Unidad 1, Sesión 3/4
Adquisición de Imágenes biológicas y biomédicas III

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Sesión nº3/4 del Curso de Postgrado:

Procesamiento de Imágenes y Bioseñales I

Facultad de Medicina, U. de Chile

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inverse problems and crimes

- **detective novels**: the scene of the crime, clues and a mystery to discover.
- more than one suspect, the facts and observations, the logical deductions led to a single and surprising explanation.

CRIME? → CLUES

- one goes back in time, connecting the available evidence to **reconstitute** the hidden and most plausible truth.
- in mathematical language, this is an **inverse problem**, instead of going from the cause to the effect, it is the contrary: going from the effect to the cause.

A → ?
direct

? → B
inverse

motivation: medical diagnosis, imaging the human body

- focus: medical **diagnosis** is an inverse problem *par excellence*, and one of the oldest that has confronted humanity: we are faced with the problem of determining the cause of the symptoms of an illness.
- we are often asked for **images** of some kind: **x-rays, ultrasounds, resonances, scanners, electrocardiograms**, etc.
- behind each of these images there is an **inverse problem** and involve revolutionary physics, mathematics and technology to build the electronic devices that make a reality to see images of our **inner world**.

illness → symptoms

body composition and living tissues...

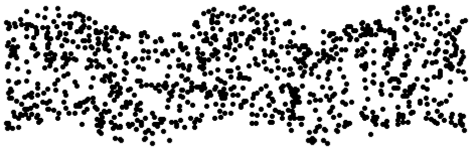
- the human body is more than **50% water**. The rest of their mass are **living tissues**, softer and harder: fat, muscles, bones.

	water	fat (storage)	fat (essential)	muscle	bone	remainder
women	**52**%	15%	12%	36%	12%	25%
men	**57**%	12%	3%	45%	15%	25%

Behnke's model of reference man and woman 1978

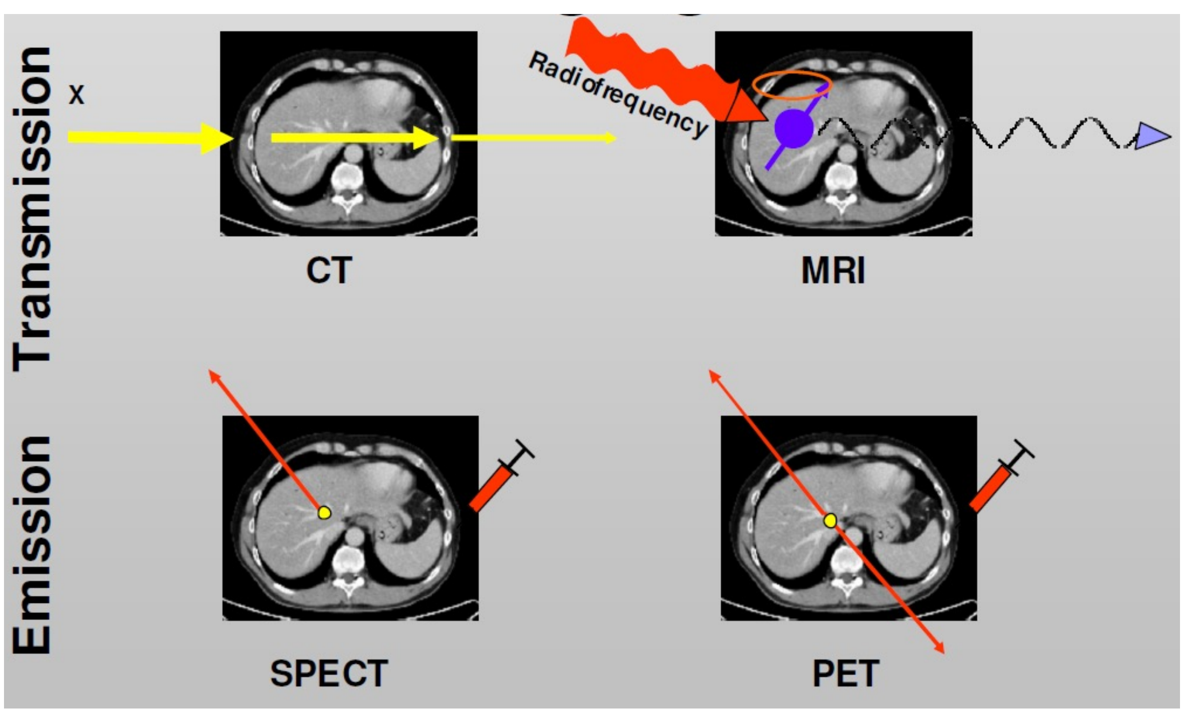
- waves or particles can **travel through** the body: **sound or elastic waves, electricity, radiation, light**.
- we can register their effect to see the inner body→ **inverse problem**

photon transport/scattering



wave propagation

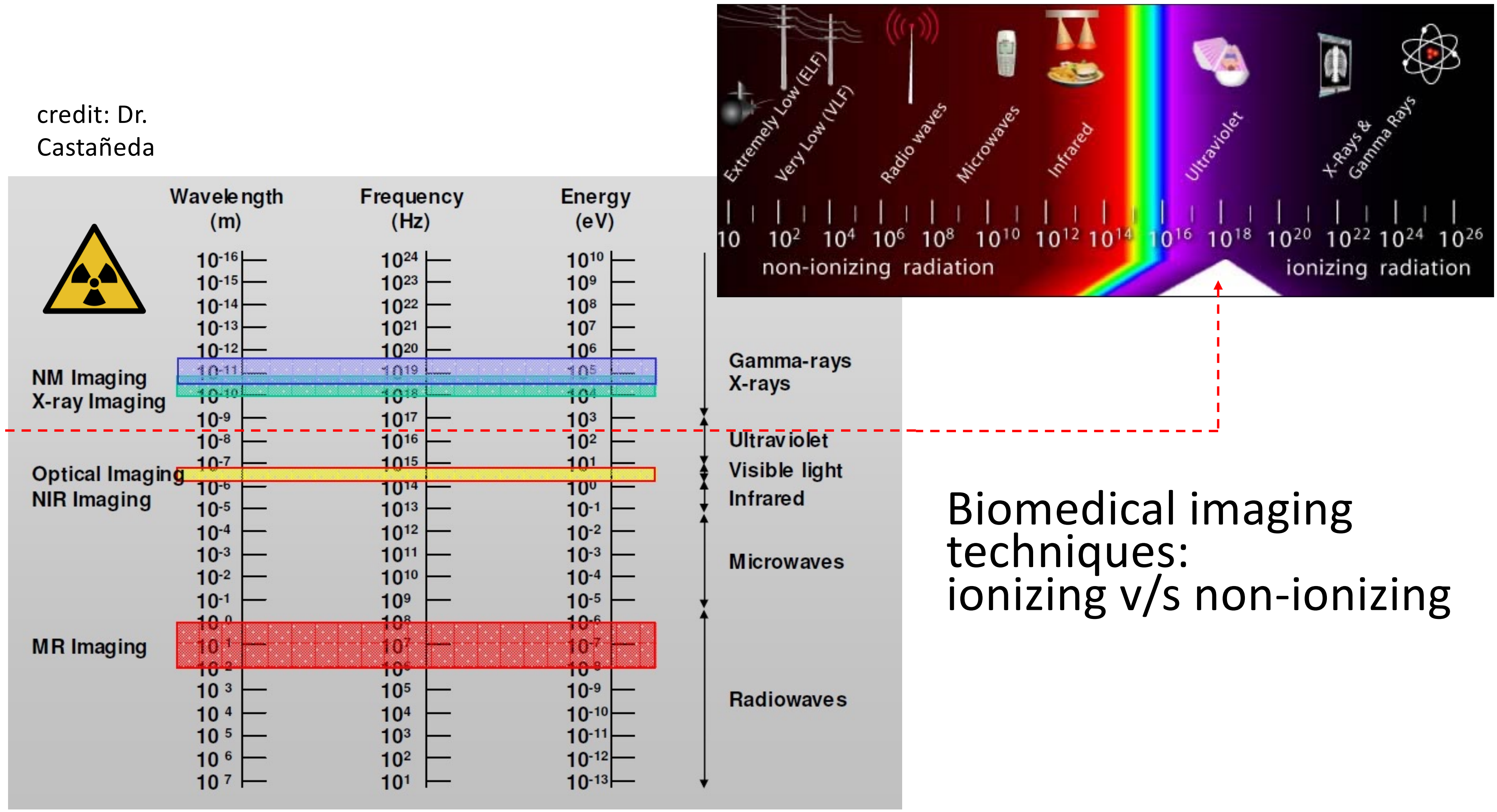
Biomedical imaging techniques: emission v/s transmission...



credit: Dr. Castañeda

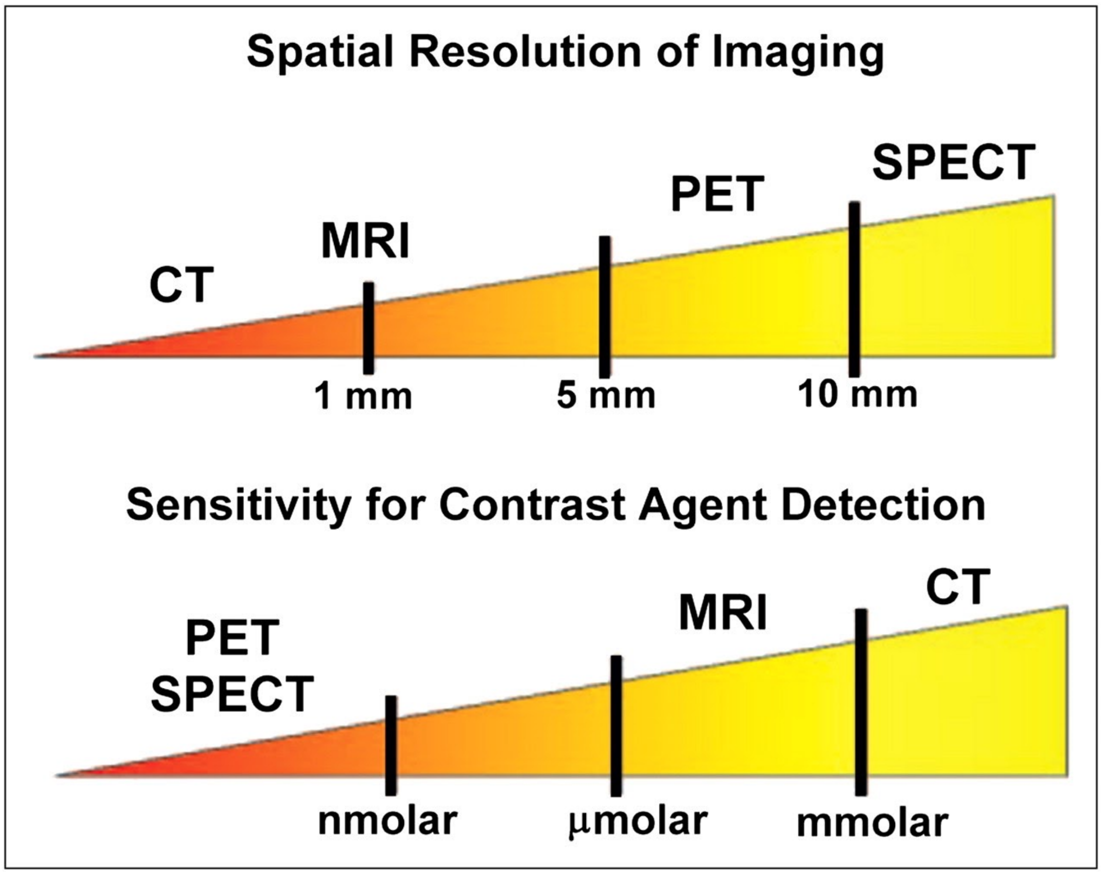
+ ultrasound
+ EI

credit: Dr. Castañeda



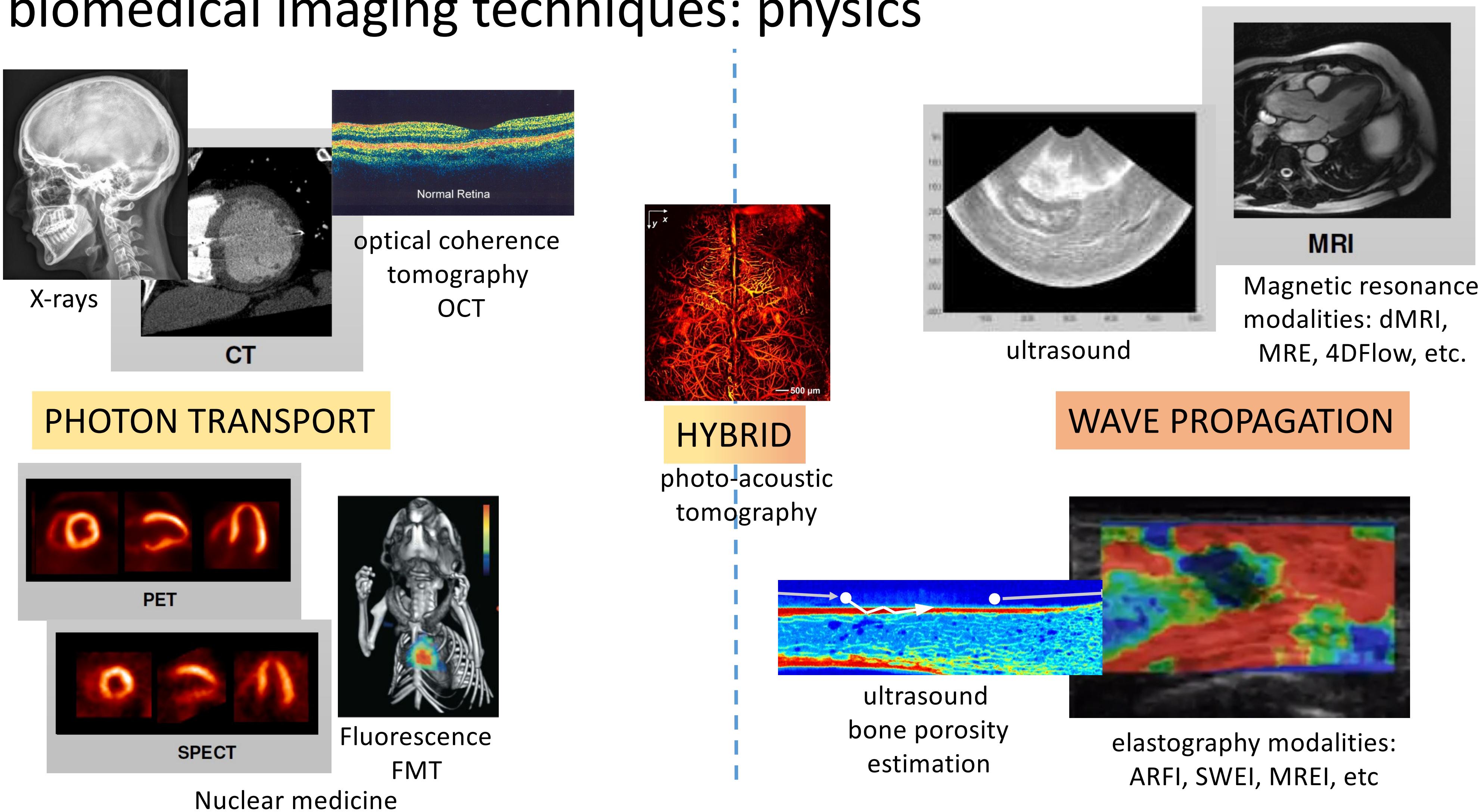
Biomedical imaging techniques: ionizing v/s non-ionizing

Biomedical imaging techniques: resolution v/s sensitivity...



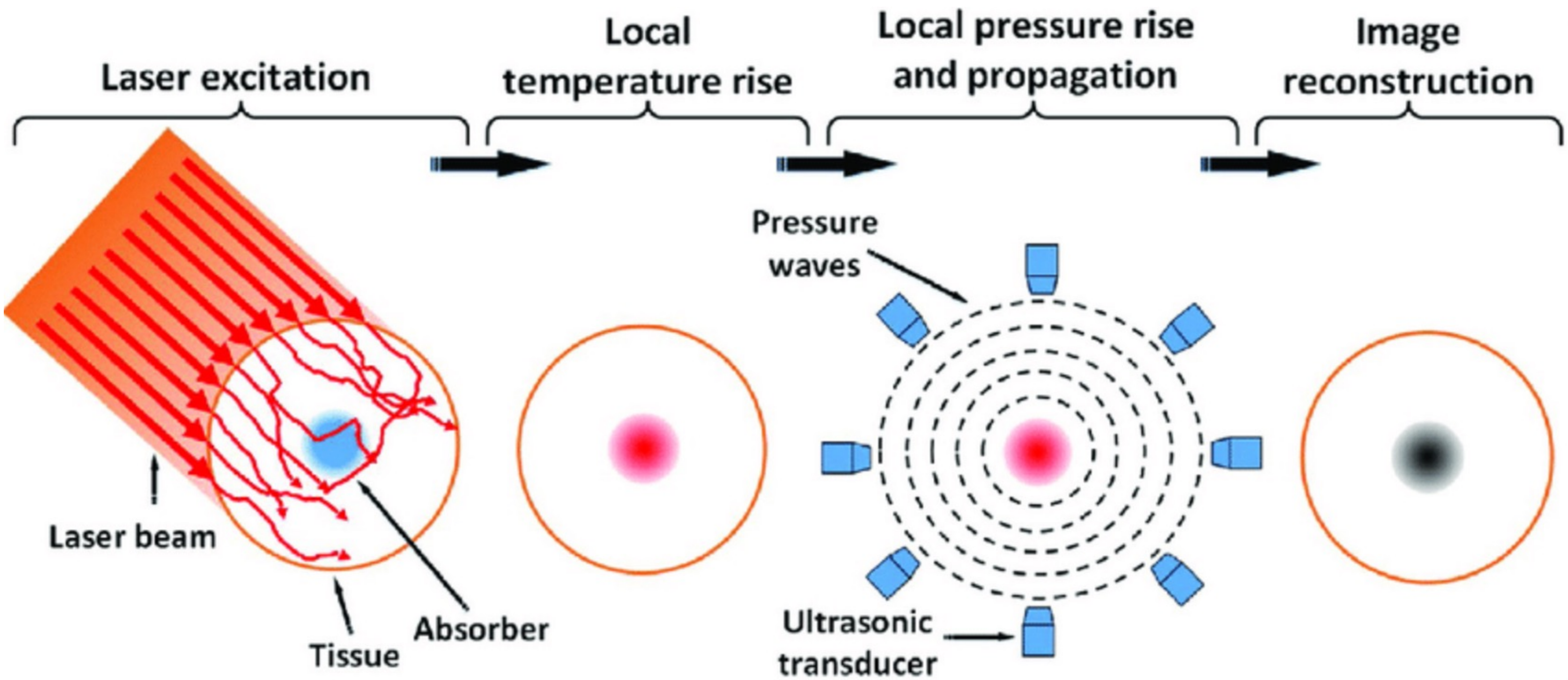
credit: web

biomedical imaging techniques: physics



Hybrid methods: photo-acoustic tomography (PAT)

based on the photoelectric effect : Hertz 1997, Einstein 1905 nobel prize



credit: Ali-Reza et al. Neonatal brain resting-state functional connectivity imaging modalities, Photoacoustics 10, 2018

First part (photon transport):

- 1.- X-rays, CT, nuclear medicine, PET, SPECT:
  - *currect research topic: simultaneous source and attenuation in SPECT*
- 2.- Fluorescence molecular tomography FMT :
  - *currect research topic: mathematics of light-sheet microscopy*

Second part (wave phenomena):

- 3.- Ultrasound, elasticity imaging, MRE:
  - *current research topic: bone porosity estimation by ultrasound*
- 4.- Magnetic resonance MRI:
  - *current research topic: non-invasive pressure and blood flow estimation*

First part (photon transport)

