Ultrafast dynamics in atoms or molecules in strong fields

Dynamique ultra-rapide dans les atomes et molécules en champs intenses

Teachers : R. Taïeb, M. Trasinelli and A. Dubois

Course objectives:

➔ To present phenomena induced when atomic or molecular species interact with strong and ultra-fast electromagnetic fields (laser or highly charged ion).

➔ To introduce a number of fundamental aspects that are used to predict, describe and analyse the highly non-linear response of these systems:

- Processes induced by such interaction
- Experimental aspects
- Theoretical (analytical and numerical) approaches

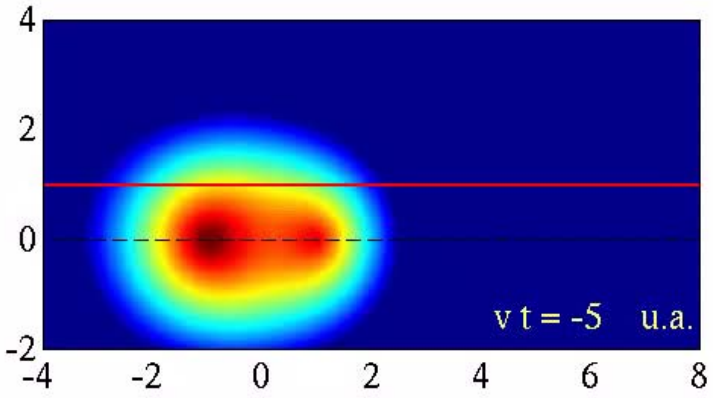
General aspects

Similarities and differences between laser and ion interaction

with atomic and molecular systems

time-scale, energy scale, and strength

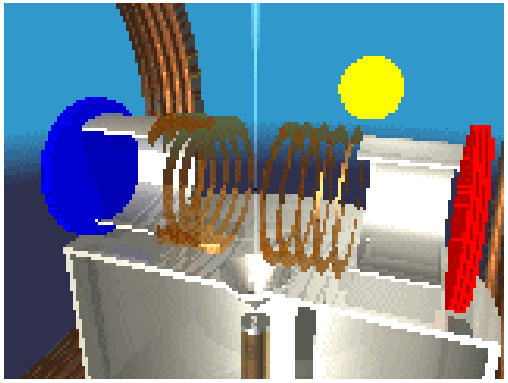
Theoretical approaches



• Main features of atomic and molecular collisions : processes, cross sections and characteristic quantities (time, energy, space) which govern the description of the collisions.

• Quantum/semiclassical approaches, non perturbative **time-dependent treatments**.

