Basis of radiation-matter interaction process.

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Three main processes of EMR interaction with matter

Absorption:

- Converts radiative energy into internal energy.

Emission:

- Converts internal energy into radiative energy.

Scattering:

- Radiative energy is first absorbed and then radiated.

Elastic scattering

- No exchange of internal energy of the medium with the radiated field
- No change of frequency of incident wave upon scattering

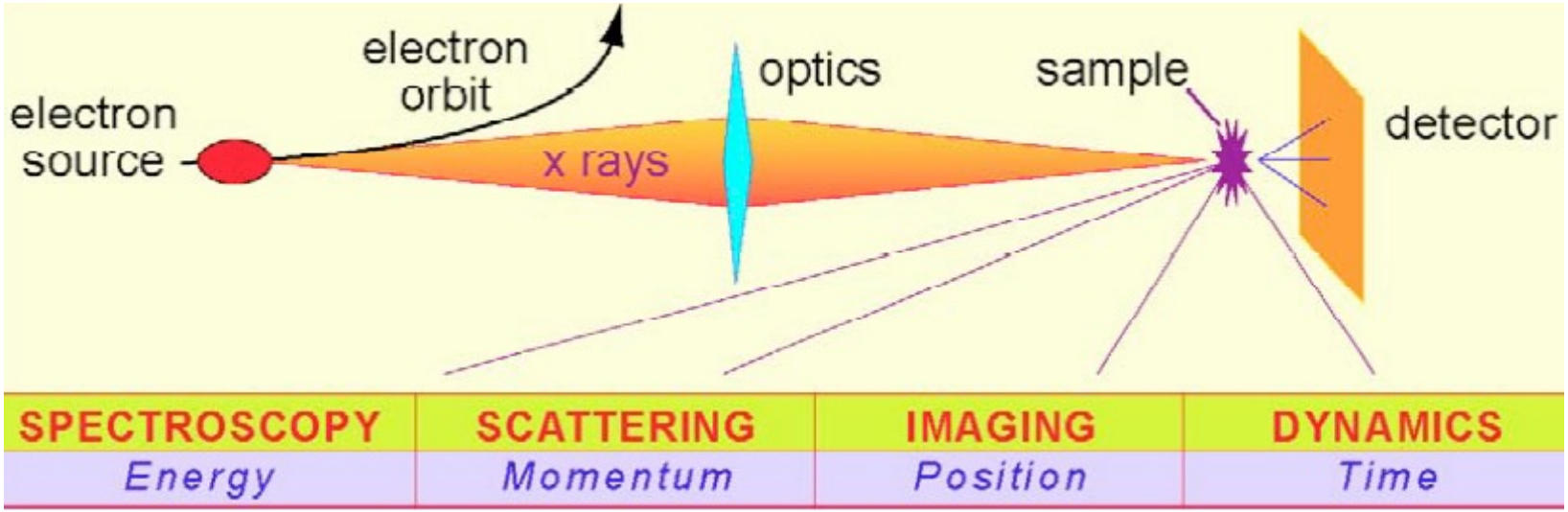
Inelastic scattering

- Involves exchange of internal energy of the medium with that of the radiated field.