1.- X-rays, CT, nuclear medicine, PET, SPECT

currect research topic: simultaneous source-attenuation identification in SPECT

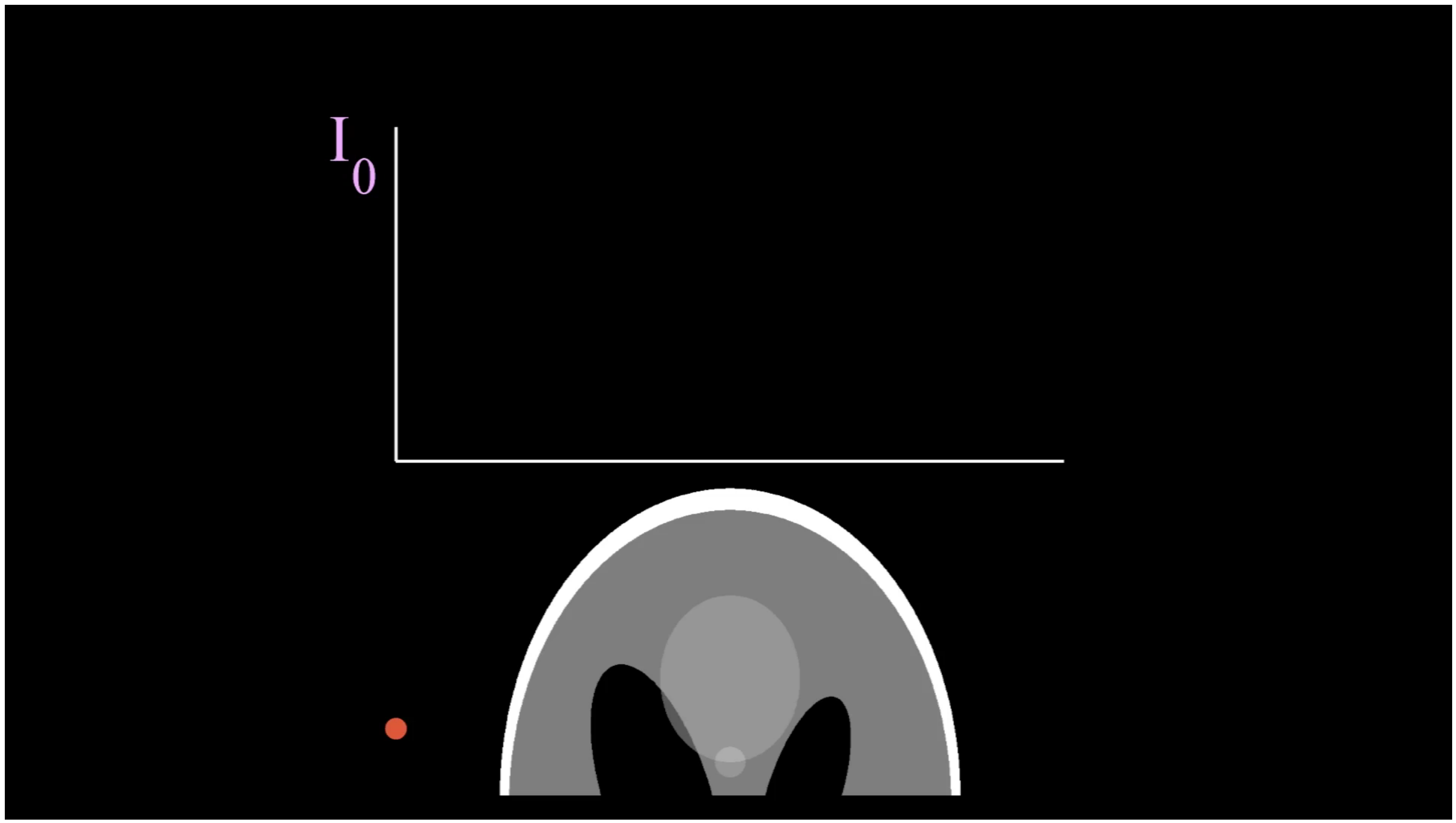
first the basis... X-rays... the scanner

- Wilhelm Röntgen, a German engineer, obtained the Nobel in 1901 for detecting and producing **X-rays** for the first time.
- X-rays: invisible high energy electromagnetic waves that cross the body almost as if it were transparent, **attenuated** principally by bones.
- In 1917, Johann Radon, an Austrian mathematician, developed the mathematical basis for combining X-rays at different angles to obtain **three-dimensional images**.
- The British engineer Godfrey Hounsfield build the **first scanner** in 1971 and obtained the Nobel for this in 1979.
- Before that, in 1953, diffraction X-ray images were used by the crystallographer Rosalind Franklin to discover the form of the **ADN double helix** (1962 Nobel)

X-ray attenuation

credit: Samuli Siltanen

the
measurent
$\log(I_0/I_1)$
is the integral
of the
attenuation
along the
line



The Shepp-Logan phantom: Larry Shepp and Benjamin F. Logan for their 1974 paper *The Fourier Reconstruction of a Head Section*

Beer's law

(monochromatic, X-ray beam no refraction or diffraction)

Intensity decay...

$$\Delta I = I_{out} - I_{in}$$

is proportional to attenuation, thickness and intensity...

$$\Delta I = -a(x) I \Delta x$$

The infinitesimal change...

$$\frac{dI}{dx} = -a(x) I$$

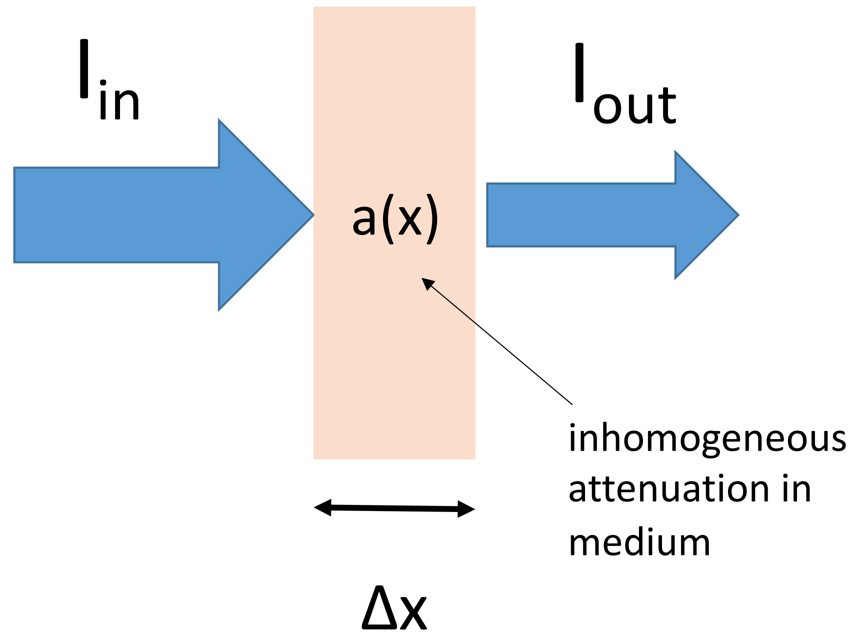
gives by integration on lines the solution:

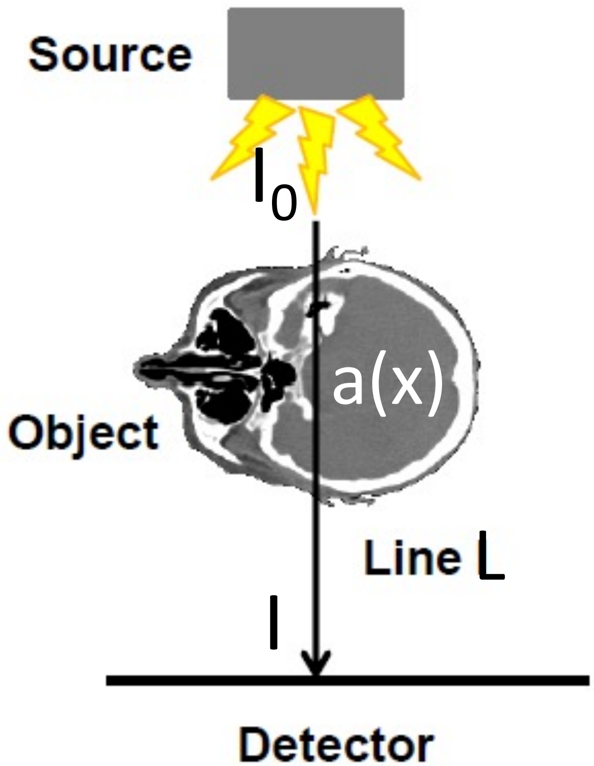
$$I = I_0 \exp\left(- \int_L a \right)$$

$$L : \text{line from } x_0 \text{ to } x$$

so the sum over lines can be measured

$$\int_L a = -\ln \frac{I}{I_0}$$





attenuation integral

$$\int_L a = -\ln \frac{I}{I_0}$$

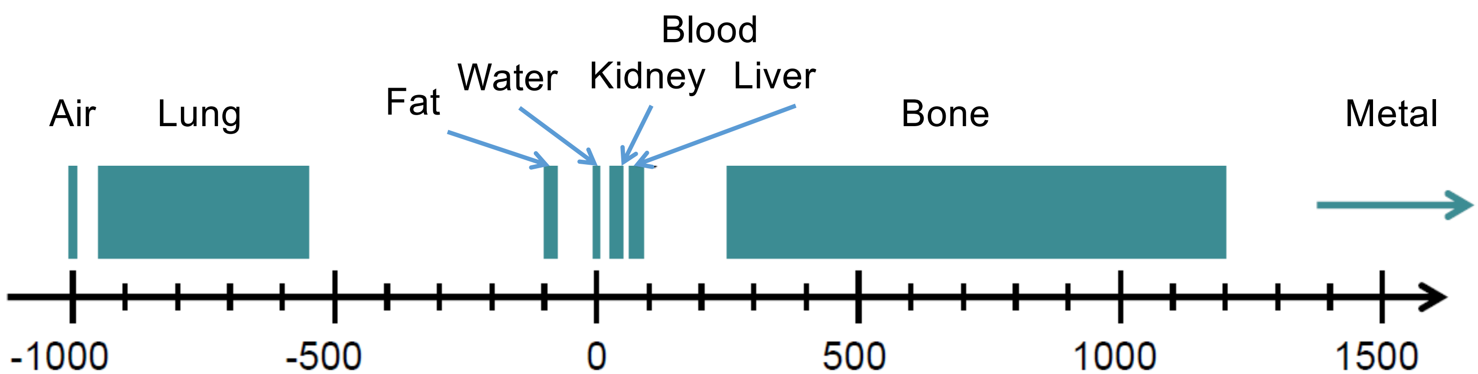
- Photons with energies 50-120 keV are emitted by an X-Ray source
- Interaction with biological tissue absorbs & scatters some of the photons (photo-electric and Compton effect)

credit: Dr. Castañeda

Typical X-ray data: Hounsfield Units (HU)

CT-scanner callibration Air=-1000, Water=0

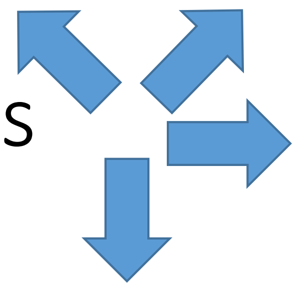
$$HU = \frac{\mu - \mu_{Water}}{\mu_{Water}} \cdot 1000$$



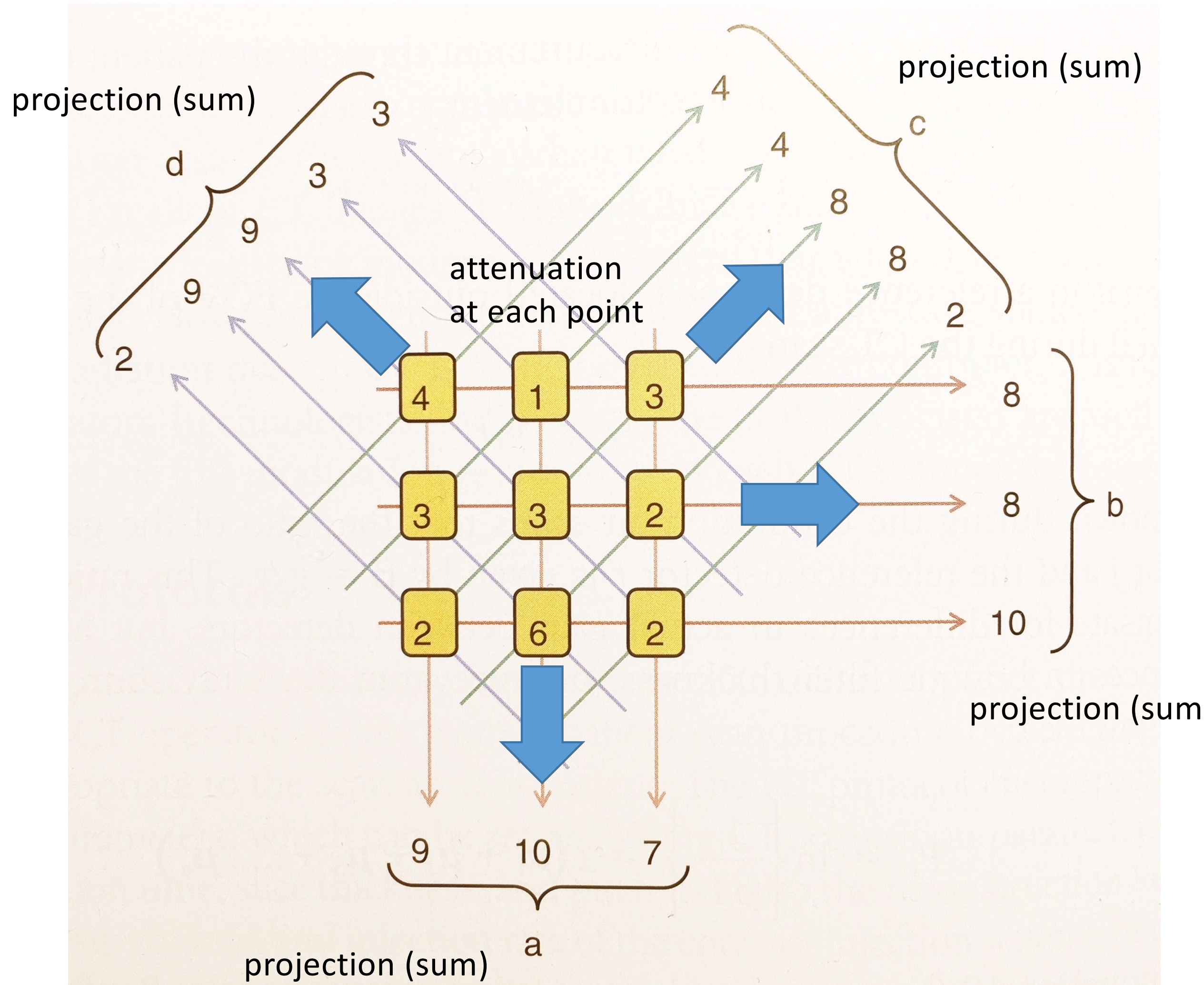
credit: Dr. Castañeda

Principle of Computed Tomography:

Projections

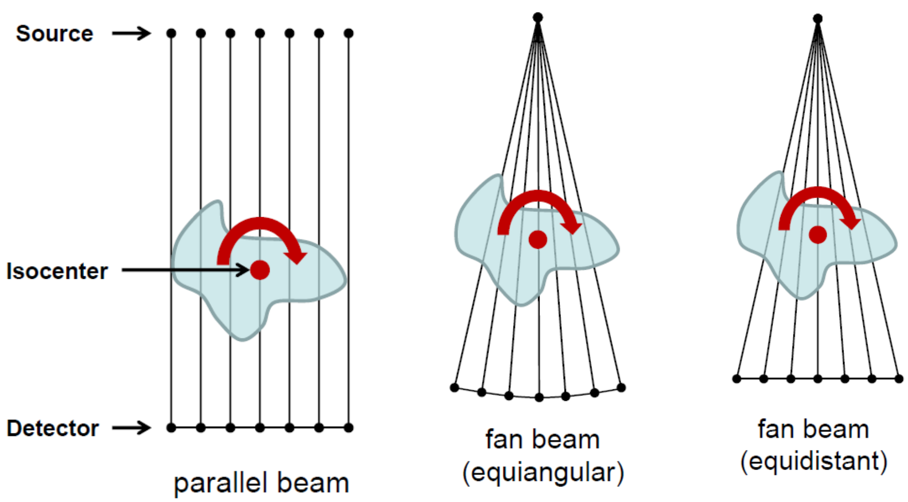


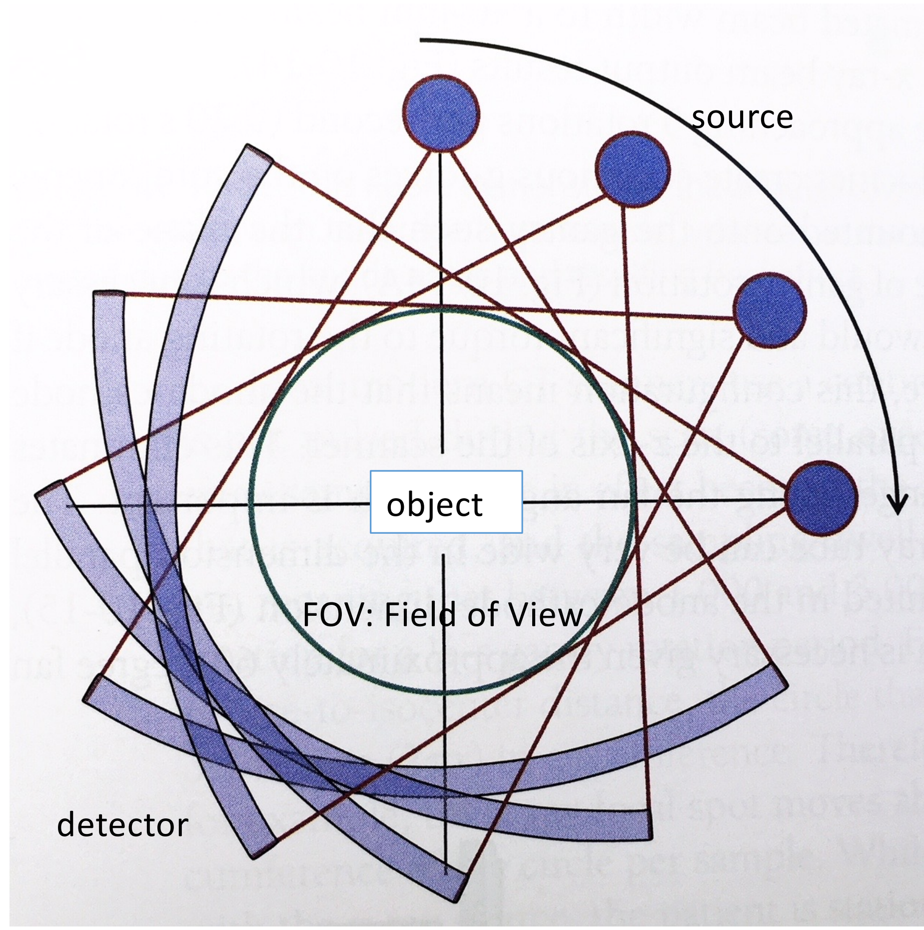
How to recover the attenuation from sum of lines?



credits figure: ref 2

CT-scanner: fan/parallel beam



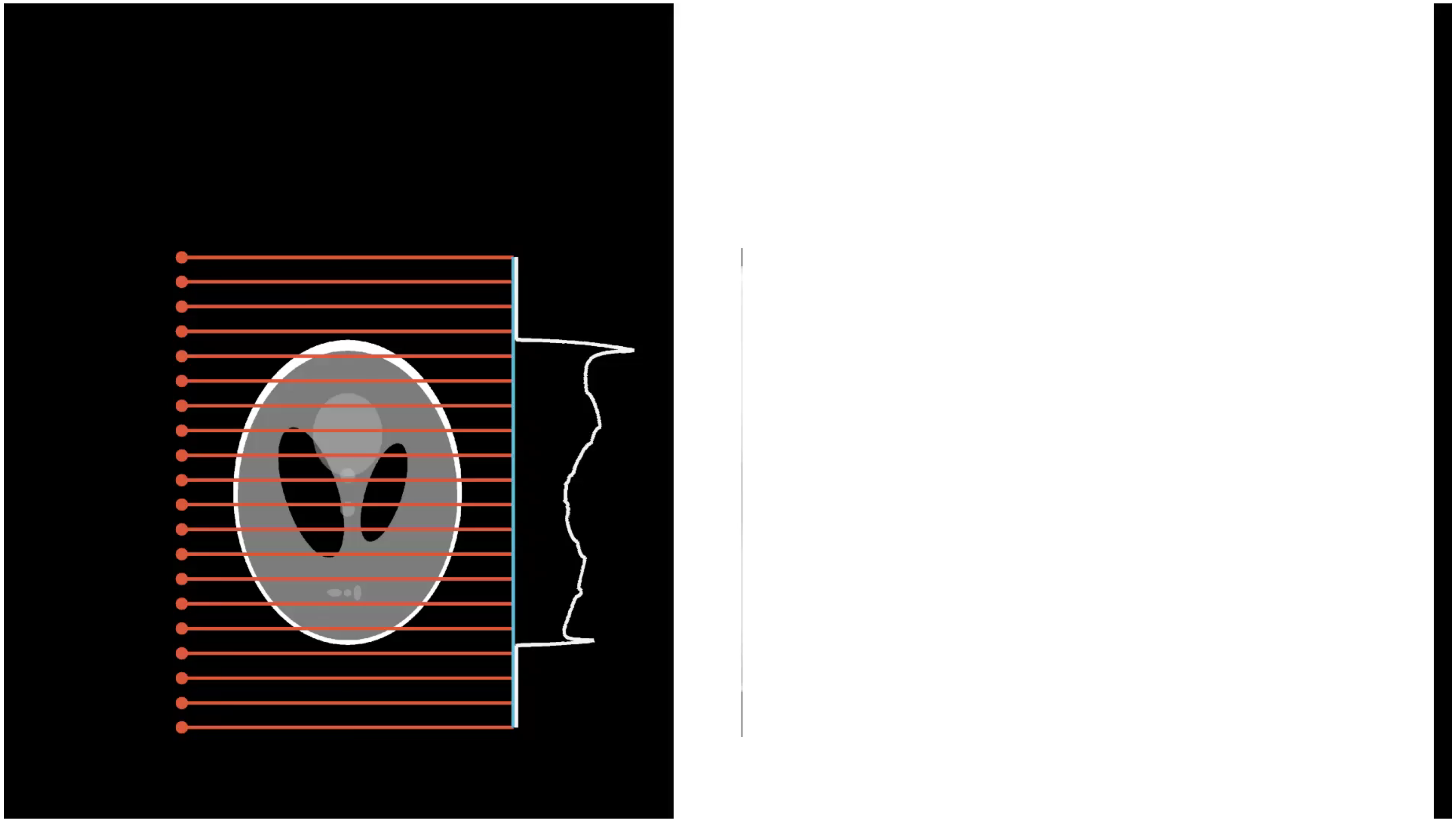


credits figure: ref 2

CT - scanner

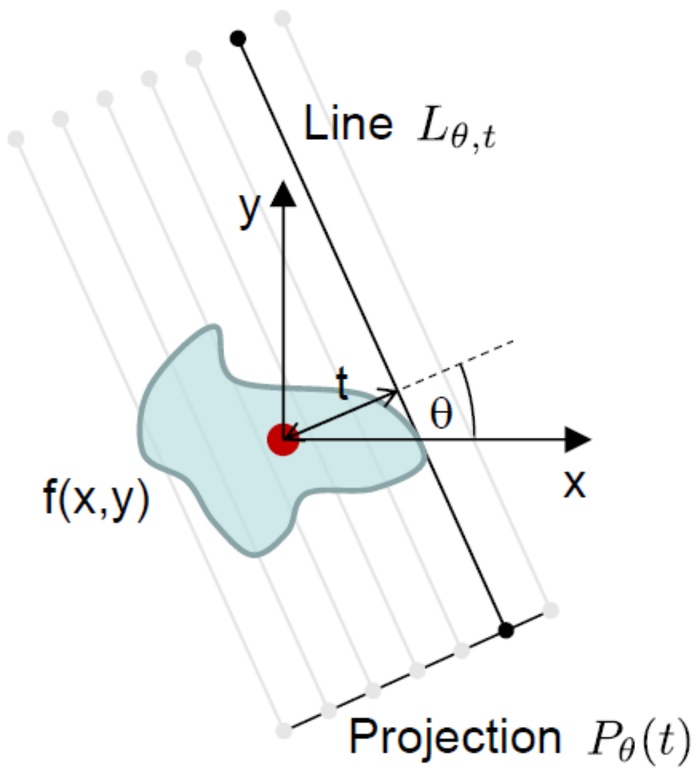
image? → sinogram (Radon transform)

