

# Chapter 1 - Motivation

Computação Visual

# Get CV\_MATERIAL

(Download the material in the following link)

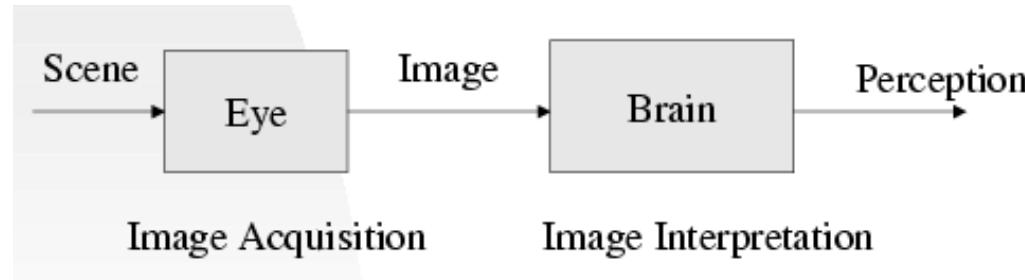
<https://github.com/JacintoCNascimento/ist-cv-2526>

# Topics to be addressed

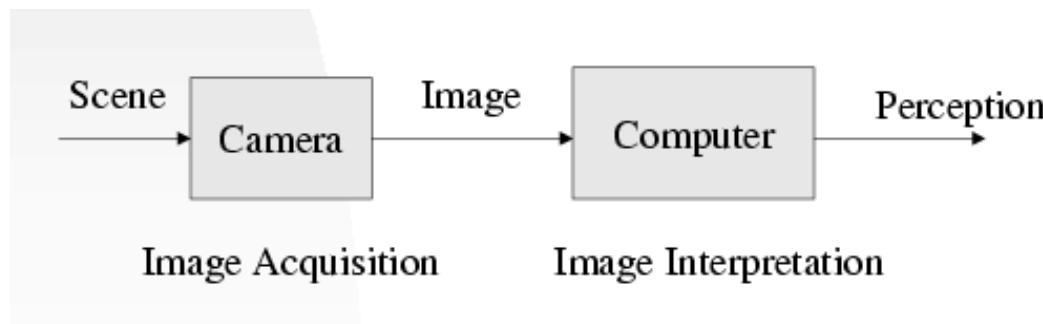
- What is the Image digital processing ?
- Digital images throughout the history;
- Applications (energy source):
  - Electromagnetic;
  - Acoustic;
  - Ultrasound;
  - Electronics (Electron beams /feixes de electrões);
- Components of the DIP (digital image processing);

# What is the digital image processing ?

Vision is the most advanced human sensory system!



Naturally, we try to replicate these capacities using machines.



# What is the digital image processing ?

An image can be defined by:

$f(x, y)$  where  $x, y$  are spatial coordinates and  $f$  defines the intensity or the color in that point.

If  $x, y$  and  $f$  are finite and discrete, the image can be considered as digital.

Thus, one possible definition for DIP :

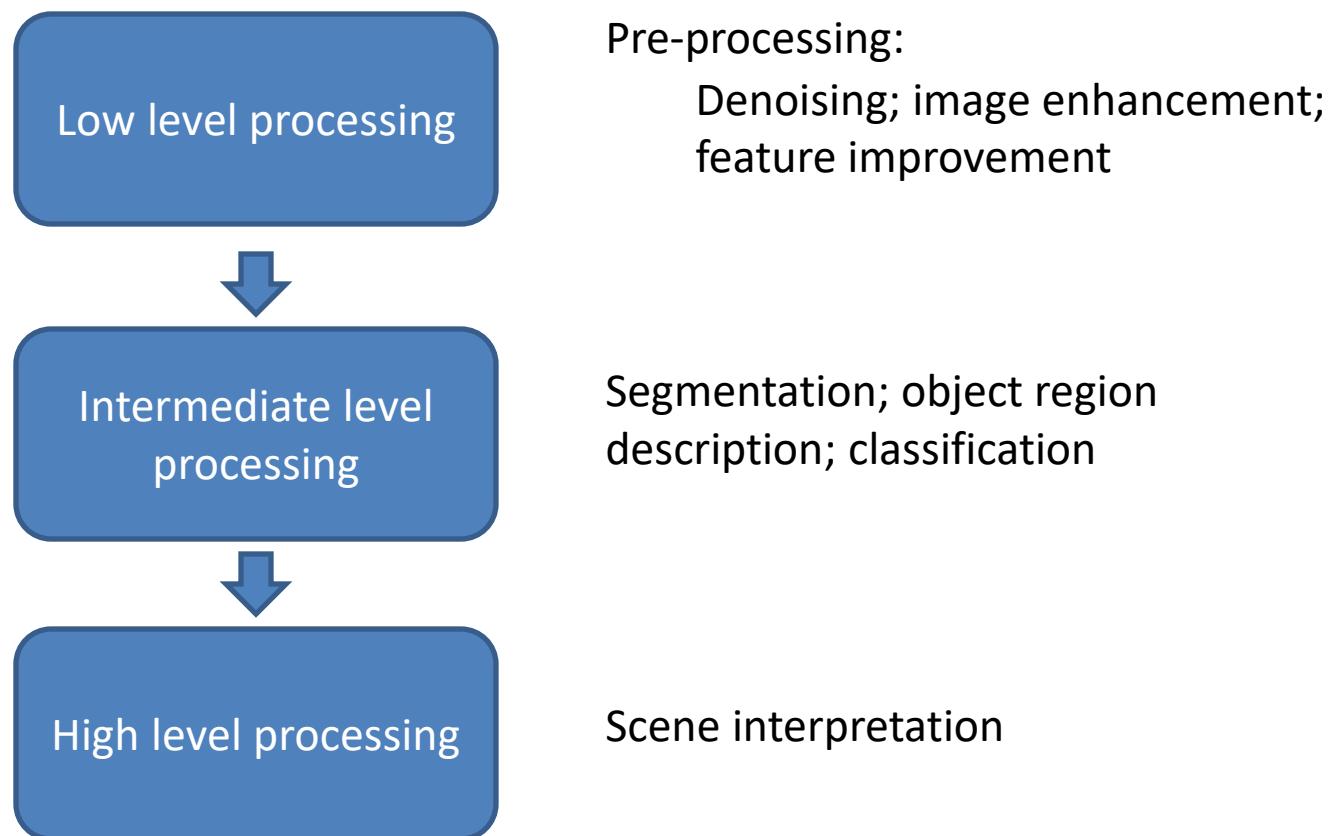
Encompasses processes whose inputs and outputs are images, also it encompasses processes of features extraction

# Related research areas

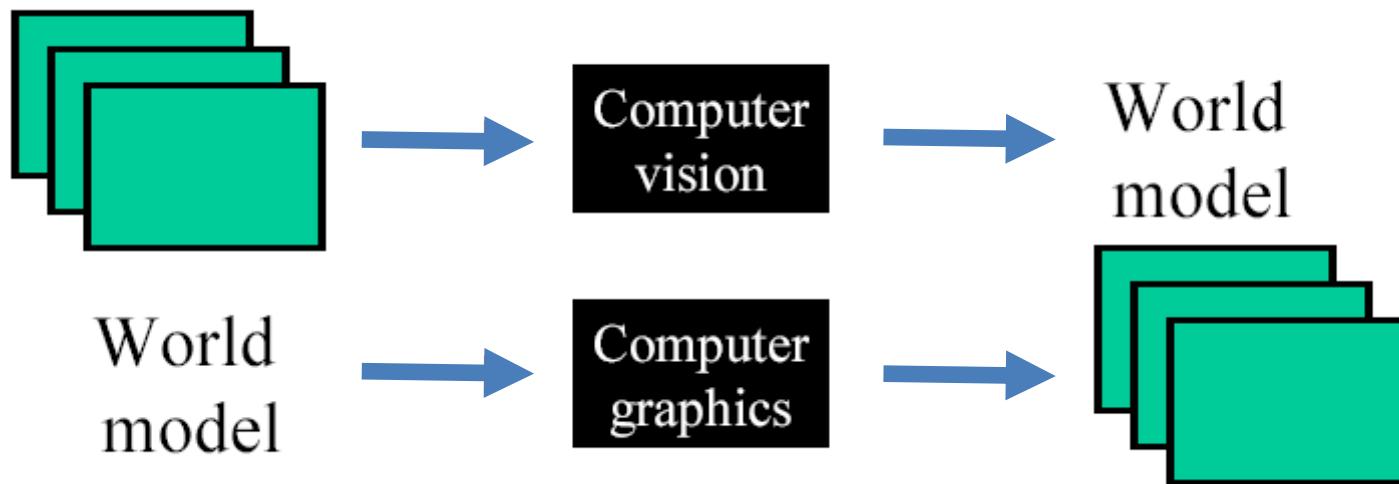
- *Image understanding*
- *Image Analysis*
- *Computer Vision*
- *Computer Graphics*
- Pattern Recognition
- *Artificial Intelligence*
- Etc...

# Frontiers between CV and IP

- Fuzzy! (not well defined)



# Computer Vision and Computer Graphics



# Digital imaging: some history



**FIGURE 1.1** A digital picture produced in 1921 from a coded tape by a telegraph printer with special type faces. (McFarlane.<sup>†</sup>)

Harry G. Bartholomew  
and  
Maynard D. McFarlane

Jet Propulsion Laboratory (Pasadena, California) -> *birth of the PDI*



**FIGURE 1.4** The first picture of the moon by a U.S. spacecraft. *Ranger 7* took this image on July 31, 1964 at 9:09 A.M. EDT, about 17 minutes before impacting the lunar surface. (Courtesy of NASA.)