Brief overview of the interaction photons-matter

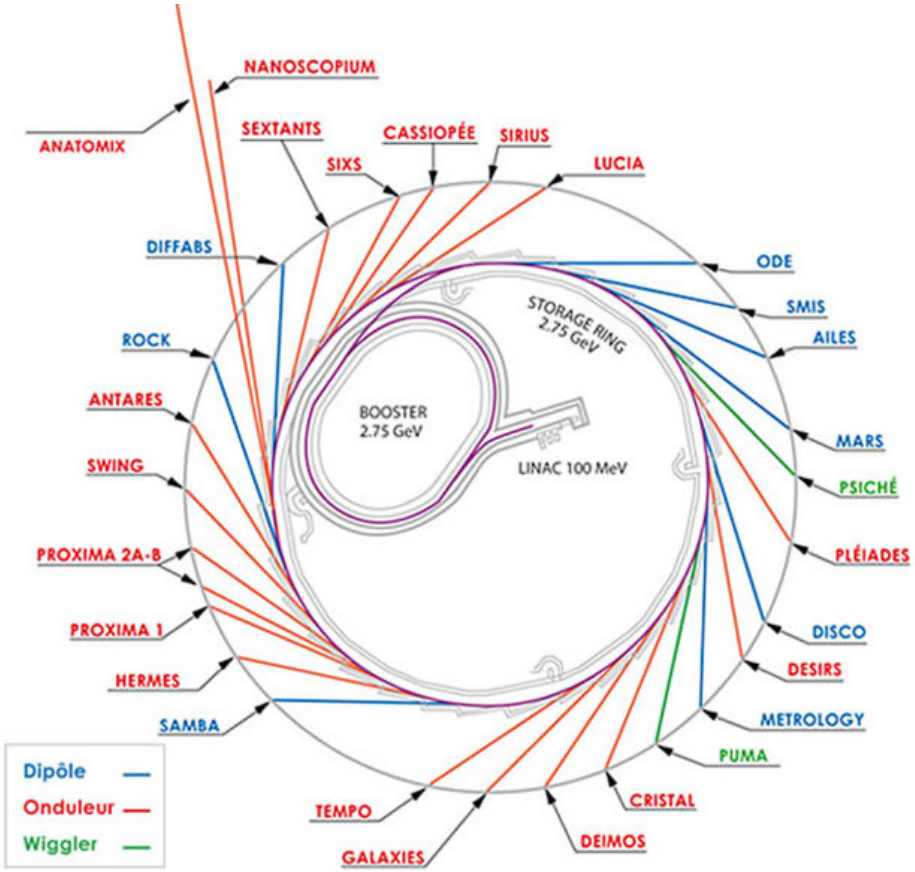
Stimulus → **sample** → **answer**

under different environments



Synchrotron pulse duration few tens of picosecond

XFEL ideal tool for femto and even subfemtosecond Time-Resolved experiments (Pump-Probe)