Mathematical
tool:
the inverse
Radon transform



credit: Samuli Siltanen

The Radon transform

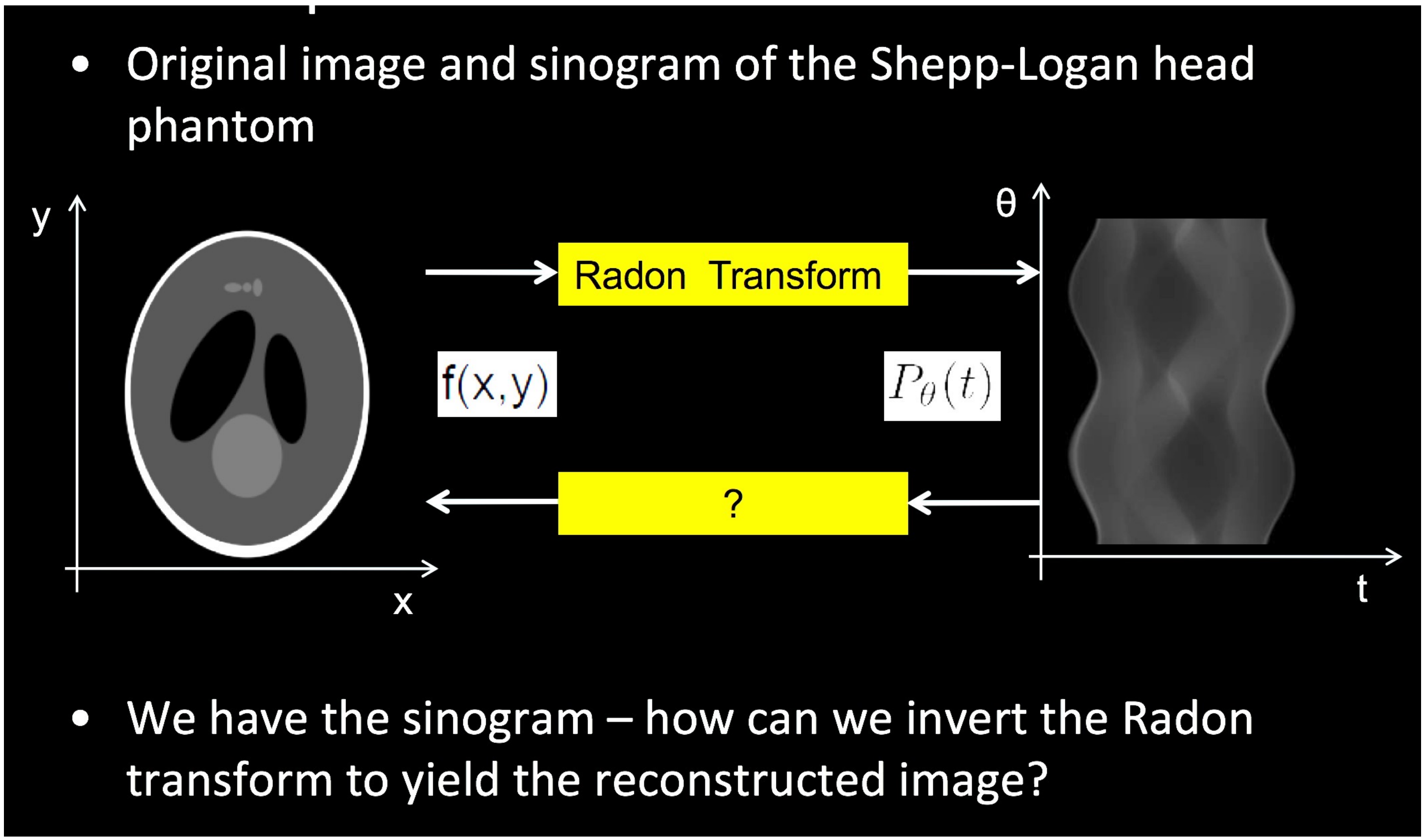


Integral of a function over lines

$$P_\theta(t) = (R \circ f)(\theta, t) = \int_{L_{\theta,t}} f(\vec{x})\, ds$$

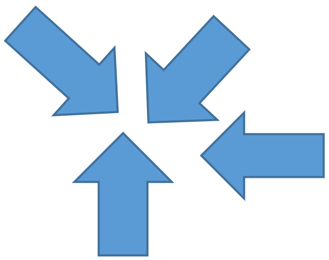
credit: Dr. Castañeda

The inverse problem (Johann Radon, 1917)



credit: Dr. Castañeda

Backprojections

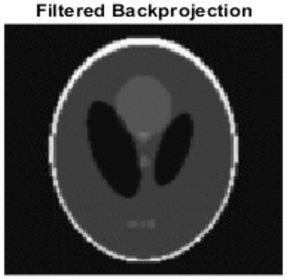


30	25	26
30	35	26
29	37	28

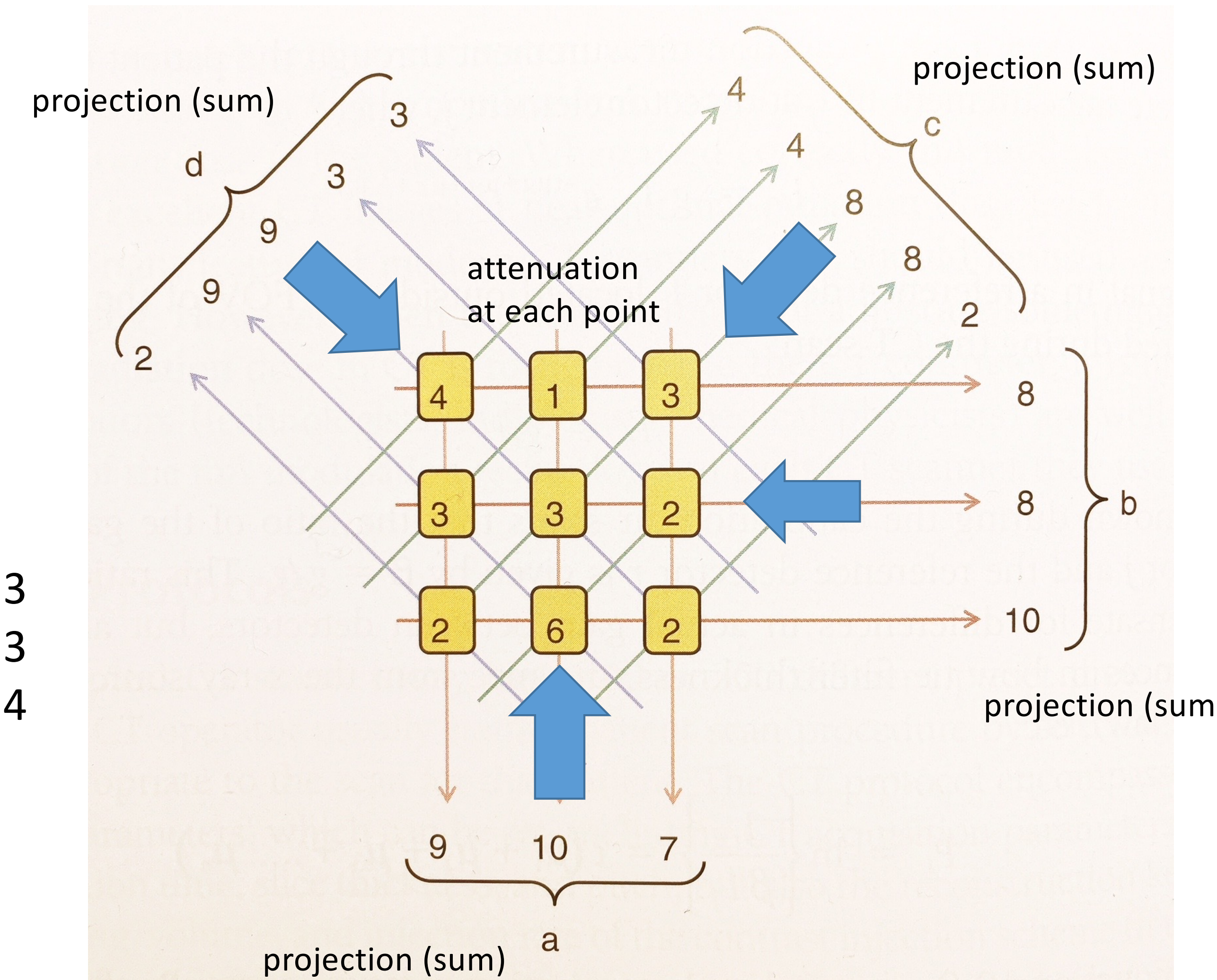
*9/26/4

2.6	2.2	2.3
2.6	3.0	2.3
2.5	3.2	2.4

Filtered Backprojection



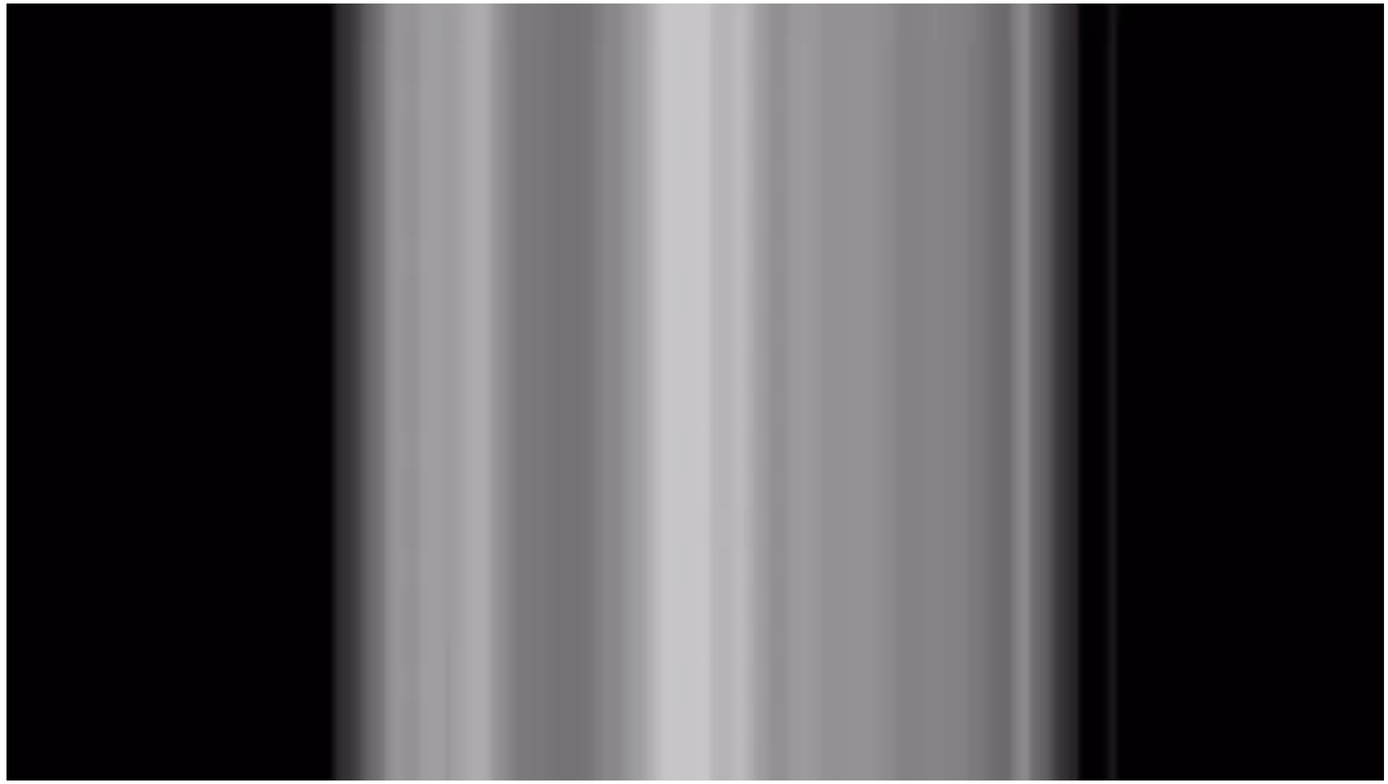
Unfiltered Backprojection



credits figure: ref 2

Backprojection:
effect of an increasing number of projections

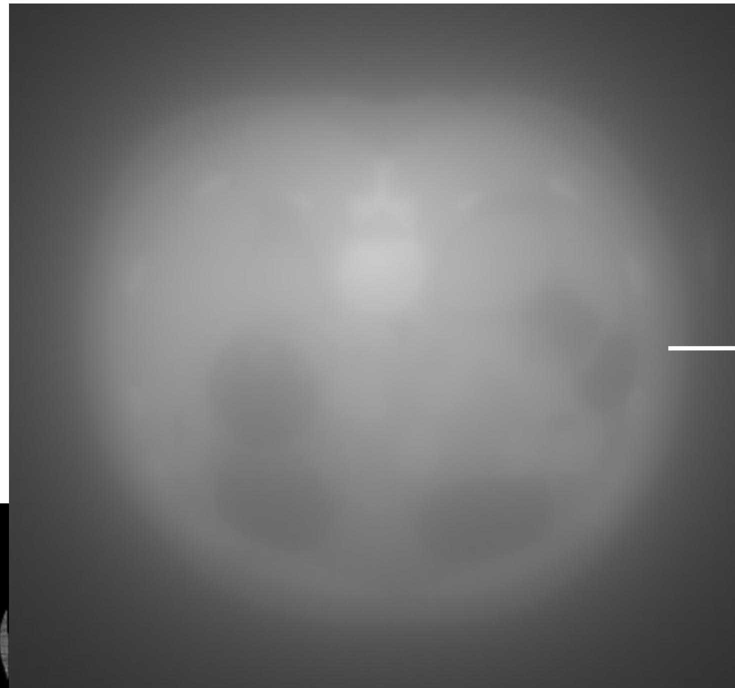
original (axial view)



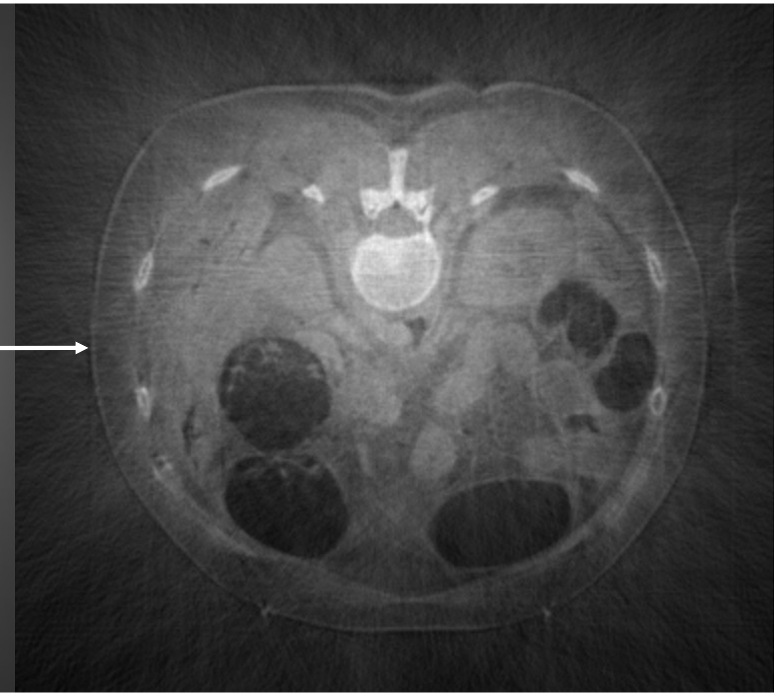
magic!

Deconvolution
Filter

original (axial view)



backprojection

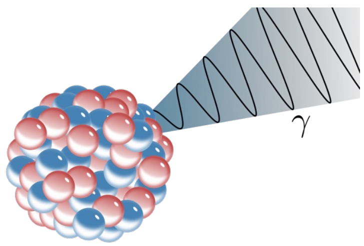


filtered backprojection

Source: http://www.perlproductions.at/index.php?choice=referenz&lang=en&id=15

2nd... gamma rays

- Paul Villard discovered the **gamma rays** in 1900 in his laboratory of rue d'Ulm in Paris.



- 3 years later Marie and Pierre Curie, together with Henri Becquerel, would receive the Nobel Prize for the discovery of **radioactivity**.
- Nowadays, in **nuclear medicine**, radio-pharmaceuticals are used to emit gamma rays into the body.
- The idea is to mark certain key molecules that reflect the activity in the study of diseases such as **Alzheimer's or epilepsy,** or evidence of the metabolism when evaluating an **oncological** treatment.

Nuclear Medicine

- Radioisotop

  What do we want:

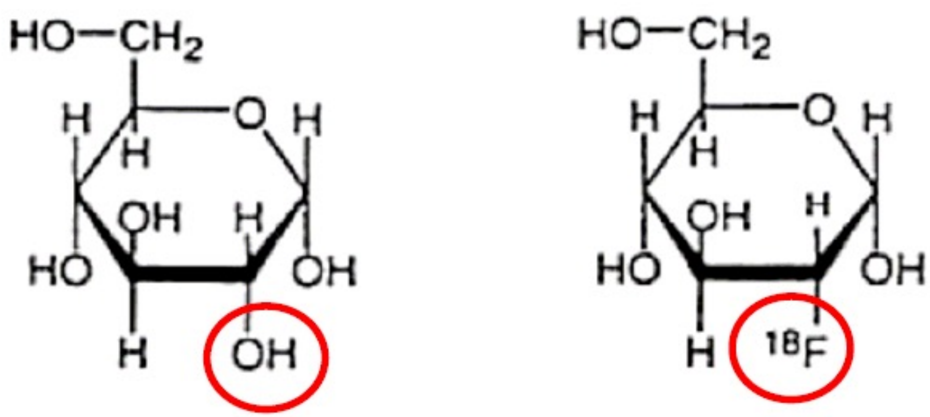
  - not too short and not too long half life time
  - only γ radiation (α & β would increase patient dose without gain for diagnosis)

Nuclide	Half life time	Decay	Energy
^{99m}Tc	6 h	γ	140 keV
^{201}Tl	73 h	γ	70 keV
^{123}I	13 h	γ	159 keV
^{18}F	110 min	$e^+, \gamma\gamma$	511 keV
^{11}C	20 min	$e^+, \gamma\gamma$	511 keV
^{13}N	10 min	$e^+, \gamma\gamma$	511 keV

credit: Dr. Castañeda

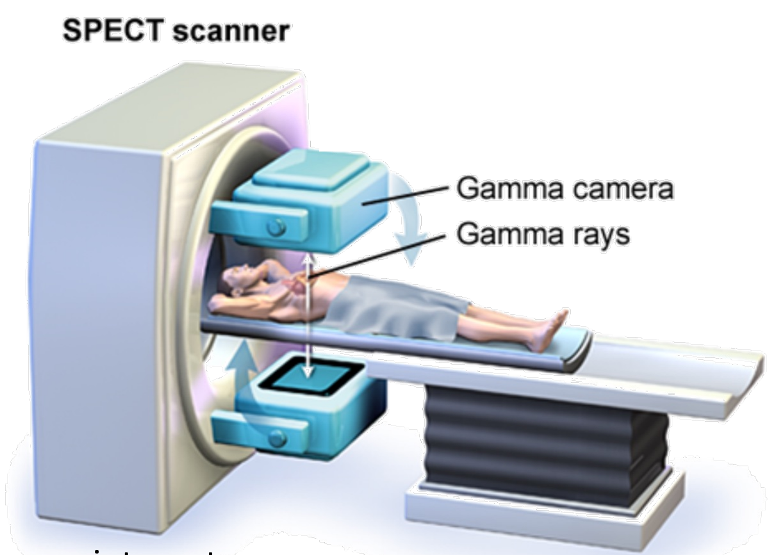
Nuclear Medicine

- **Radiopharmaceuticals**
  - The radioisotope has to be connected (labelling) to a pharmaceutical based on the organ specific question.
  - Radiopharmaceuticals should not disturb the process under investigation.
  - e.g. FDG (18F-Fluorodesoxyglucose) to analyze the Glucose metabolism