# Digital images throughout history

- Landmark points in digital age

**1940** - John von Neumann Machine (CPU);

**1948** - Invention of the transistor (Bell Labs);

**1950/60** – Language development such as COBOL e FORTRAN;

**1958** – Invention of the integrated circuit (Texas);

**1960** – Development of the operating systems;

**1970** – Development of the microprocessors (Intel);

**1981** – Introduction of the personal computers (IBM – International Business Machines);

**1980** – Components miniaturisation (LI, VLSI, ULSI), for storing and visualization.

# Digital images throughout history

- Landmark points in digital age

2000- GPU [GeForce GTX 1070 – Nvidia](#)

GPU [GeForce GTX 1080 – Nvidia](#)

GPU [NVIDIA TITAN X Graphics Card](#)

TPU [TENSOR Processor Unit](#)

# Applications

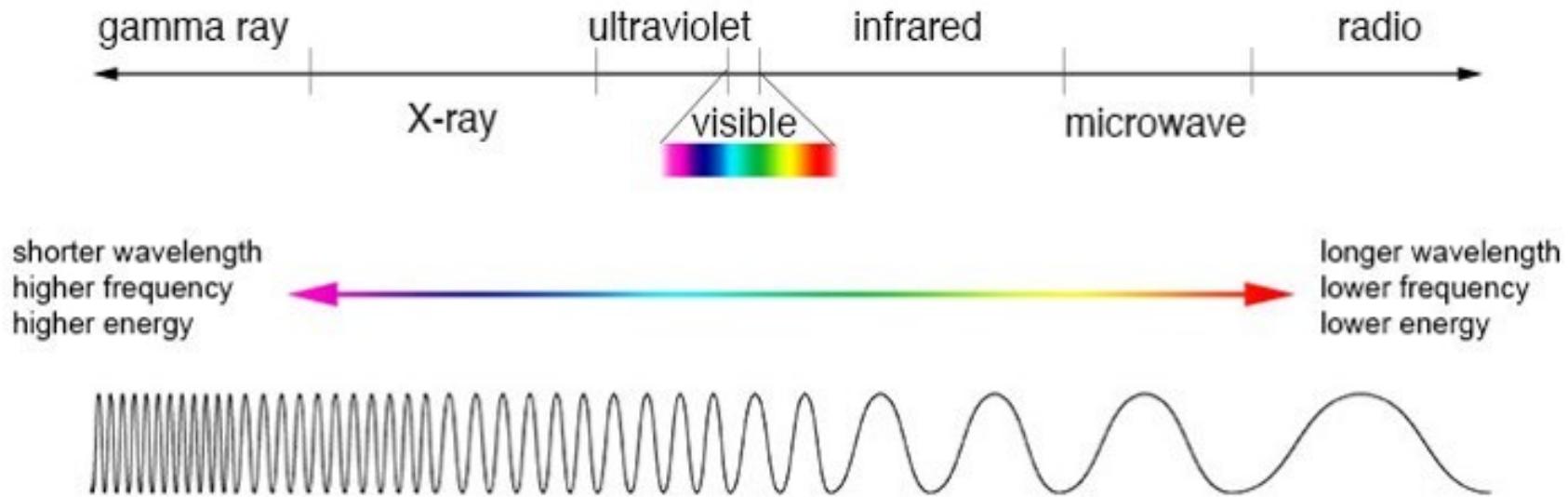
- Is there any area where image digital processing is not used?

One way to describe its application is to resort to the signal energy font:

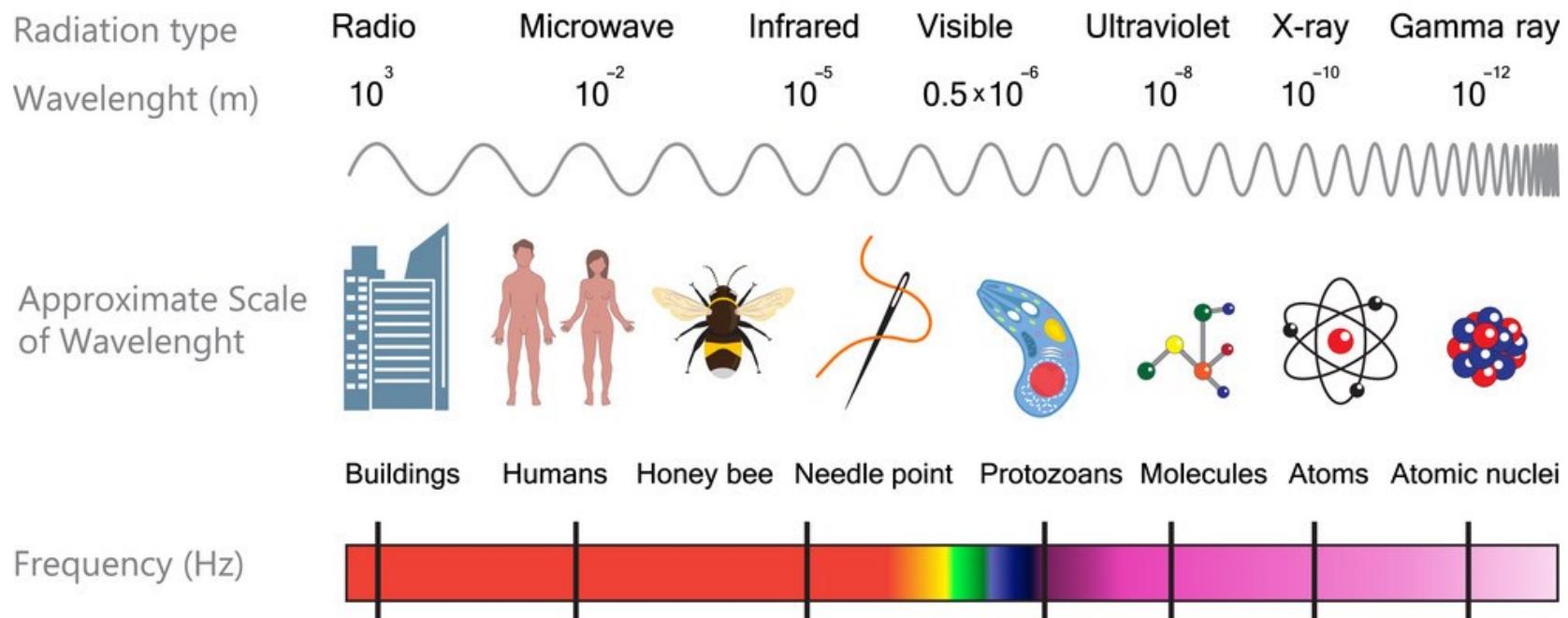
- Electromagnetic;
- Acoustic;
- Ultra-sound;
- Electronic;

# Electromagnetic Spectrum

(the main source of energy for images in use)



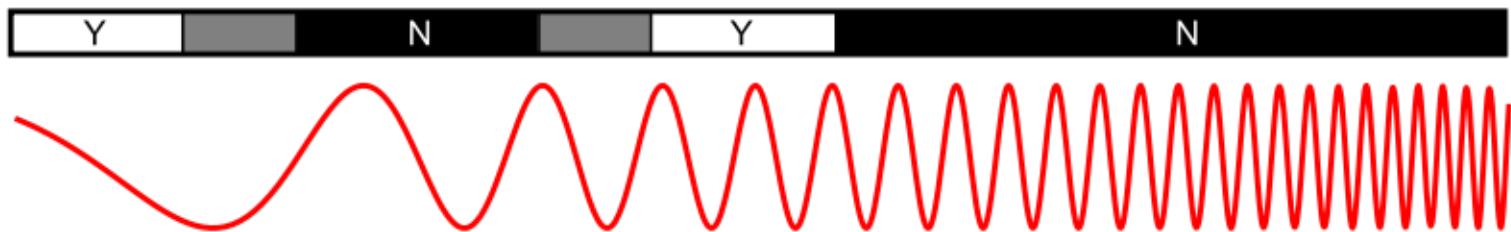
# Electromagnetic Spectrum



# Electromagnetic Spectrum

(the main source of energy for images in use)

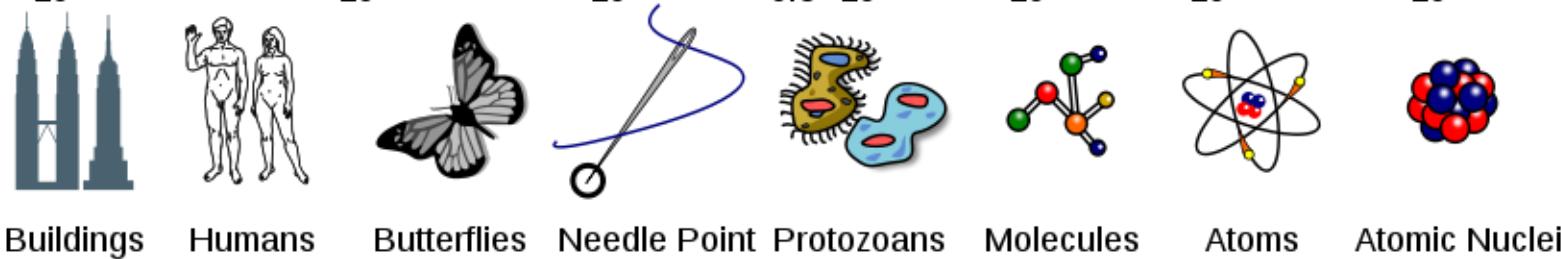
Penetrates Earth's Atmosphere?



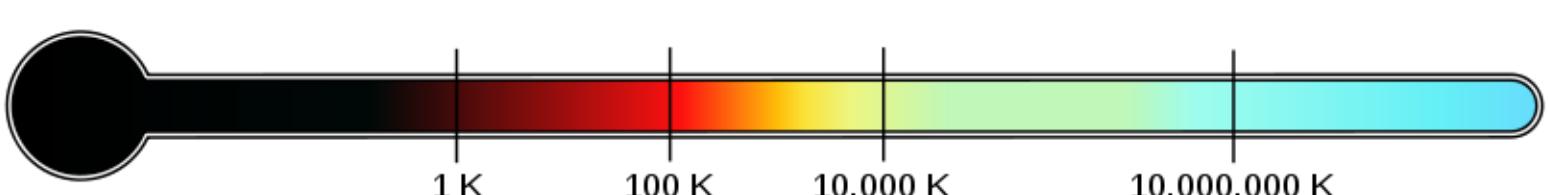
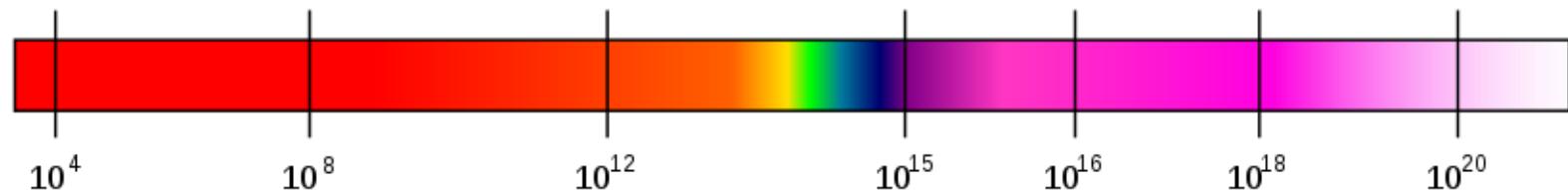
Radiation Type  
Wavelength (m)

Radiation Type	Radio	Microwave	Infrared	Visible	Ultraviolet	X-ray	Gamma ray
Wavelength (m)	$10^3$	$10^{-2}$	$10^{-5}$	$0.5 \times 10^{-6}$	$10^{-8}$	$10^{-10}$	$10^{-12}$