NANOSCOPIUM
ANATOMIX
SEXTANTS
CASSIOPÉE
SIRIUS
SIXS
LUCIA
DIFFABS
ODE
SMIS
AILES
STORAGE RING
2.75 GeV
ROCK
BOOSTER
2.75 GeV
ANTARES
MARS
LINAC 100 MeV
SWING
PSICHÉ
PROXIMA 2A-B
PLÉIADES
PROXIMA 1
DISCO
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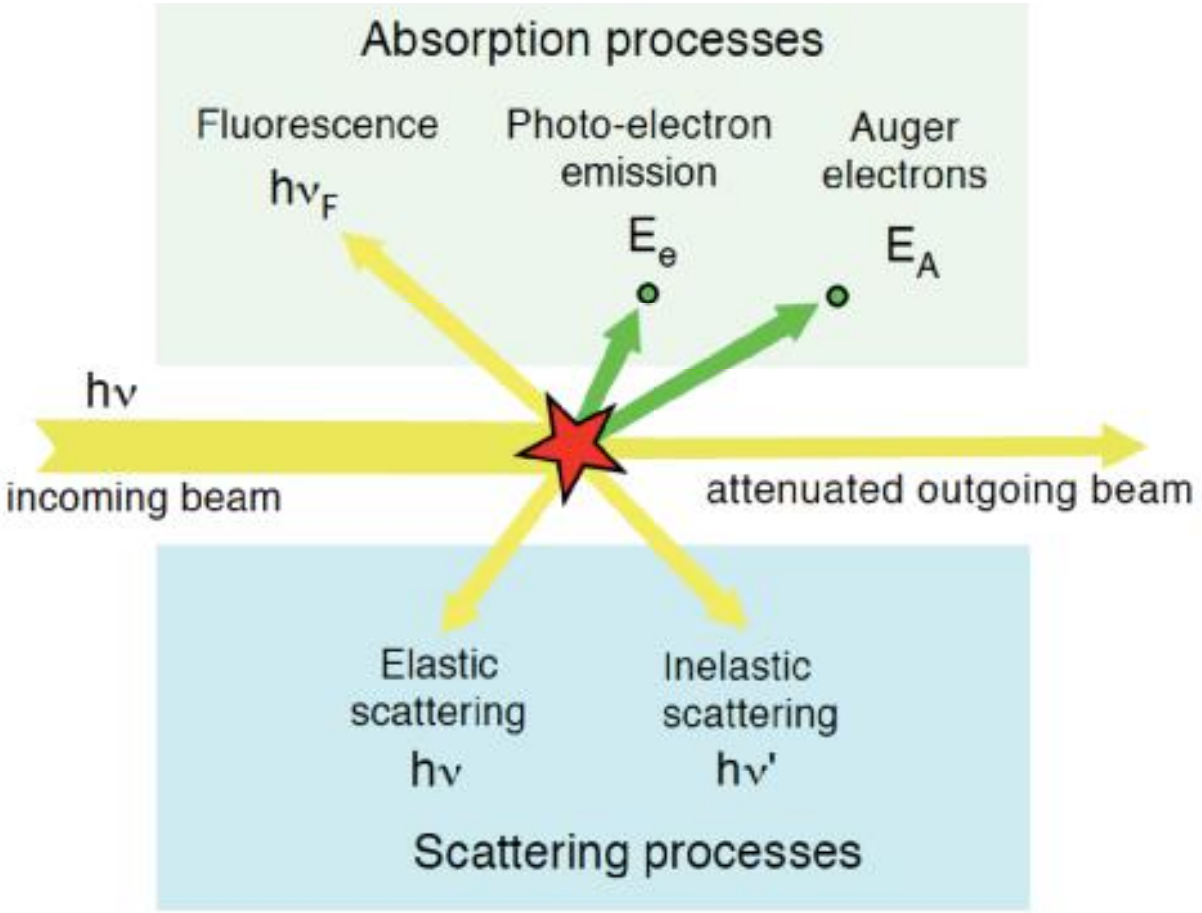
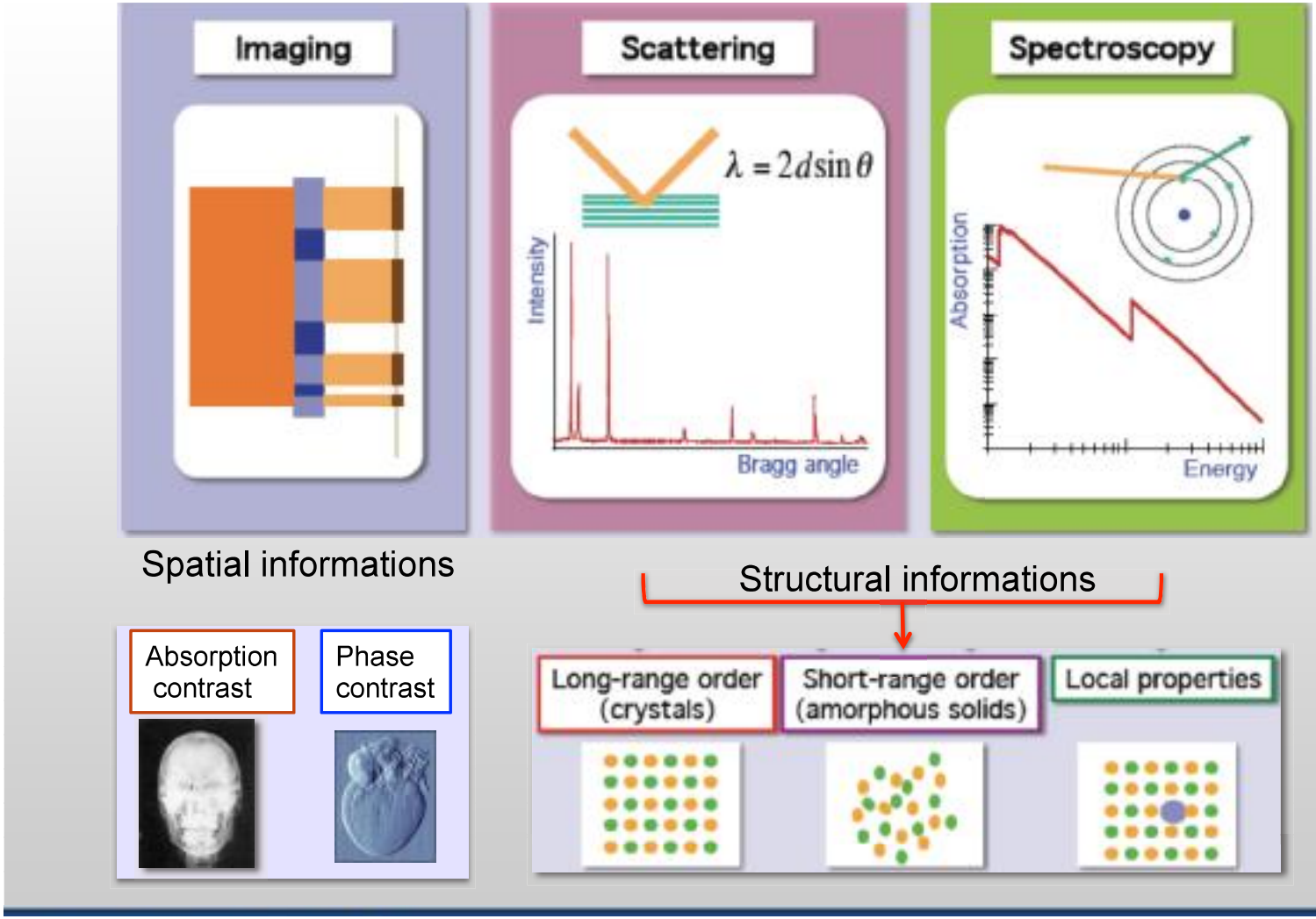
SAMBA
PUMA
CRISTAL
TEMPO
DEIMOS
GALAXIES
Dipôle
Onduleur
Wiggler


Absorption processes
Fluorescence
hν_F
Photo-electron emission
E_e
Auger electrons
E_A
hν
incoming beam
attenuated outgoing beam
Elastic scattering
hν
Inelastic scattering
hν'
Scattering processes


Imaging
Scattering
$\lambda = 2d\sin\theta$
Intensity
Bragg angle
Spectroscopy
Absorption
Energy
Spatial informations
Structural informations
Absorption contrast
Phase contrast
Long-range order (crystals)
Short-range order (amorphous solids)
Local properties

