CTT310: Digital Image Processing

Examples of Fields that Use Digital Image Processing

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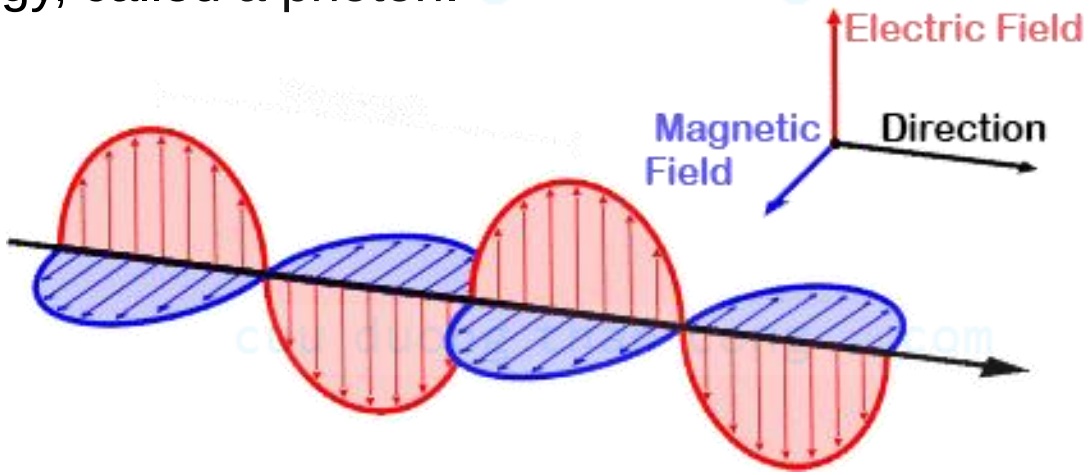
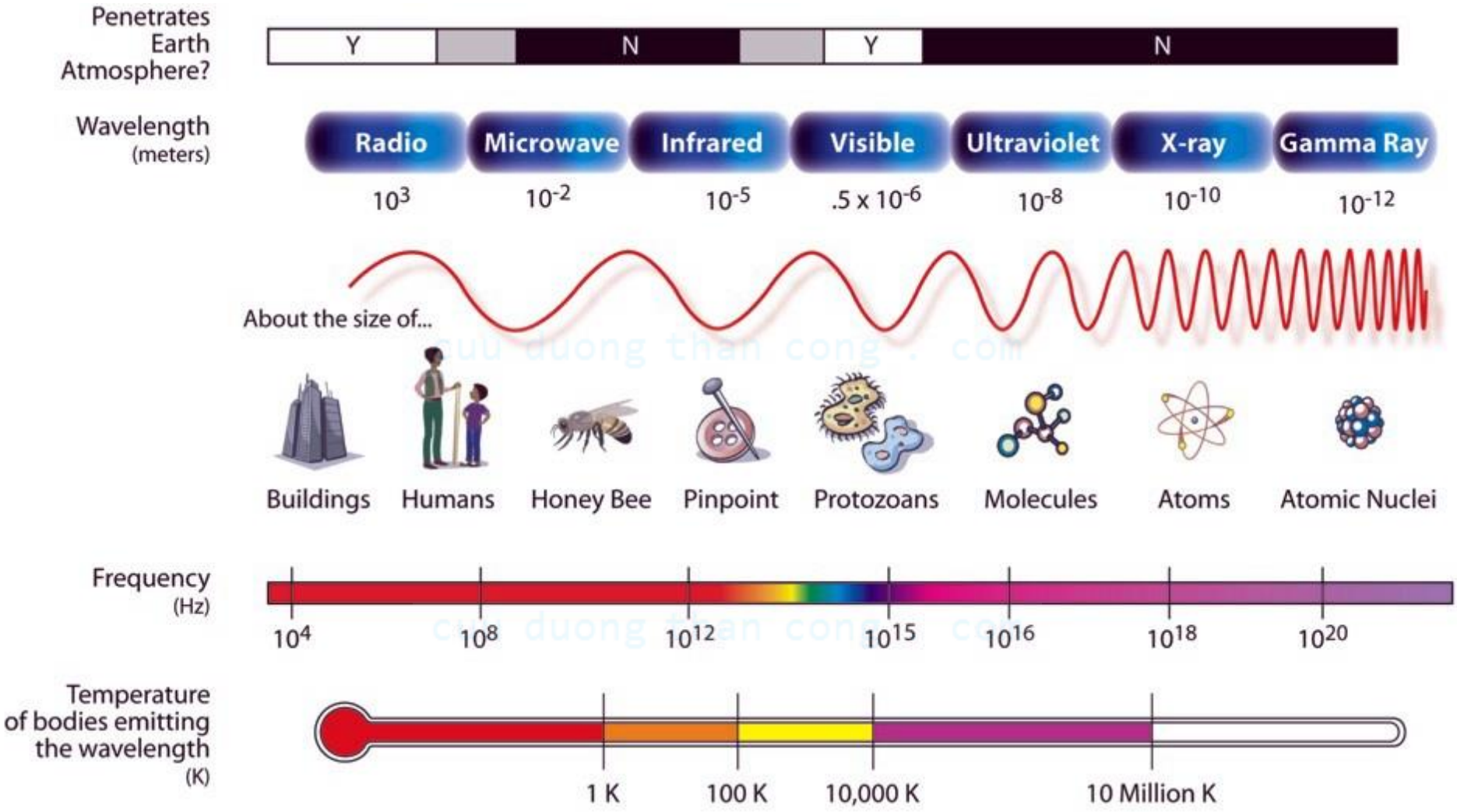
Electromagnetic spectrum

- Electromagnetic waves are conceptualized as propagating sinusoidal waves of varying wavelengths
  - A stream of massless particles, each traveling in a wavelike pattern and moving at the speed of light.
  - Each massless particle contains a certain amount (or bundle) of energy, called a photon.



Electromagnetic spectrum



Outline

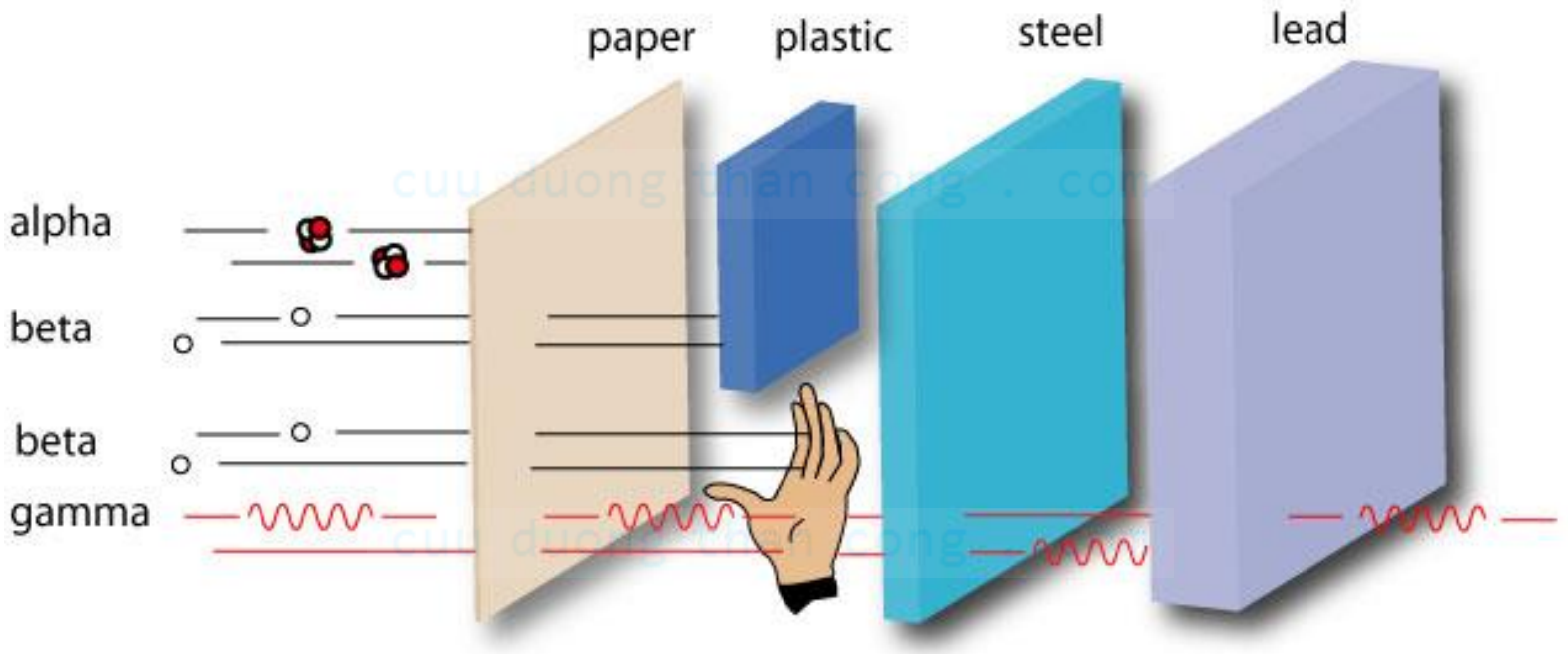
- Gamma-ray imaging
- X-ray imaging
- Imaging in the ultraviolet band
- Imaging in the visible and infrared bands
- Imaging in the microwave band
- Imaging in the radio band
- Examples of other imaging modalities

Section A.1

GAMMA-RAY IMAGING

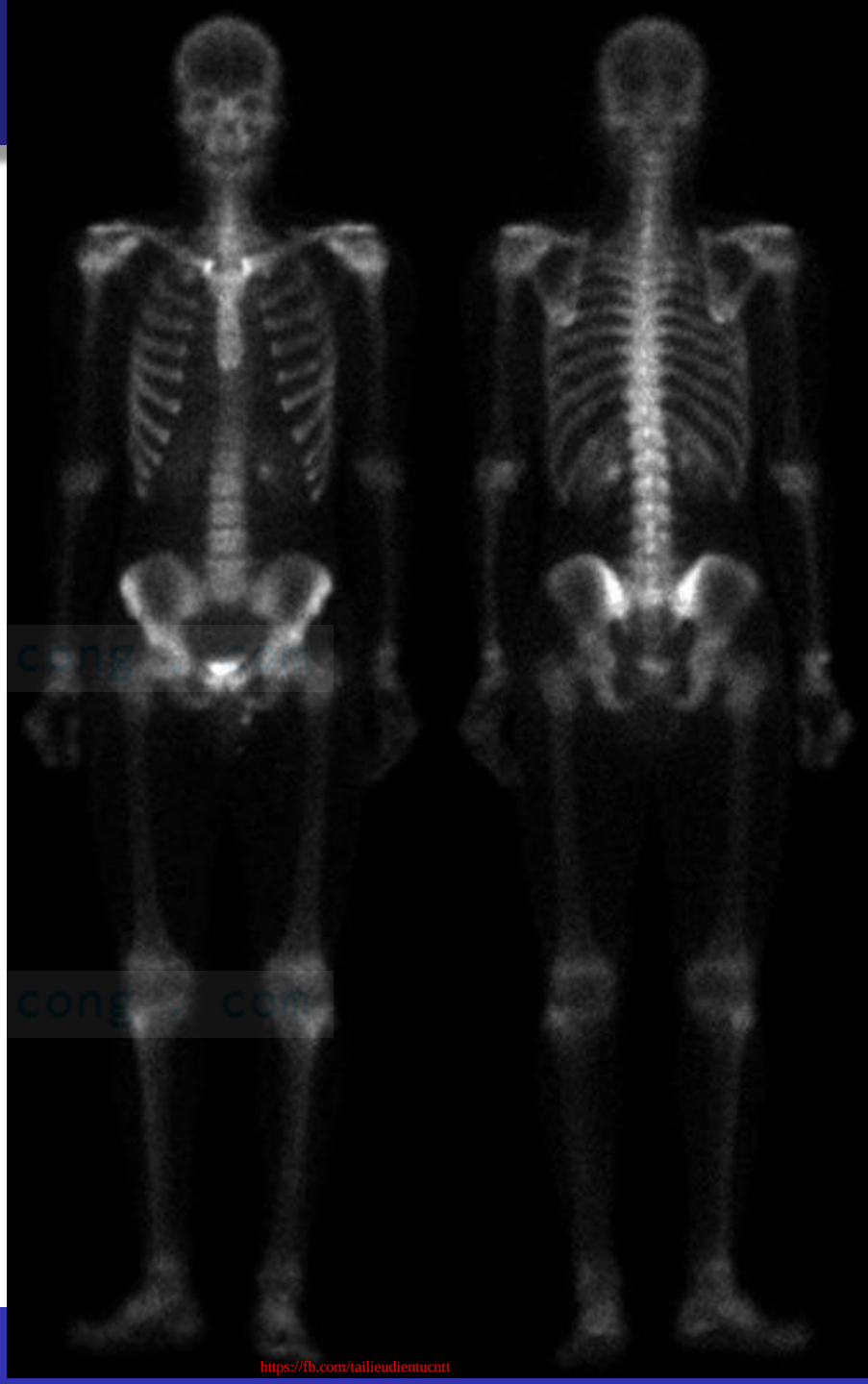
Gamma-ray imaging

- Major uses of imaging based on gamma rays include **nuclear medicine** and **astronomical observations**.



Nuclear medicine

- The patient is injected with a radioactive isotope that emits gamma rays as it decays.
- Emissions are collected by gamma ray detectors.
- It is used to locate site of bone pathology, such as infections or tumors.