Approximate Scale  
of Wavelength



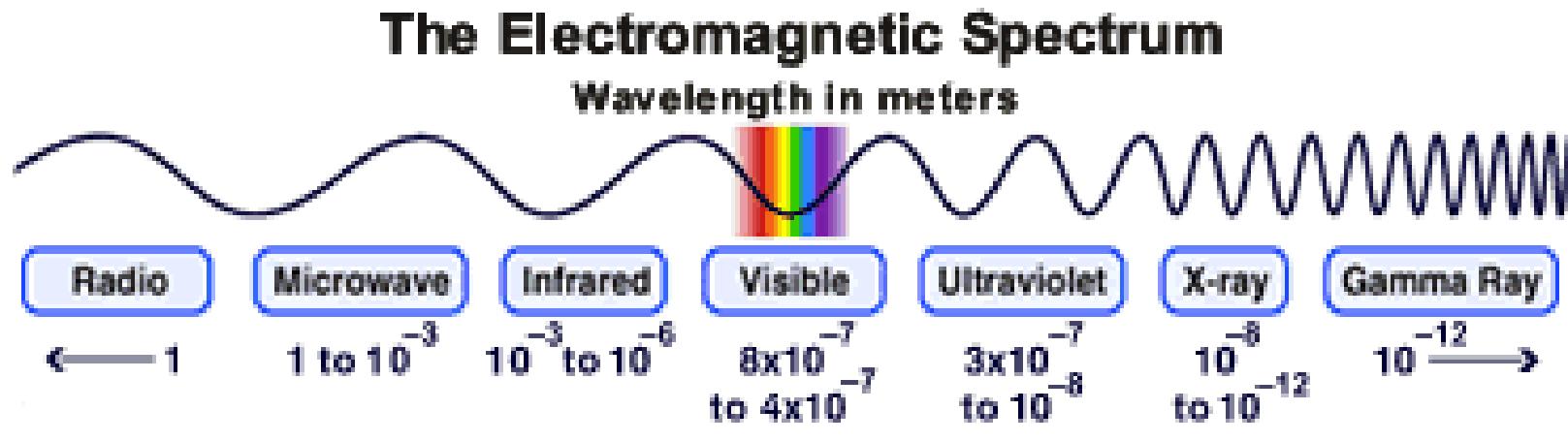
Frequency (Hz)



Temperature of  
objects at which  
this radiation is the  
most intense  
wavelength emitted

# Electromagnetic Spectrum

(the main source of energy for images in use)



About the size of:



Buildings



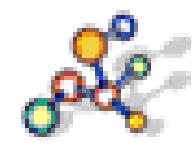
Grains  
of sugar



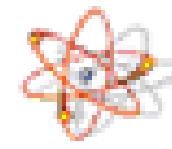
Protozoans



Bacteria



Molecules



Atoms

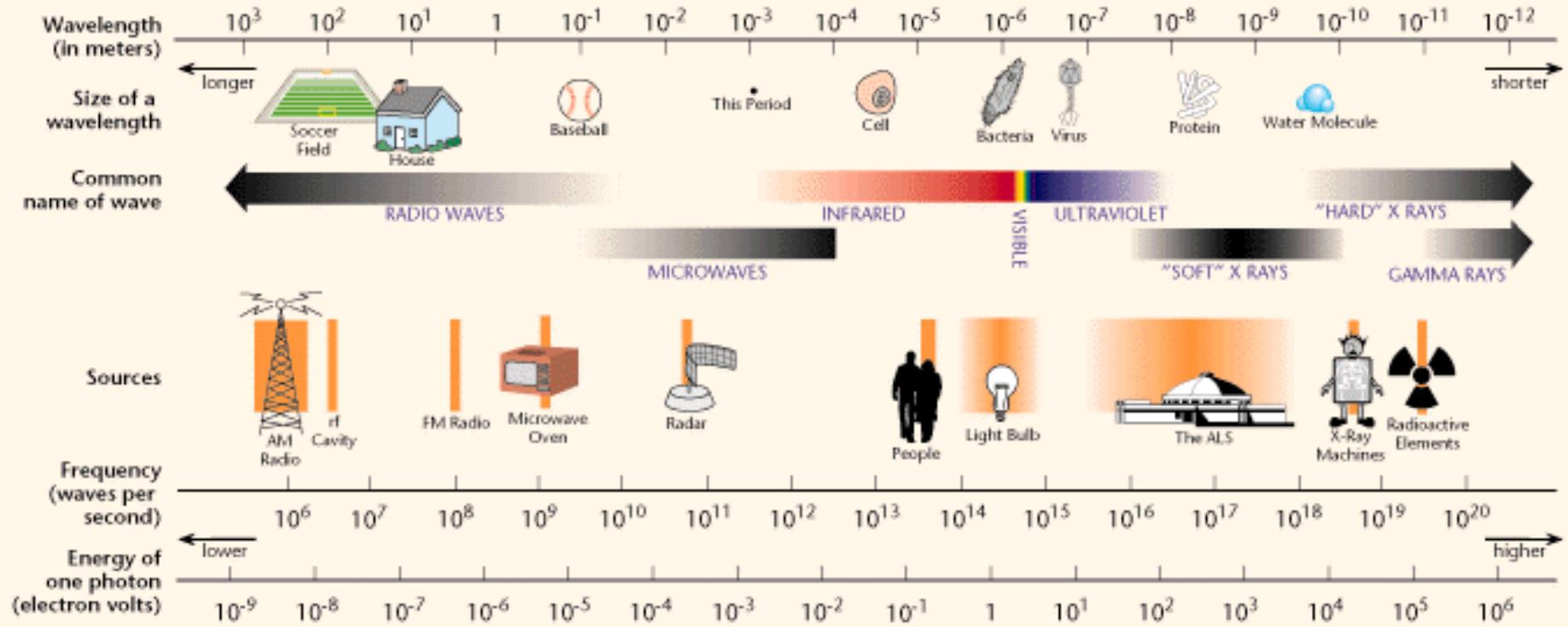


Atomic  
nuclei

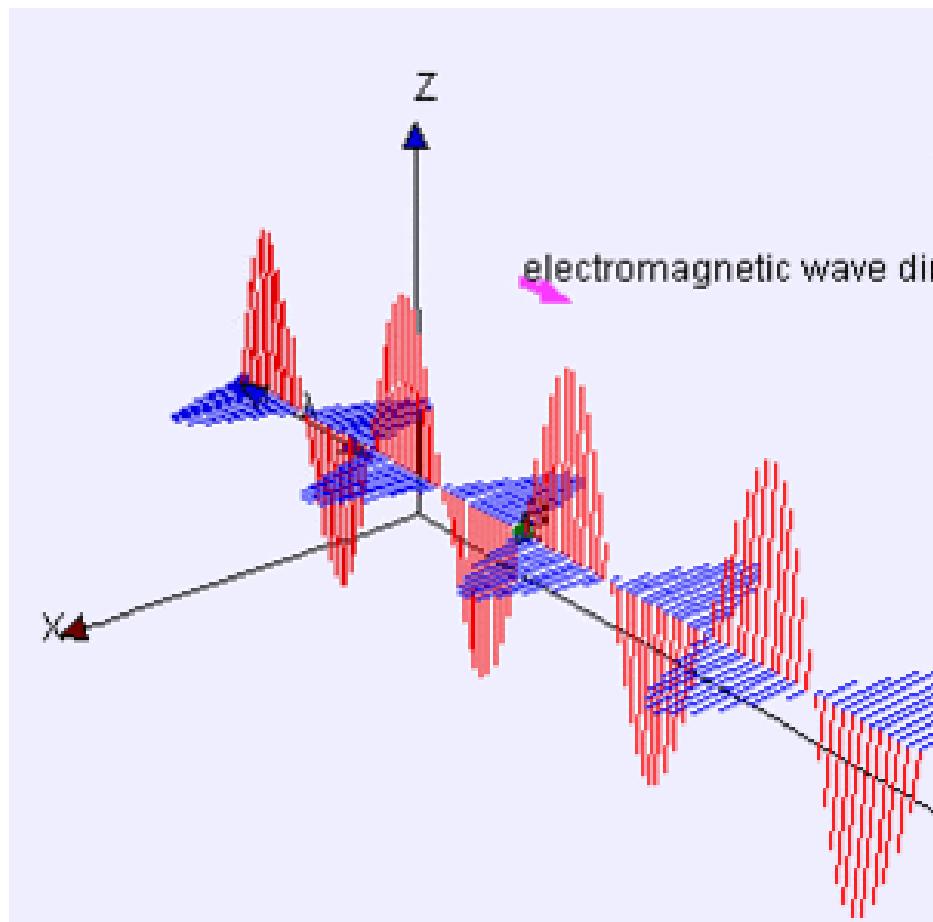
# Electromagnetic Spectrum

(the main source of energy for images in use)

## THE ELECTROMAGNETIC SPECTRUM



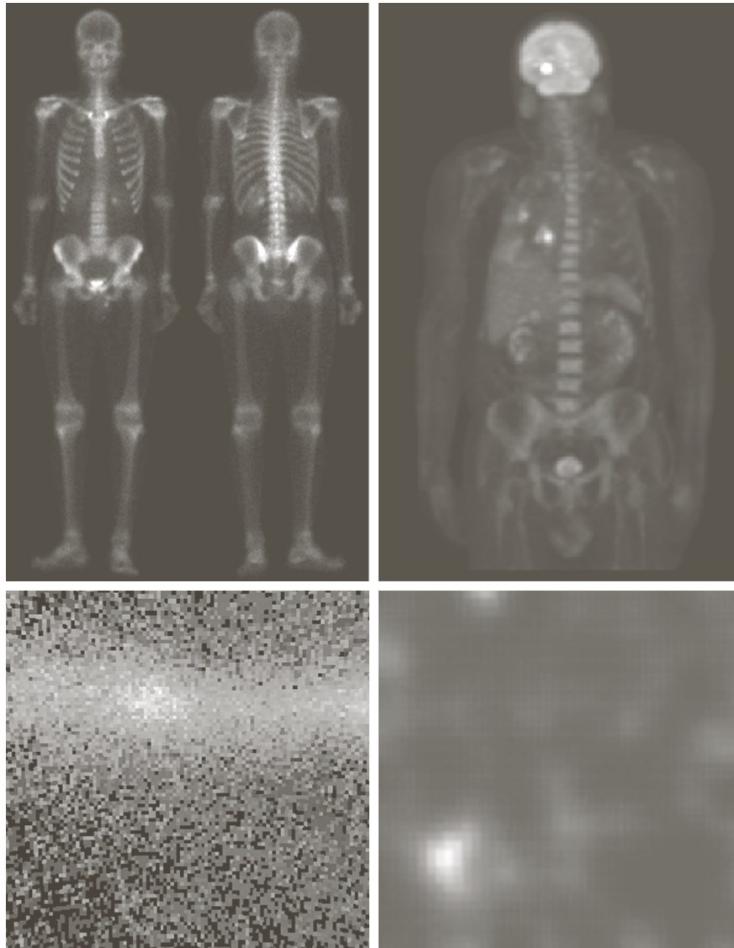
# Behaviour of the Electromagnetic Waves



# Imaging in Gamma ray

Applications in  
Nuclear medicine

A star in the  
constellation  
of Cygnus  
that exploded  
generating  
gas clouds



a b  
c d

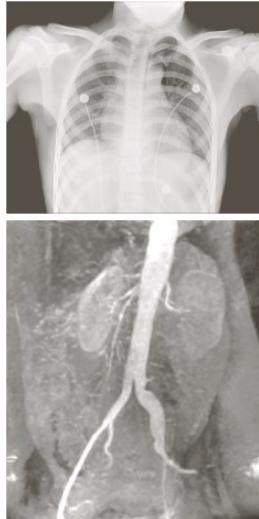
**FIGURE 1.6**  
Examples of  
gamma-ray  
imaging. (a) Bone  
scan. (b) PET  
image. (c) Cygnus  
Loop. (d) Gamma  
radiation (bright  
spot) from a  
reactor valve.  
(Images courtesy  
of (a) G.E.  
Medical Systems,  
(b) Dr. Michael  
E. Casey, CTI  
PET Systems,  
(c) NASA,  
(d) Professors  
Zhong He and  
David K. Wehe,  
University of  
Michigan.)

