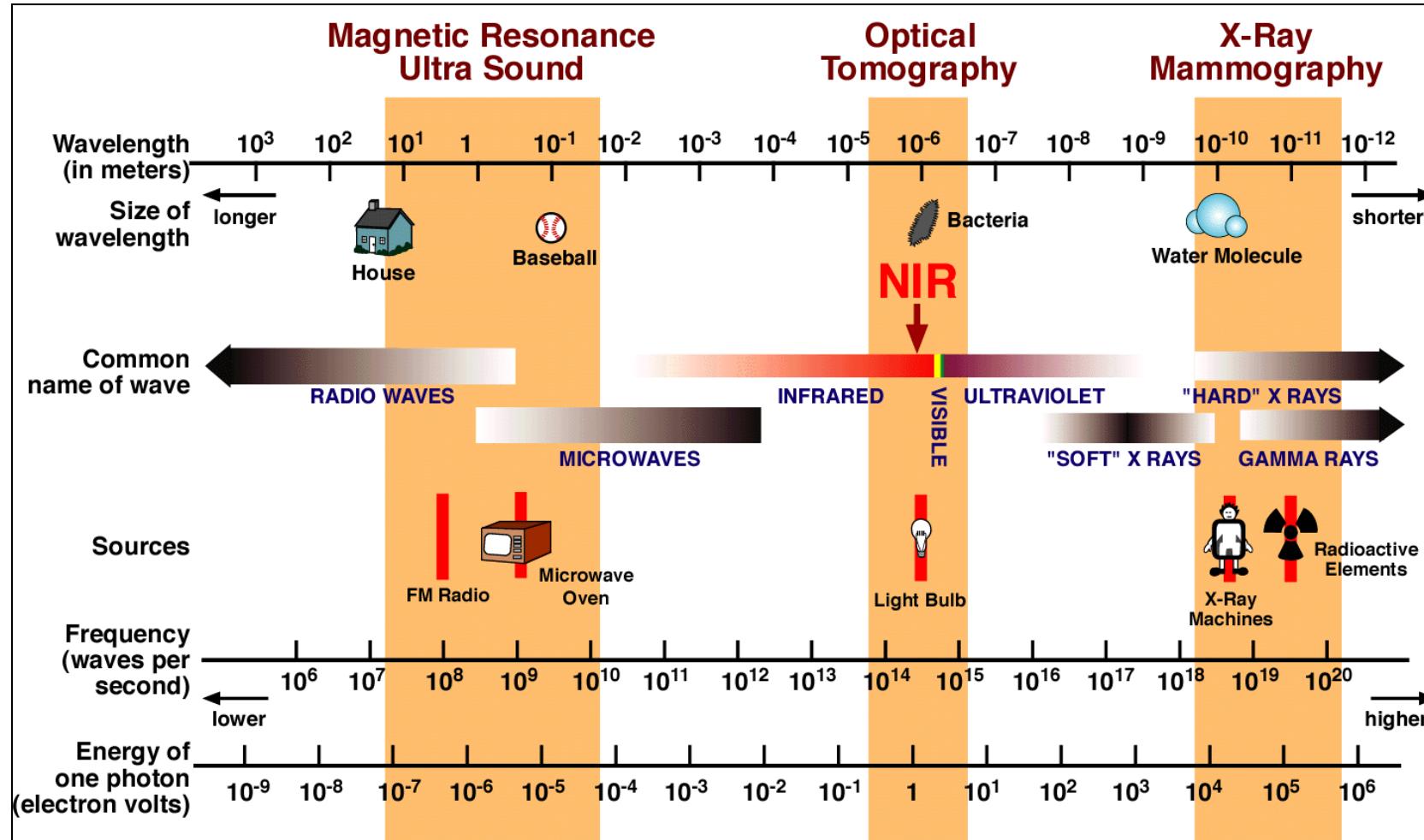
Scattering



Transmittance



# Multispectral imaging – from radiowaves to gammarays



# Multispectral imaging – from astronomy to microscopy