PET

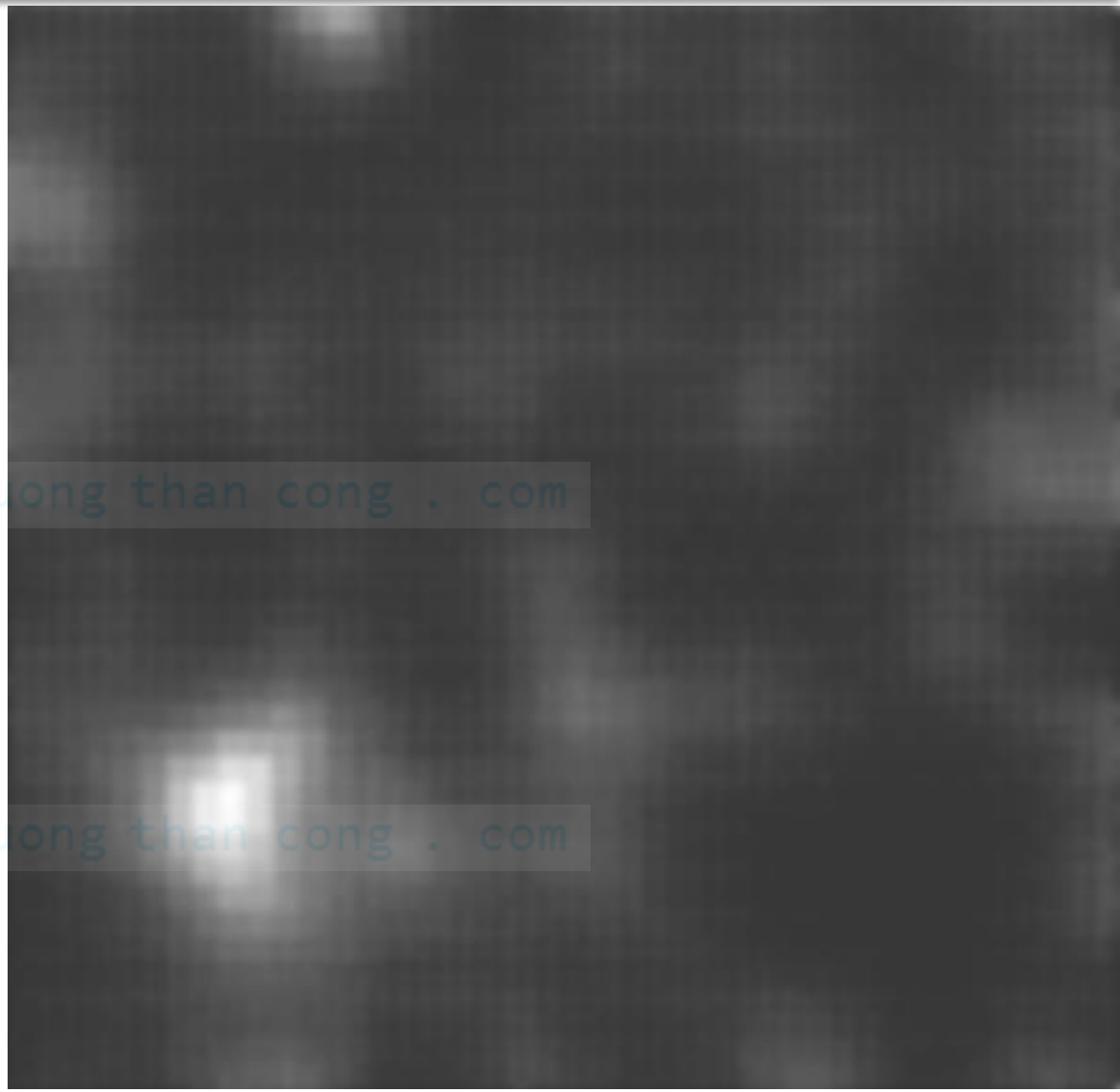
- Positron emission tomography (PET)
- The patient is given a radioactive isotope that emits positrons as it decays.
- When a positron meets an electron, both are annihilated and 2 gamma rays are given off.
- A tomographic image is created using the basic principles of tomography.

Astronomical observations

- A star in the constellation of Cygnus exploded about 15,000 years ago.
- Superheated stationary gas cloud (called the Cygnus Loop) glows in a spectacular array of colors.
- Natural radiation of the object is being imaged.

Nuclear reaction

- Gamma radiation from a valve in a nuclear reactor

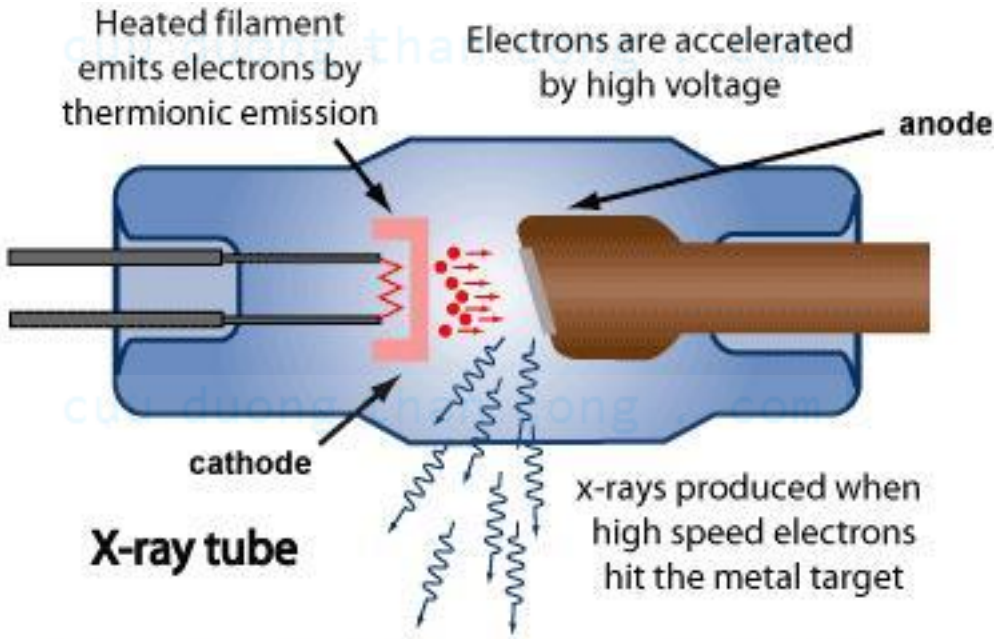


Section A.2

X-RAY IMAGING

X-ray imaging

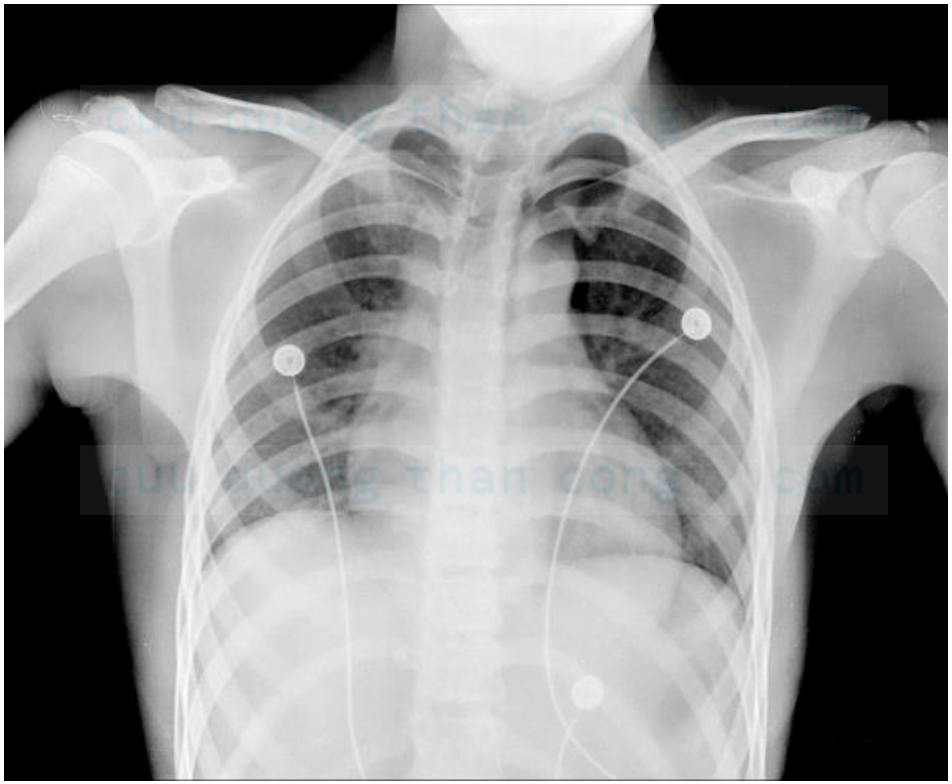
- X-rays are among the oldest sources of EM radiation used for imaging.
- Major uses are in **medical diagnostics**, also in **industry** and other areas, like **astronomy**.



http://www.arpansa.gov.au/radiationprotection/basics/xrays.cfm

Medical diagnostics

- The patient is placed between an X-ray source and a film sensitive to X-ray energy.
  - The intensity of the X-rays is modified by absorption as they pass through the patient, and the resulting X-ray film is digitized.

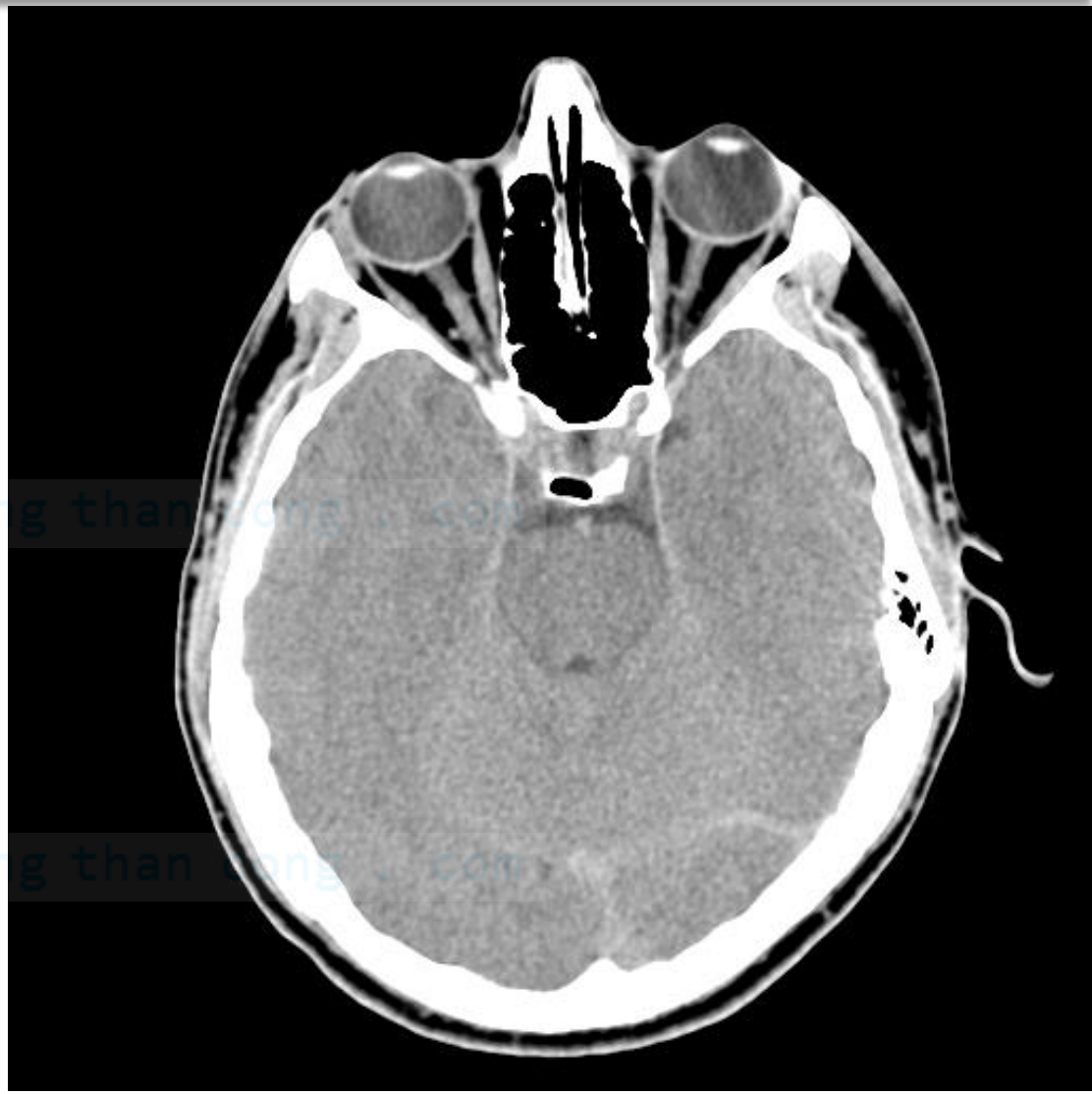


Angiography

- Contrast-enhancement radiography
- Angiograms of blood vessels
- An X-ray contrast medium is injected through the catheter.
- This enhances contrast of the blood vessels and enables the radiologist to see any irregularities or blockages.