Image of gamma  
radiation from a valve in  
a nuclear reactor

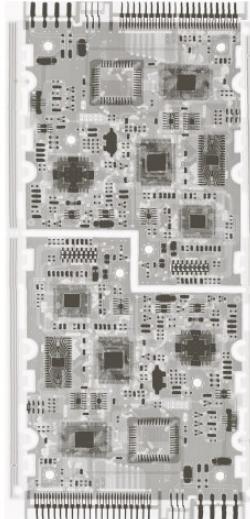
# Imaging in X ray

(are among the oldest sources of EM, best known use in medical diagnosis, e.g. Tomography)

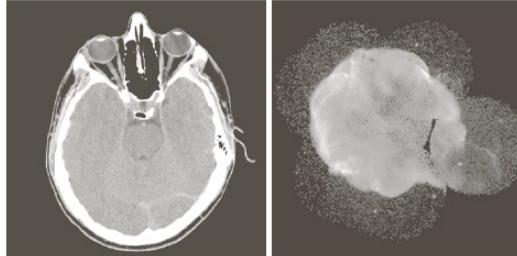
(angiography)



(TAC)



(TAC industrial)



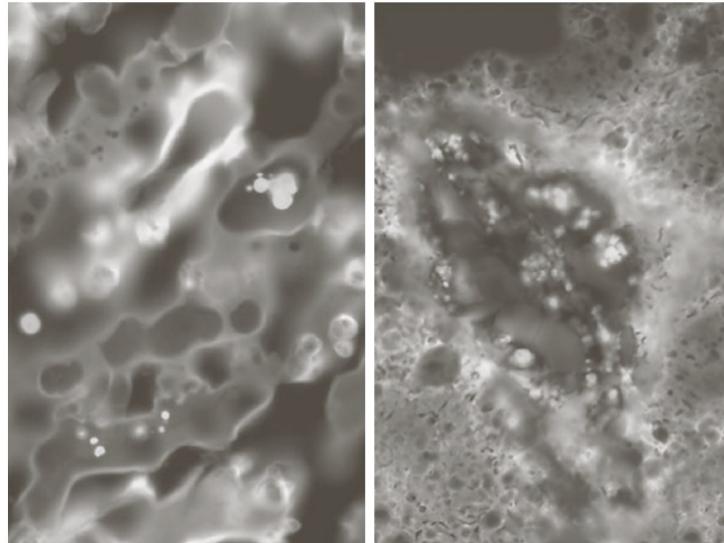
(TAC astronomic)

a  
b  
c  
d  
e

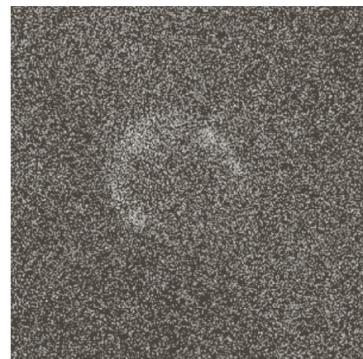
**FIGURE 1.7** Examples of X-ray imaging. (a) Chest X-ray. (b) Aortic angiogram. (c) Head CT. (d) Circuit boards. (e) Cygnus Loop. (Images courtesy of (a) and (c) Dr. David R. Pickens, Dept. of Radiology & Radiological Sciences, Vanderbilt University Medical Center; (b) Dr. Thomas R. Gest, Division of Anatomical Sciences, University of Michigan Medical School; (d) Mr. Joseph E. Pascente, Lixi, Inc.; and (e) NASA.)

# Imaging in the UV band

(fluorescent microscopy)



(astronomy)



(Cygnus Loop in high-region of the ultraviolet band)

a b  
c

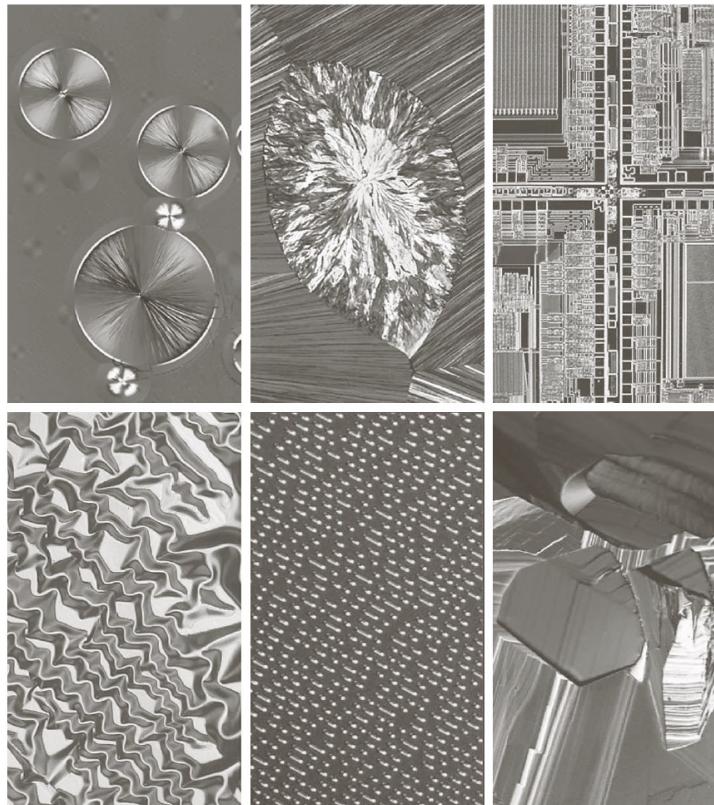
## FIGURE 1.8

Examples of ultraviolet imaging.

- (a) Normal corn.
- (b) Smut corn.
- (c) Cygnus Loop.  
(Images courtesy of (a) and (b) Dr. Michael W. Davidson, Florida State University, (c) NASA.)

# Imaging in the visible and infrared Band (1)

(Images obtained with a light microscope)



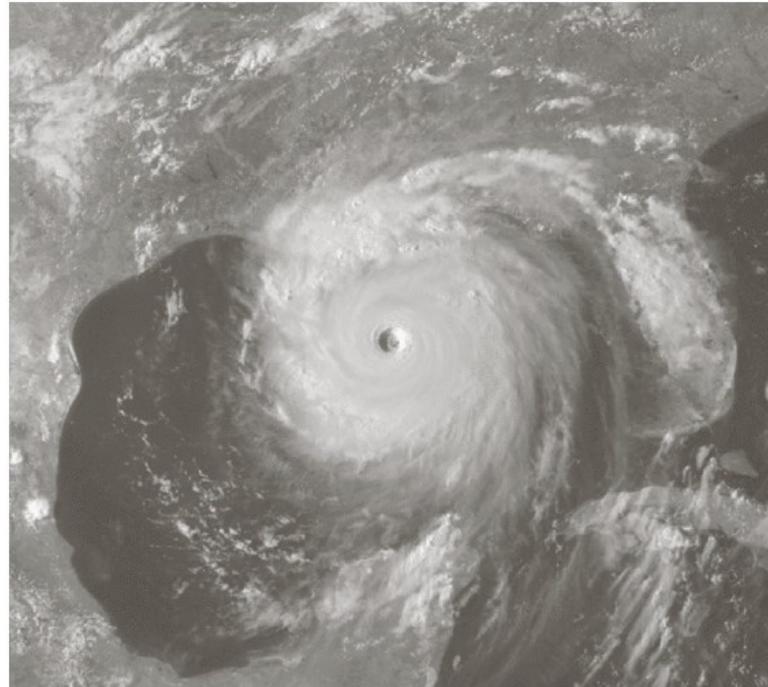
These examples range from Pharmaceutical and Micro-inspection to material characterization

**FIGURE 1.9** Examples of light microscopy images. (a) Taxol (anticancer agent), magnified 250×. (b) Cholesterol—40×. (c) Microprocessor—60×. (d) Nickel oxide thin film—600×. (e) Surface of audio CD—1750×. (f) Organic superconductor—450×. (Images courtesy of Dr. Michael W. Davidson, Florida State University.)