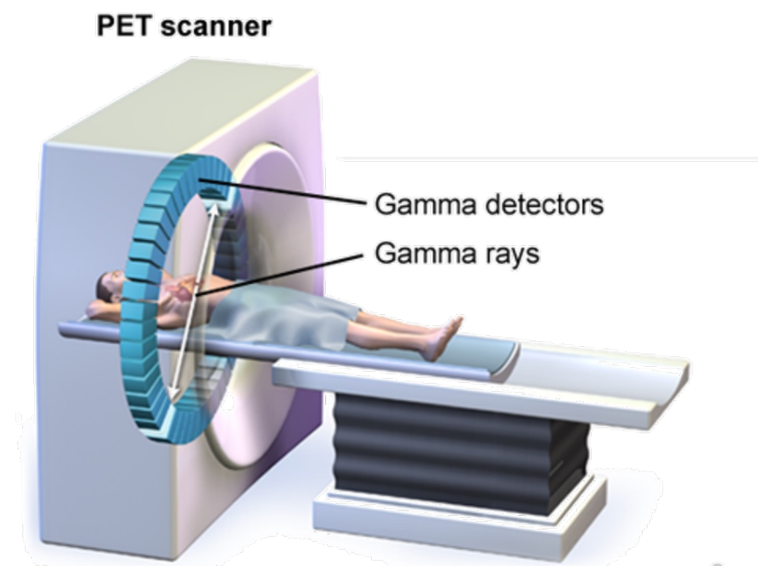


credit: Dr. Castañeda

Nuclear medicine

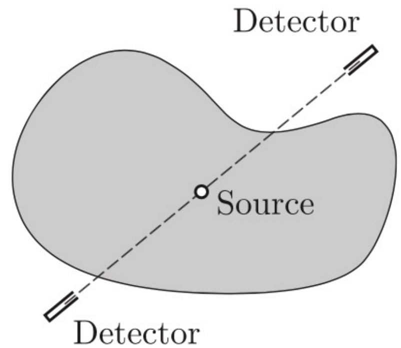


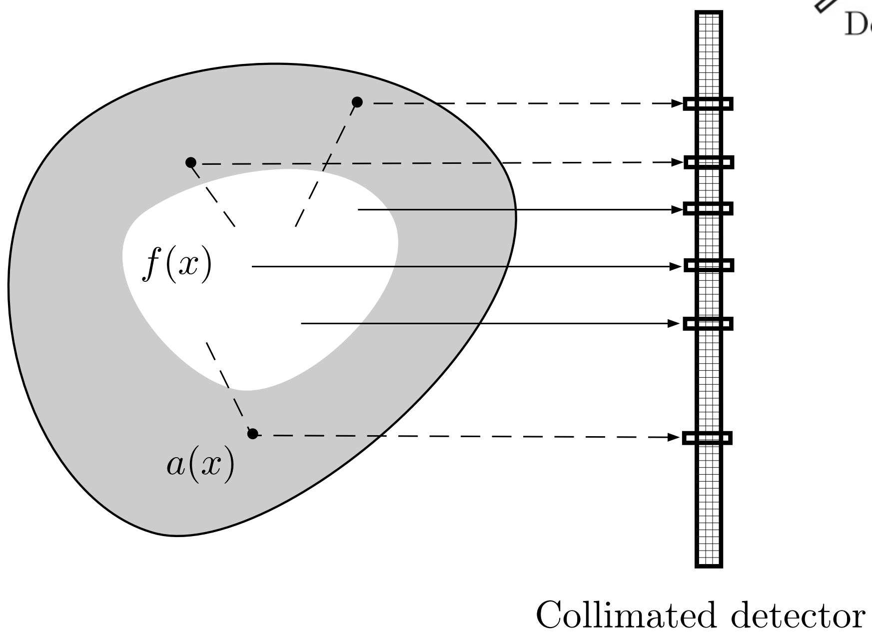
source: internet



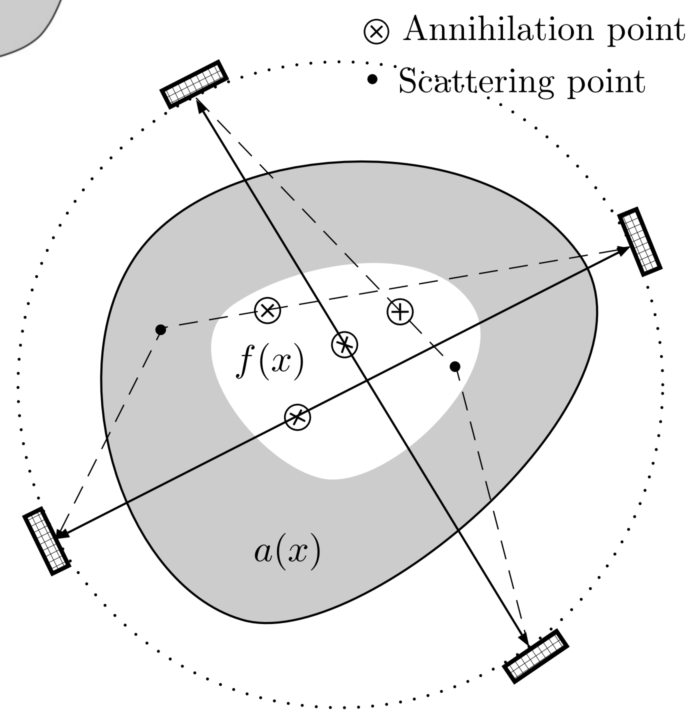
- monophotonic (SPECT) and biphotonic (PET) emission tomography the most extensively used in nuclear medicine

SPECT and PET





SPECT: Single photon emission computed tomography

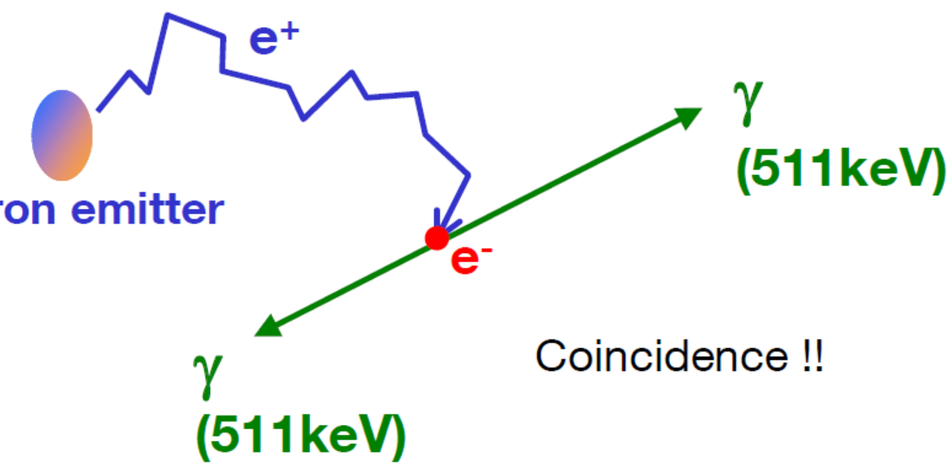


PET: Positron emission tomography

Nuclear Medicine

- **Positron Emission Tomography – PET**
  - Positron decay: $^{18}F \rightarrow {}^{18}O + e^{+} + \nu_e$

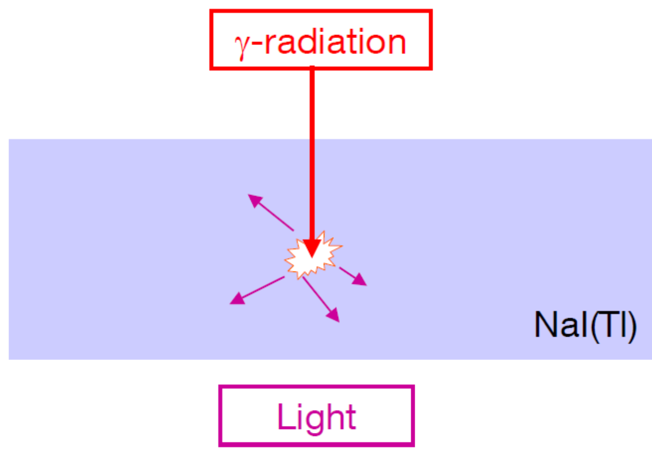
$$p \rightarrow n + e^{+} + \nu_e$$



credit: Dr. Castañeda

Nuclear Medicine

- **Radiation-Detection**
  - Scintillators, e.g. NaI(Tl) – Thallium doped Sodium Iodide

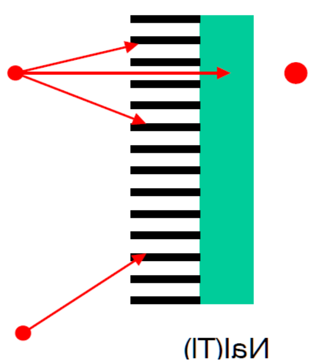


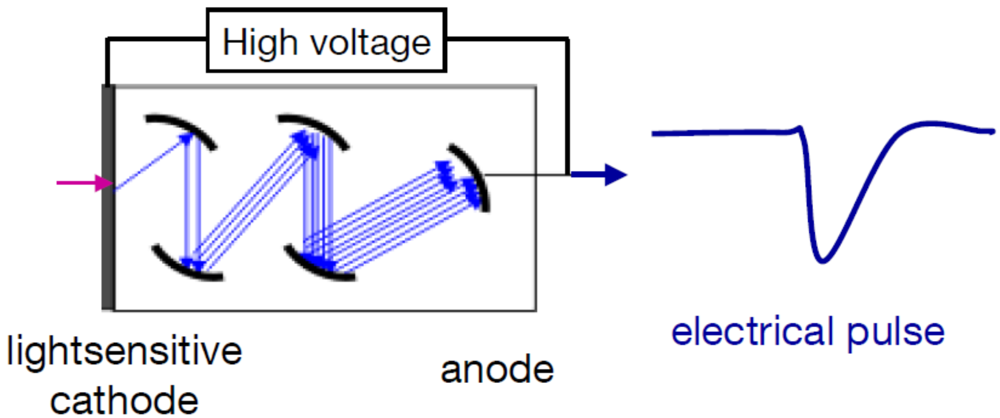
credit: Dr. Castañeda

Nuclear Medicine

- Photo multiplier
  - multiply the signal produced by incident
  - light by as much as 100 million times

- Gamma camera





γ-energy ~ light ~ pulse height

credit: Dr. Castañeda

Example: SPECT scan of the brain

- primarily used to view how blood flows through arteries, veins and capillars;
- can detect reduced blood flow (more sensitive than MRI or CT);
- tracer stays in blood stream rather than being absorbed by tissues;
- cheaper and more readily available than higher resolution PET scans.

(source: www.mayfieldclinic.com)

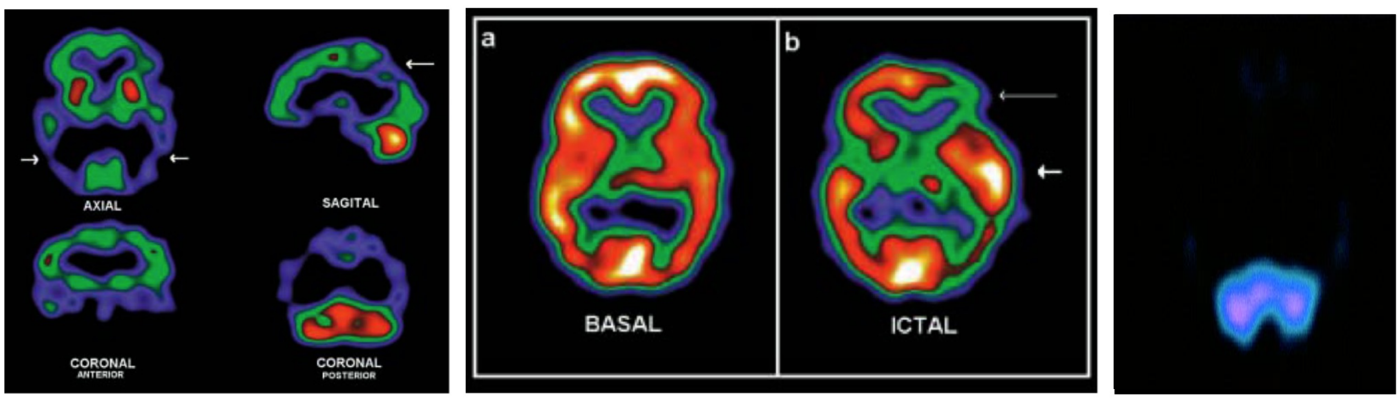
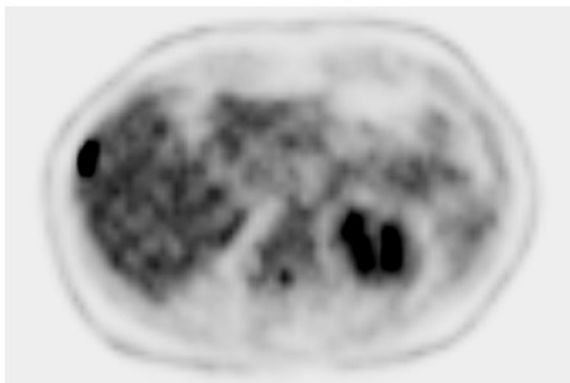
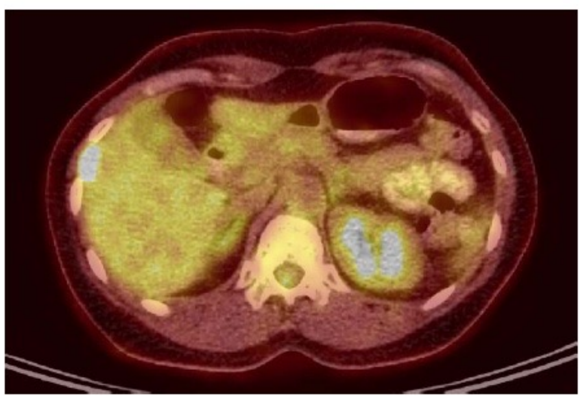


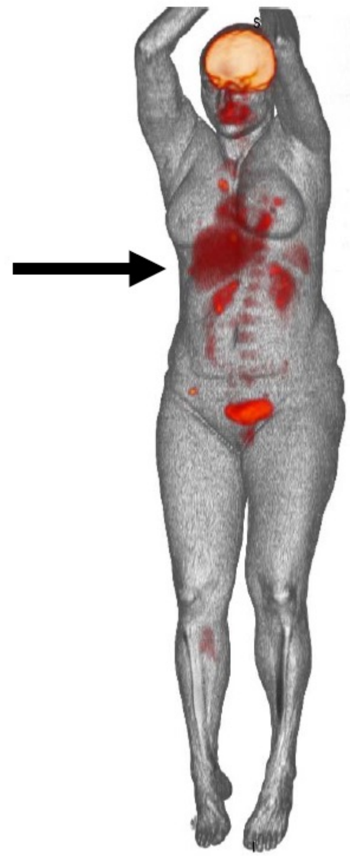
Figure: Left: Alzheimer desease patient with low blood perfusion (arrows);
Right: different blood flow before and during an epileptic seizure (arrows).
(source: Quintana, J.-C., Neuropsiquiatría: PET y SPECT . Rev. chil. radiol. 2002)

Nuclear Medicine

- **Multimodality – PET/CT**







credit: Dr. Castañeda

Break: application of Fourier Transform

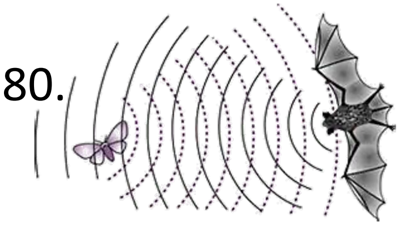
Second part (wave phenomena)

3.- ultrasound, elasticity imaging

current research topic: bone porosity estimation by ultrasound

obstacles… ultrasound

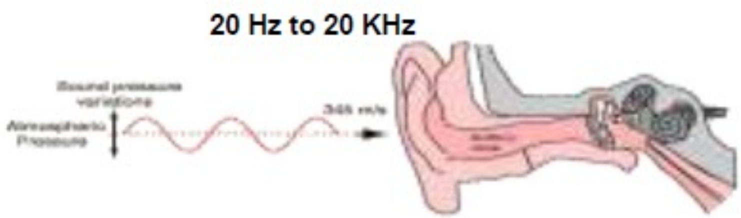
- Ultrasound date back to 1930 and basically detect **obstacles** and allow you to see them on a screen. Used today to follow the fetal development.
- Ultrasound was first used with **hydrophones** to detect icebergs, after the tragic sinking of the Titanic, or submarines during the first war world.
- Pierre Curie discovered the basis of **ultrasound transducers** in 1880.
- The key **mathematical rule** behind ultrasound is that used by the bat when hunting in the dark: when emitting echoes before an obstacle, the distance to it is proportional to the time it takes to **go and return**.
- This assume that most of the body is water and that the sound propagates in it at a **constant speed** and in straight lines, this is not completely true and the images are somewhat confusing.



d=t/v

Ultrasound

- What is Ultrasound?

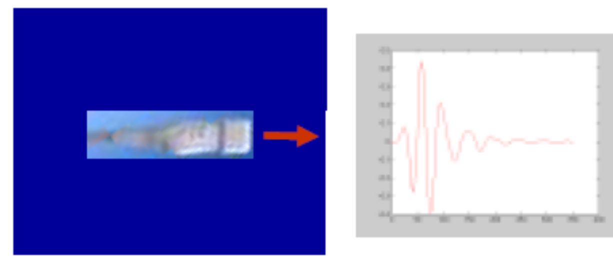


- Medical ultrasound uses frequencies in the range of 500 KHz to 30 MHz.
- For imaging 1MHz to 10 MHz.
- Intravascular imaging up to 30 MHz. (Higher the frequency better the resolution!!)

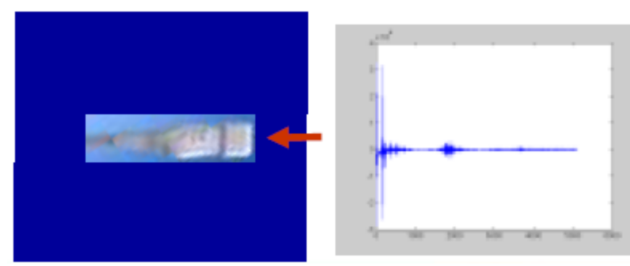
credit: Dr. Castañeda

Ultrasound

- Workflow
  1. An ultrasound probe is used to generate a short burst of the ultrasound signal, which is sent into the tissue.



  2. The same ultrasound probe is usually used to Record the echoes (RF signals) returned back from the tissue.

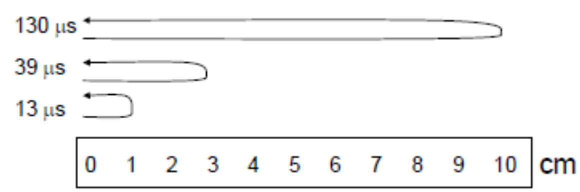


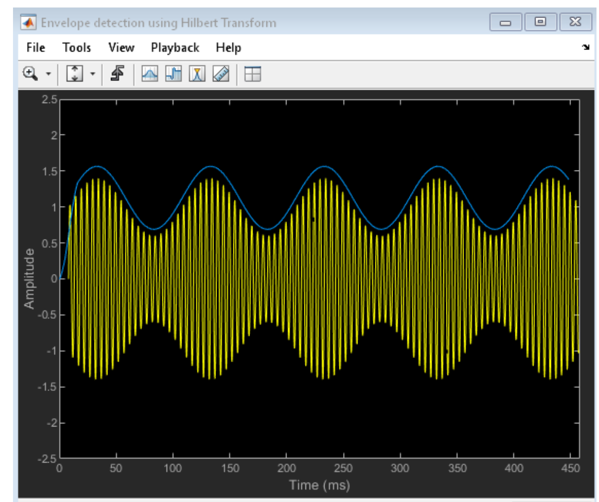
Different tissues show different reflection properties.

credit: Dr. Castañeda

Ultrasound

- The sound speed in soft tissue is about 1540 m/s
- As round-trip increases, reflector's distance increases
- For c = 1540 m/s = 1.54 mm/micro s:



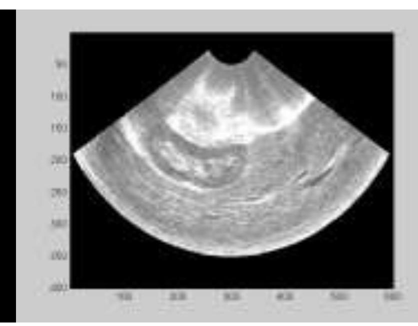


3. Processing the RF signals
    - Envelope detection by Hilbert Transform
    - Dynamic range reduction by *log function*
    - Decimation for data reduction (5100 samples into 300 samples)

credit: Dr. Castañeda

Ultrasound

- Examples:

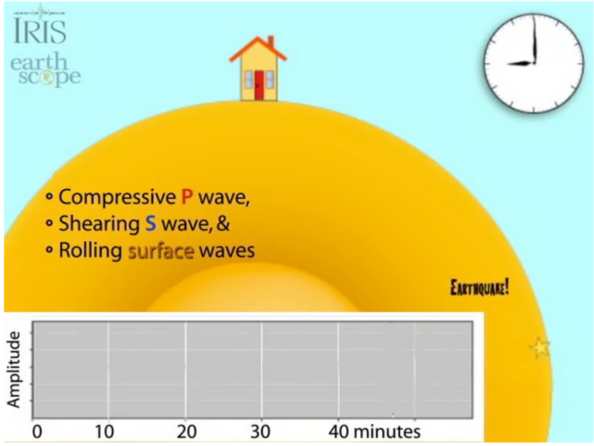


credit: Dr. Castañeda

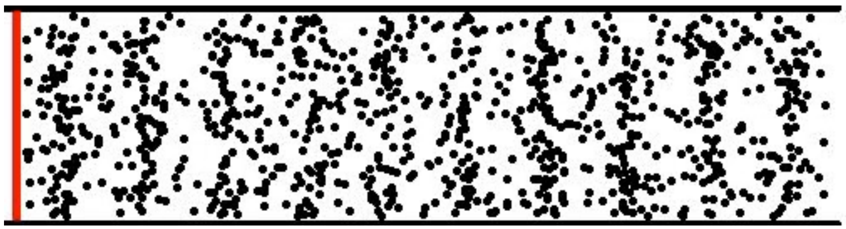
Ultrasound elastography

- Elastography is used in the detection of breast or liver cancer, and use **elastic P or S waves** (the same of **earthquakes**!) to detect hardness tissues.
- It is a sophisticated form of the ancient technique of **palpation** to detect hardness parts inside the body.