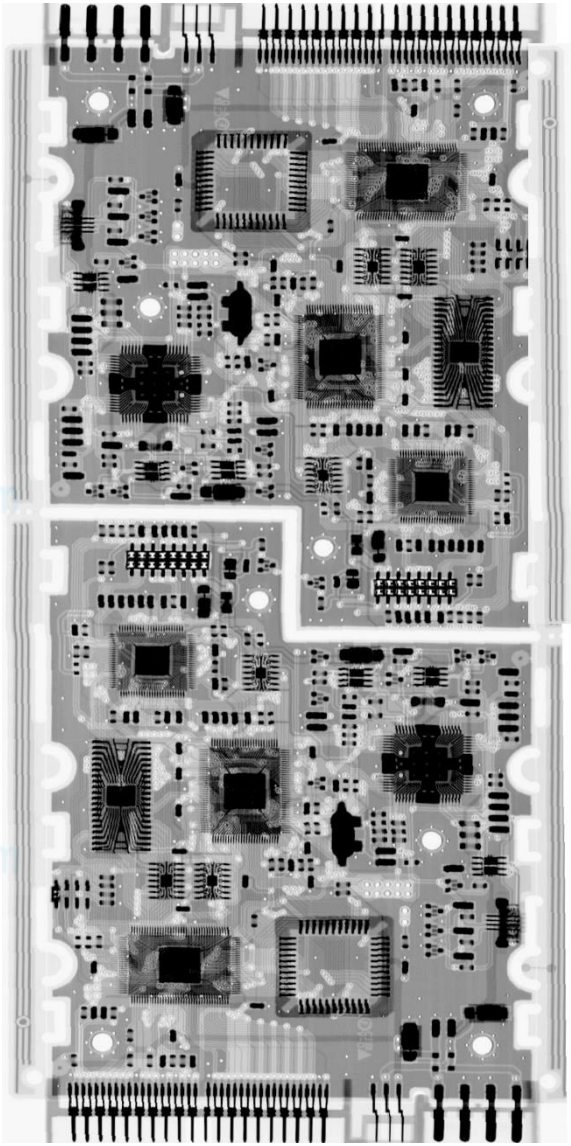
Computerized axial tomography (CAT)

- CAT scans revolutionized medicine due to their 3-D capabilities and resolution.



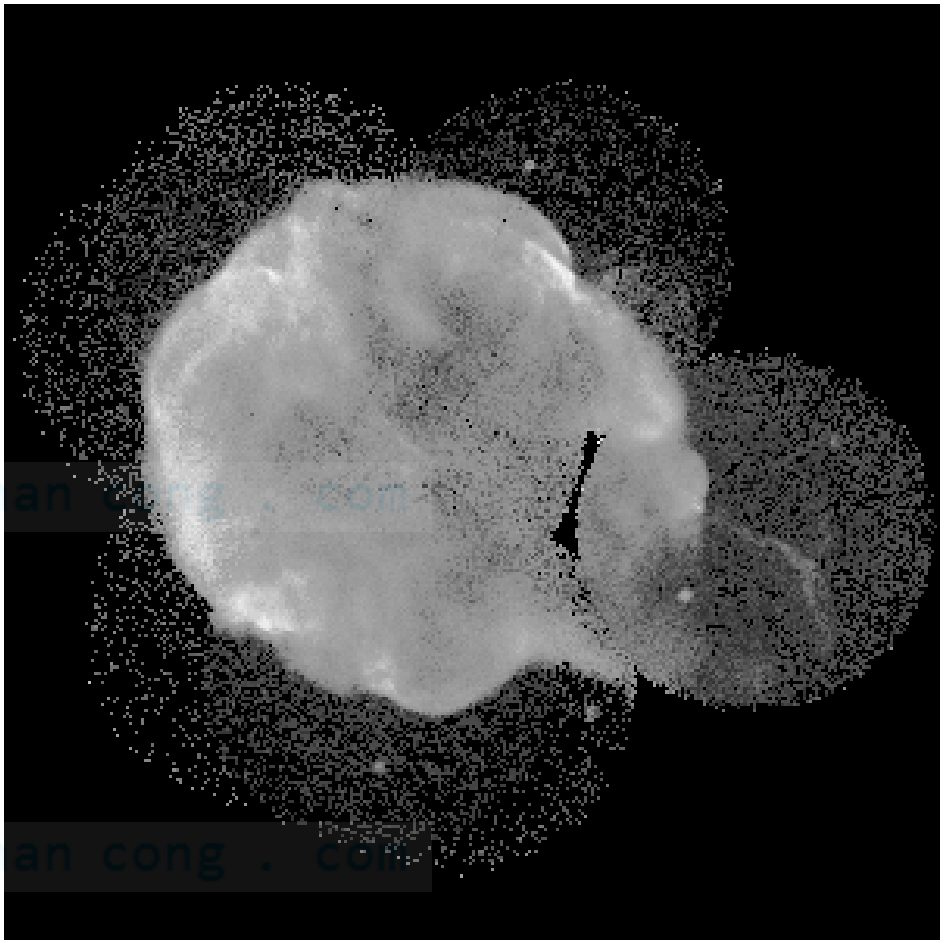
Industrial processes

- Examine circuit boards for flaws in manufacturing, such as missing components or broken traces.



Astronomy

- The Cygnus Loop is imaged this time in the X-ray band.

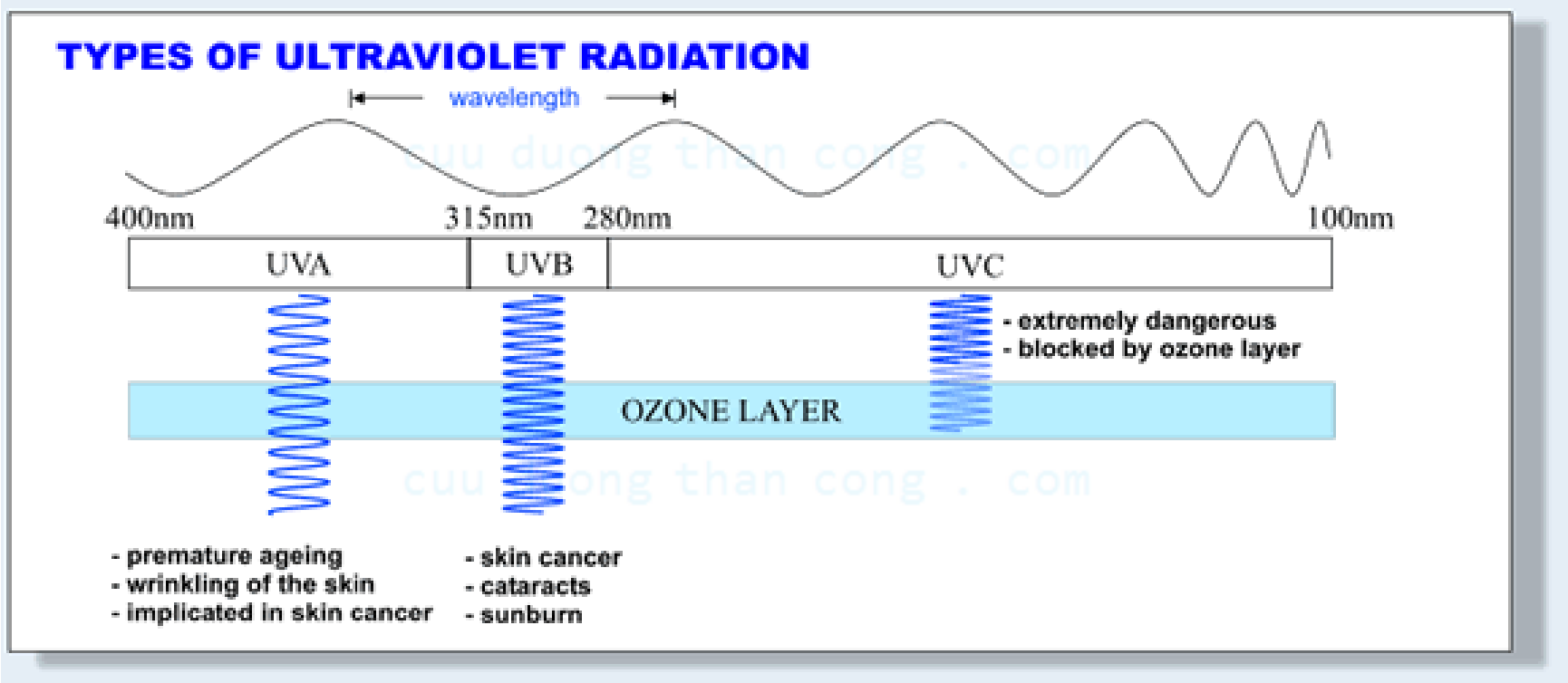


Section A.3

IMAGING IN THE ULTRAVIOLET BAND

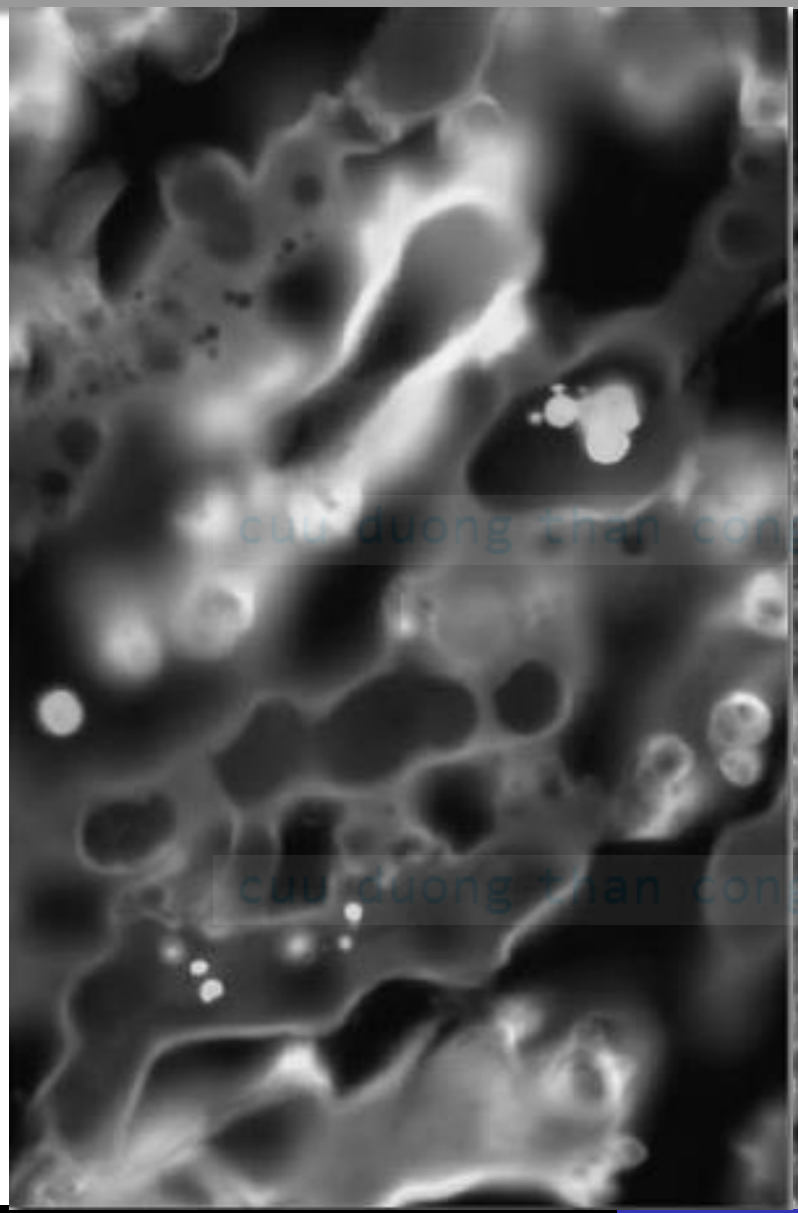
Ultraviolet imaging

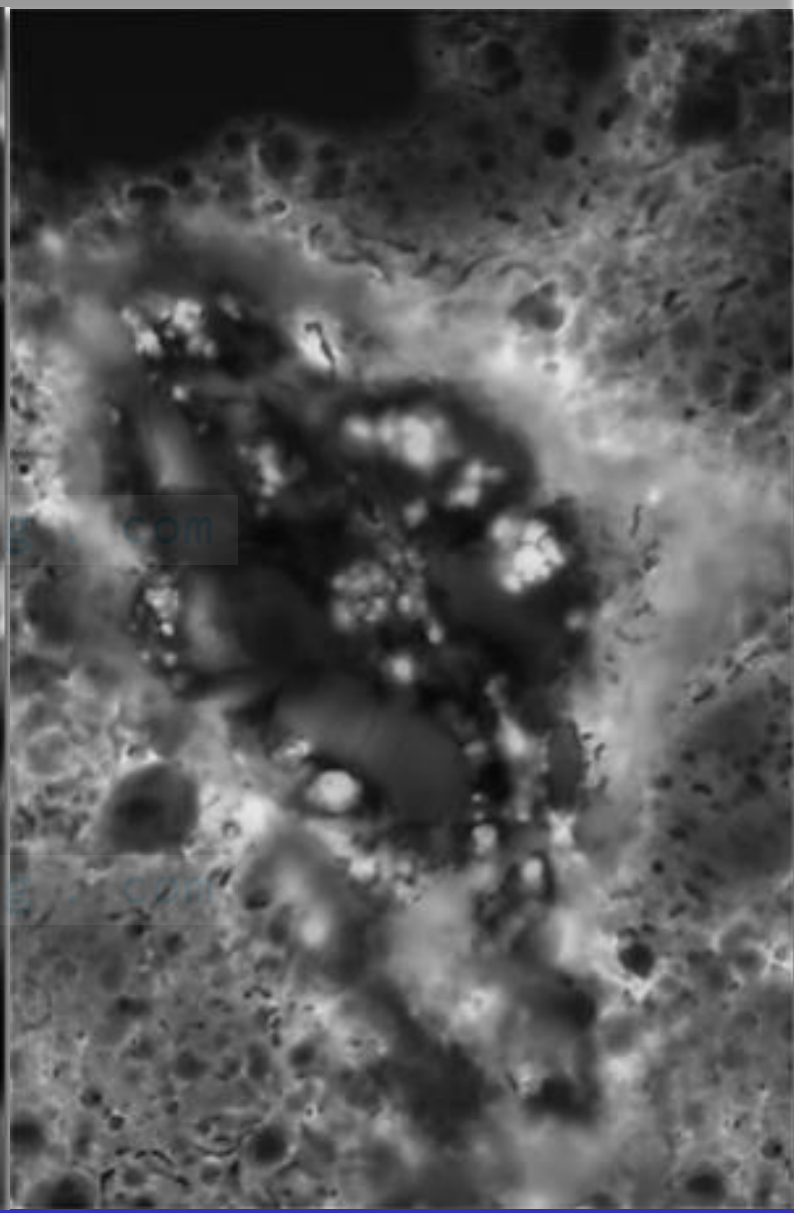
- Applications of ultraviolet “light” varied among **lithography**, **industrial inspection**, **microscopy**, **lasers**, **biological imaging**, and **astronomical observations**.