January 16 to 18, 2023

TUNTWIN Project

"WORKSHOP PROGRAM"

Session A: Basics in Synchrotron Techniques for Environmental and Food From Basics to application

DAY 1: Monday 16th January 2022

Introductory session	
9:00-11:00h	Introduction to synchrotron radiation. Historical overview about X-ray production: from X-ray tubes to modern synchrotrons and X-ray free electron lasers. Brief introduction about synchrotron radiation (SR) light generation. Parts of the synchrotron. Properties of SR light that makes it unique (high brilliance, broad energy spectrum, polarization, pulsed time structure). SR sources and XFELs around the world (in Europe and closer to the Mediterranean basin). Teacher: ***Marc Simon** LCPMR France*
11:00-11:30h	**Coffee break**
11:30-12:30h	Basis of radiation-matter interaction process. Teacher: ***Marc Simon** LCPMR France*
12:30-14:00h	**Lunch break**
14:00-15:30h	Overview of the different families of synchrotron radiation techniques. Spectroscopy, scattering, diffraction, imaging). Teacher: ***Iris H. Valido** UAB Spain*
15:30-16:30h	Beam quality factors that affect the performance of a beamline. Brilliance, photon flux at sample, resolving power, harmonics, variable polarization…. Teacher: ***Roberto Boada** UAB Spain*

DAY 2 Tuesday 17th 2023

Spectroscopy techniques session	
9:00-10:30h	X-ray absorption/emission spectroscopy XAS, XRF; micro and nano applications Teacher: ***Roberto Boada** UAB Spain*
10:30-11:00h	**Coffee break**
11:00-12:30h	X-ray photoemission XPS principles and applications Teacher: ***Marc Simon** LCPMR France*
12:30-14:00h	**Lunch break**
14:00-15:00h	**Fourier transform infrared (FTIR)** Teacher: ***Iris H. Valido** UAB Spain*
Scattering and diffraction techniques session	
15:00-16:00h	X-ray diffraction Teacher: ***Iris H. Valido** UAB Spain*
16:00-17:00h	X-ray scattering (SAXS and WAXS) Teacher: ***Roberto Boada** UAB Spain*

DAY 3: Wednesday 18th 2023

X-ray imaging techniques session	
9:00-10:00h	Scanning X-ray microscopy Teacher: ***Roberto Boada** UAB Spain*
10:00-11:00h	X-ray tomography Teacher: ***Roberto Boada** UAB Spain*
11:00-11:30h	**Coffee break**
11:30-13:00h	**How to apply for getting beamtime at the synchrotron.** Brief introduction of how to access the synchrotron (academic, industrial), how to apply for getting beamtime (calls, contact with beamline manager in advance, steps for proposal submission), and how to write a good proposal for beamtime application. Teacher: ***Iris H. Valido** UAB Spain*
13:00-14:30h	**Lunch break**
14:30-16:30h	**Round table and discussion on specific scientific cases from the participants.**
16:30-17:00h	**Closing remarks**

Organized by: INRAP, Université de Pau et des Pays de l'Adour, UAB Universitat Autònoma de Barcelona, ALBA