# Imaging in the visible band (2)

Satellite image with a hurricane

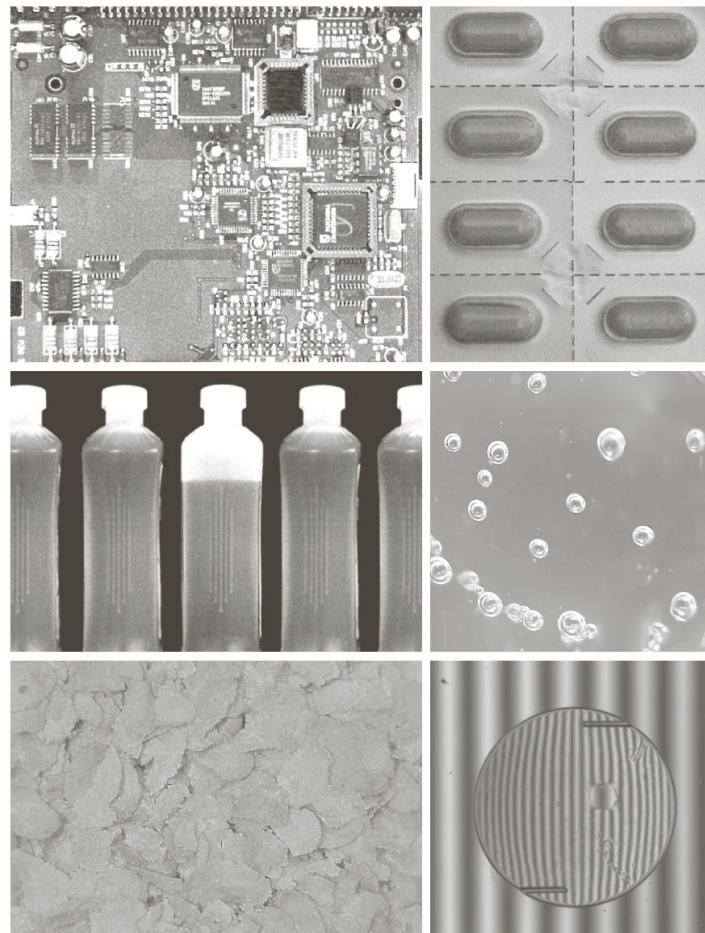
Weather observation and prediction



**FIGURE 1.11**  
Satellite image of Hurricane Katrina taken on August 29, 2005.  
(Courtesy of NOAA.)

# Imaging in the visible band (3)

## Automatic visual inspection



a | b  
c | d  
e | f

**FIGURE 1.14**  
Some examples of manufactured goods often checked using digital image processing.  
(a) A circuit board controller.  
(b) Packaged pills.  
(c) Bottles.  
(d) Air bubbles in a clear-plastic product.  
(e) Cereal.  
(f) Image of intraocular implant.  
(Fig. (f) courtesy of Mr. Pete Sites, Perceptics Corporation.)

# Imaging in the visible band (4)

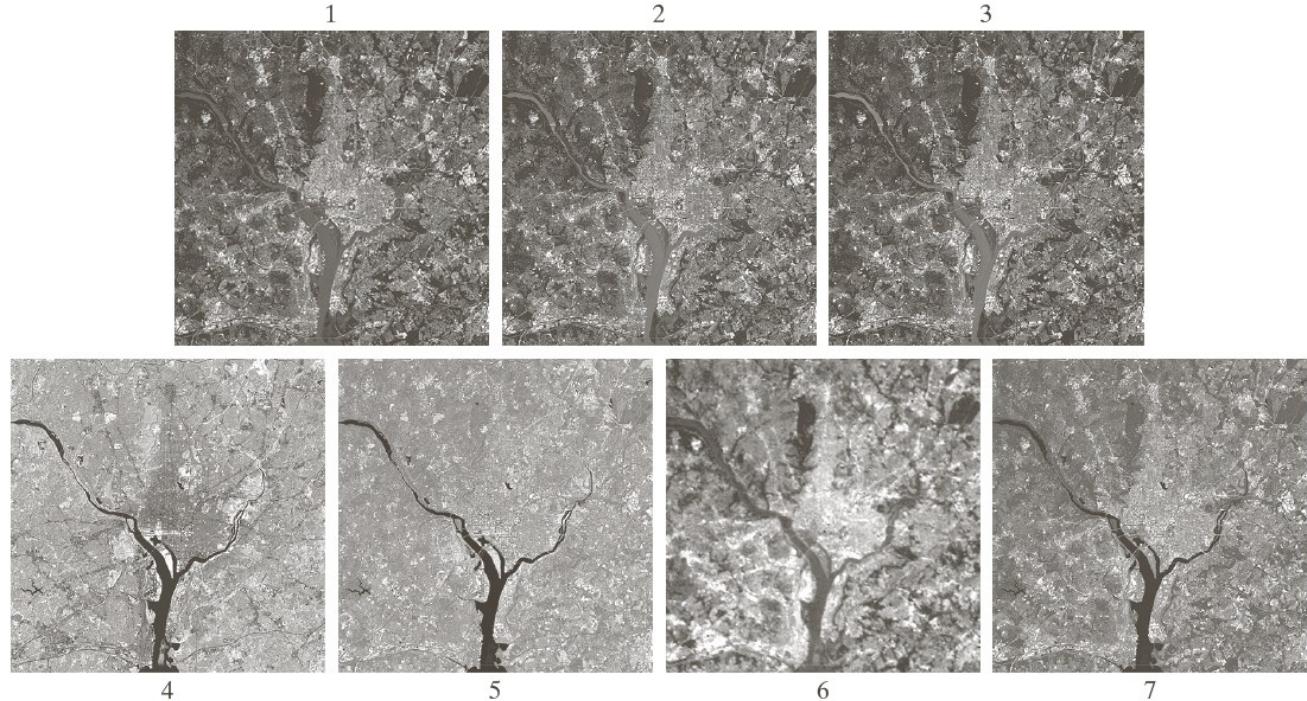
(which we are more accustomed to seeing)



a b  
c  
d

**FIGURE 1.15**  
Some additional examples of imaging in the visual spectrum.  
(a) Thumb print.  
(b) Paper currency.  
(c) and (d) Automated license plate reading.  
(Figure (a) courtesy of the National Institute of Standards and Technology.  
Figures (c) and (d) courtesy of Dr. Juan Herrera, Perceptics Corporation.)

# Imaging in infrared band (1)



**FIGURE 1.10** LANDSAT satellite images of the Washington, D.C. area. The numbers refer to the thematic bands in Table 1.1. (Images courtesy of NASA.)

Band No.	Name	Wavelength ( $\mu\text{m}$ )	Characteristics and Uses
1	Visible blue	0.45–0.52	Maximum water penetration
2	Visible green	0.52–0.60	Good for measuring plant vigor
3	Visible red	0.63–0.69	Vegetation discrimination
4	Near infrared	0.76–0.90	Biomass and shoreline mapping
5	Middle infrared	1.55–1.75	Moisture content of soil and vegetation
6	Thermal infrared	10.4–12.5	Soil moisture; thermal mapping
7	Middle infrared	2.08–2.35	Mineral mapping

**TABLE 1.1**  
Thematic bands  
in NASA's  
LANDSAT  
satellite.

# Imaging in infrared band (2)

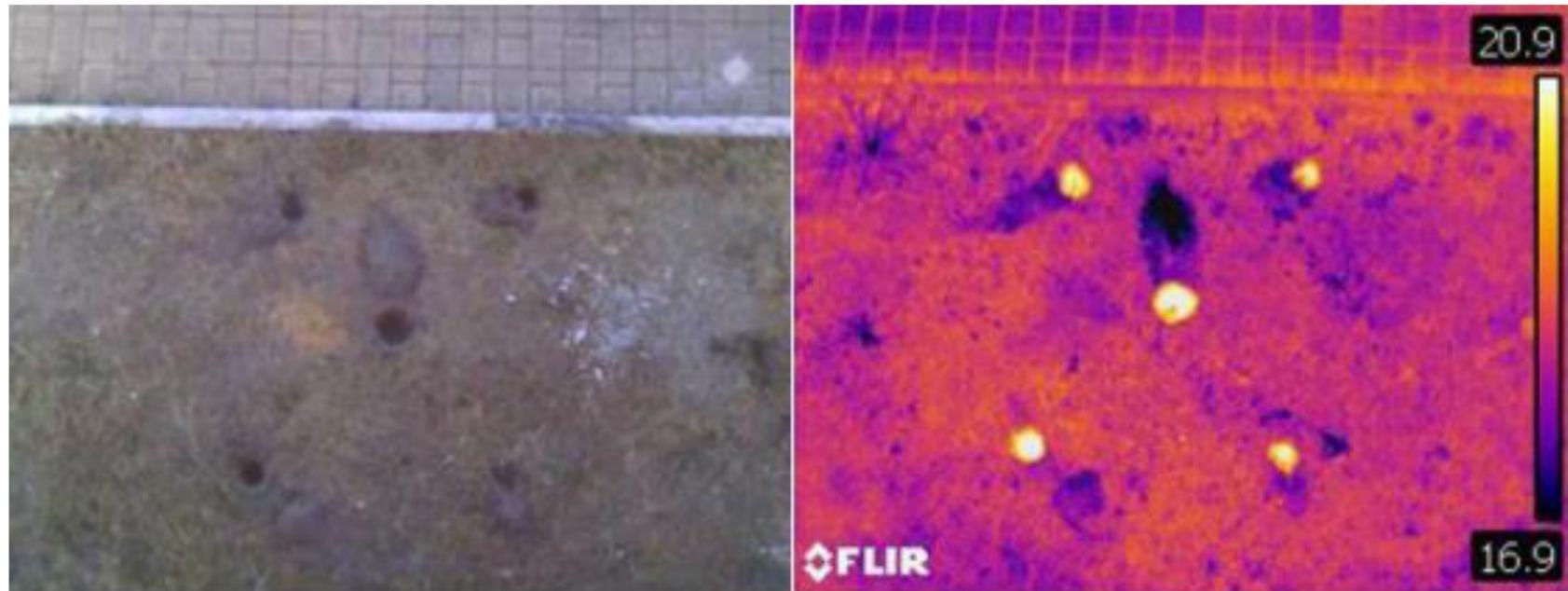
Unique capability  
to observe faint  
sources of  
visible near  
infrared emissions  
presente on Earth.



**FIGURE 1.13**  
Infrared satellite  
images of the  
remaining  
populated part of  
the world. The  
small gray map is  
provided for  
reference.  
(Courtesy of  
NOAA.)