Fluorescence microscopy

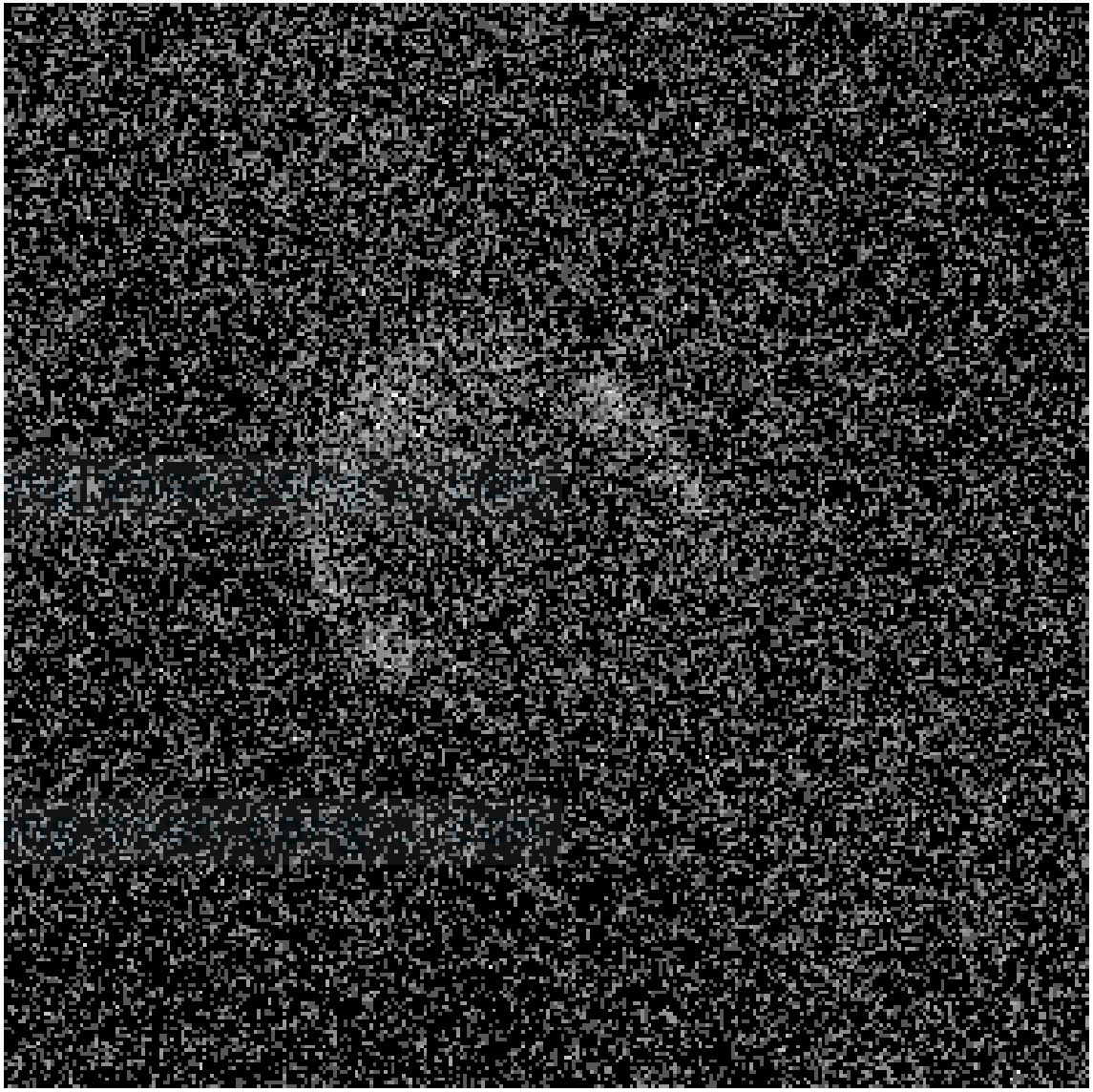
- A fluorescence microscope image of normal corn and corn infected by “smut”





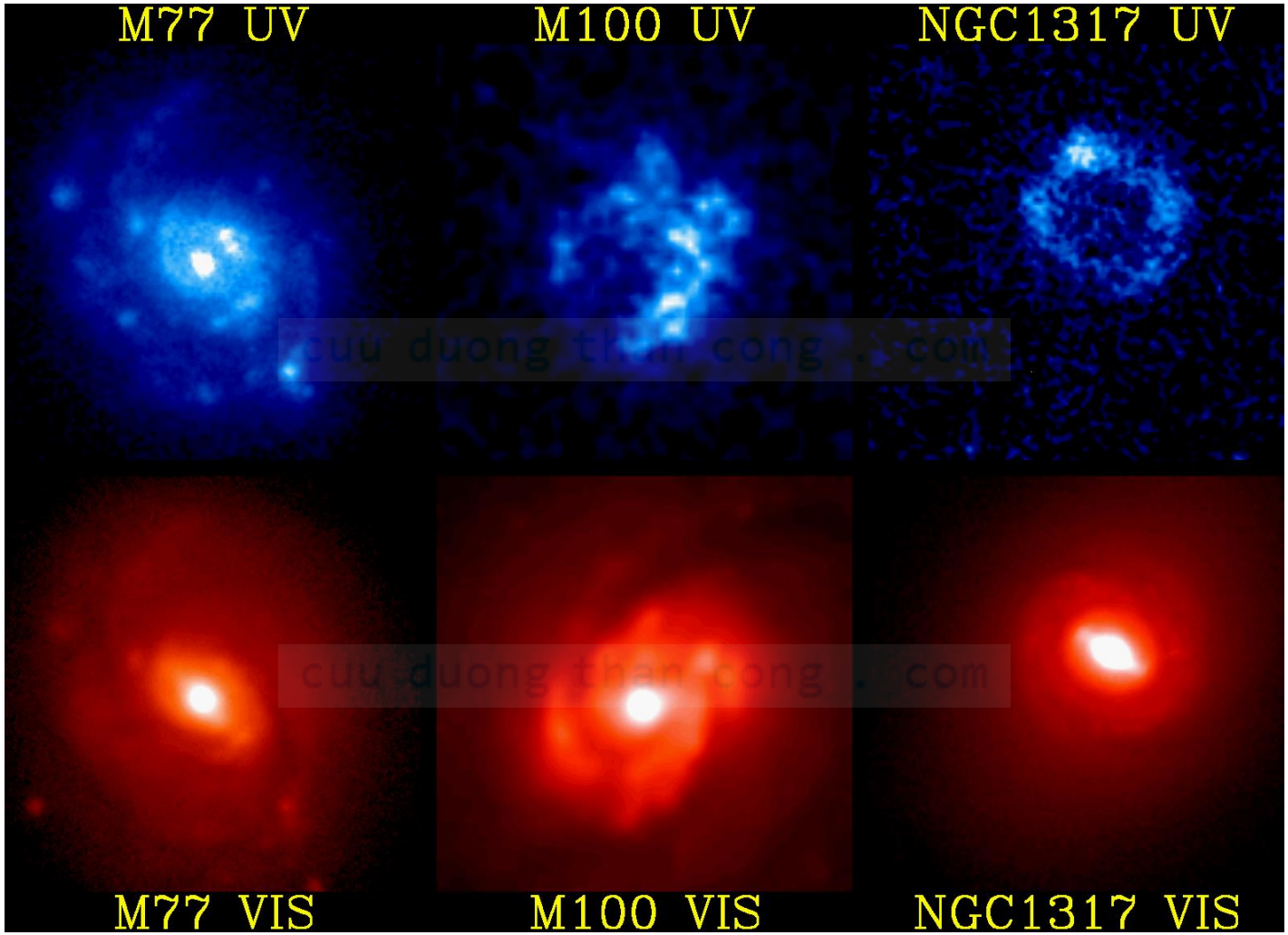
Astronomy

- The Cygnus Loop is imaged in the high-energy region of the ultraviolet band.



Astronomy

- Three different galaxies are taken in visible light and ultraviolet light.

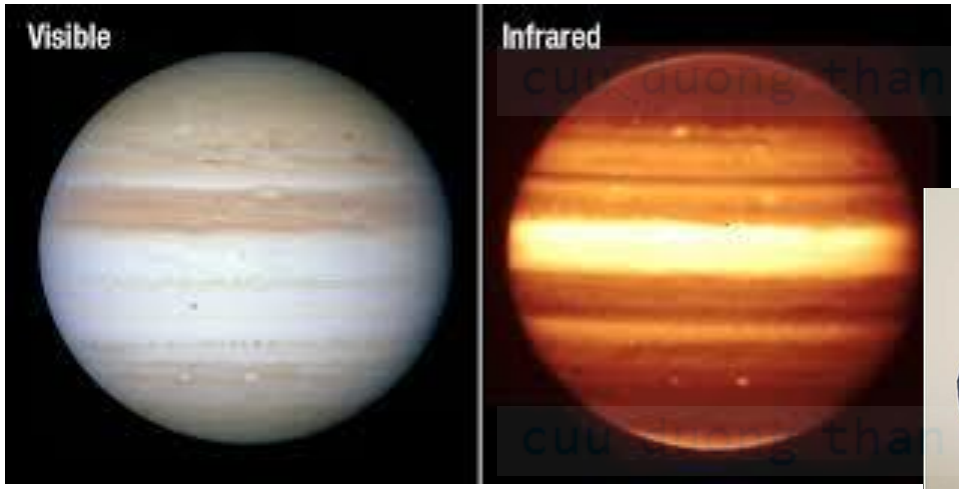


Section A.4

IMAGING IN THE VISIBLE AND INFRARED BANDS

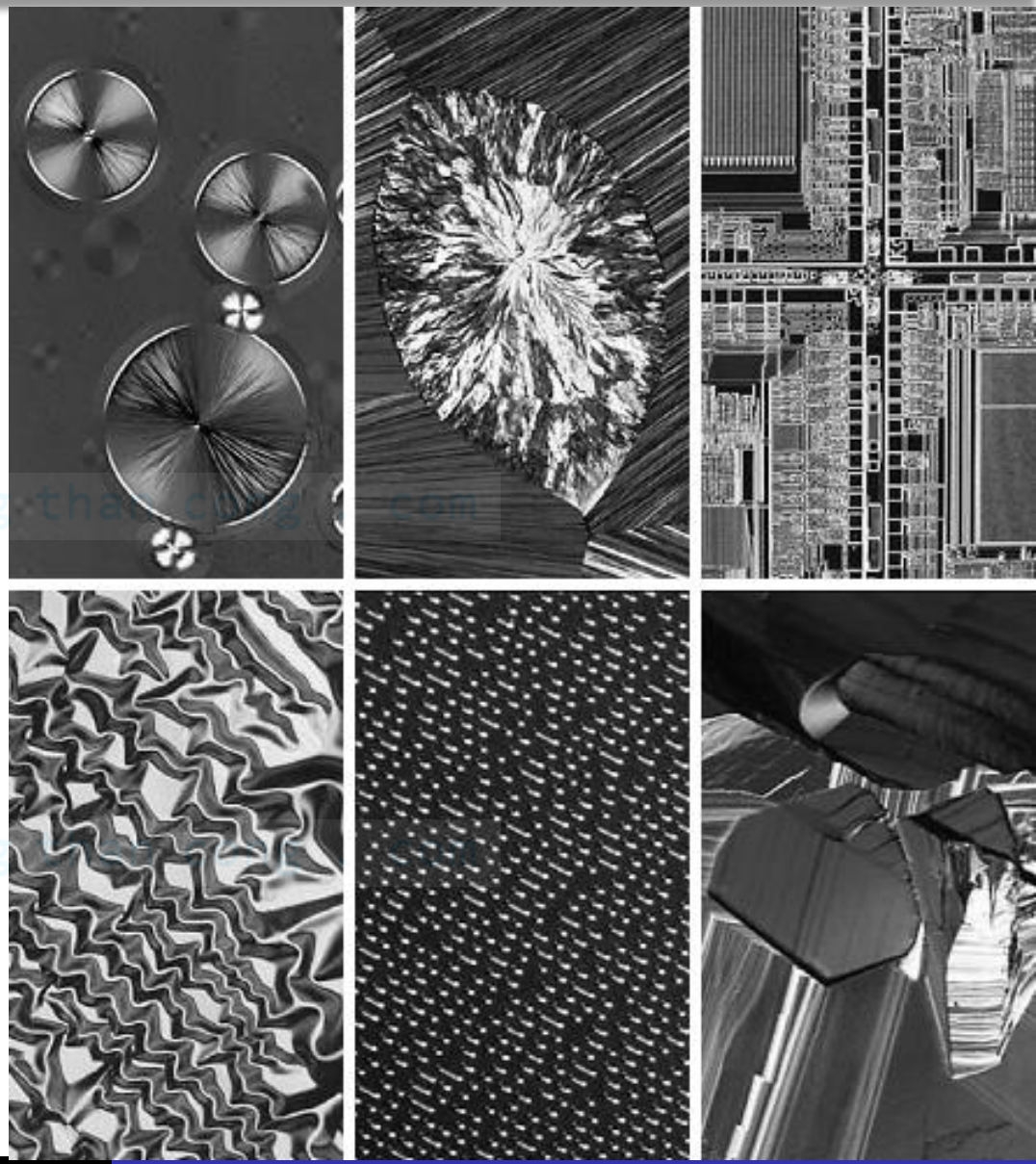
Imaging in the visible and infrared bands

- Imaging in this band outweighs by far all the others in terms of breadth of application.
- **Light microscopy**, **astronomy**, **remote sensing**, **industry**, and **law enforcement**



Light microscope

- Examples range from pharmaceuticals and micro inspection to materials characterization.