At: Institut Français Tunisie

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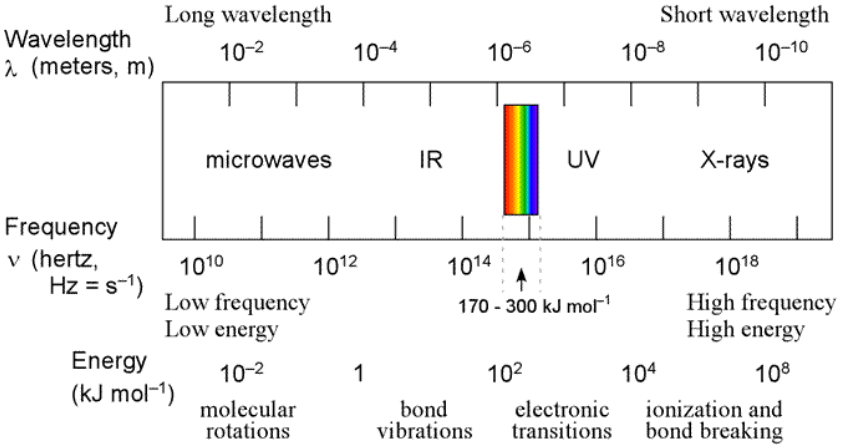
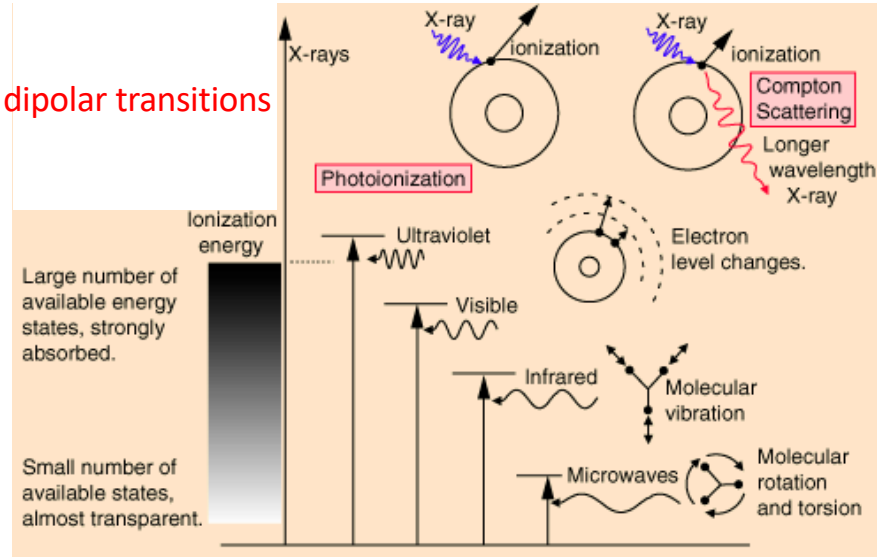
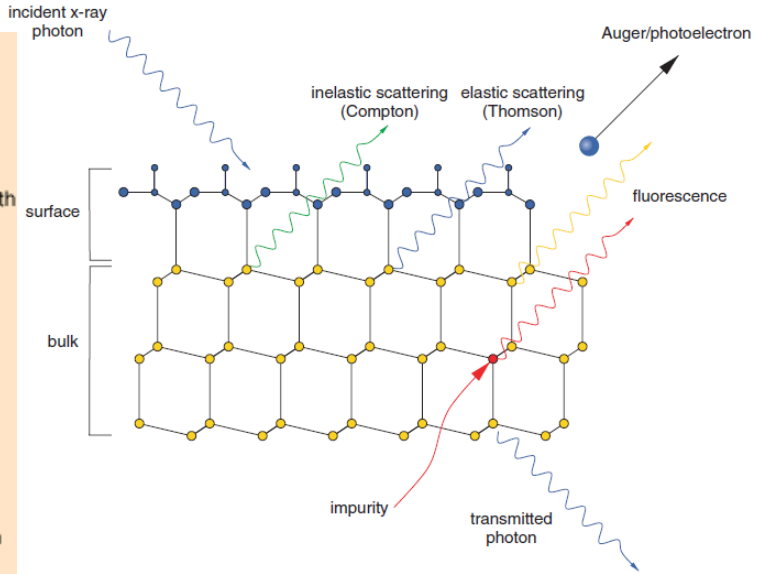
Brief overview of the interaction photons-matter

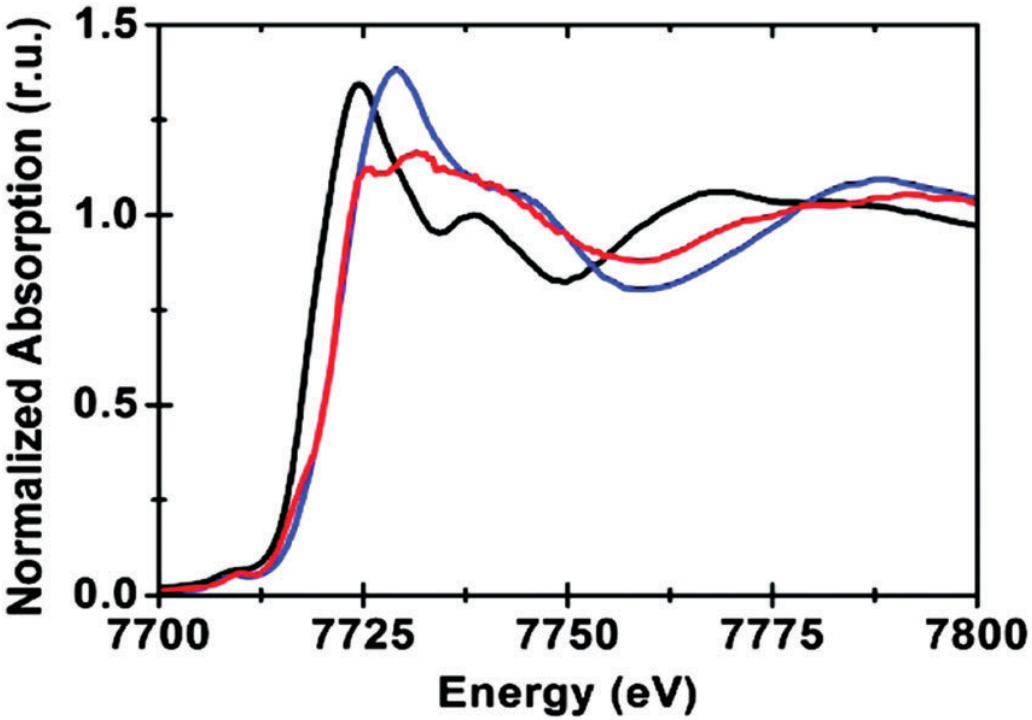


dipolar transitions





X-ray – matter interaction (discrete transitions – photoionization)