www.iris.edu



p-wave



s-wave

principles of elastography (soft tissue)

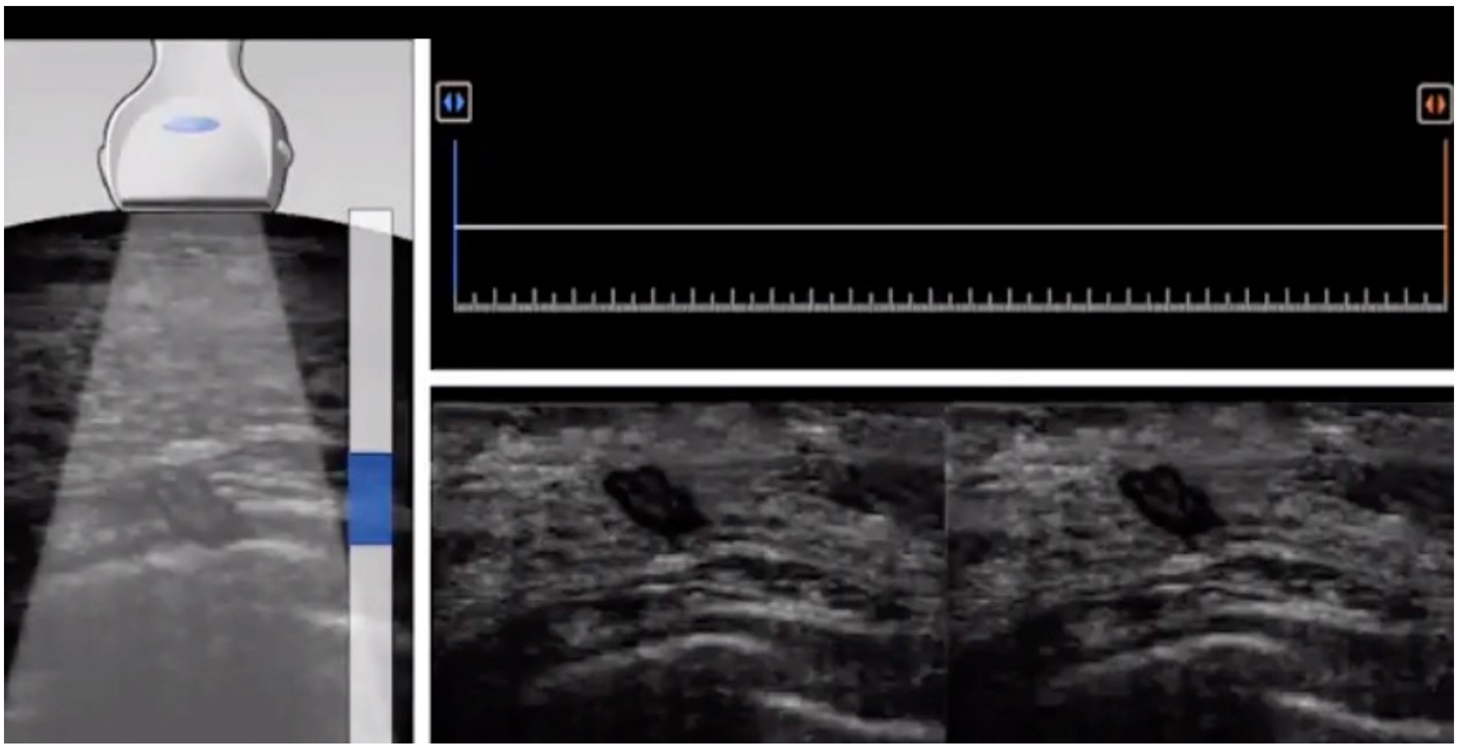
- non invasive observation of the internal displacements by an standard imaging modality such as ultrasound or MRI
- the medium is deformed by a given external force (load, vibration, acoustic radiation) or by an internal displacement (cardiac/respiration cycles, blood flow)
- dynamic elastography: time dependent or periodic forces
- quasi-static elastography: quasi-static external force
- cancer is usually stiffer than healthy tissue
- shear modulus: one of the most wide ranging physical parameters for differentiating tissue (several orders of magnitude)

Ultrasound elastography

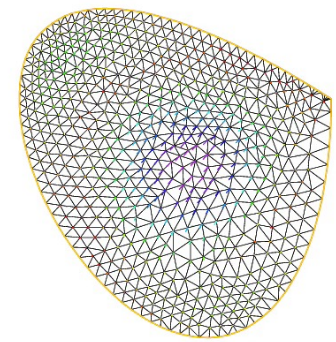
Toshiba medical systems

ultrasound transducer

wave



Elasticity v/s viscoelasticity (soft tissue: brain, liver, skin, breast, prostate, etc.)

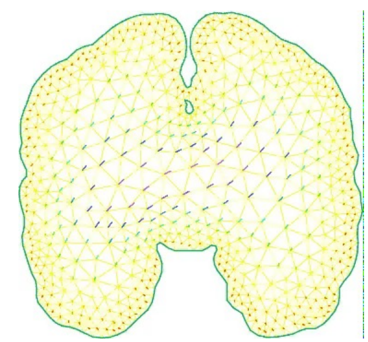


- Most of living tissues have a **mix of solid/fluid behaviour** : skin, blood, bones, muscles, liver, brain, lungs, etc.
- This is called **visco-elasticity**. Viscosity is a property of fluids, elasticity is a property of solids.
- The idea is to obtain images of the **viscoelastic parameters** and the **fading memory**.

$$\mathcal{P}u := \partial_t^2 u - \underbrace{\nabla\cdot\left(2\overline{\mu}_0\epsilon(u) + \overline{\lambda}_0(\nabla\cdot u)I\right)}_{\text{elasticity}}$$

$$+ \underbrace{\nabla\cdot\int_0^t (2\tilde{\mu}(t-s)\epsilon(u(s)) + \tilde{\lambda}(t-s)(\nabla\cdot u)(s)I)ds}_{\text{viscoelasticity}} = 0.$$

Maxwell viscoelastic mathematical model



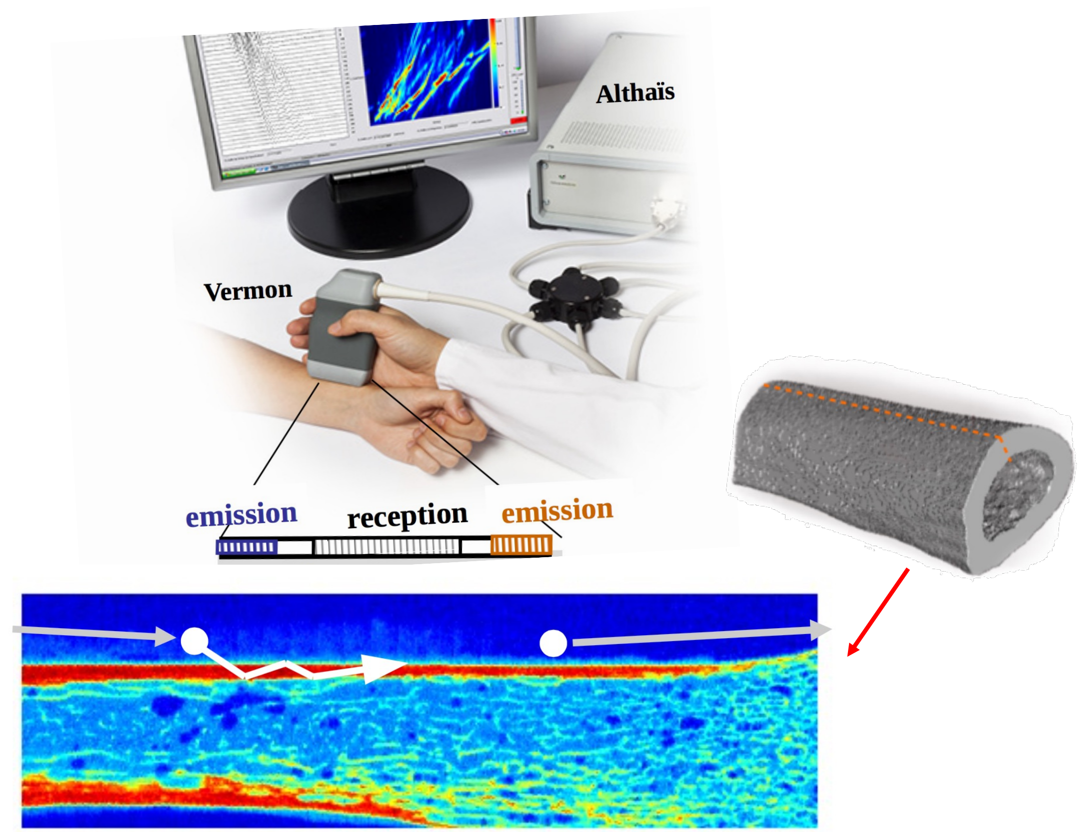
- *Logarithmic stability in determination of a 3D viscoelastic coefficient and a numerical example*

M. de Buhan, A. Osses, Inverse Problems, 2010.

Ultrasonic guided waves and bone tomography

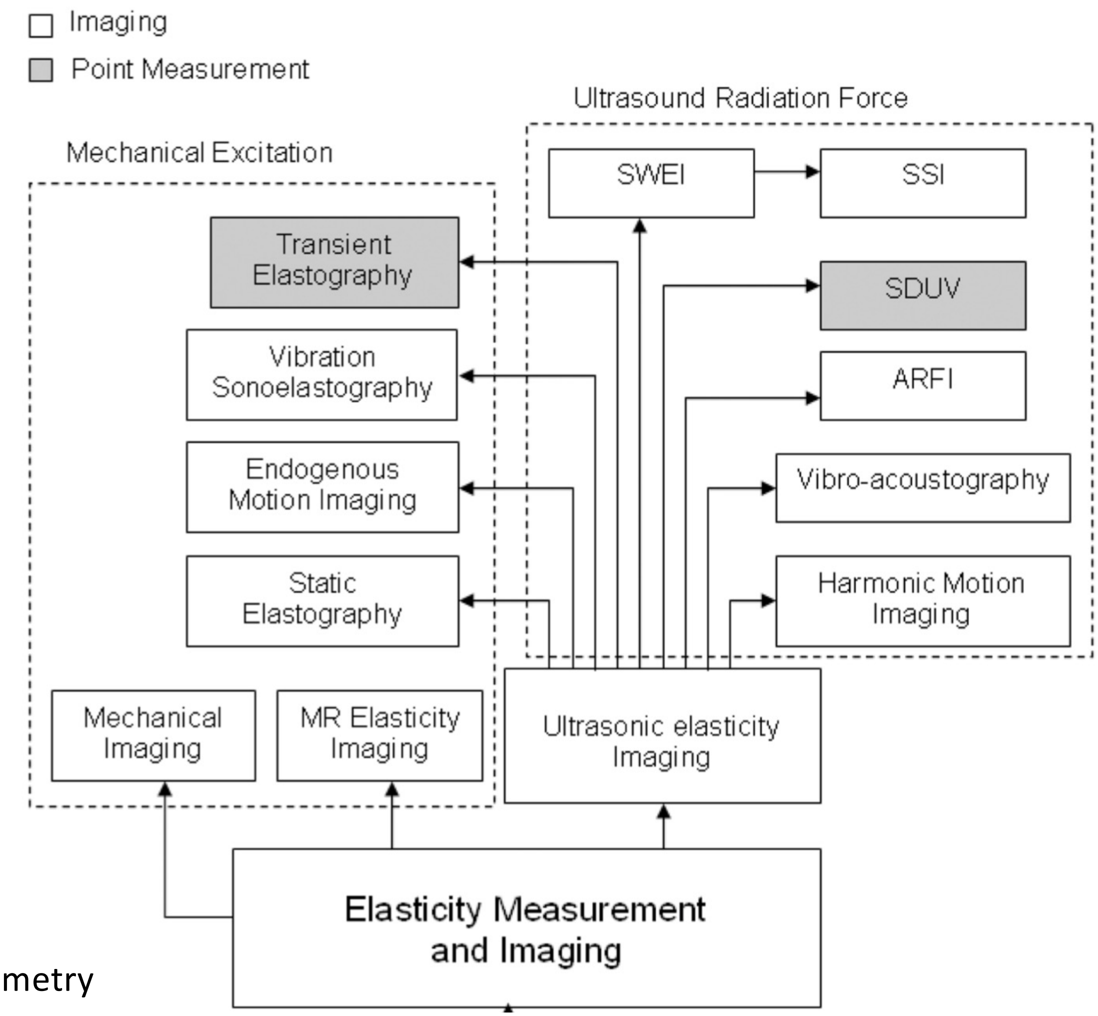
- a new development for **osteoporosis** detection instead of the classic X-rays
- allow bone **porosity** and bone **thickness** estimation
- mathematical model: homogenized elastic material, **guided waves** (as optical fibers)

Images coutesy of Jean-Gabriel Minonzio, LIB, France and CMM, Chile



HR-pQCT voxel 82 µm

elastography:
there are
many modalities!



SWEI: Shear wave elasticity imaging
SSI: Supersonic shear imaging
SDUV: Shearwave dispersion ultrasound vibrometry
ARFI: Acoustic radiation force impulse imaging

credit: Sarvazyan 2011

2.- magnetic resonance

current research topic: enhanced phase contrast technique for MRI-4DFlow adquisition and applications to non-invasive pressure and blood flow estimation

Credits: Lighbox Radiology, Australia

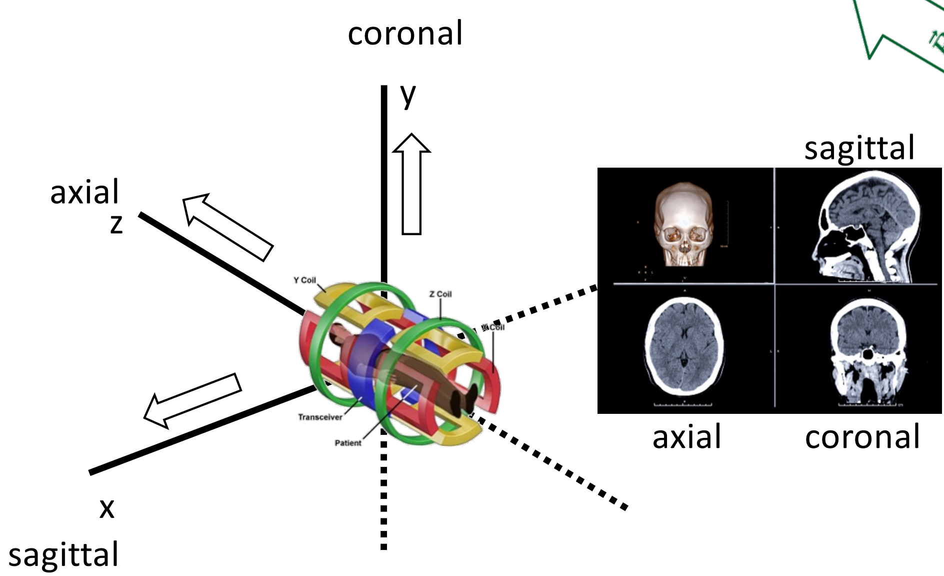
imaging the body... magnetism... MRI

- **Magnetic Resonance Imaging** (MRI).
- Strong magnetic fields are induced in the body with suitable forms that force the **spin of water hydrogen nuclei** into the body, to obtain:
  - images of high resolution inside the body
  - the speed of blood in an artery or
  - the displacement of the heart when barking
- Discovered by Felix Bloch and Edward Mills Purcell in 1947.
- The **first MRI machine** for human patients was built and patented in 1972 by the American physician Raymond Damadian. First clinical images obtained in 1977 (Lauterbur-Mansfield-Damadian).

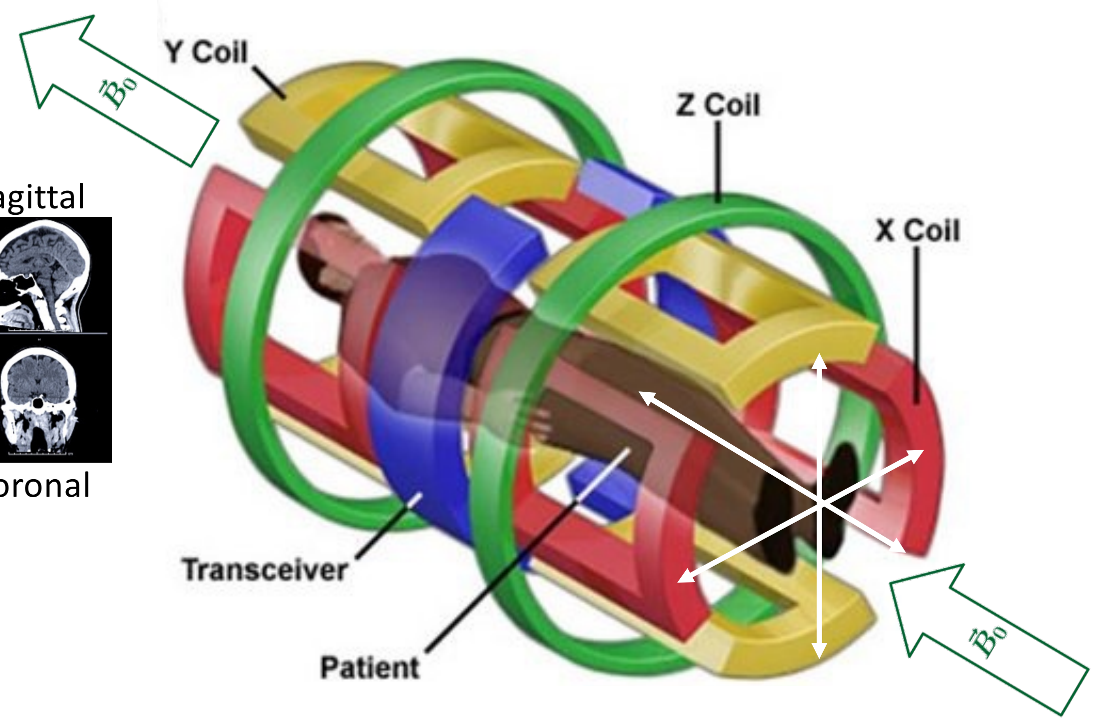
Magnetic Resonance Imaging… In 4 Steps

- No ionizing radiation
- Excellent image resolution
- Relatively easy to set up
- T1, T2 images, velocity, displacements
- Slow compared with physiological motion
- Medium contrast detection

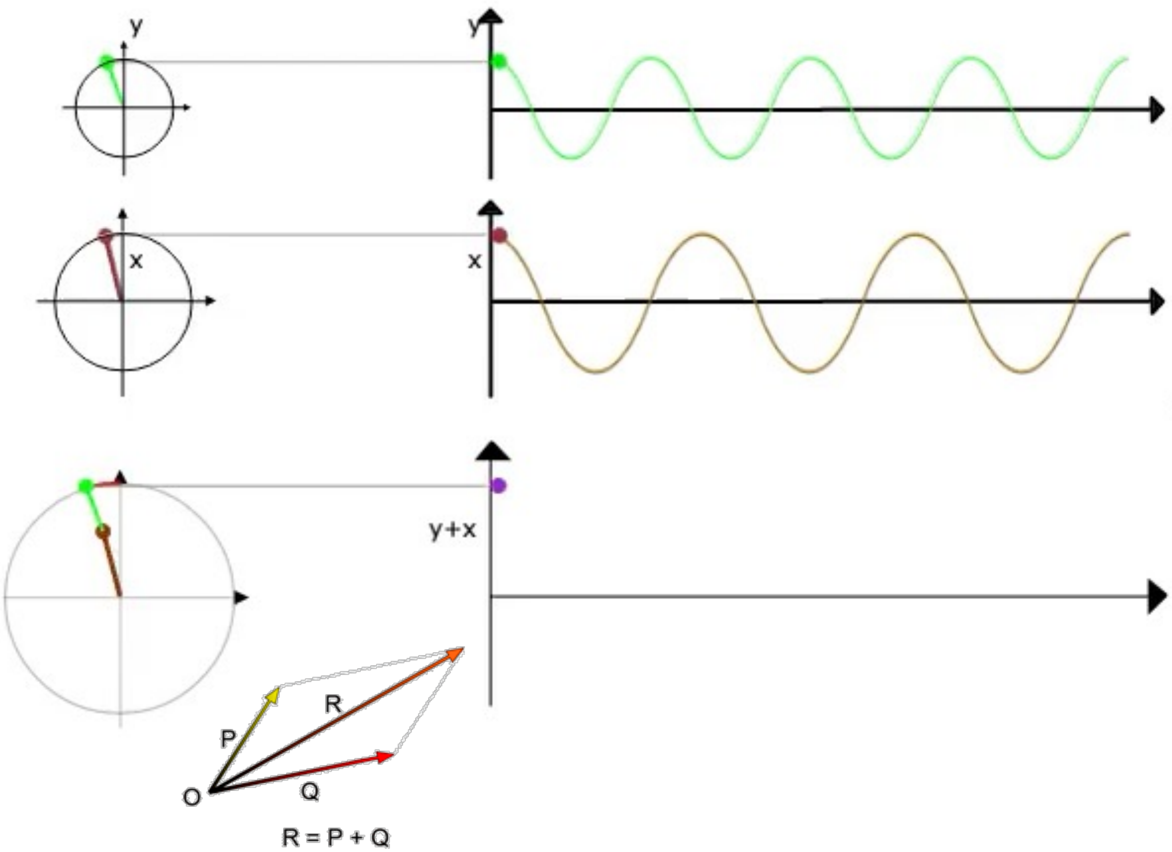
Source: Kurzhunov, 2017

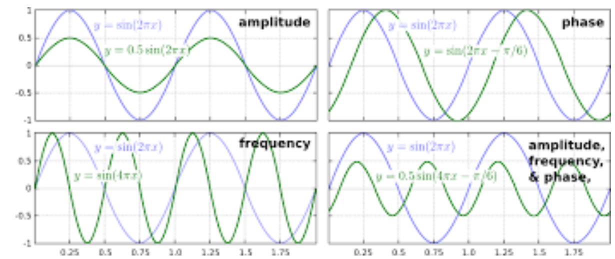


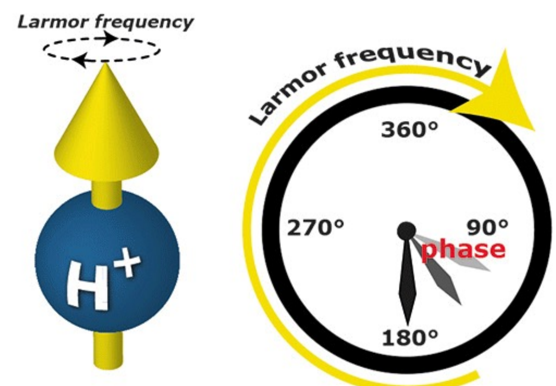
Reference frame and gradients



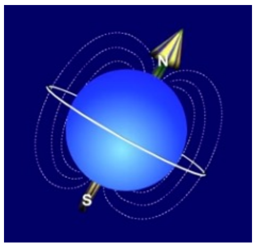
Basic concepts: amplitude, frequency, phase, sum of magnetic forces