a b c
d e f

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×

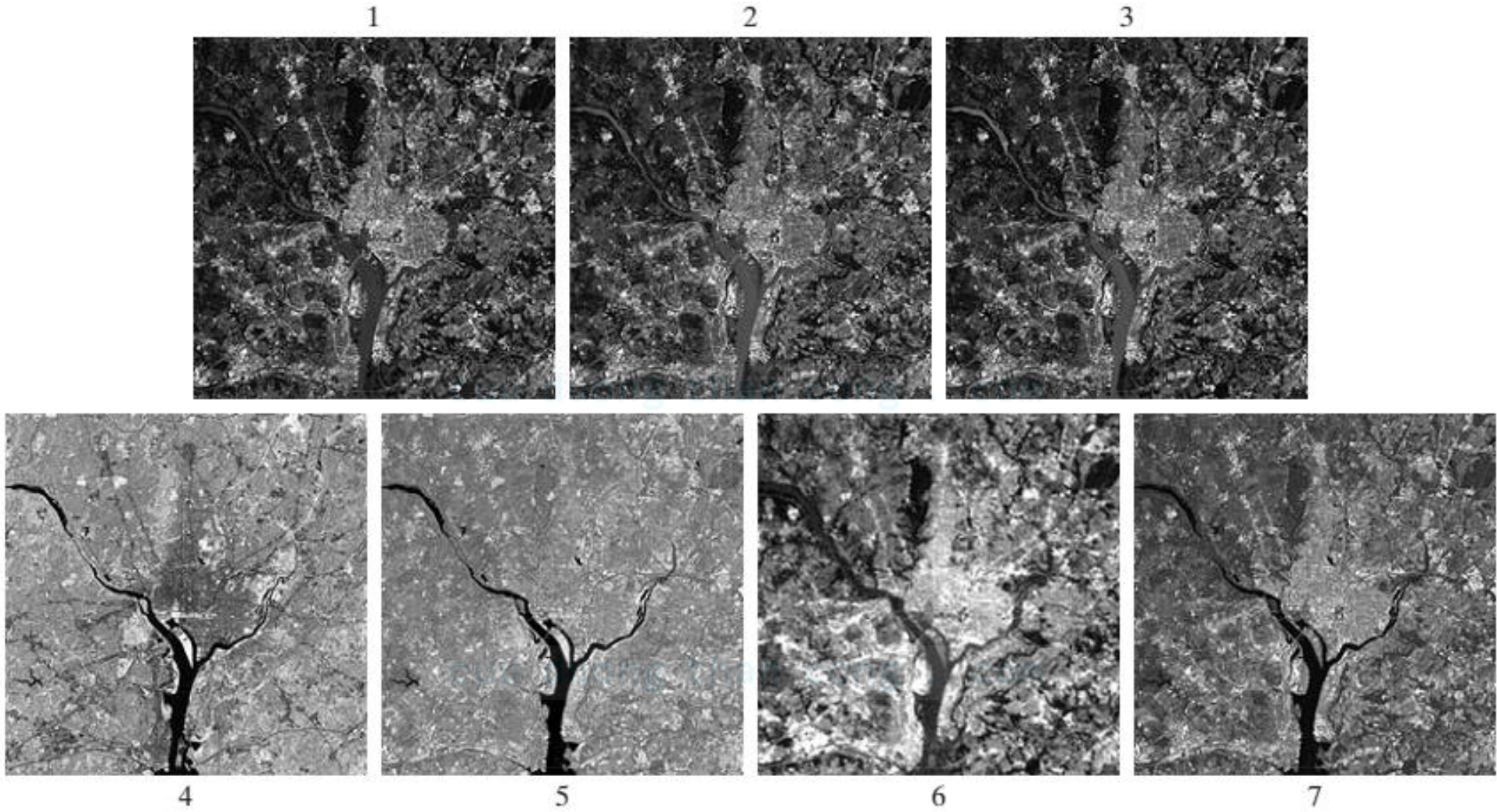
Multispectral imaging

- Usually include several bands in the visual and infrared regions of the spectrum.

Band No.	Name	Wavelength (μm)	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

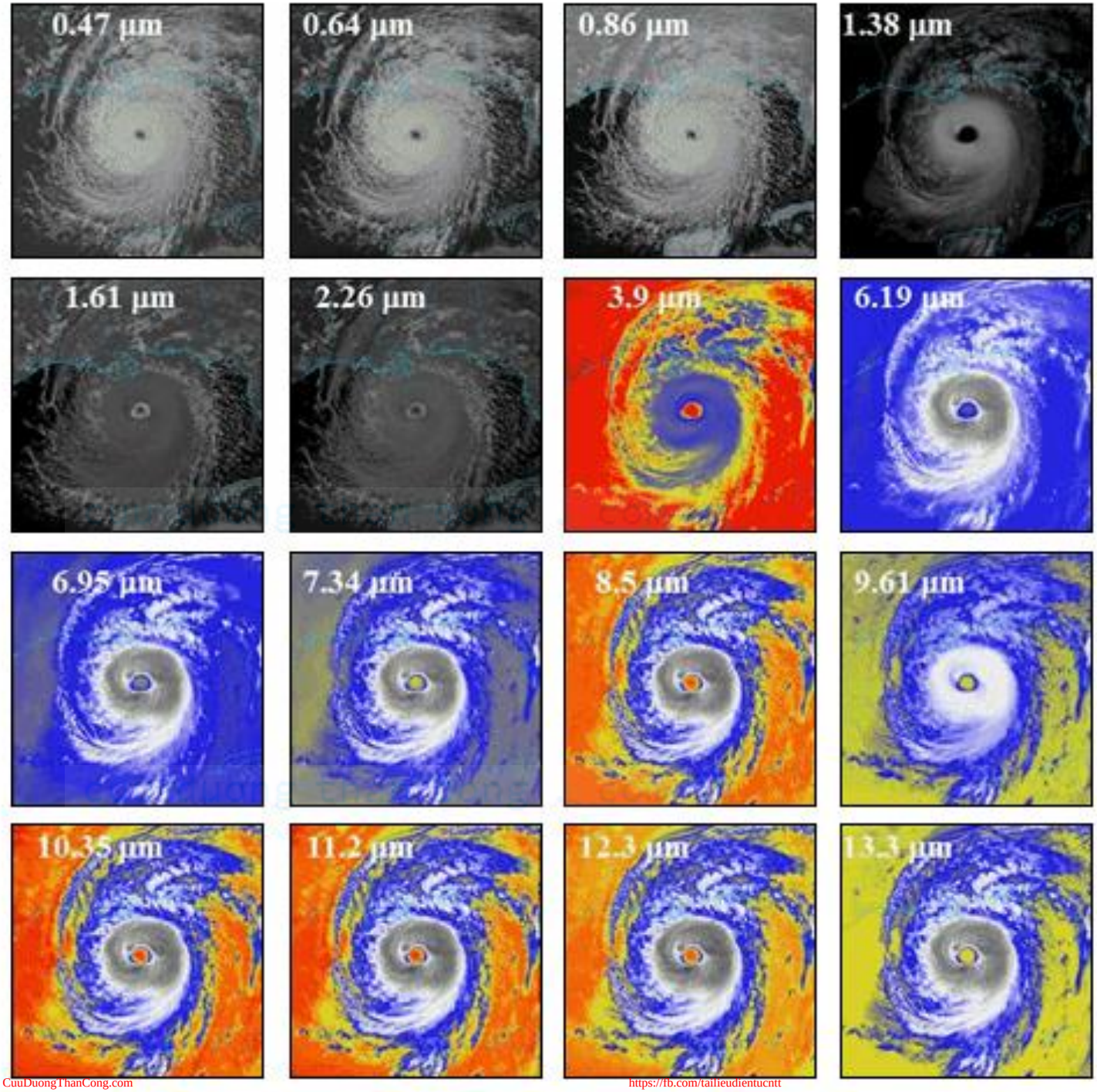
Thematic bands in NASA's LANDSAT satellite.

Multispectral imaging



LANDSAT satellite images of the Washington, D.C. area.
The numbers refer to the thematic bands in the previous slide..

Imagery of Hurricane Katrina From the 16 Channels on GOES-R ABI



Weather observation and prediction

CIMSS AWG Proxy Team / SSEC / UW-Madison

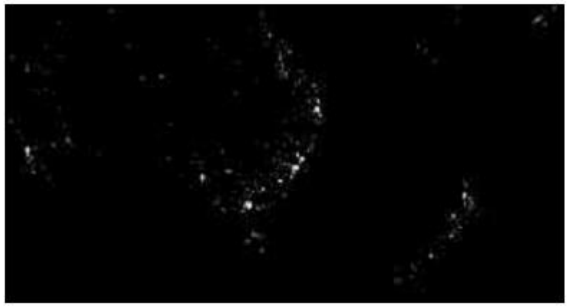
Nighttime Lights of the World data set

- A global inventory of human settlements
- Generated by the infrared imaging system mounted on a NOAA DMSP (Defense Meteorological Satellite Program) satellite, operating in the band 10.0 to 13.4 μm.
- Observe faint sources of visible-near infrared emissions present on the Earth's surface, including cities, towns, villages, gas flares, and fires.

Nighttime Lights of the World data set

Infrared satellite images of the Americas.
The small gray map is provided for reference

Nighttime Lights of the World data set

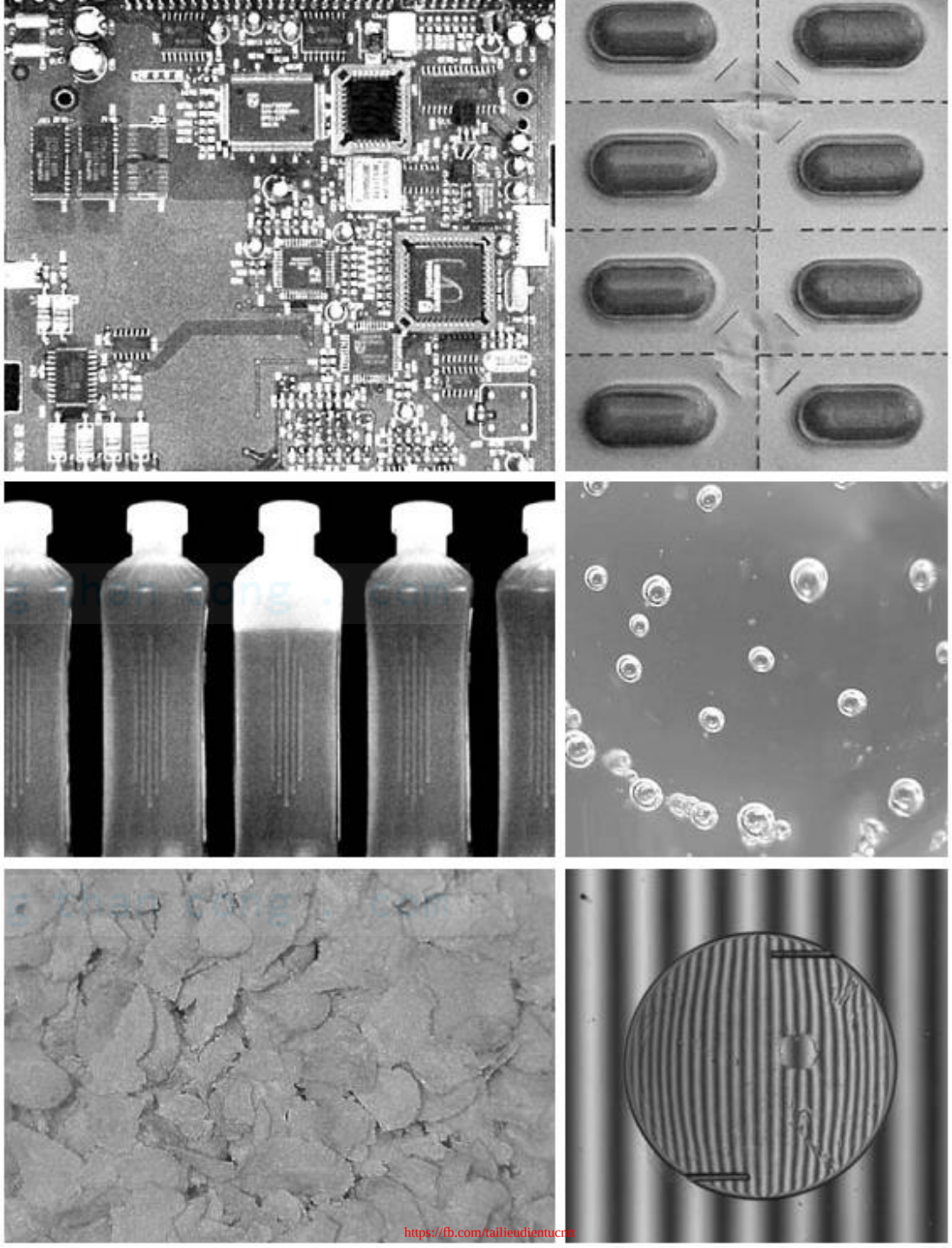


Infrared satellite images of the remaining populated part of the world.