# Imaging in infrared band

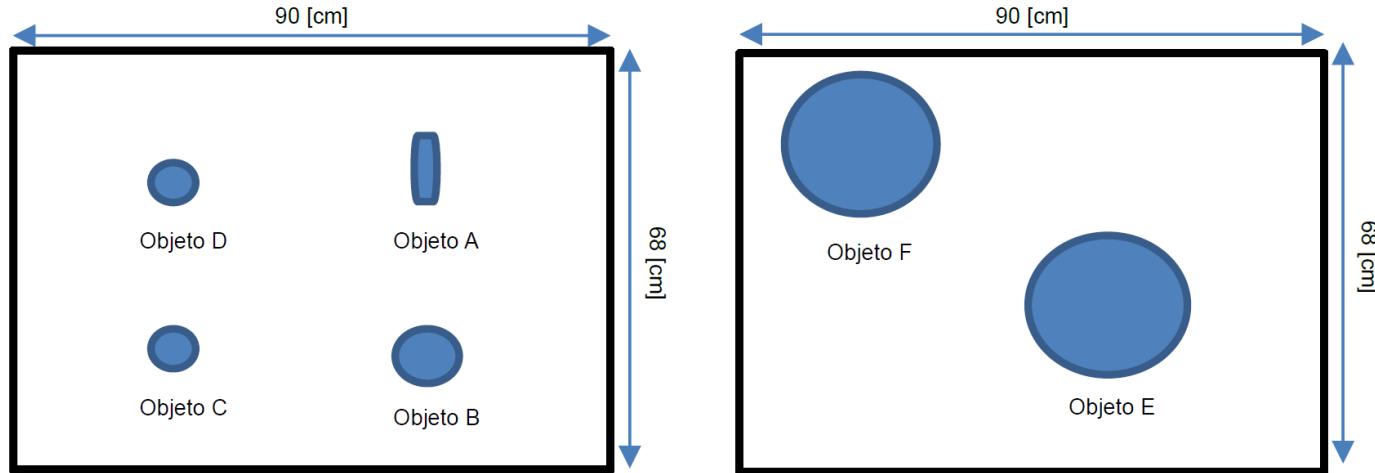
## Mine detection



RGB image containing five mines under the ground (left), and the corresponding infra-red image (right)

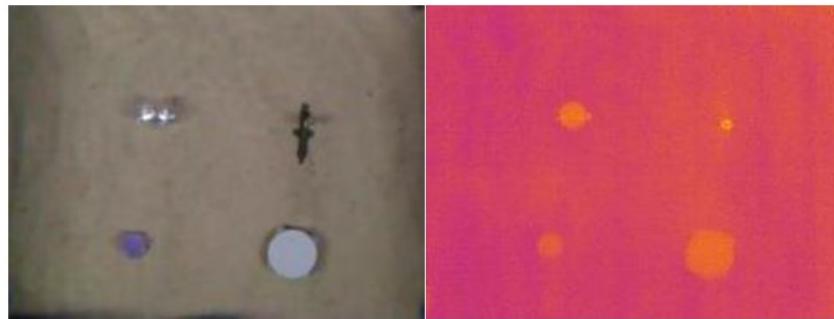
# Imaging in infrared band

## Mine detection – mine-laying diagram



# Imaging in infrared band

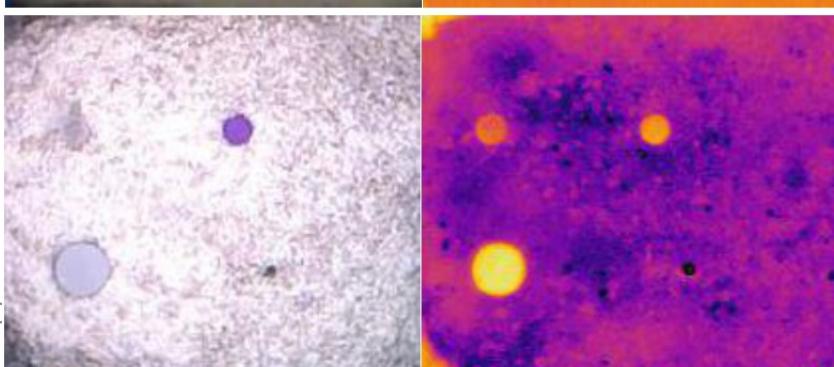
## Mine detection – burying the mines



The mines are placed at the surface



The mines are buried at 1-10 mm deeper

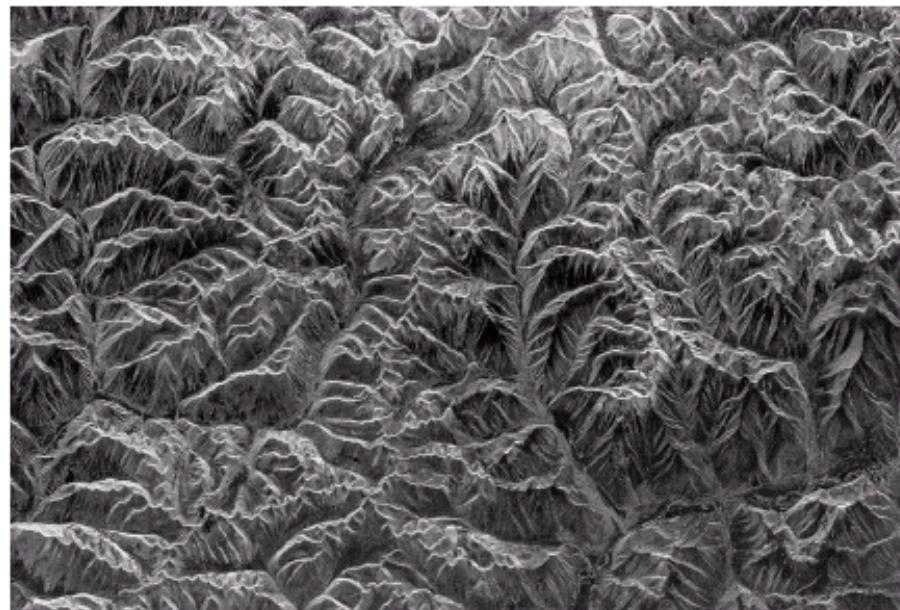


The mines are buried at 1-10 mm deeper

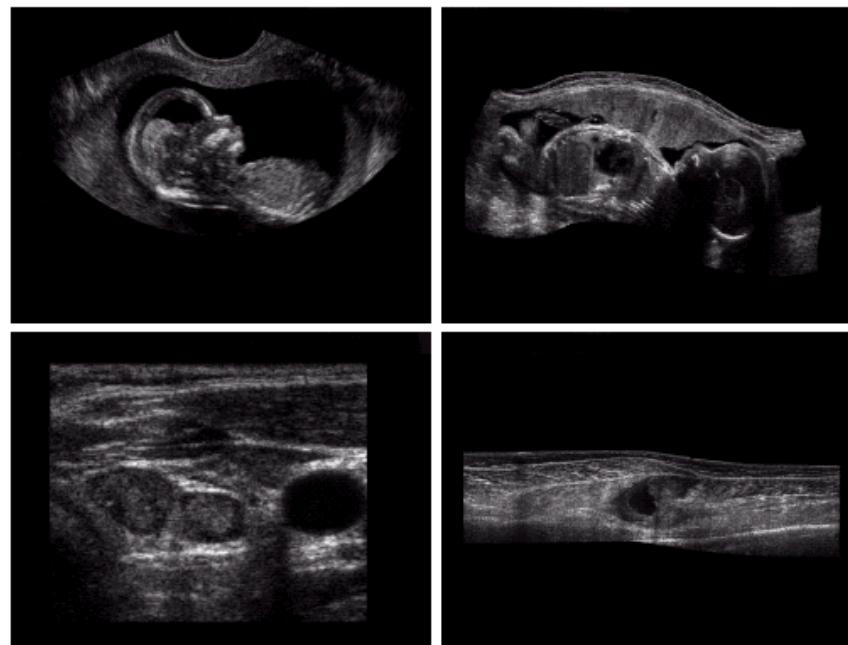
# Imaging in the microwave band

**FIGURE 1.16**  
Spaceborne radar  
image of  
mountains in  
southeast Tibet.  
(Courtesy of  
NASA.)

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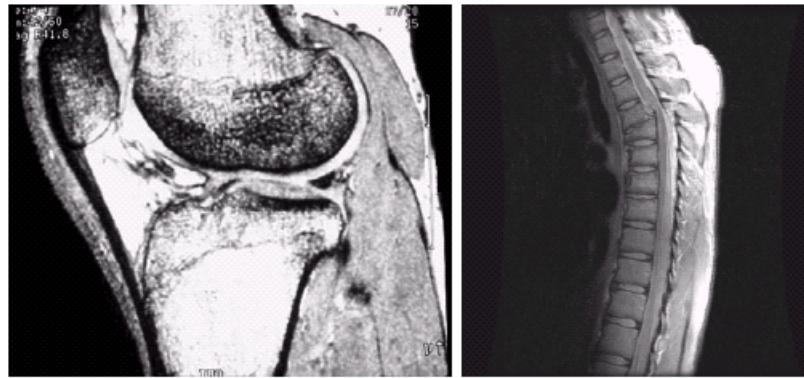
# Imaging in Ultrasound



a b  
c d

**FIGURE 1.20**  
Examples of ultrasound imaging. (a) Baby.  
(2) Another view of baby.  
(c) Thyroids.  
(d) Muscle layers showing lesion.  
(Courtesy of Siemens Medical Systems, Inc., Ultrasound Group.)

# Imaging in the radio band (I)



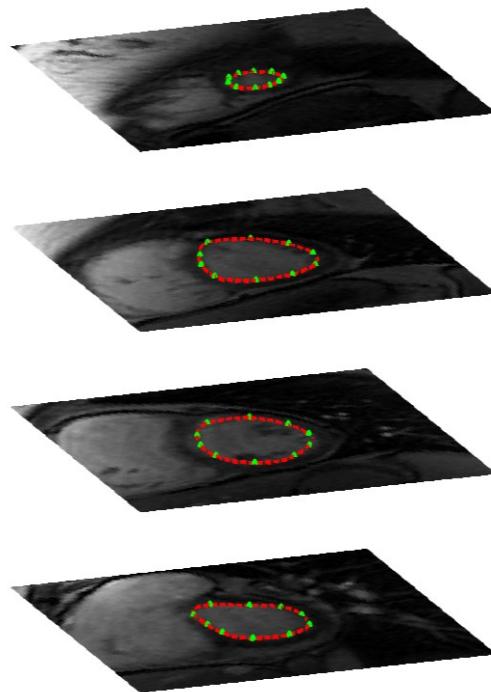
a b

**FIGURE 1.17** MRI images of a human (a) knee, and (b) spine. (Image (a) courtesy of Dr. Thomas R. Gest, Division of Anatomical Sciences, University of Michigan Medical School, and (b) Dr. David R. Pickens, Department of Radiology and Radiological Sciences, Vanderbilt University Medical Center.)