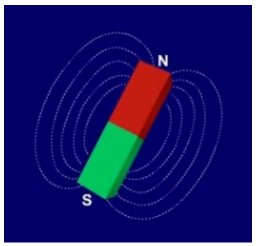


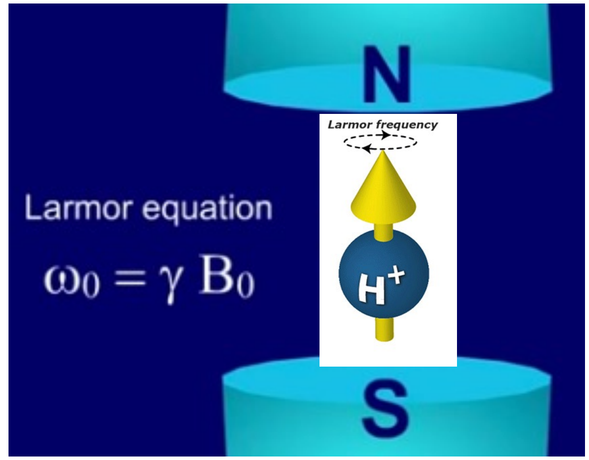




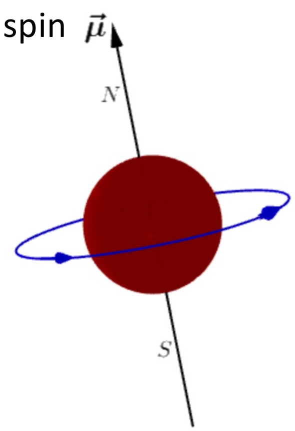
Spin and Magnetization





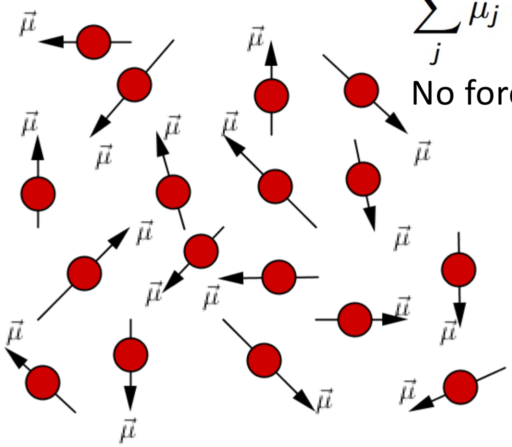


Precession frequency is proportional to strength of the magnetic field



proton

1



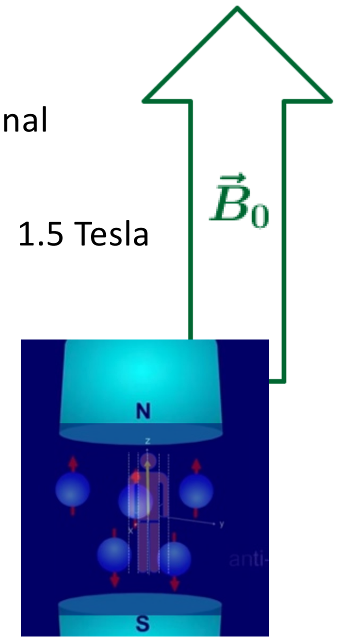
$\sum_j \vec{\mu}_j = 0$

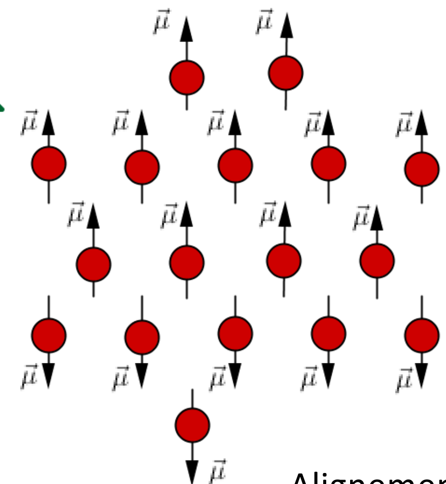
No force-no signal

tissue protons

2

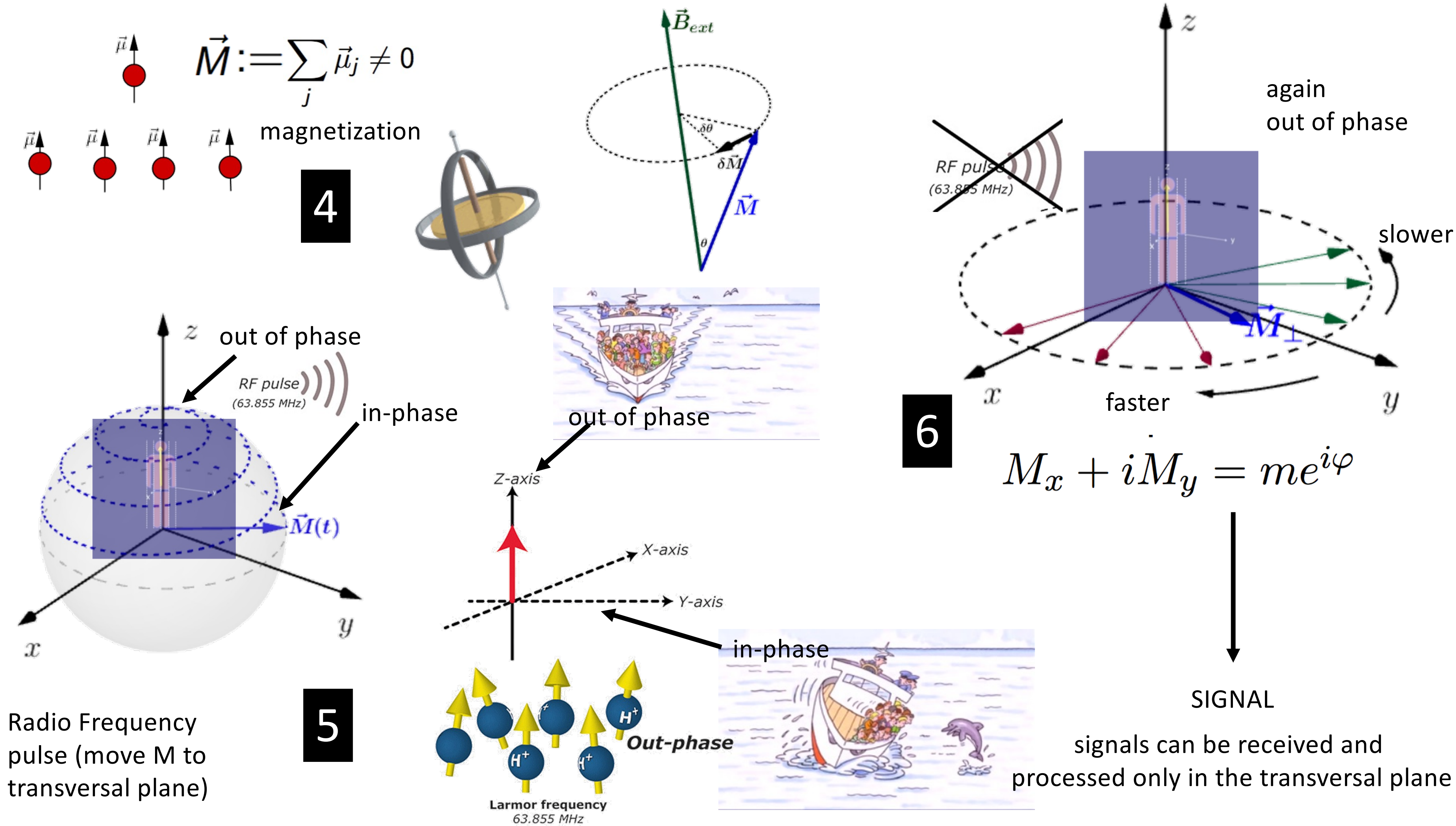
1.5 Tesla





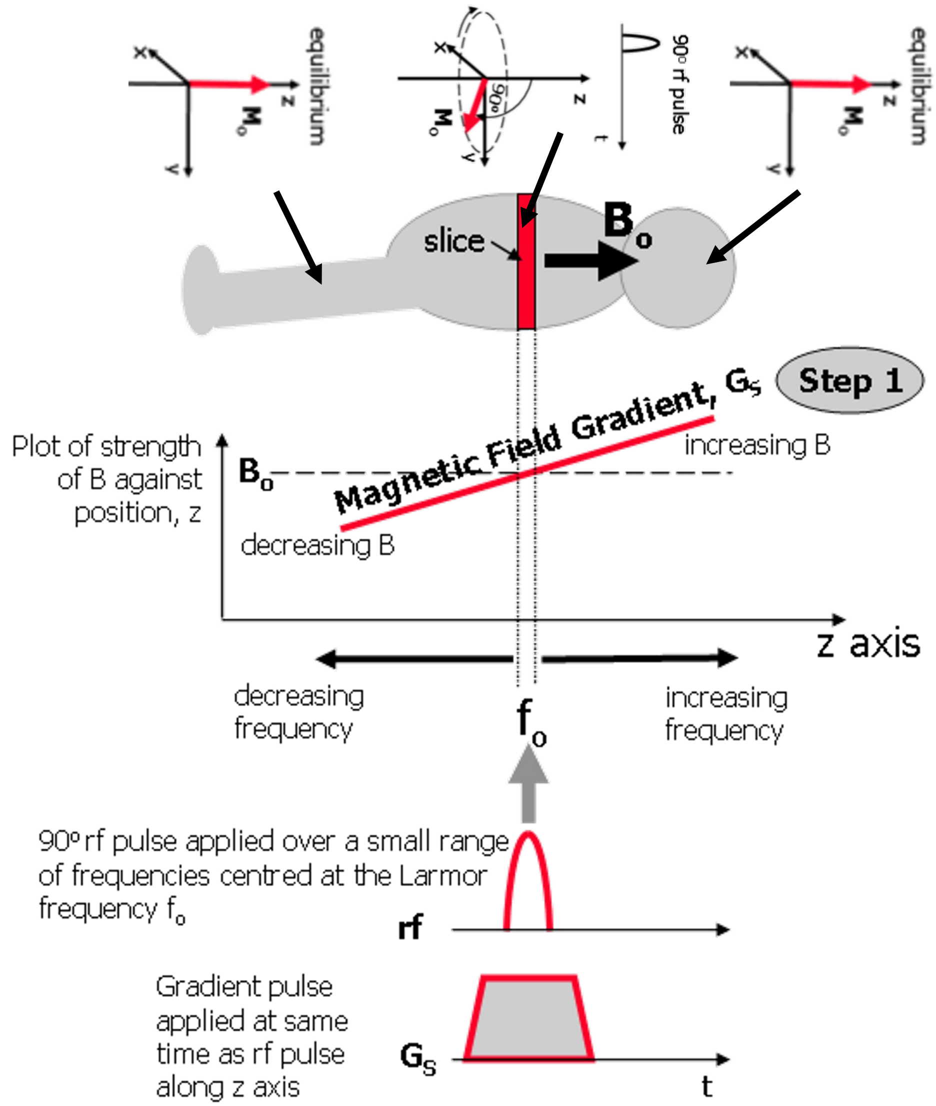
Alignement parallel or antiparallel

3



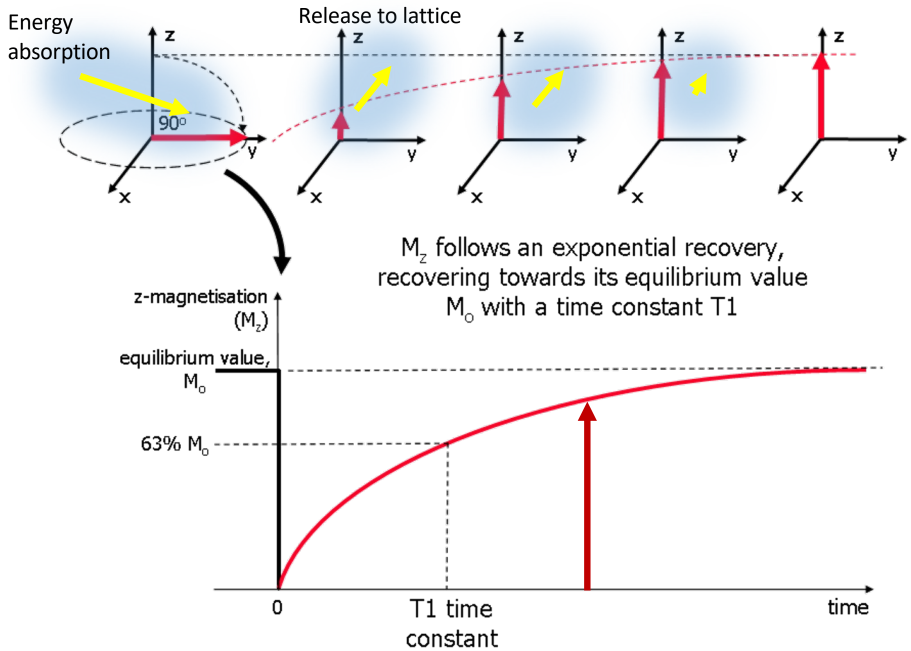
$\vec{M} := \sum_j \vec{\mu}_j \neq 0$
magnetization
4
$\vec{B}_{ext}$
$\delta\theta$
$\delta\vec{M}$
$\vec{M}$
θ
z
again
out of phase
RF pulse
(63.855 MHz)
slower
$\vec{M}_\perp$
x
faster
y
6
$M_x + iM_y = me^{i\varphi}$
out of phase
RF pulse
(63.855 MHz)
in-phase
$\vec{M}(t)$
out of phase
Z-axis
X-axis
Y-axis
in-phase
Out-phase
Larmor frequency
63.855 MHz
5
Radio Frequency
pulse (move M to
transversal plane)
SIGNAL
signals can be received and
processed only in the transversal plane

MRI Step 1: RF pulse and slice selection (axial)

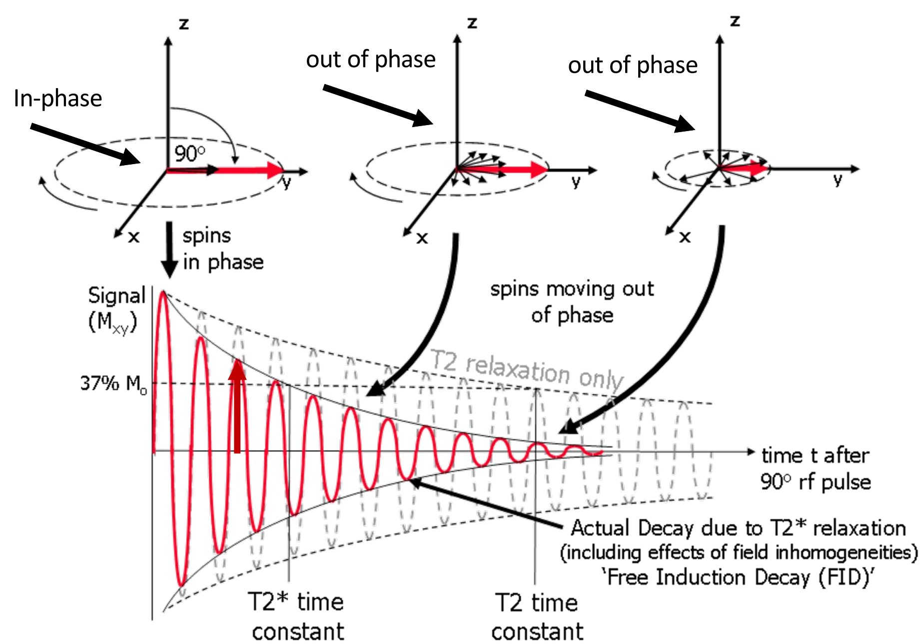


MRI relaxation times

T1: longitudinal relaxation (spin-lattice)



T2: transversal relaxation (spin-spin interaction)



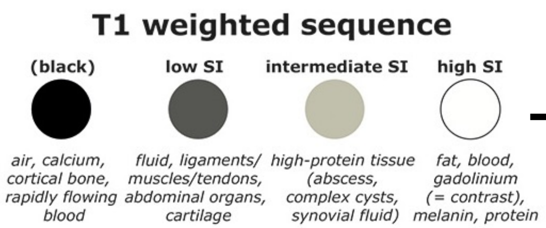
MRI relaxation times

T1: longitudinal relaxation

(spin-lattice)