Automated visual inspection of manufactured goods

a b
c d
e f

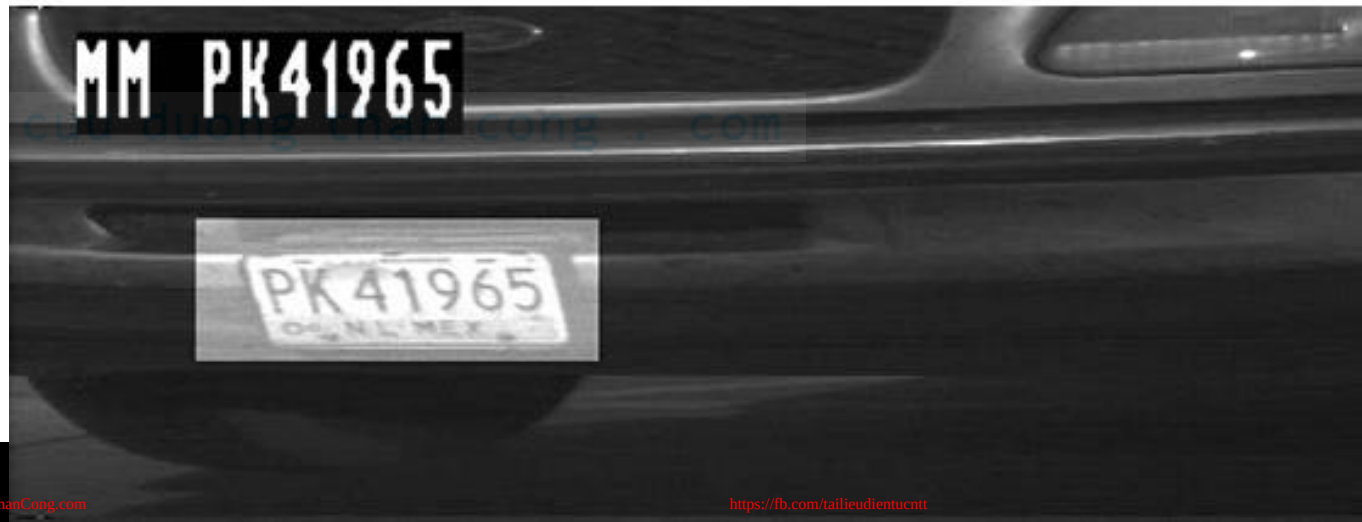
Some examples of manufactured goods often checked using digital image processing.
(a) A circuit board controller.
(b) Packaged pills.
(c) Bottles.
(d) Air bubbles in a clear-plastic product.
(e) Cereal.
(f) Image of intraocular implant.



Security and law enforcement

a b
c
d

Some additional examples of imaging in the visual spectrum.
(a) Thumb print.
(b) Paper currency.
(c) and (d) Automated license plate reading.



Section A.5

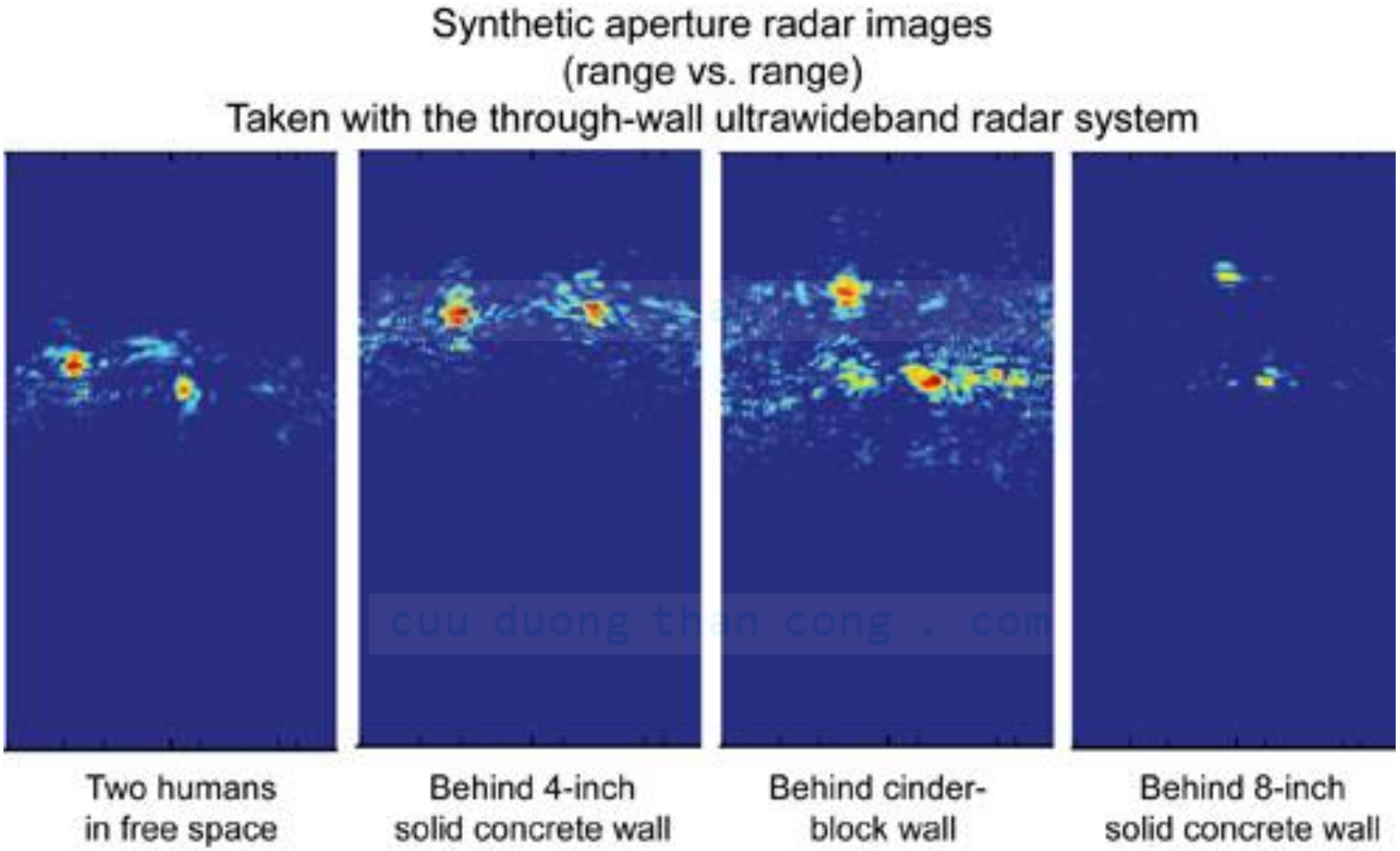
IMAGING IN THE MICROWAVE BANDS

Imaging in the microwave band

- Radar imaging is a dominant application.
- It is able to collect data over virtually any region at any time, regardless of weather or ambient lighting conditions.
  - Radar waves can penetrate clouds, and under certain conditions can also see through vegetation, ice, and dry sand.
  - In many cases, radar is the only way to explore inaccessible regions of the Earth's surface

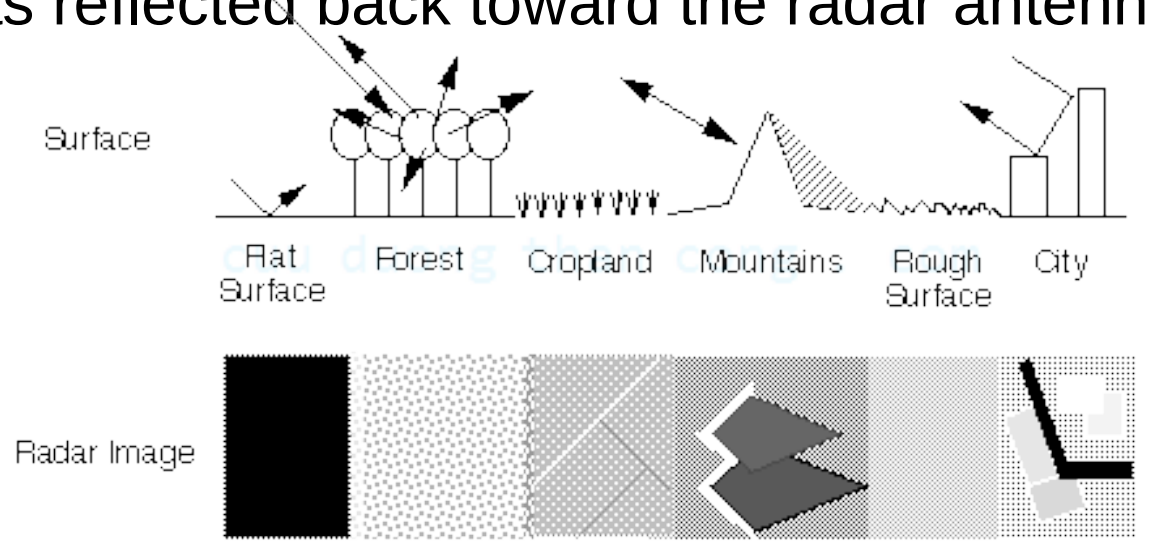
Imaging in the microwave band

- An example of radar imaging



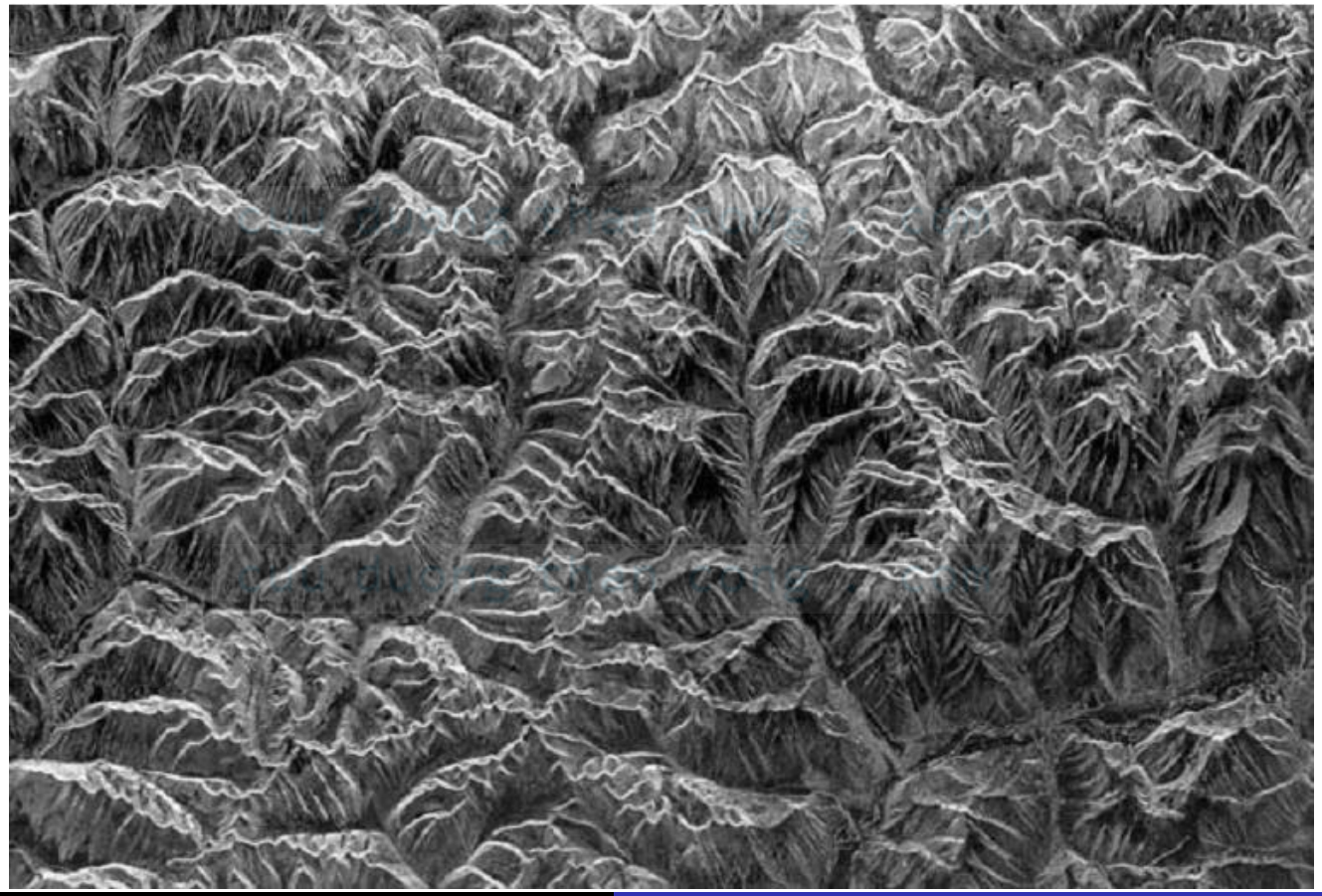
Imaging radar

- An imaging radar works like a flash camera.
  - It provides its own illumination (microwave pulses) to illuminate an area on the ground and take a snapshot.
  - Instead of a camera lens, a radar uses an antenna and digital computer processing to record its images.
- In a radar image, one can see only the microwave energy that was reflected back toward the radar antenna.



Spaceborne radar image

- Spaceborne radar image of mountains in southeast Tibet.
  - Mountains reach about 5800 m (19,000 ft.) above sea level, while the valley floors lie about 4300 m (14,000 ft.) above sea level.



Section A.6

IMAGING IN THE RADIO BANDS

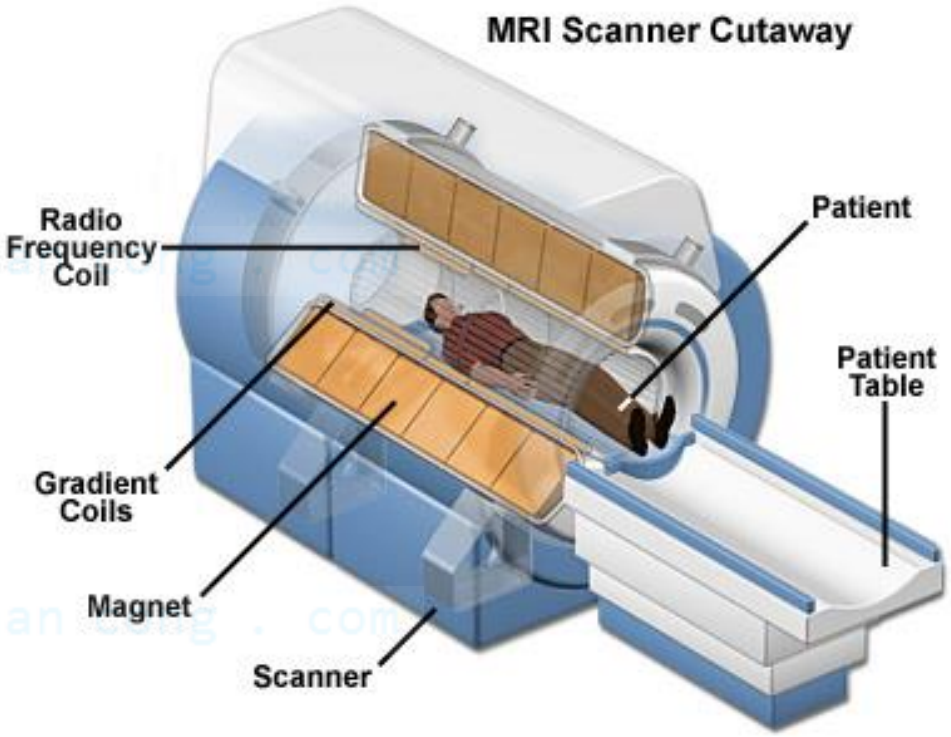
Imaging in the radio band

- Major applications of imaging in the radio band are in **medicine** and **astronomy**.