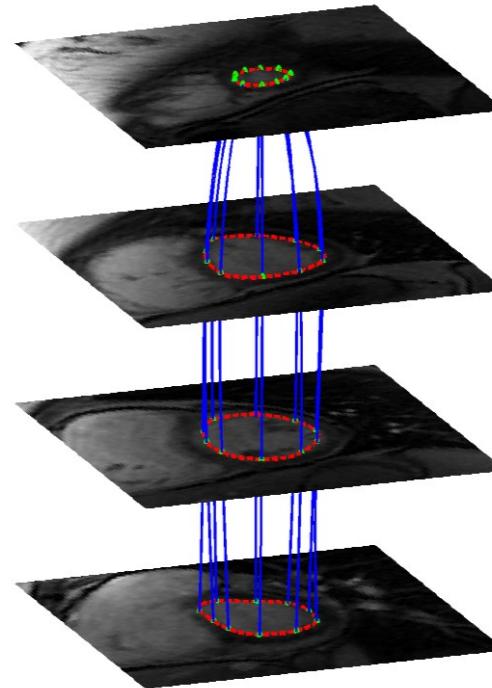
Human knee and spine (e.g.  
chondromalacia in the kneee)

# Imaging in the radio band (II)

Available  
Annotations

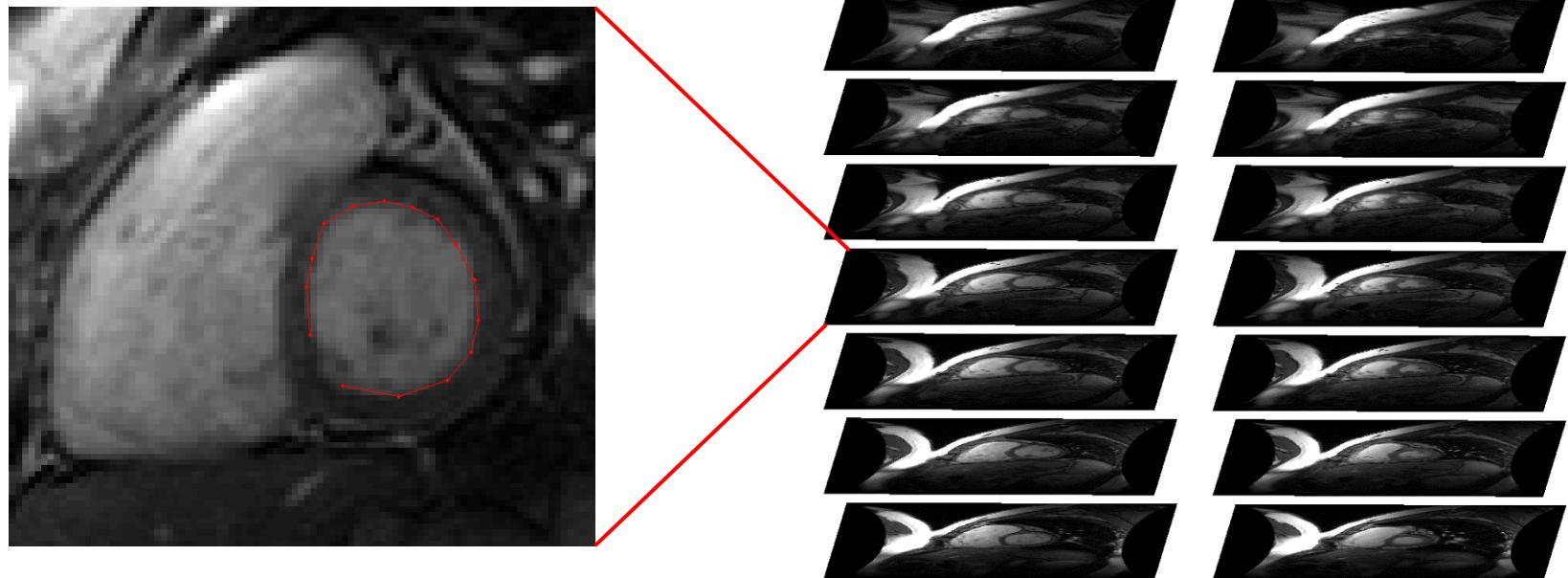


Interpolation  
Model



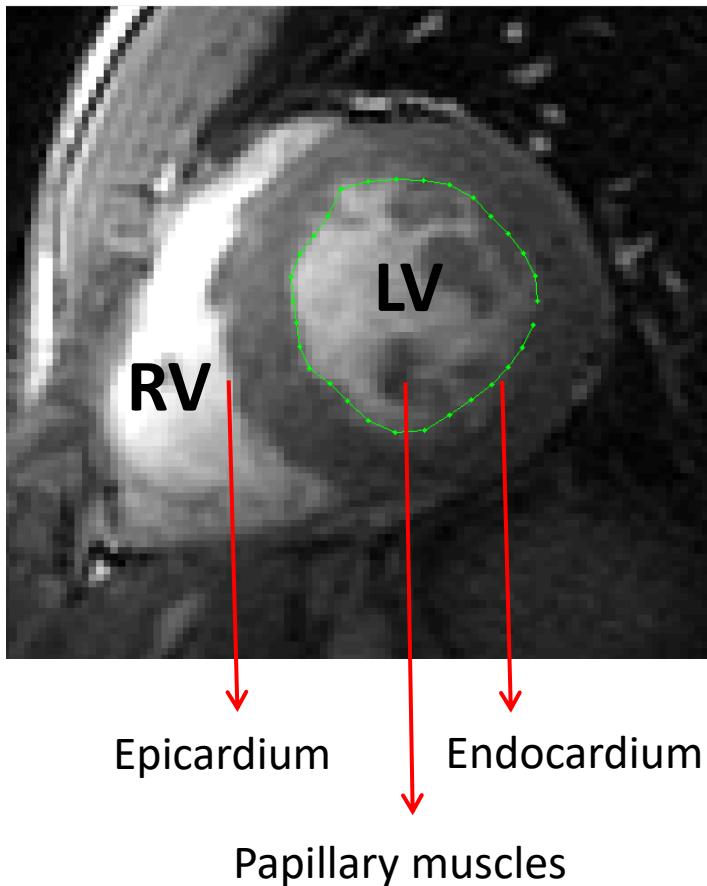
# Imaging in the radio band (III)

Application to the segmentation of the endocardium of the left ventricle (in 3D)

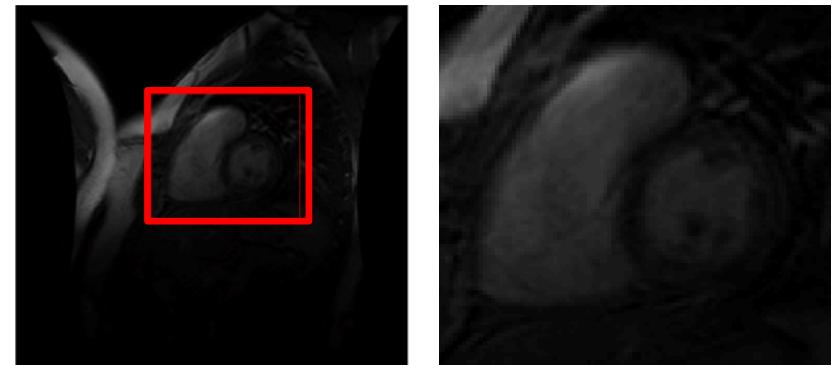


# Imaging in the radio band (IV)

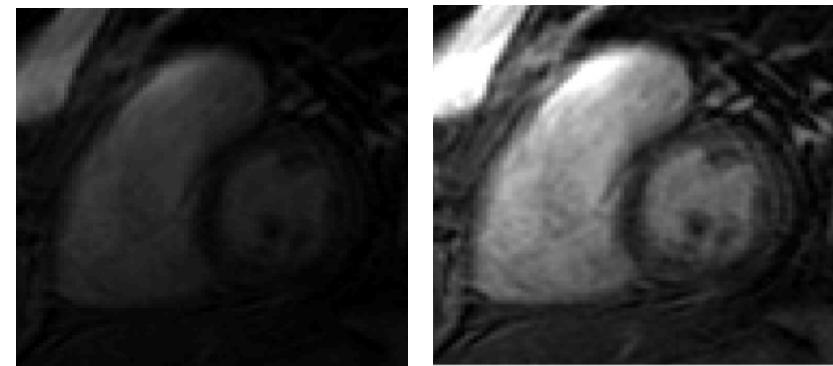
Goal – Segmenting the endocardium  
of the LV



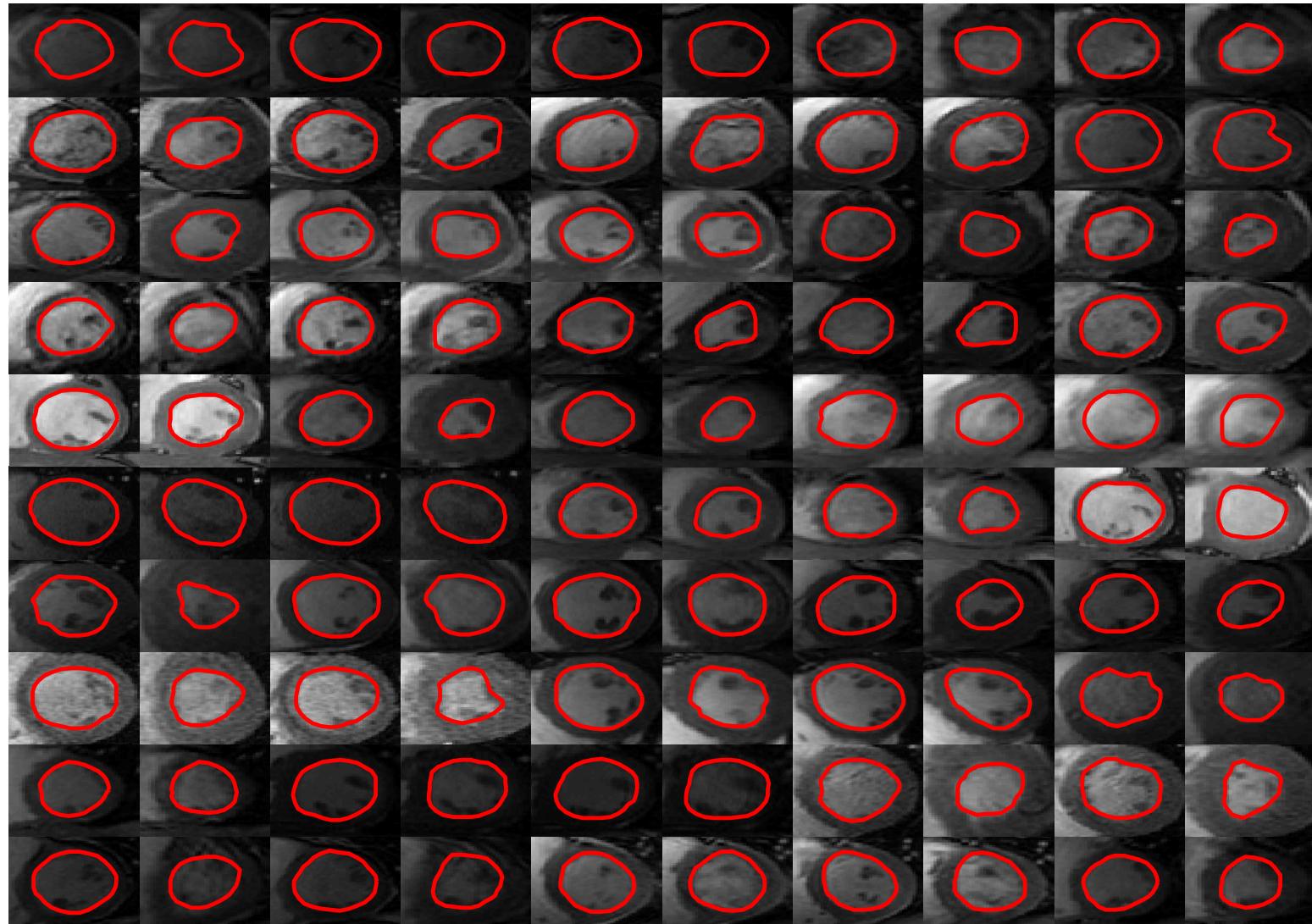
1) ROI (region of interest)