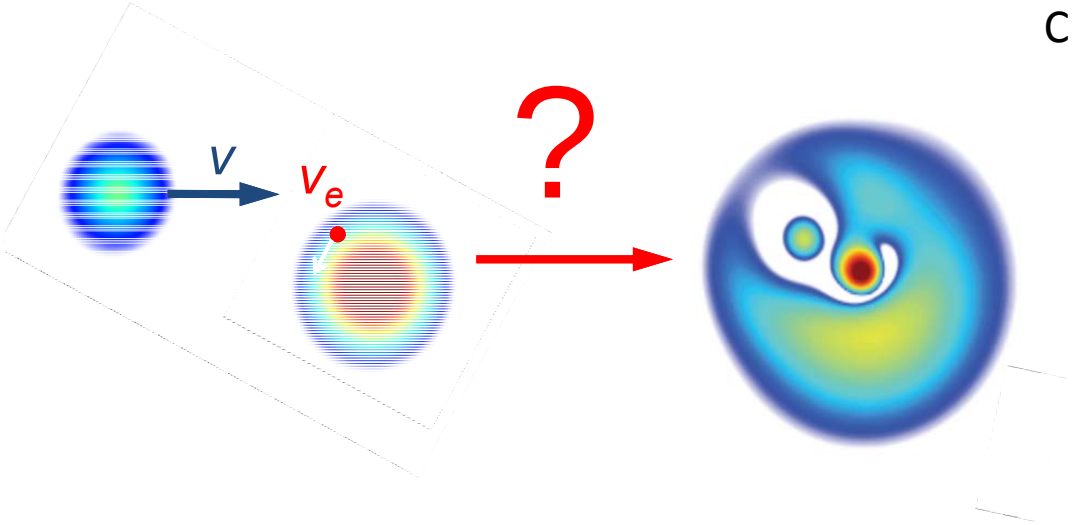
Experimental aspects



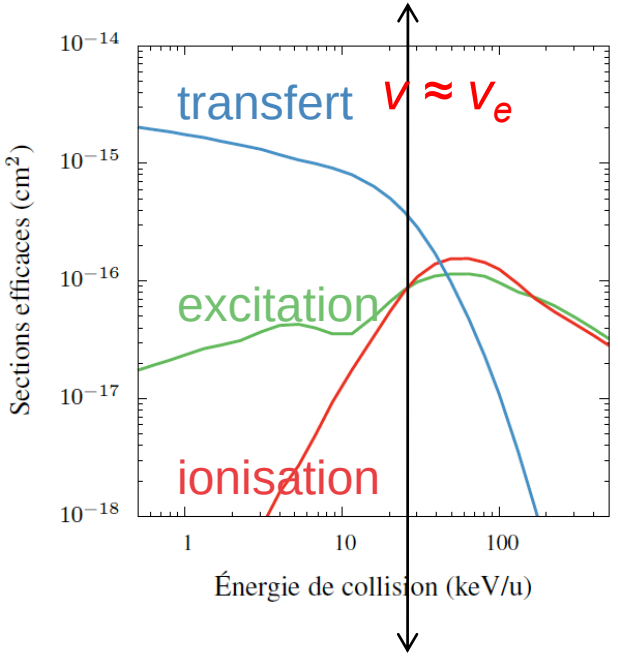
• Beams : ion sources, accelerators (GANIL, GSI), intense and ultra-short laser.

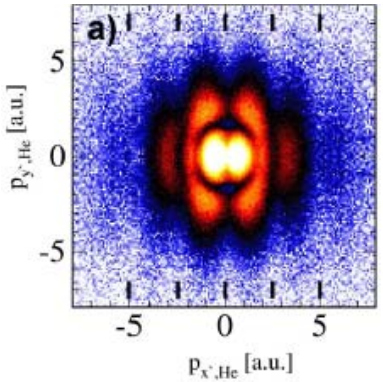
• Detection : photon (x-ray) and electron spectroscopies, electron and ion momentum spectroscopy (COLTRIMS). Coincidence.