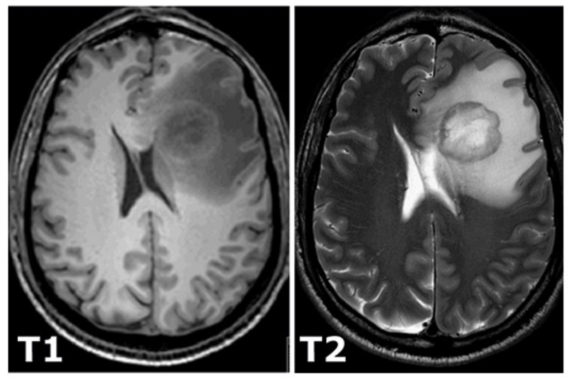
T2: transversal relaxation

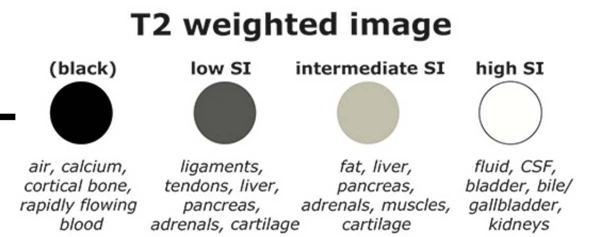
(spin-spin interaction)



dark fluid

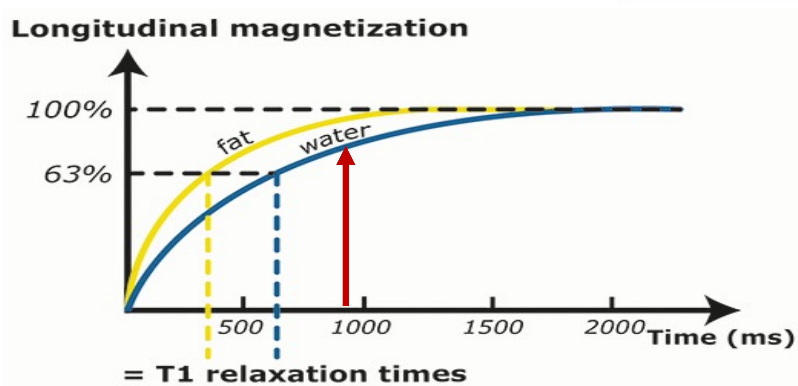
bright fat

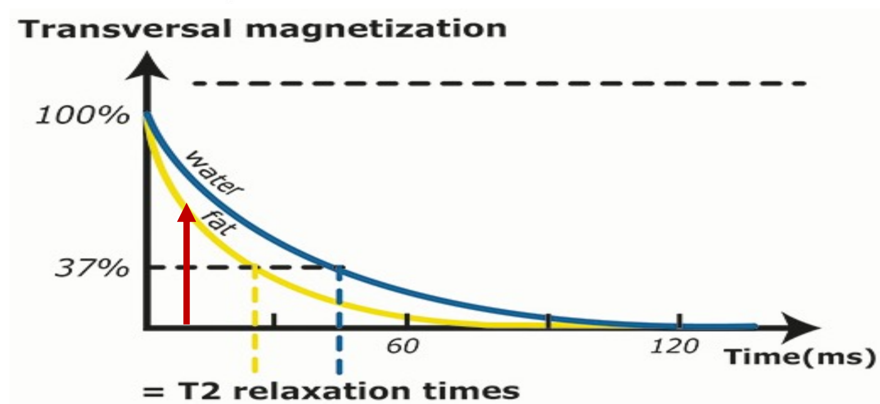




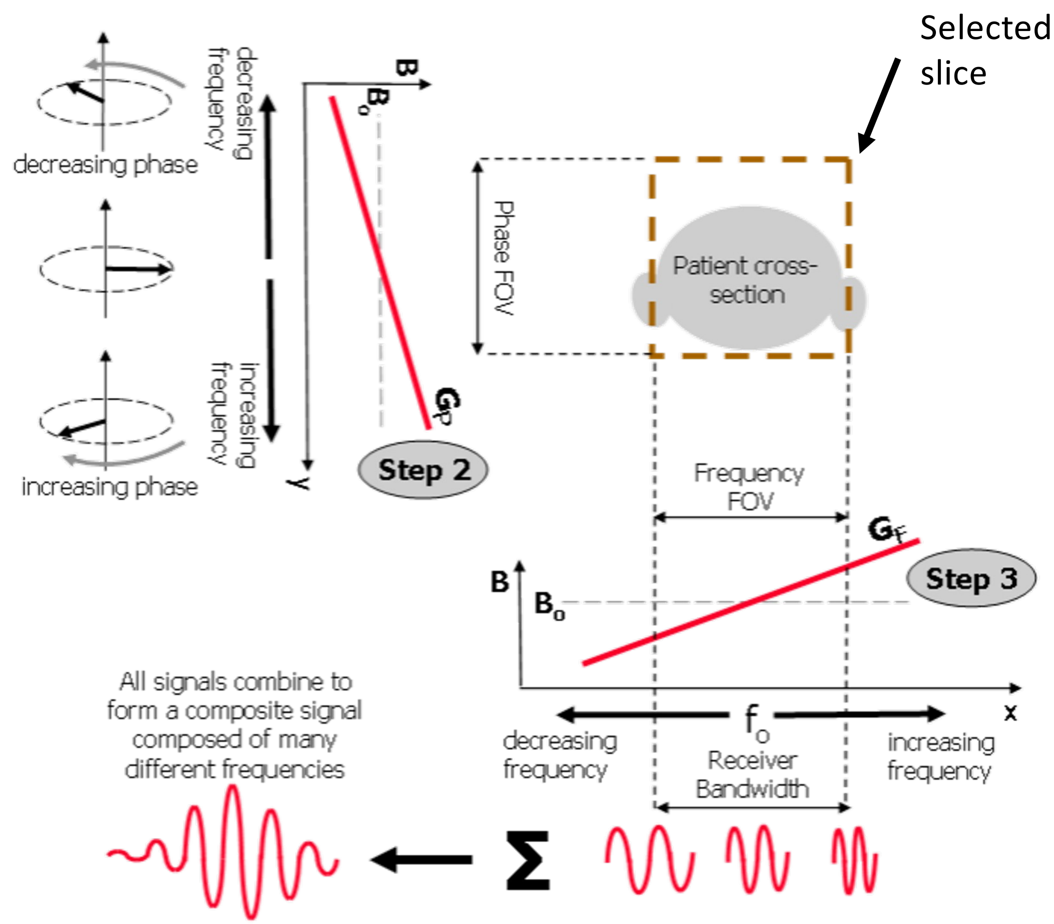
dark fat

bright fluid

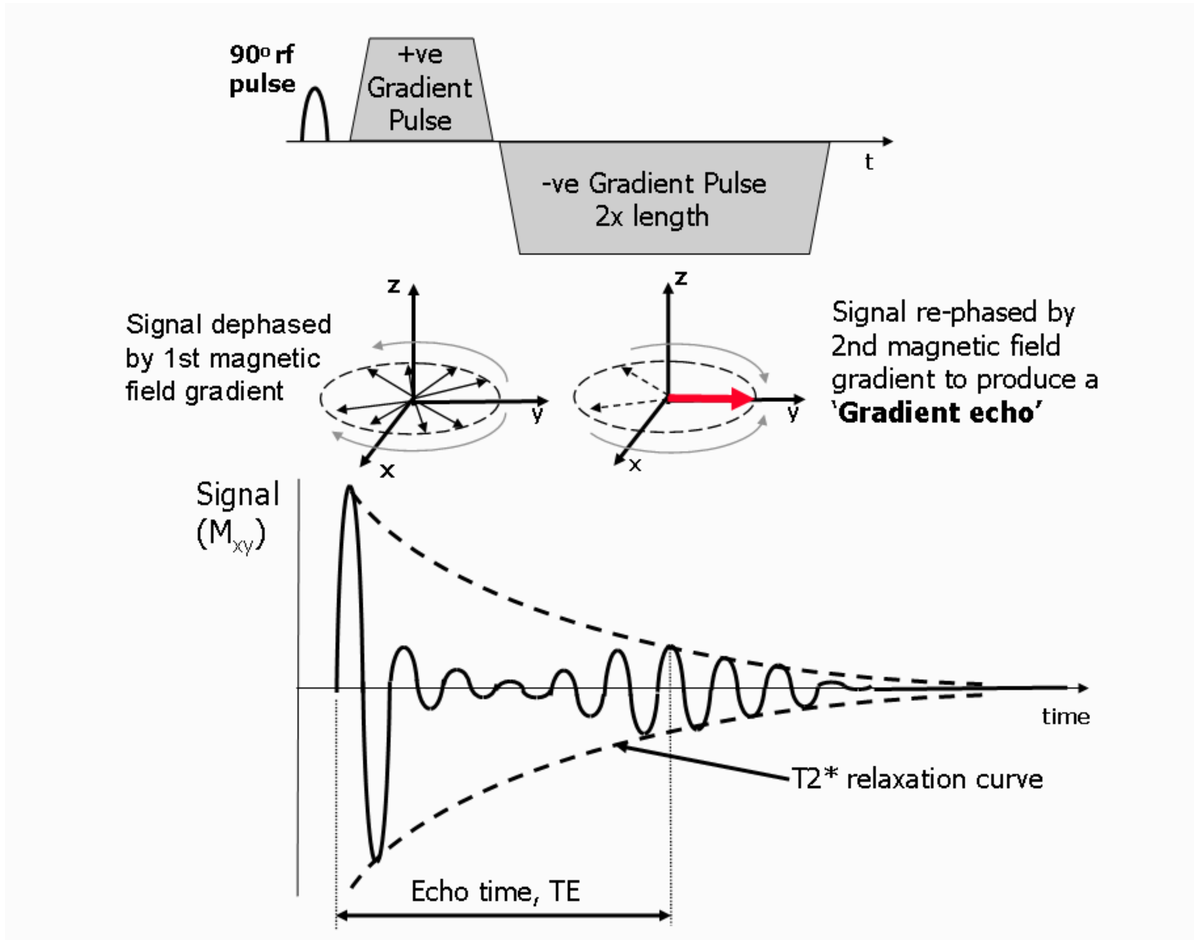




MRI Step 2: frequency and phase encoding



MRI Step 3: Echo registration and sampling



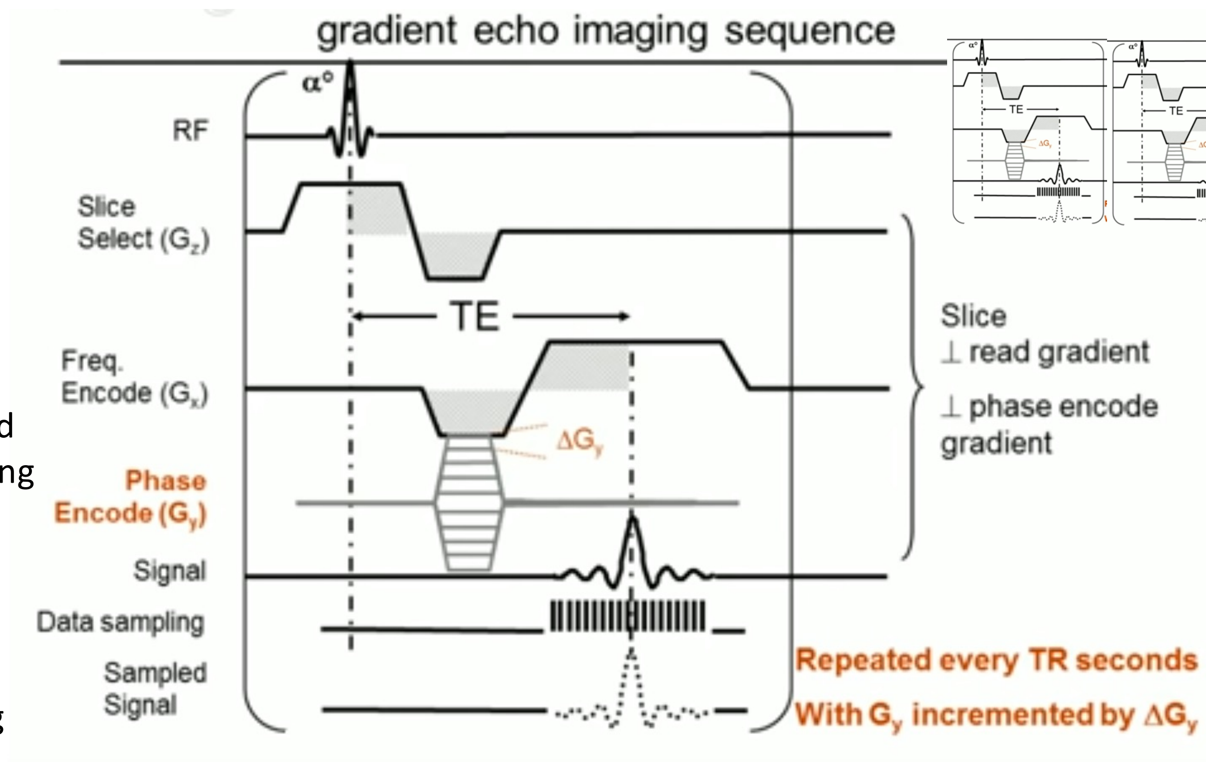
TE: echo time

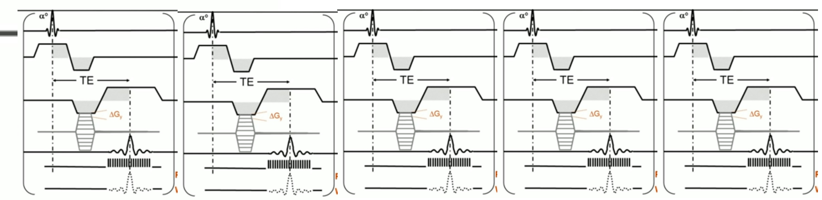
Principles of MRI: all steps combined

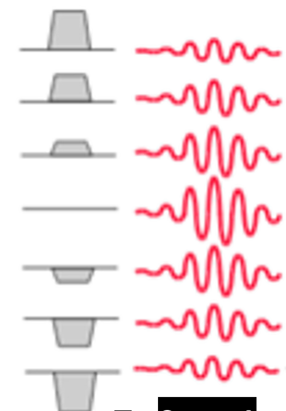
Step 1
RF Pulse and slice selection

Step 2, frequency and phase encoding

Step 3 echo registration and sampling



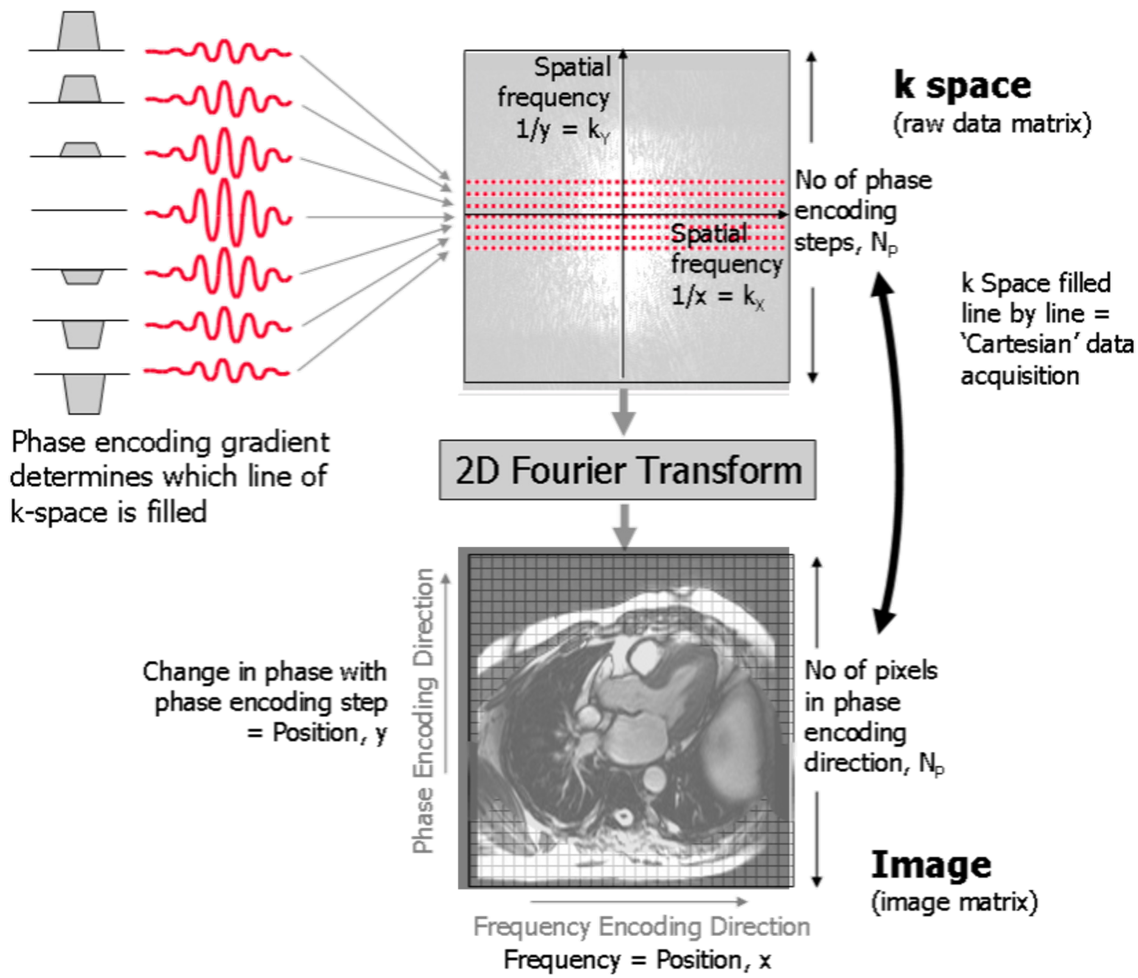




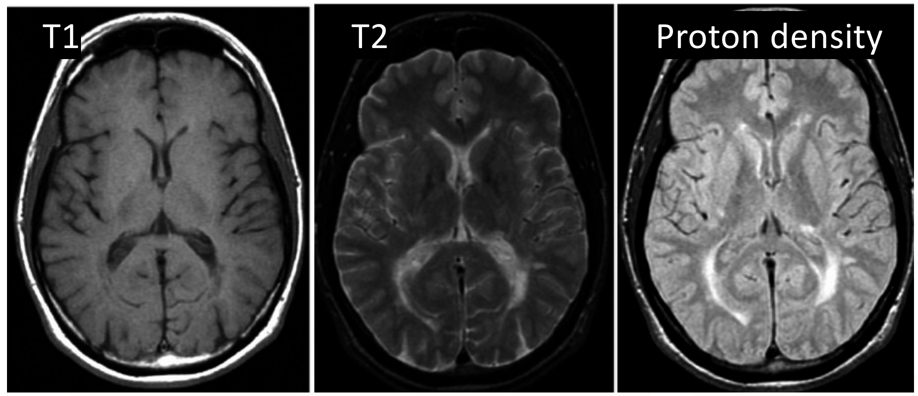
To Step 4
Image reconstruction

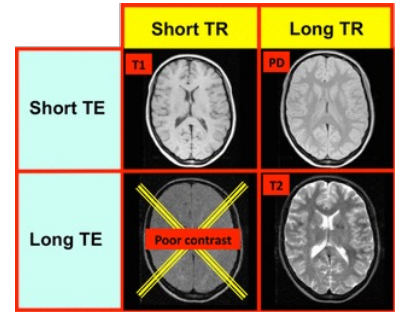
TR: repetition time

MRI Step 4: image reconstruction

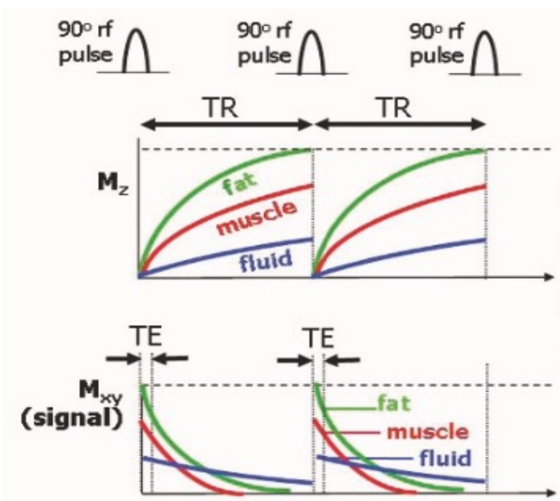


Contrast mechanisms: TR/TE combined



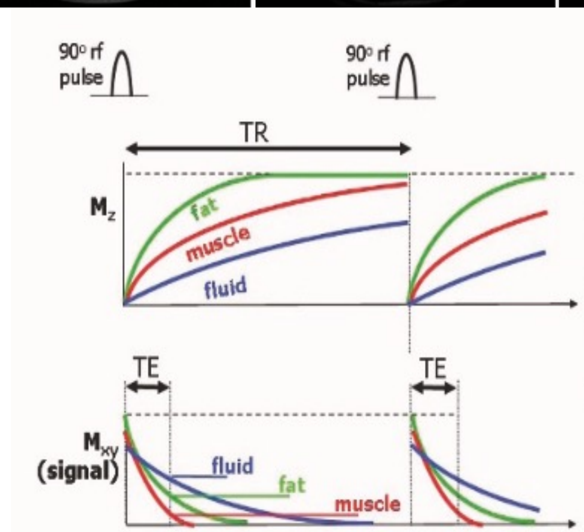


E. Ashton 2004



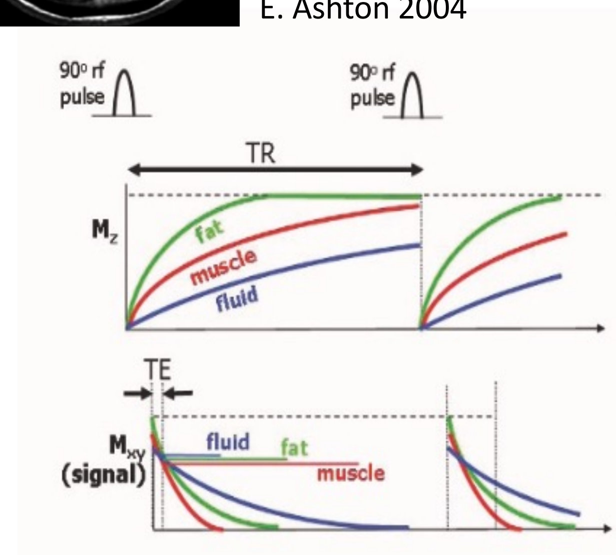
Short TR-short TE

T1-weighted contrast
Bright fat



Long TR-Long TE

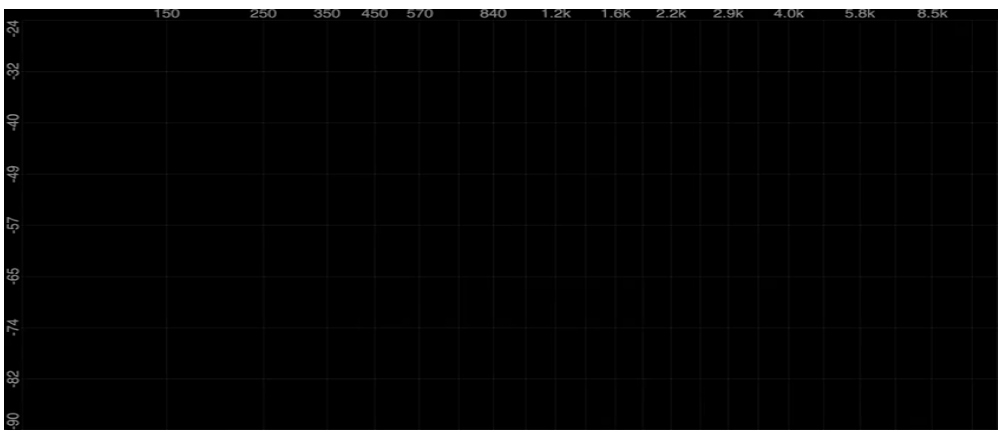
T2-weighted contrast
Bright fluid



Long TR-Short TE

Proton density
High signal-low contrast

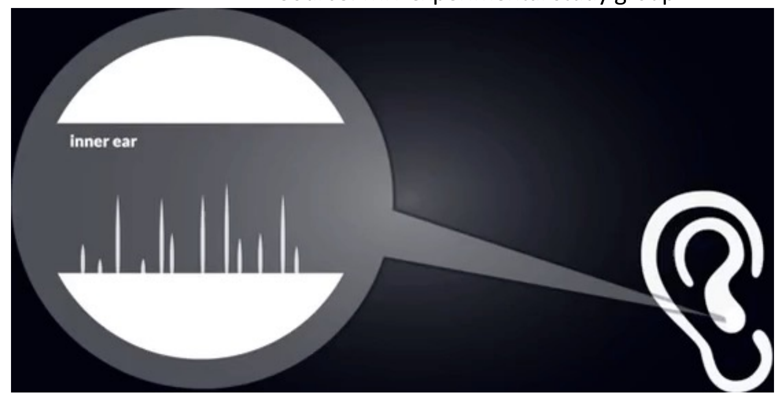
Inverse Fourier Transform

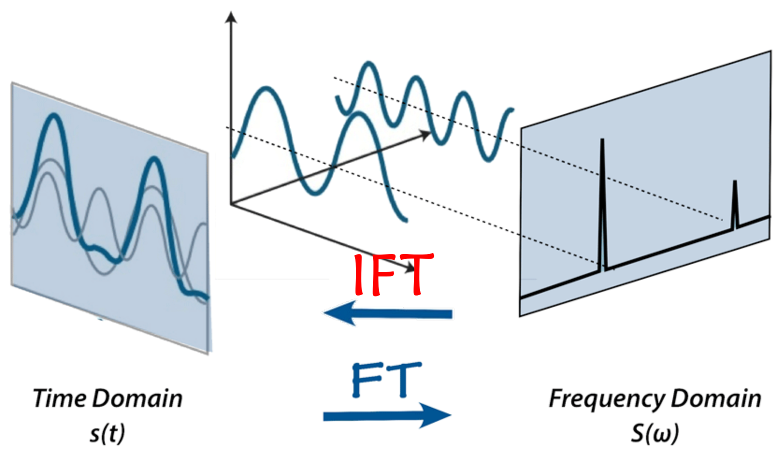


Source: spectrum app

- distinguish different frequencies

Source: MIT experimental study group





Source: barnesanalytics.com

Applications: mp3, jpg, earthquakes, signal analysis, image processing, radioastronomy, MRI, acoustics, structure of molecules, microscopy