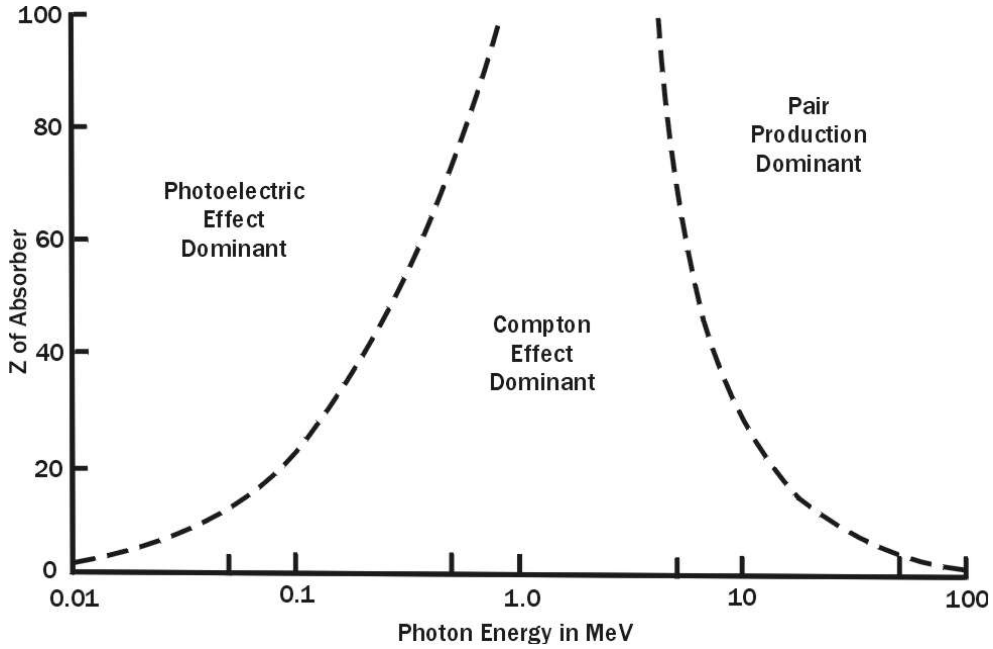


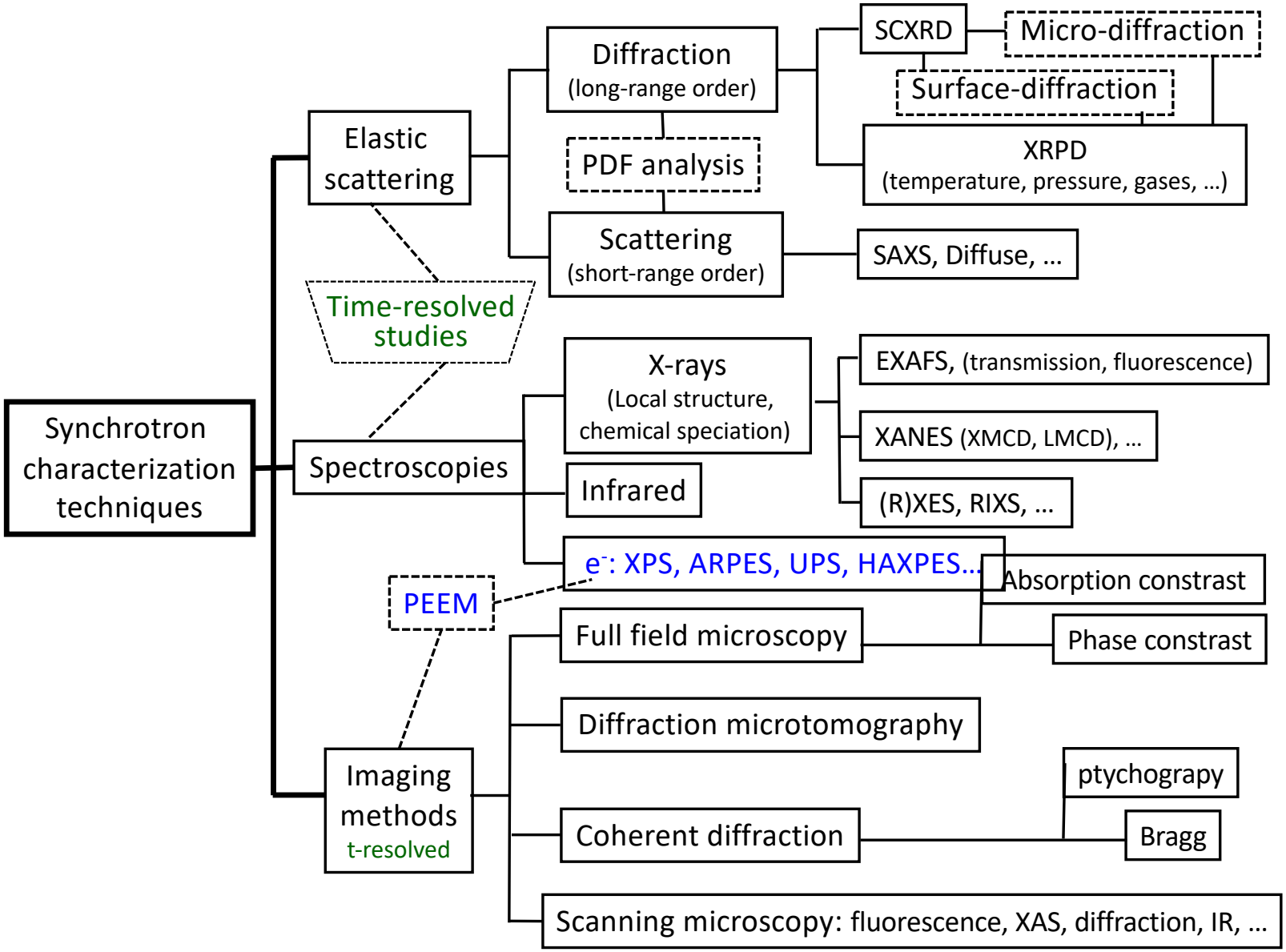
The Co K-edge XANES structure of the CoCat (blue) and two references: [CoII(OH2)6](NO3)2 (black) and [CoIII(NH3)6]Cl3 (red).