Atomic and molecular collisions

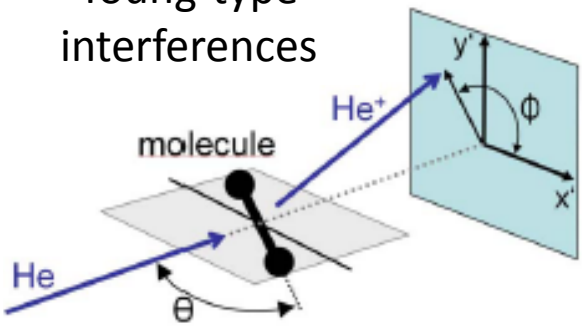


Cross sections for $H^+ + H$ collisions

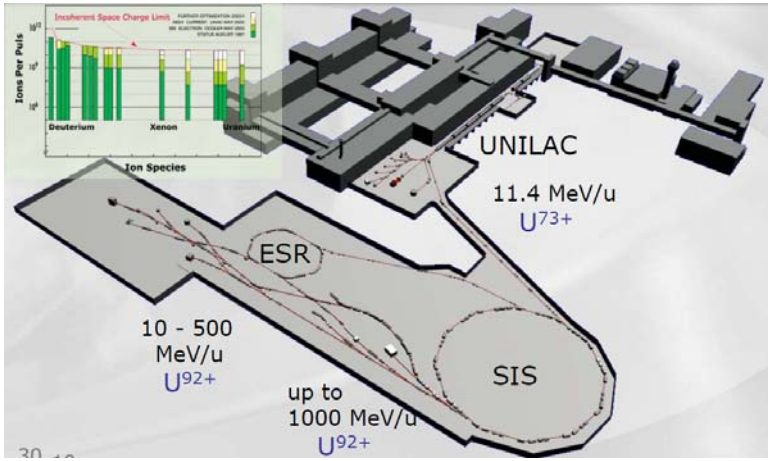




Young-type interferences



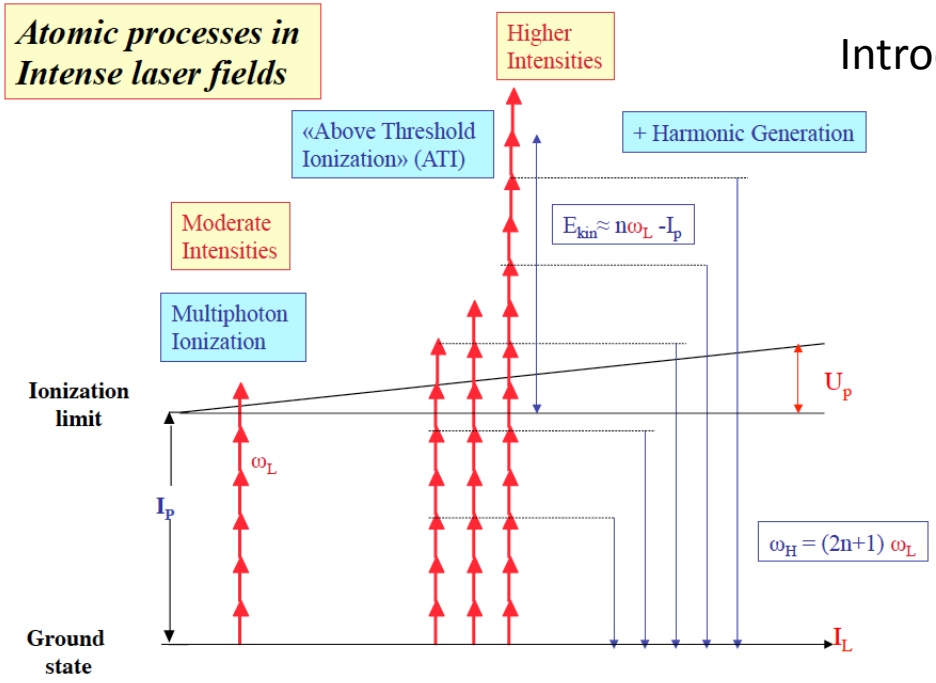
GSI / Allemagne



Atomic and molecular systems + laser pulses

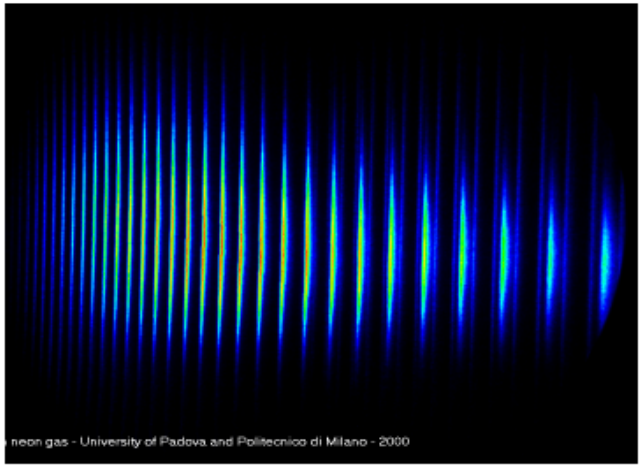
Pump – Probe experiments- Coherent control