MRI velocity encoding

Bloch's mathematical model
of magnetization

$$\frac{\partial \vec{M}}{\partial t} + (\vec{v} \cdot \nabla)\vec{M} = \gamma \vec{M} \times \vec{B} - \frac{M_x\hat{x} + M_y\hat{y}}{T_2} - \frac{M_z - M_0}{T_1}\hat{z}$$

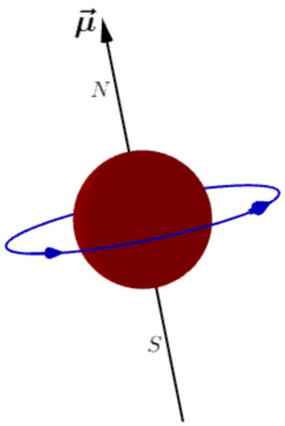
bloodstream velocity

transport

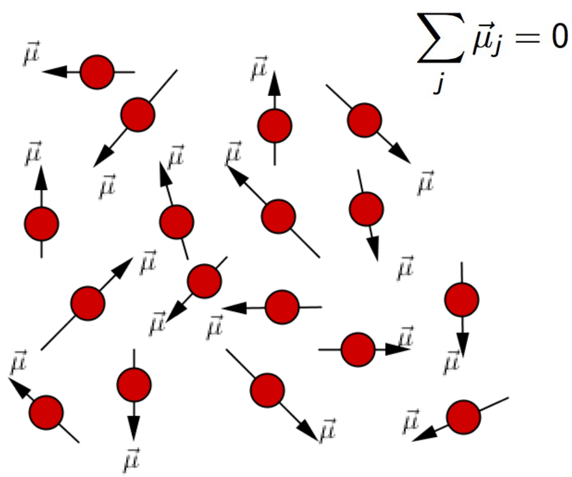
spins precesion

transverse relaxation

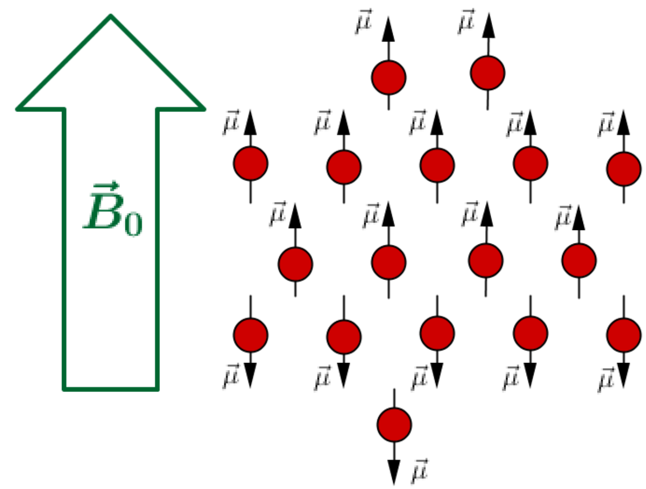
longitudinal relaxation



1



2



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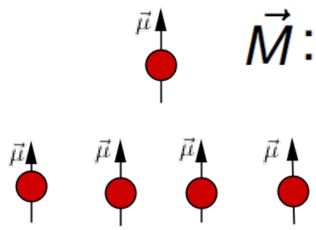
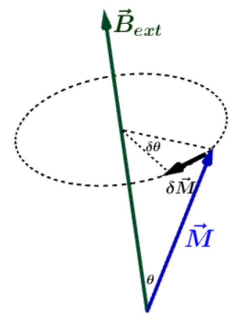
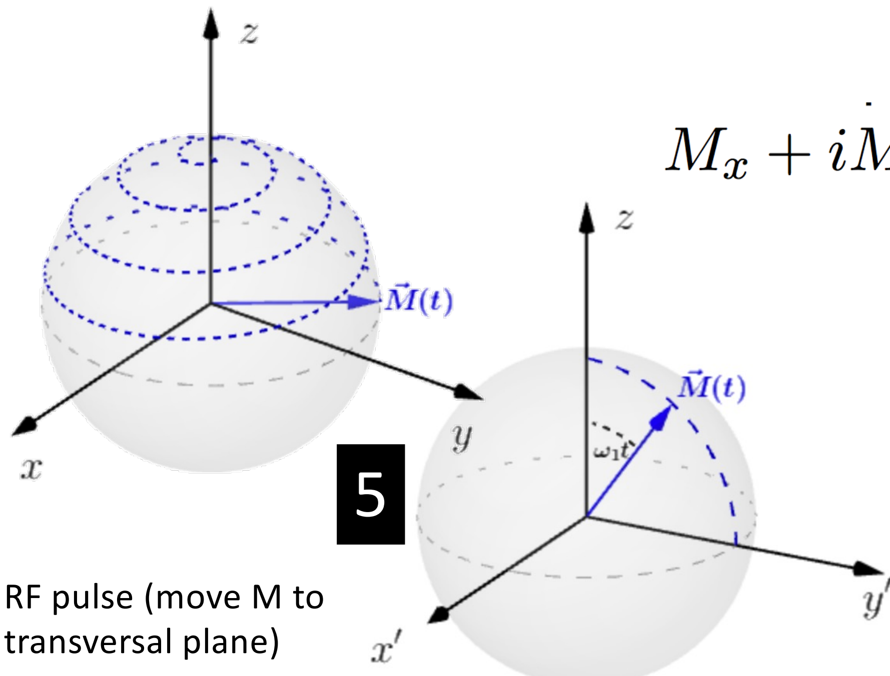


$$\vec{M} := \sum_j \vec{\mu}_j \neq 0$$

magnetization

4





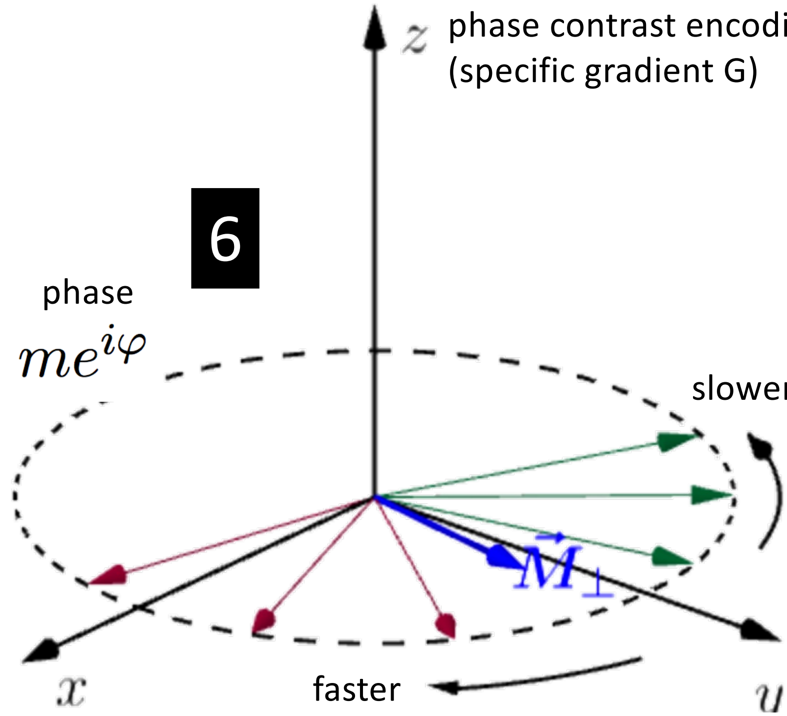
5

RF pulse (move M to transversal plane)

phase

$$M_x + iM_y = me^{i\varphi}$$

6



$$\frac{\partial\varphi}{\partial t} + \vec{v}\cdot\nabla\varphi = -\gamma((B_0 + \delta B) + \vec{x}\cdot\vec{G}(t))$$

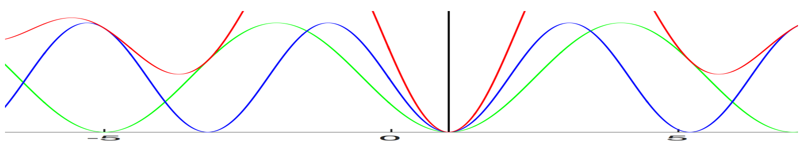
bloodstream velocity

Dual-venc method: better MRI bloodstream estimation

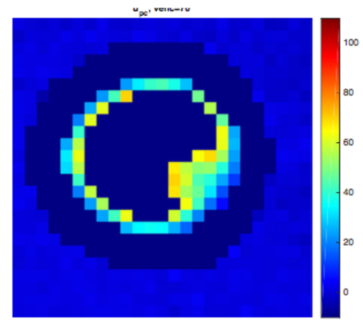
$$u_{pc} = \frac{\varphi_1 - \varphi_2}{\gamma \Delta M_1} \;,\; \Delta M_1 = (M_1(G_1) - M_1(G_2))$$

$$venc(G_1, G_2) = \left| \frac{\pi}{\gamma \Delta M_1} \right|$$

$$u_{true} \in \{u_{pc} + 2k venc, \quad k \in \mathbb{Z}\}$$

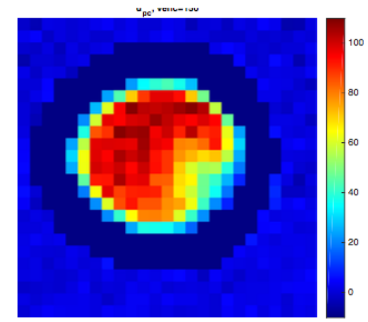


- *A least-squares dual-venc (LSDV) method for effective velocity de-aliasing in PCMRI.* H. Carrillo,1, A. Osses, S. Uribe, C. Bertoglio. To be submitted to Magnetic Resonance in Medicine Journal.



clean but incorrect

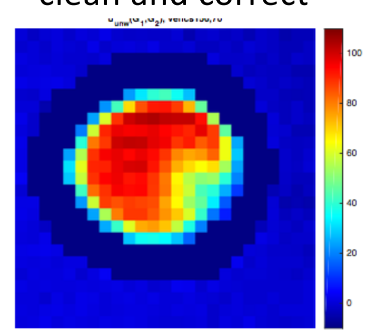
(a) venc 70



good but noisy

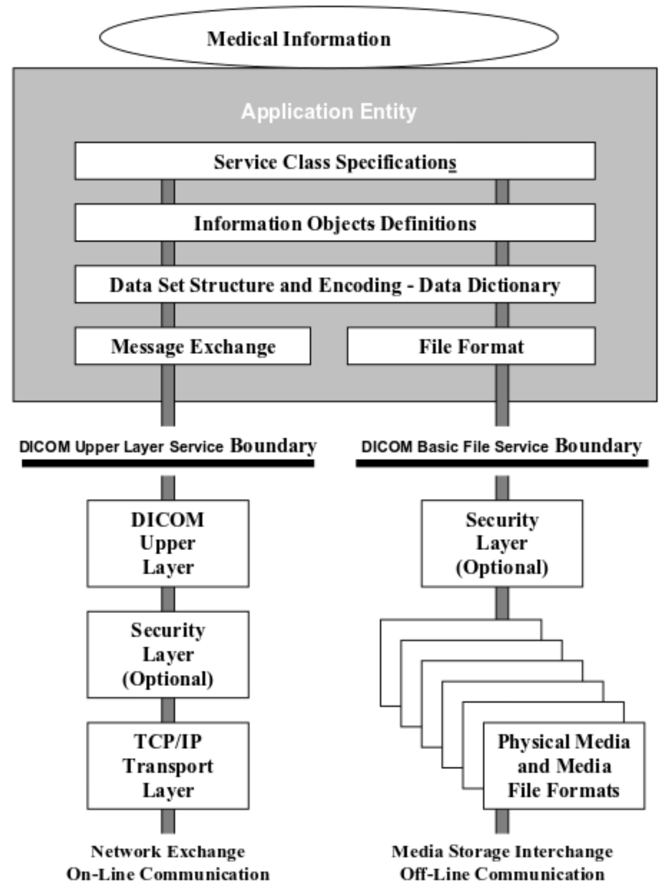
(b) venc 150

clean and correct



3D imaging format?

- Digital Imaging and Communications in Medicine (DICOM)
  - standard for handling, storing, printing, and transmitting information in medical imaging
  - File format
  - Network communications protocol
  - Owned by National Electrical Manufacturers Association (NEMA)

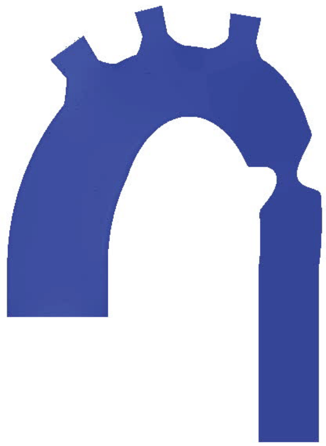


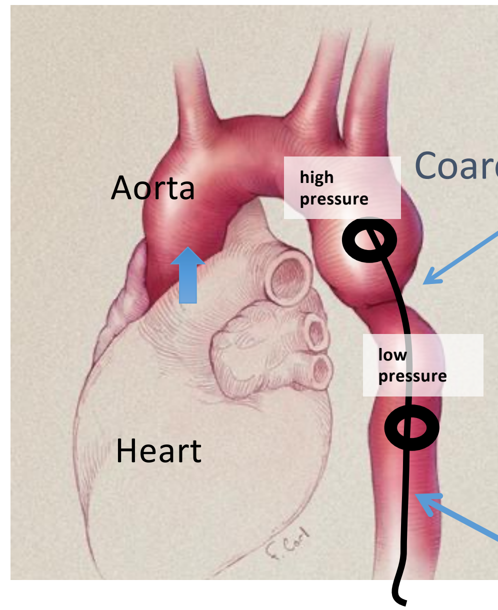
http://medical.nema.org/Dicom/2011/

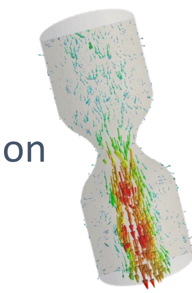
credit: Dr. Castañeda

Cardiovascular medicine: pressure gradients

- Non invasive estimation of **pressure gradients** in arteries







Bertoglio et al. 2017

Navier-Stokes Equations:

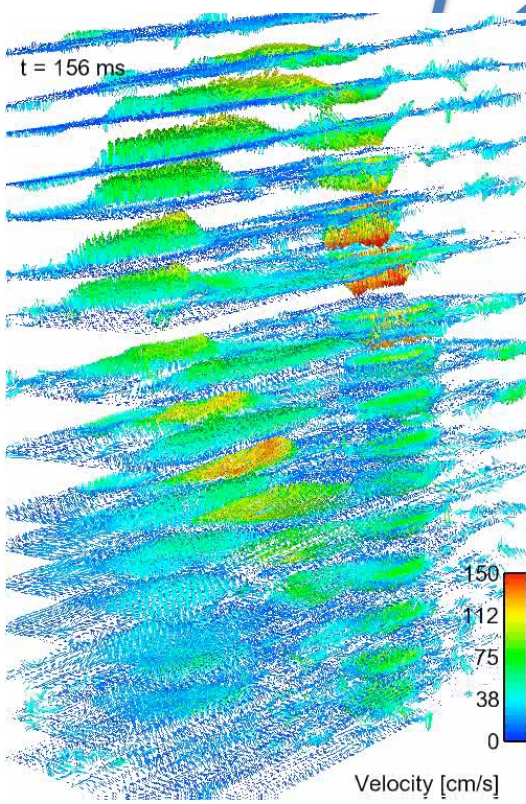
$$\rho_{\mathrm{f}} \frac{\partial \boldsymbol{u}_{\mathrm{f}}}{\partial t} + \rho_{\mathrm{f}} (\boldsymbol{u}_{\mathrm{f}} \cdot \boldsymbol{\nabla}) \boldsymbol{u}_{\mathrm{f}} - \mu \Delta \boldsymbol{u}_{\mathrm{f}} + \boldsymbol{\nabla} p = \boldsymbol{0}, \quad \text{in} \quad \Omega^{\mathrm{f}},$$

$$\boldsymbol{\nabla} \cdot \boldsymbol{u}_{\mathrm{f}} = 0, \quad \text{in} \quad \Omega^{\mathrm{f}}$$

?

Phase contrast MRI

- MRI 4-dimensional flow measures of the speed of the **bloodstream**



Courtesy of KCL

Measurements of velocity field

Spatial resolution: 1.5-3.0 mm3

Temporal resolution: 30-40 ms

Noise around 10% of maximal velocity (set for each acquisition)

- Relative pressure estimation from velocity measurements in blood flows: state-of-the-art and new approaches. C. Bertoglio, R. Núñez, F. Galarce, D. Nordsletten, A. Osses. *Int. J. Numer. Meth. Biomed. Engng. 2017*

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- Other consulted pages:
  - Animatios of CT (Samuli Siltanen)
    https://www.youtube.com/watch?v=q7Rt_OY_7tU
  - Start Radiology the basics:
    https://www.startradiology.com/the-basics/mri-technique/index.html
  - Animations of Silver Swan:
    https://www.youtube.com/channel/UCdYDbiK5SSC3HPKY6WdhmSg/videos?view=0&sort=da&flow=grid
  - Introduction to biomedical images course EPFL:
    https://www.youtube.com/watch?v=LdiJLkYgZ2M&list=PLTCZivgYYpFpVnxdGrxcuL5YOvPwespXy
  - MRI questions and answers:
    http://mriquestions.com/image-contrast-trte.html
- Other videos MRI:
  - School of Medicine, Washington University:
    https://www.youtube.com/watch?v=zf5oX01bRgk
  - Lighbox Radiology, Australia:
    https://www.youtube.com/watch?v=Ok9ILIYzmaY

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    - http://www.jcmr-online.com/content/12/1/71

Guía de re-lectura: a conocer/entender/retener

- Cuáles son y qué distingue las distintas modalidades de adquisición de imágenes biomédicas según emisión v/s transmisión, ionizante v/s no ionizante, resolución v/s sensitividad o proceso físico: transporte de fotones v/s ondas.
- Conocer aspectos de la génesis e historia de las distintas modalidades ¿Por qué cada una de estas modalidades se considera un problema inverso?
- Para CT, entender cuál es el proceso de adquisición de las imágenes (rayos X, ley de Beer y sinograma) y cómo se recupera la imagen de atenuaciones (etapas de retroproyección y filtrado de la transformada de Radón inversa).
- Para MRI, entender las etapas del proceso de adquisición de imágenes distinguiendo primero que nada la presencia de un campo magnético general que alinea los espines de los protones y la presencia de otros 3 gradientes magnéticos asociados a las diferentes direcciones espaciales.
- Para MRI, entender que la frecuencia de giro de precesión de los protones es proporcional a la intensidad del campo magnético aplicado (ley de Larmor) por lo que si el campo magnético varía (gradientes) la frecuencia de precesión varía y este es el fenómeno que se explota para obtener imágenes con MRI.
- Para MRI distinguir las etapas de: 1) el pulso de radiofrecuencias y la selección de una sección usando un primer gradiente, 2) que los distintos tejidos se diferencian por los tiempos de relajación de los espines de sus protones una vez que el pulso de radiofrecuencia es apagado y que la codificación de esta información en la sección seleccionada se puede hacer usando los otros dos gradientes, 3) la adquisición de señales se hace en el tiempo de eco TE o tiempo en que los protones oscilan de nuevo en fase, 4) finalmente la construcción de la imagen de frecuencias línea a línea usando tiempos de repetición TR.
- Para MRI: conocer que es la transformada de Fourier Inversa (IFT) la que convierte la imagen de frecuencias en una imagen visible de la sección.
- Para MRI: Conocer que las distintas modalidades de una imagen MRI llamadas T1,T2 y PD dependen de las combinaciones de tiempo TE y TR. Saber que también es posible medir desplazamientos y velocidades (de la sangre por ejemplo técnica llamada 4DFlow) usando MRI.

Thanks

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