Very low cross section for Valence electron – x-rays interaction

Electronic transition to consider : promotion of an 1s electron to an empty Molecular Orbital below threshold

Above the K shell ionization threshold: photoionization


100
80
60
40
20
0
Z of Absorber
Photoelectric
Effect
Dominant
Compton
Effect
Dominant
Pair
Production
Dominant
0.01
0.1
1.0
10
100
Photon Energy in MeV


Synchrotron characterization techniques
Elastic scattering
Time-resolved studies
Spectroscopies
Imaging methods
t-resolved
Diffraction
(long-range order)
PDF analysis
Scattering
(short-range order)
SCXRD
Micro-diffraction
Surface-diffraction
XRPD
(temperature, pressure, gases, …)
SAXS, Diffuse, …
X-rays
(Local structure, chemical speciation)
Infrared
e⁻: XPS, ARPES, UPS, HAXPES…
EXAFS, (transmission, fluorescence)
XANES (XMCD, LMCD), …
(R)XES, RIXS, …
PEEM
Full field microscopy
Diffraction microtomography
Coherent diffraction
Scanning microscopy: fluorescence, XAS, diffraction, IR, …
Absorption constrast
Phase constrast
ptychograpy
Bragg

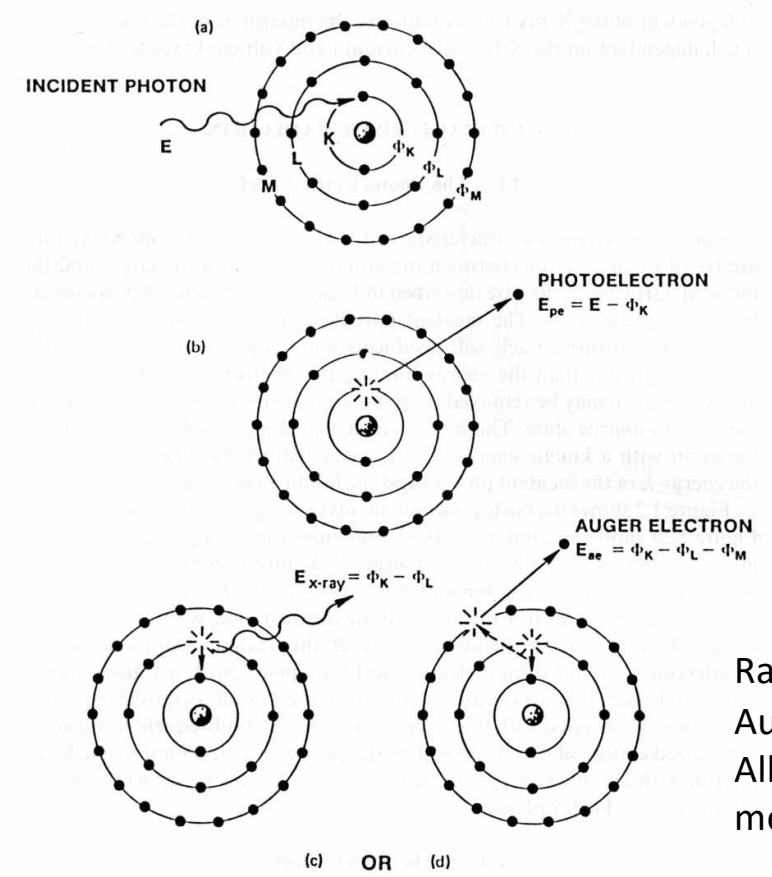
Spectroscopies

IR

UV

X-rays (soft x-rays (50-1000 eV), hard x-rays (1 keV – 1 MeV)