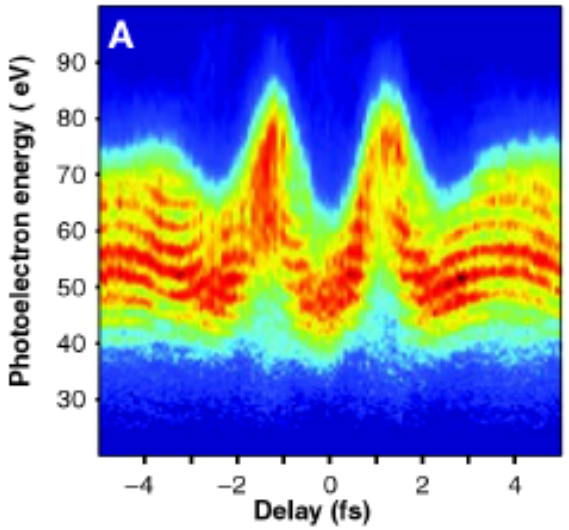
Introduction to **atto-physics**

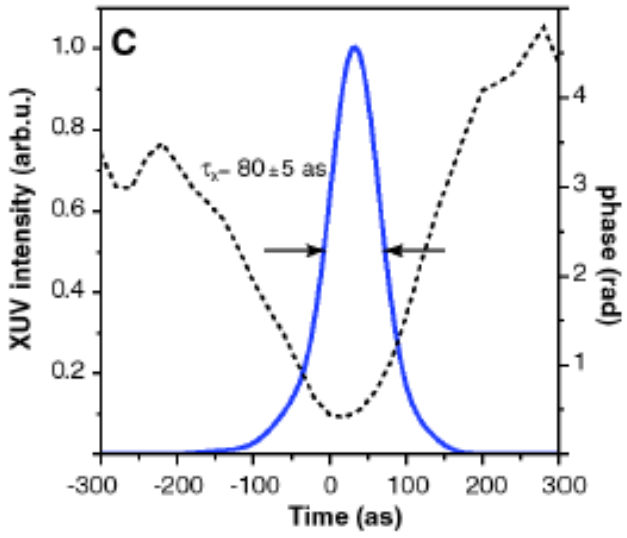


Ionisation, dissociation

High-Order harmonics generation (HHG)