Band	Frequency range	Wavelength range
Extremely low frequency (ELF)	< 3 kHz	>100 km
Very low frequency (VLF)	3 - 30 Hz	10 - 100 krn
Low frequency(LF)	30 - 300 kHz	1 - 10 km
Medium frequency (MF)	300 kHz - 3 MHz	100m - 1km
High frequency (HF)	3 - 30 MHz	10 - 100m
Very high frequency (VHF)	30 - 300 MHz	1 - 10m
Ultra high frequency (UHF)	300 MHz - 3 GHz	10cm - 1m
Super high frequency (SHF)	3 - 30 GHz	1 - 10cm
Extremely high frequency (EHF)	30 - 300 GHz	1mm - 1cm

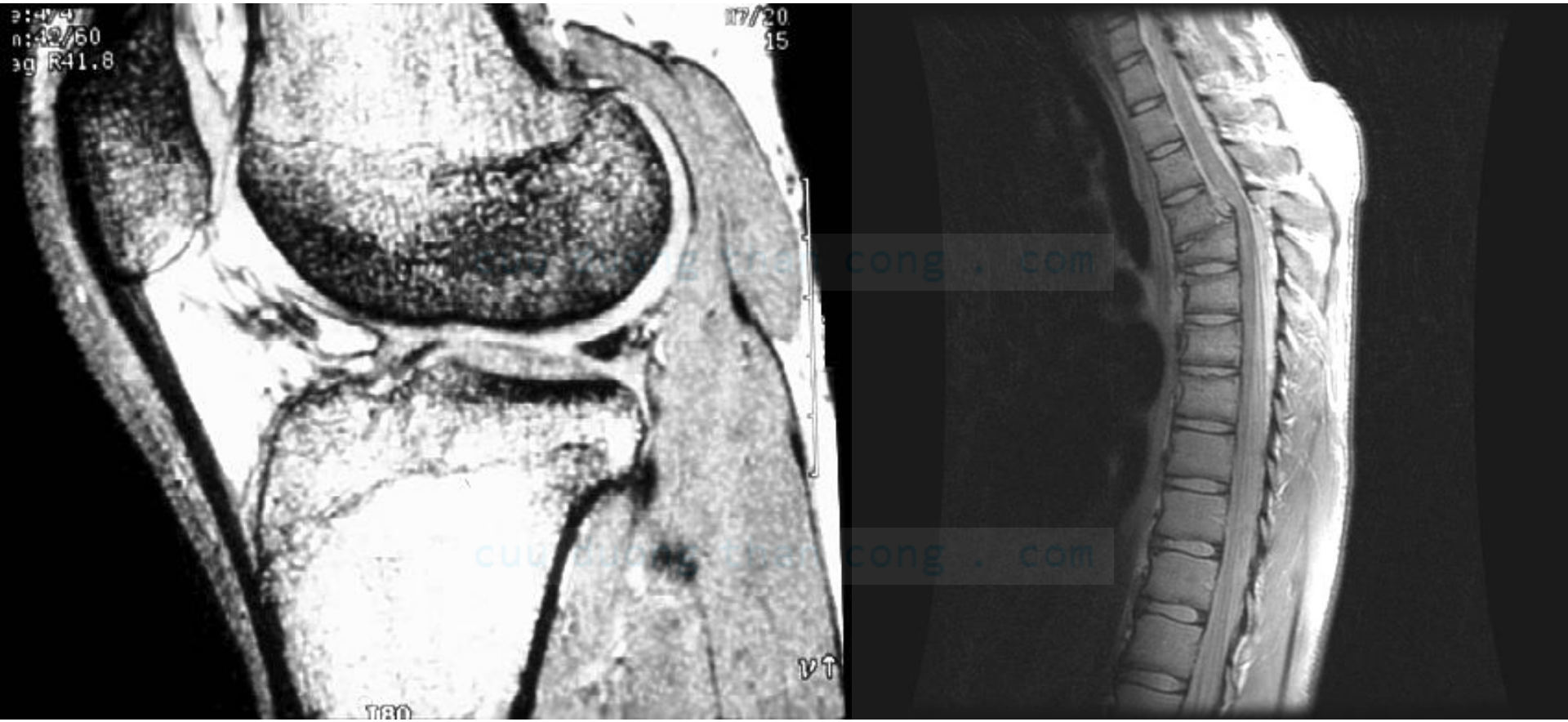
Magnetic resonance imaging (MRI)

- The patient is placed in a powerful magnet and passes radio waves through his or her body in short pulses.
- Each pulse causes a responding pulse of radio waves to be emitted by the patient's tissues.
- The location from which these signals originate and their strength produce a two-dimensional picture of a section of the patient.



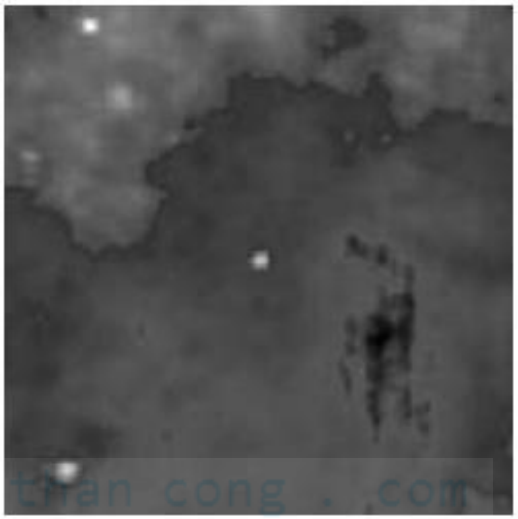
Magnetic resonance imaging (MRI)

- MRI images of a human knee and spine

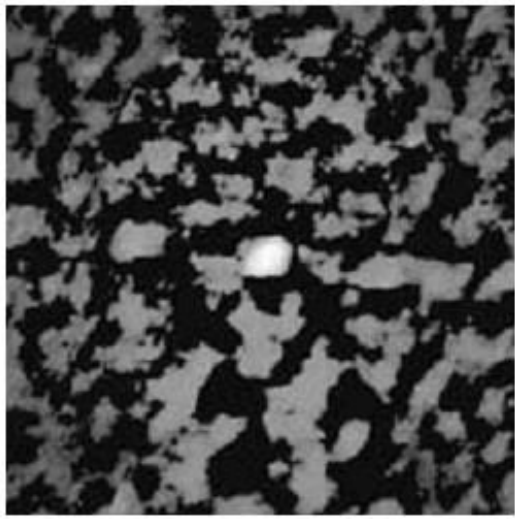


Astronomy

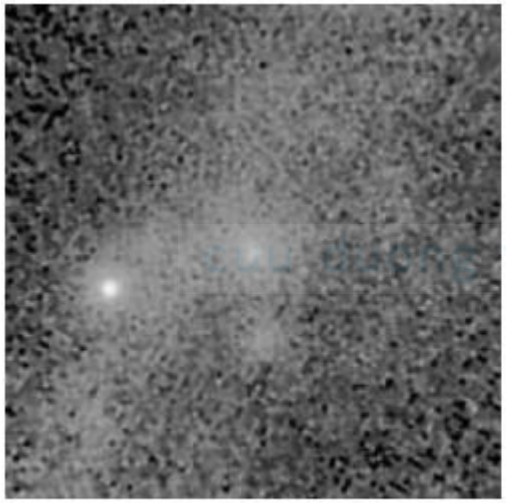
- Images of the same Crab Pulsar are taken in most of the bands discussed earlier.



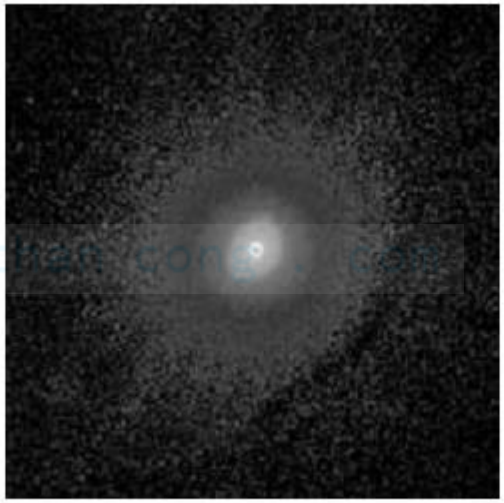
Infrared



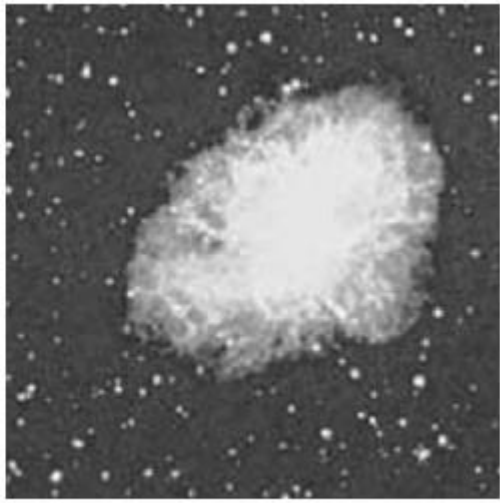
Radio



Gamma



X-ray



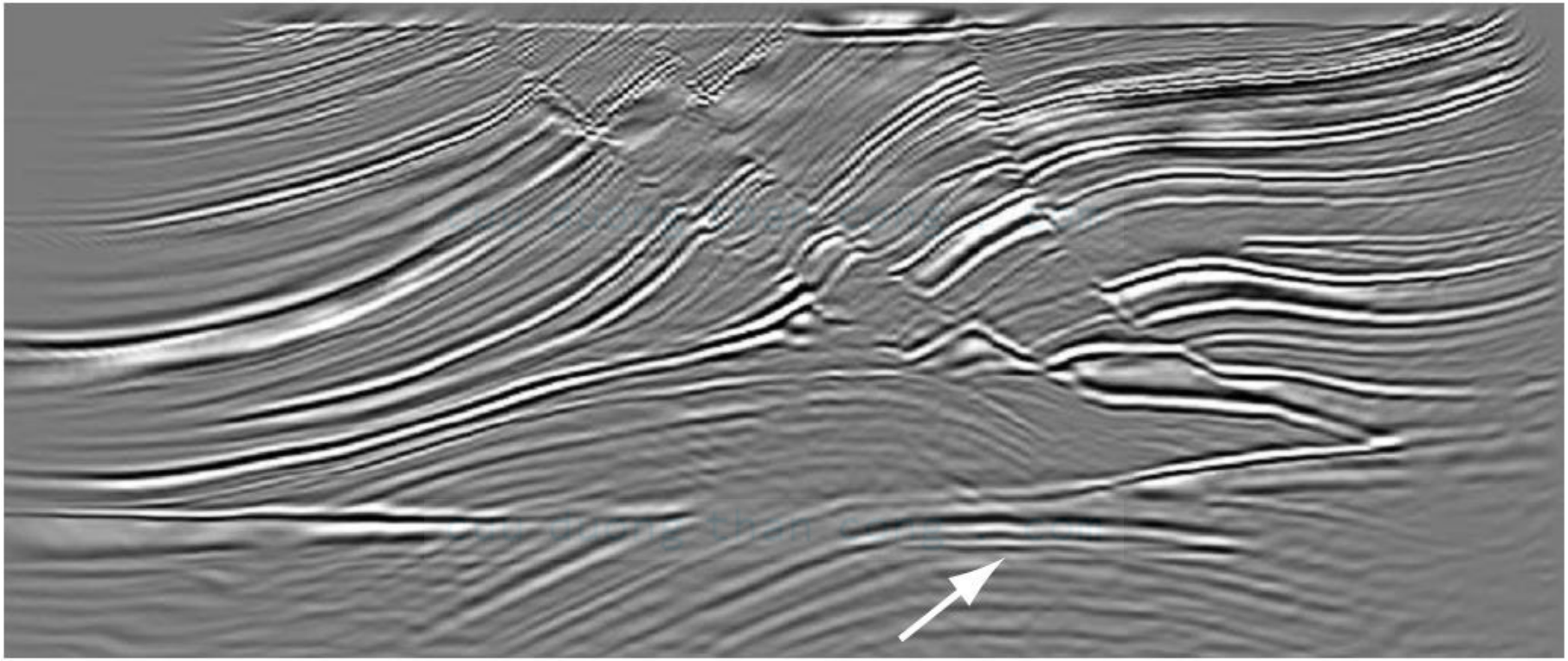
Optical

Section A.7

OTHER IMAGING MODALITIES

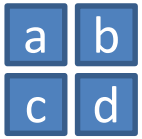
Acoustic imaging

- Imaging using “sound” finds application in geological exploration, industry, and medicine.