- Absorption spectroscopy (EXAFS (local structure), XANES (speciation))
- Photoionization (XPS, HAXPES, ARPES)
- Auger spectroscopy
- X-ray emission spectroscopy, Resonant Inelastic X-ray scattering (RIXS)



X-ray emission
Constant with x-ray energy

Radiation damage
Tin shielding

Radiation damage
Auger emission constant with x-ray energy
Allows to study doubly ionized state by measuring only one electron

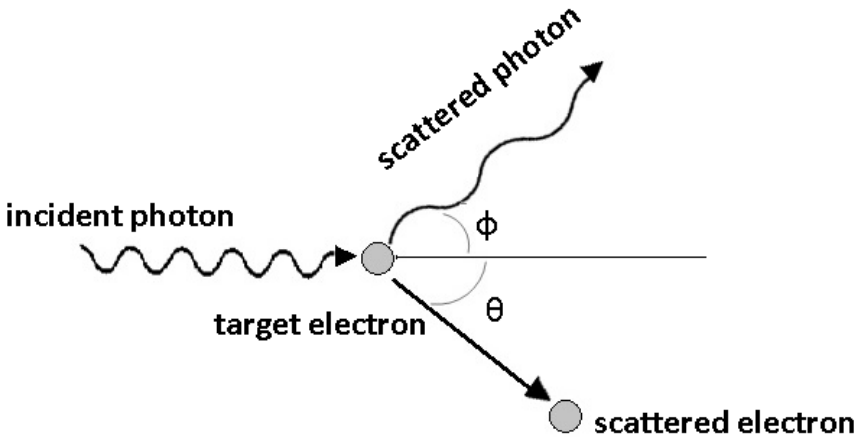
Elastic scattering

X-Ray Diffraction. Very important method to determine protein structures

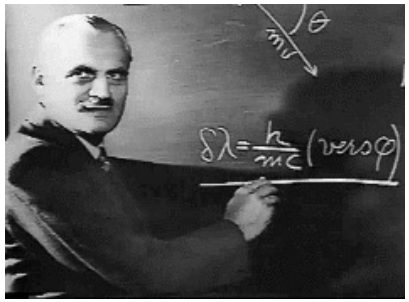
Pair Distribution Function Analysis. Analytical technique which provides structural information from disordered materials by using the complete powder X-ray Diffraction pattern. → Long range orders of the atoms can be deduced. Technic used for amorphous, poorly crystalline, nano-crystalline or nano-structured

Scattering. Short-range orders can be deduced. SAXS or diffuse scettering

Compton scattering



Arthur Compton Physics Nobel prize 1927



Inelastic scattering of x-rays by free electrons

Scientific thematic declining and coming up again thanks to gas phase measurements

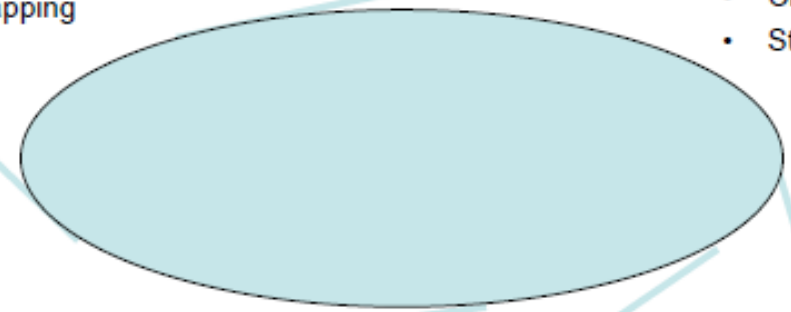
Coincidence between scattered electron and ion through reaction microscope.

Momenta of ion and electron measurements allow to determine the momentum of the scattered photon.

M. Kircher et al., Nature Physics 16 56 (2020)

Brief overview of the interaction photons-matter

Synchrotron based microprobe techniques



X-Ray Fluorescence

- Composition
- Quantification
- Trace element mapping

X-ray Diffraction & scattering

- Long range structure
- Crystal orientation mapping
- Stress/strain/texture mapping

Phase contrast X-ray imaging

- 2D/3D Morphology
- High resolution
- Density mapping

Infrared FTIR-spectroscopy

- Molecular groups & structure
- High S/N for spectroscopy
- Functional group mapping

X-ray spectroscopy

- Short range structure
- Electronic structure
- Oxidation/speciation mapping

Brief overview of the interaction photons-matter