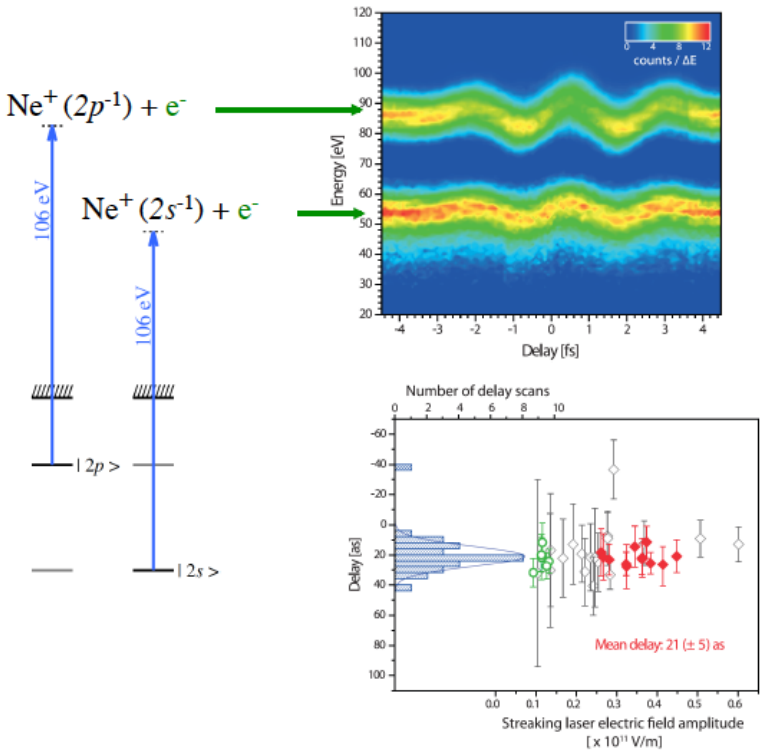






Applications …

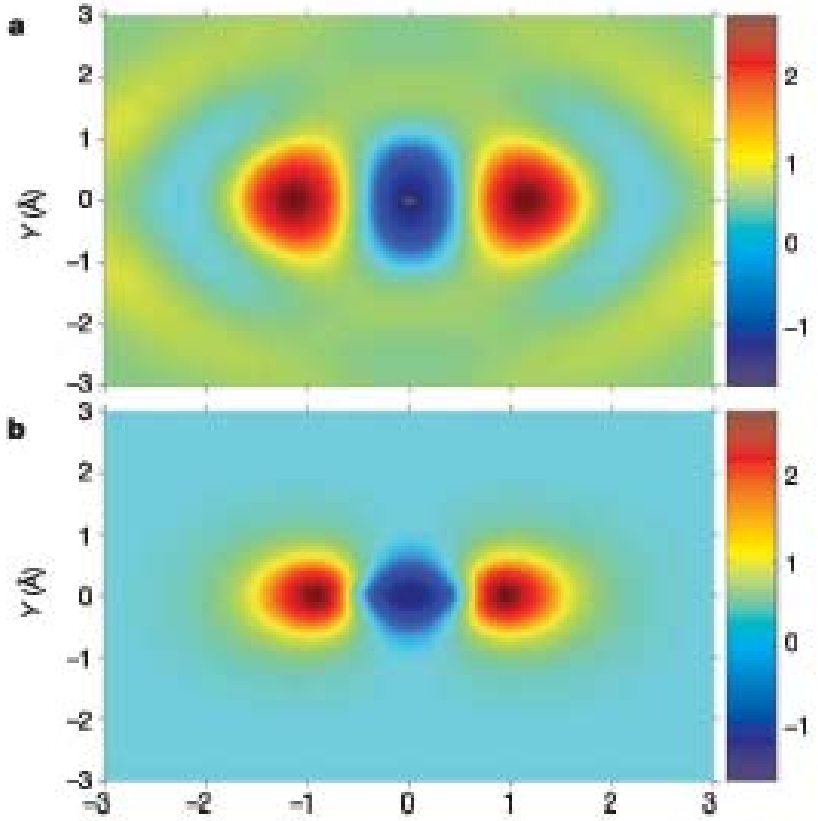
Gaz



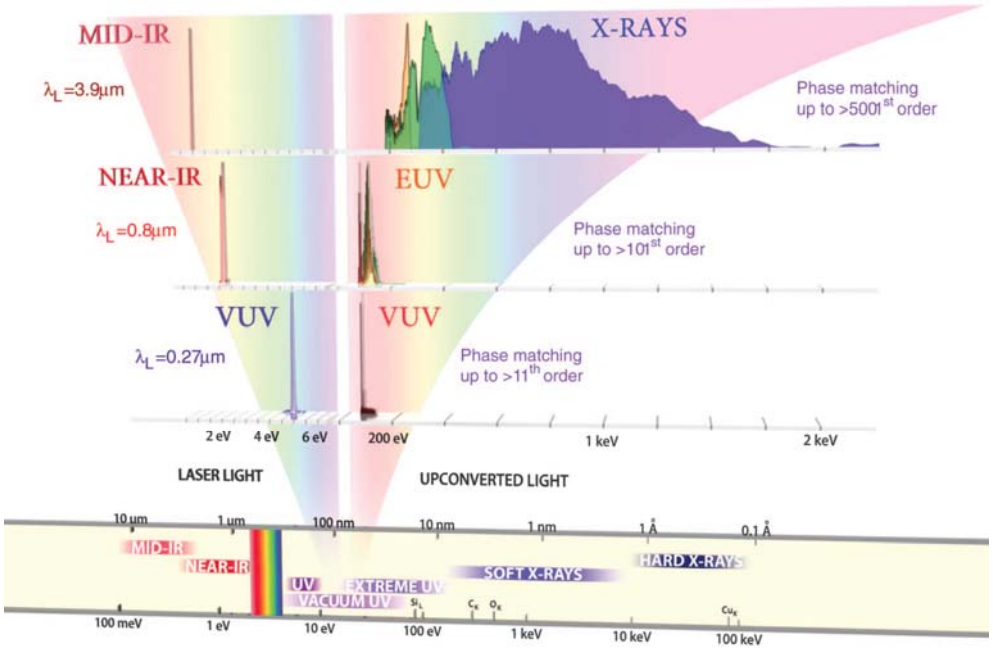
$\tau_{2p} - \tau_{2s} = 21 \pm 5$ as

Attosecond delay in ionization

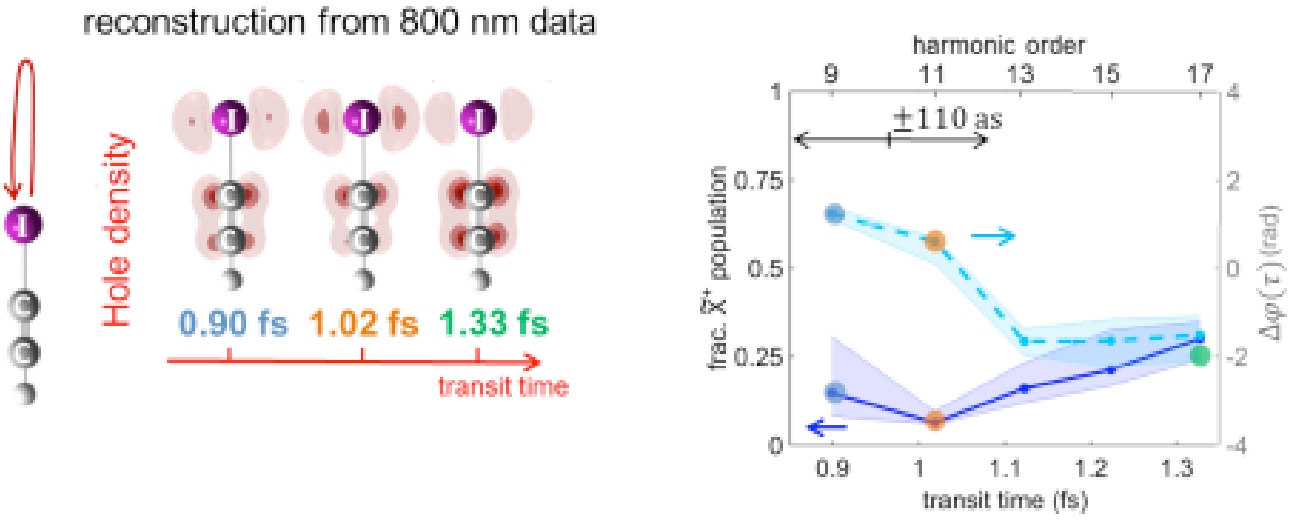