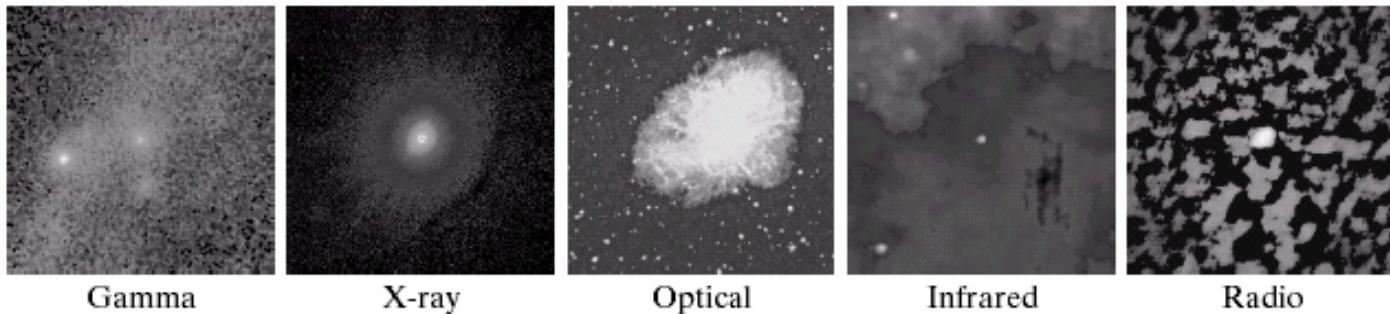
2) Adjustment of the intensity



# Imaging in the radio band (V)



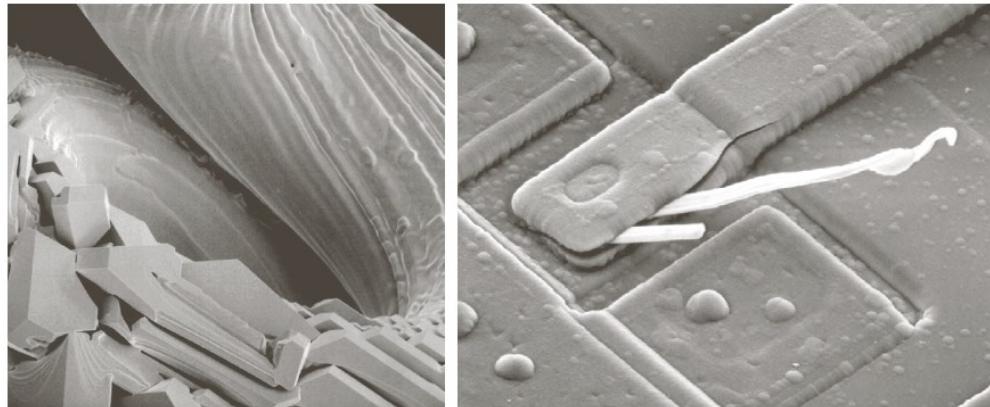
# Imaging in several bands



**FIGURE 1.18** Images of the Crab Pulsar (in the center of images) covering the electromagnetic spectrum. (Courtesy of NASA.)

Images of the Crab Pulsar, that is a star. Notice that, there is a significant difference of the same region, if we change the image modality.

# Image Scanning electron microscope (SEM)

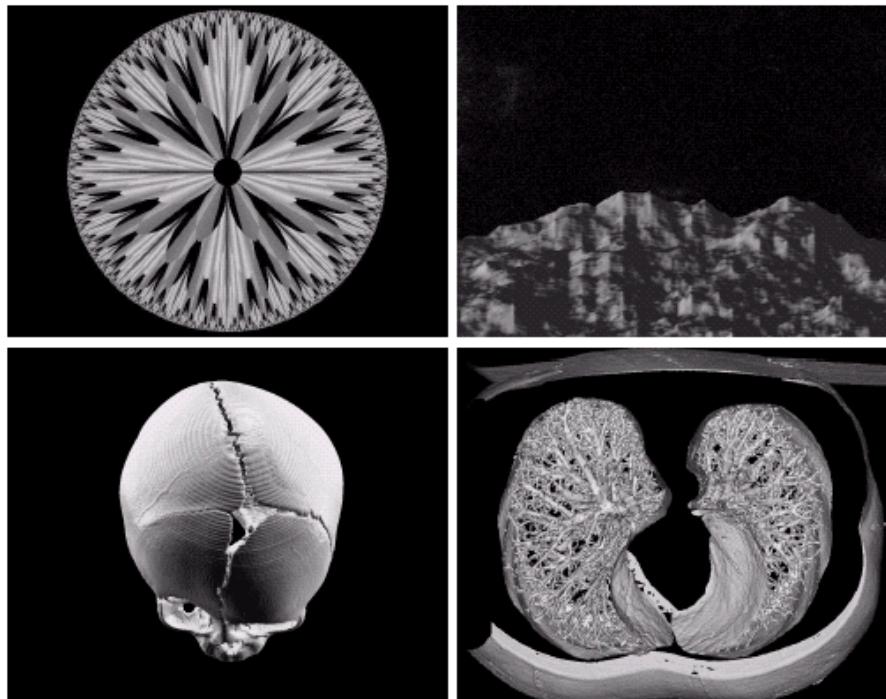


a | b

**FIGURE 1.21** (a) 250 $\times$  SEM image of a tungsten filament following thermal failure (note the shattered pieces on the lower left). (b) 2500 $\times$  SEM image of damaged integrated circuit. The white fibers are oxides resulting from thermal destruction. (Figure (a) courtesy of Mr. Michael Shaffer, Department of Geological Sciences, University of Oregon, Eugene; (b) courtesy of Dr. J. M. Hudak, McMaster University, Hamilton, Ontario, Canada.)

# Synthetic images

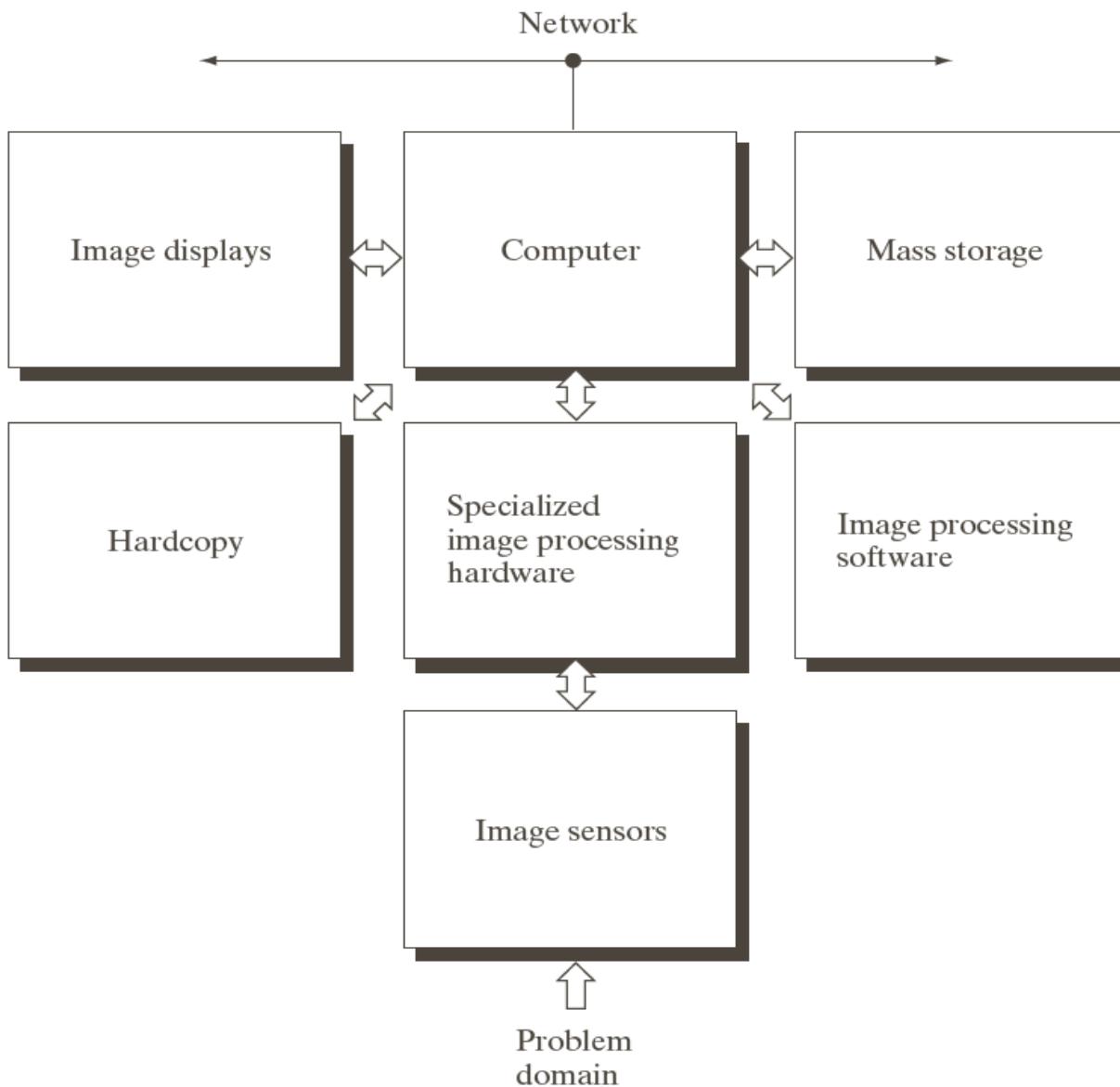
(Images that are not obtained from the physical properties of the objects)



a b  
c d

**FIGURE 1.22**  
(a) and (b) Fractal images. (c) and (d) Images generated from 3-D computer models of the objects shown. (Figures (a) and (b) courtesy of Ms. Melissa D. Binde, Swarthmore College. (c) and (d) courtesy of NASA.)

# Components of an Image Processing System



**FIGURE 1.24**  
Components of a general-purpose image processing system.

# Readings

- Chapter 1 de R. Gonzalez, R. Woods, “Digital Image Processing”, 3rd edition, 2008.