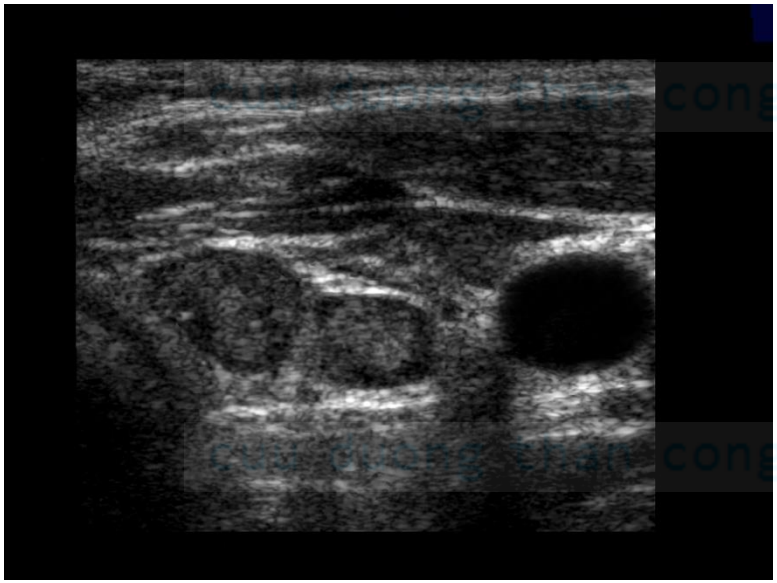


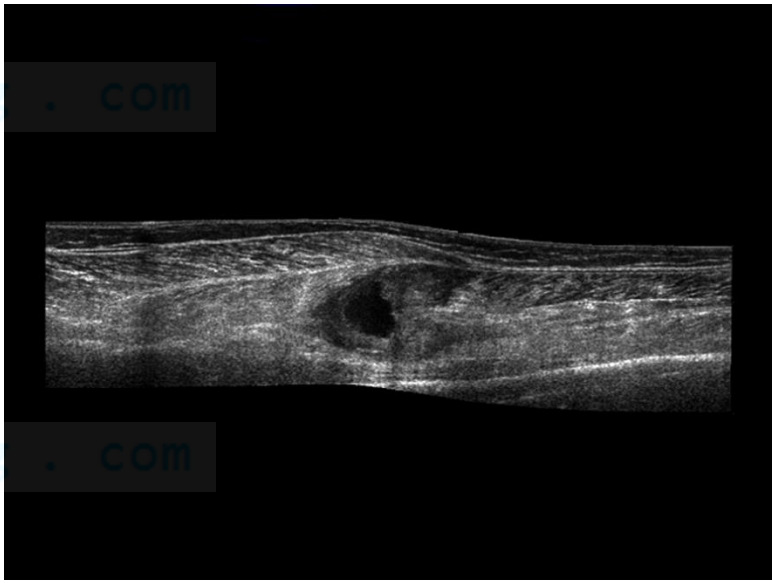
Cross-sectional image of a seismic model. The arrow points to a hydrocarbon (oil and/or gas) trap.

Examples of ultrasound imaging



(a) Baby.
(b) Another view of baby.
(c) Thyroids.
(d) Muscle layers showing lesion.

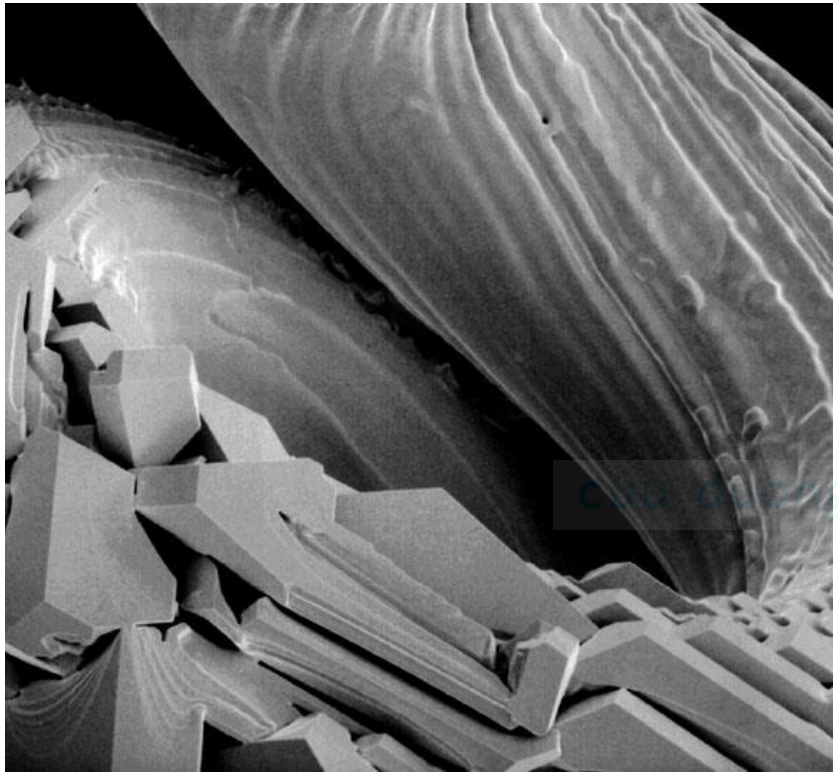


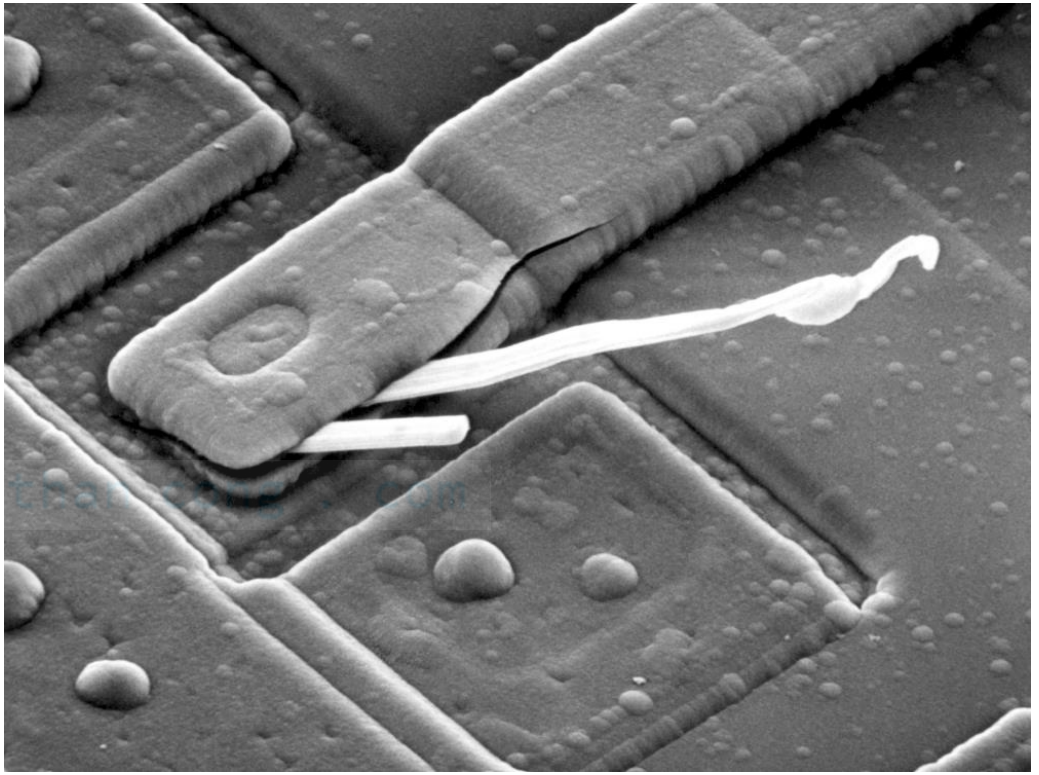


Electron microscopy

- Electron microscopes use a focused beam of electrons instead of light to image a specimen.
- A stream of electrons is produced by an electron source and accelerated toward the specimen using a positive electrical potential.
  - It is confined and focused using metal apertures and magnetic lenses into a thin, monochromatic beam, which is focused onto the sample using a magnetic lens.
- Interactions inside the irradiated sample affect the electron beam, they are detected and transformed into an image.
- Electron microscopes are of **very high magnification**.
  - 10,000× or more, while light microscopy is limited to 1,000×.

Electron microscopy



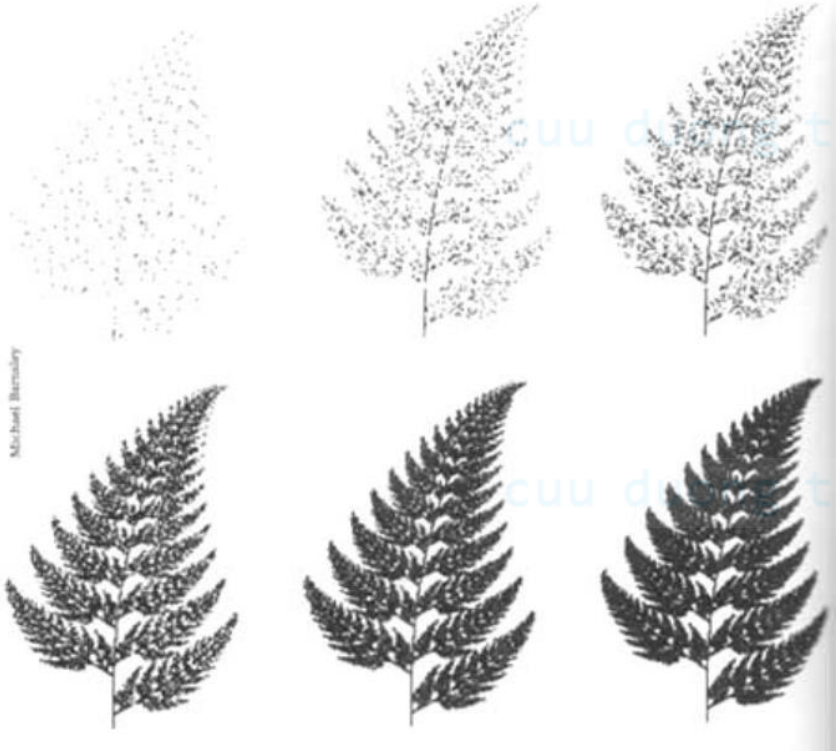


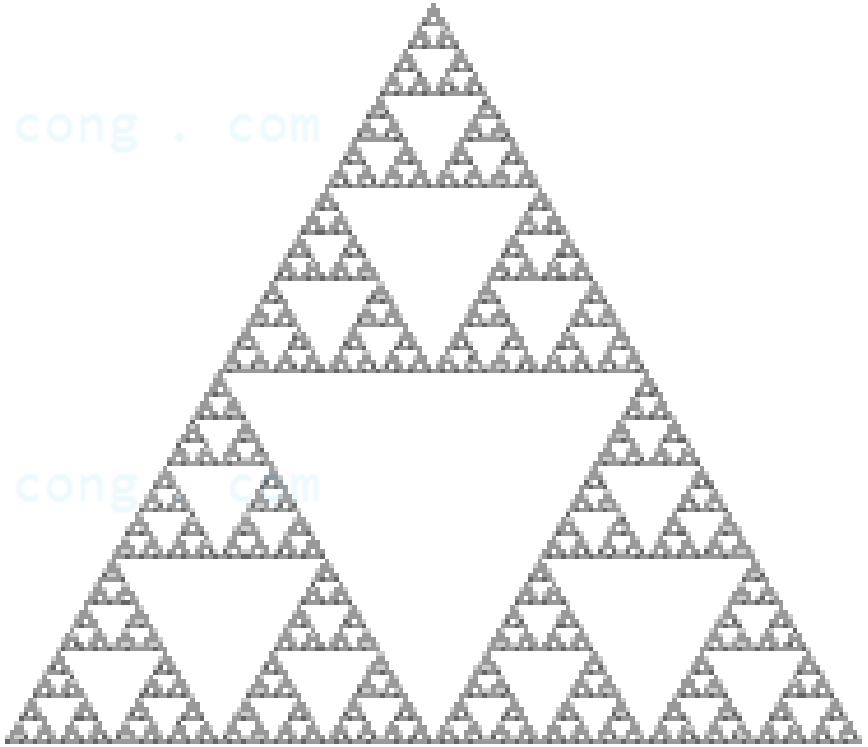
a b

(a) SEM (scanning electron microscope) image of a tungsten filament following thermal failure (note the shattered pieces on the lower left). (b) SEM image of damaged integrated circuit. The white fibers are oxides resulting from thermal destruction

Computer-generated images

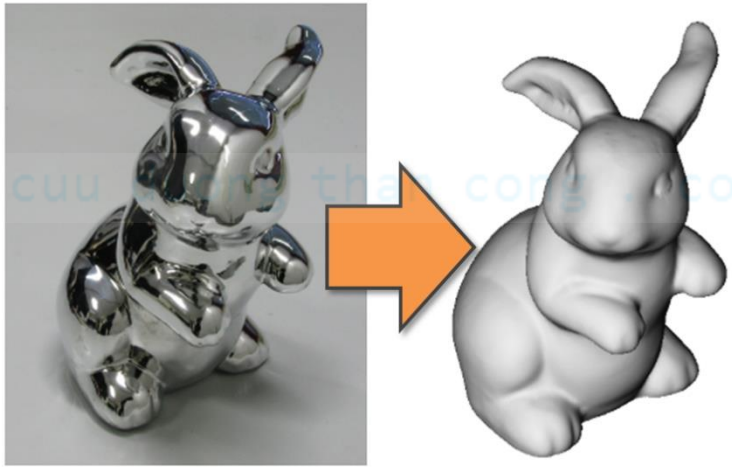
- Fractal is nothing more than an iterative reproduction of a basic pattern according to some mathematical rules.
  - Artistic, mathematical formulations of “growth” of subimage elements according to a set of rules





Computer-generated images

- 3-D images can be used for medical training, criminal forensics and special effects.



Reference

- Rafael C. Gonzalez, Richard E. Woods, “Digital Image Processing”, 3rd edition, 2008. Chapter 1
- Images are obtained from the above materials and Google