Molecular orbital tomography



Production de rayons X keV

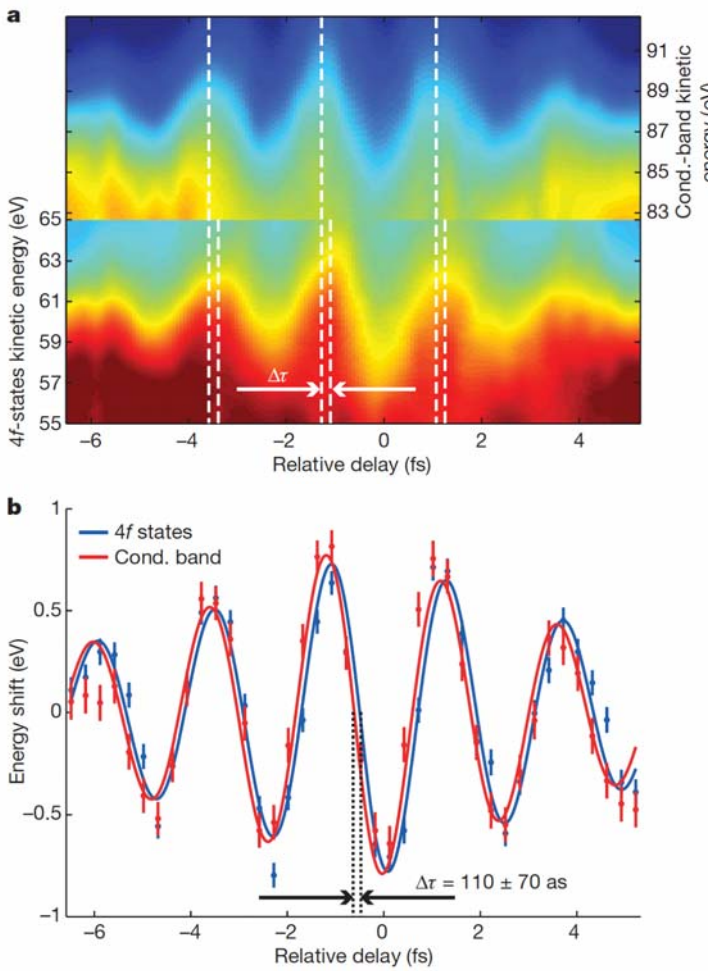


Suivie d'une dynamique attoseconde



Retard attoseconde à l'ionisation

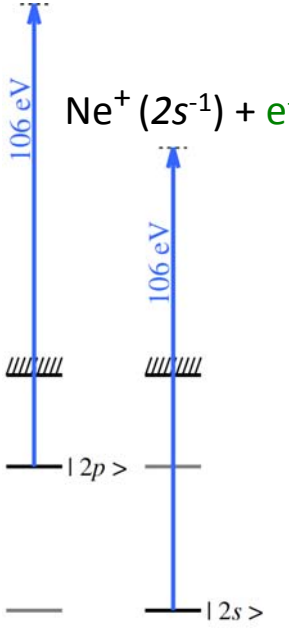
Solide



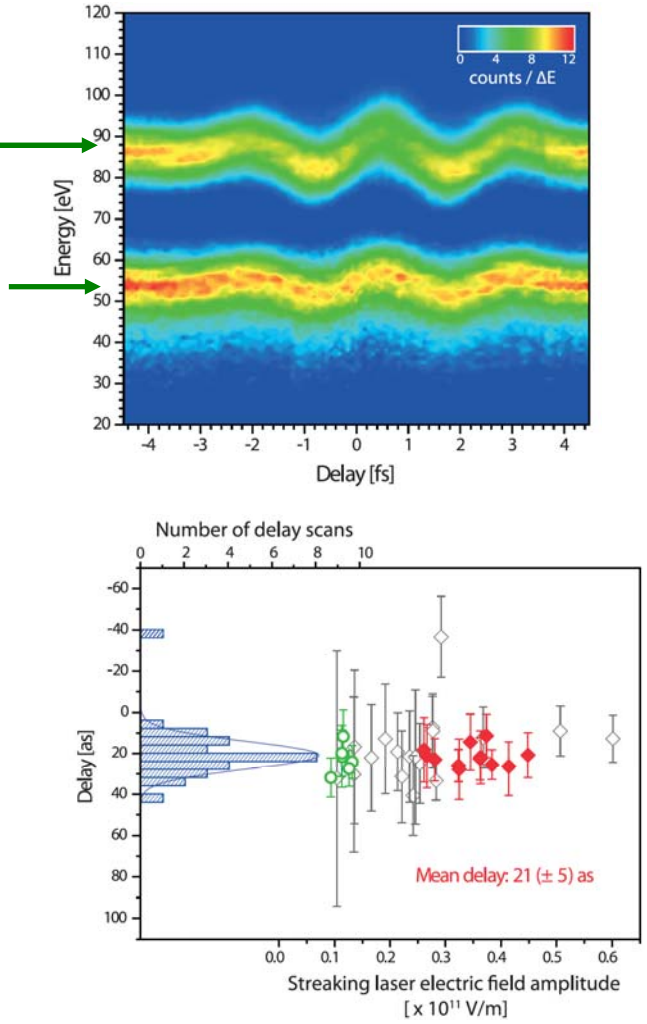
Transport

$Ne^+ (2p^{-1}) + e^-$

$Ne^+ (2s^{-1}) + e^-$



Gaz



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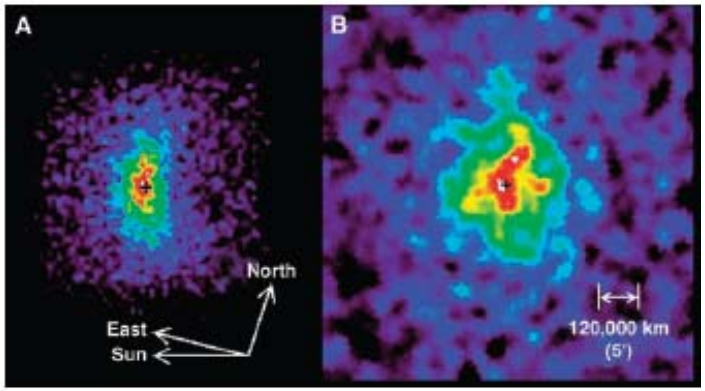
Applications

ASTROPHYSICS



x-ray emission

from comets

from T.E. Cravens, Science **296**, 1042 (2002)

MATERIAL SCIENCE

atomic scattering on surfaces

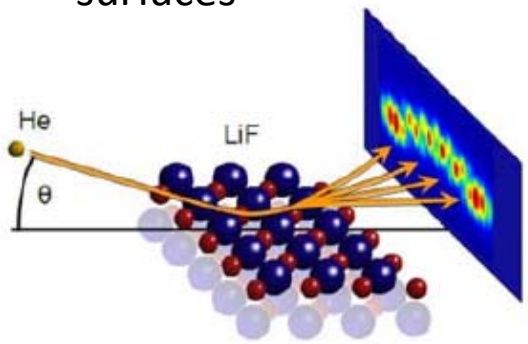
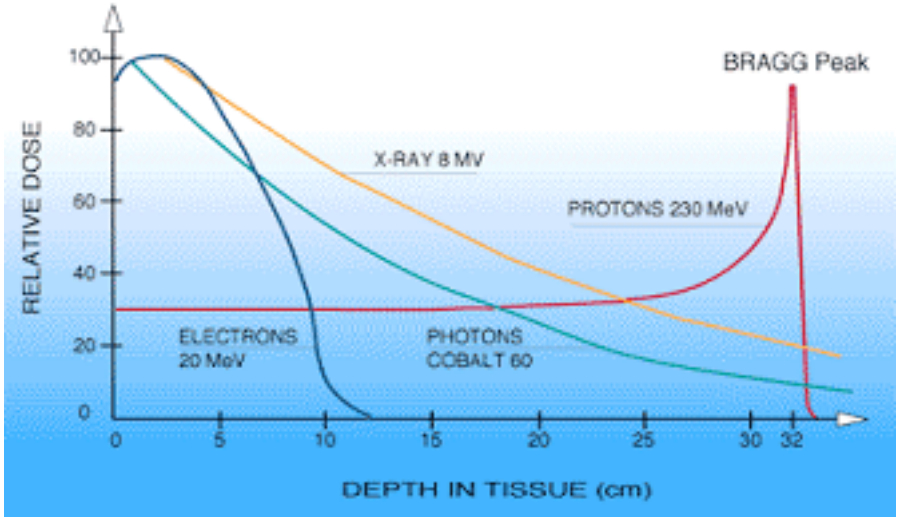
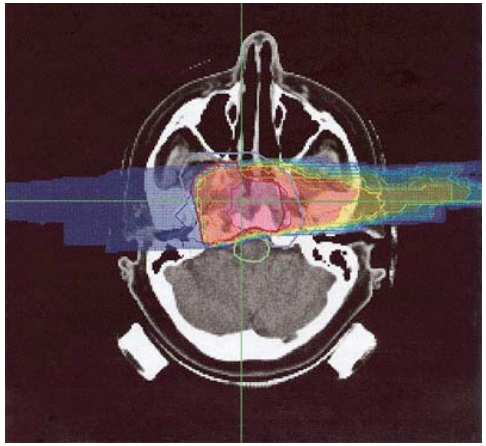


Fig 1: Helium atoms scattered at a LiF-surface at a grazing angle of incidence.

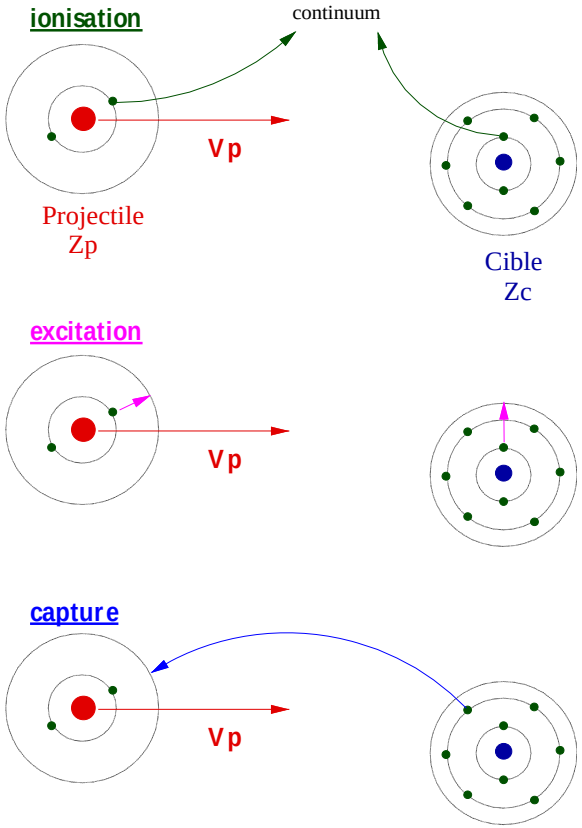
MEDICAL PHYSICS

C^{6+} → tissue : hadrontherapy

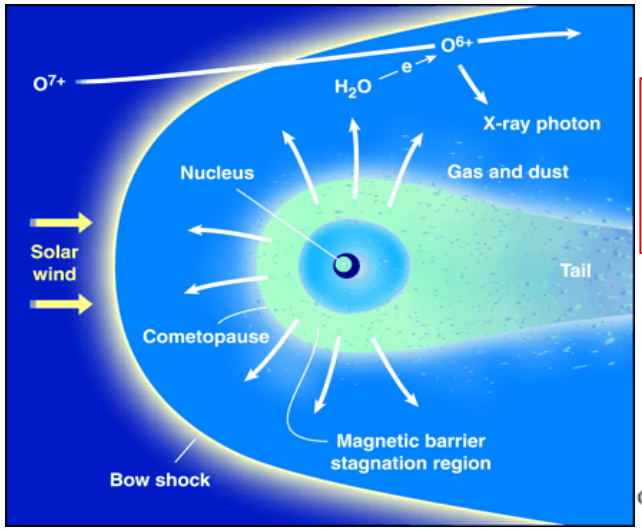




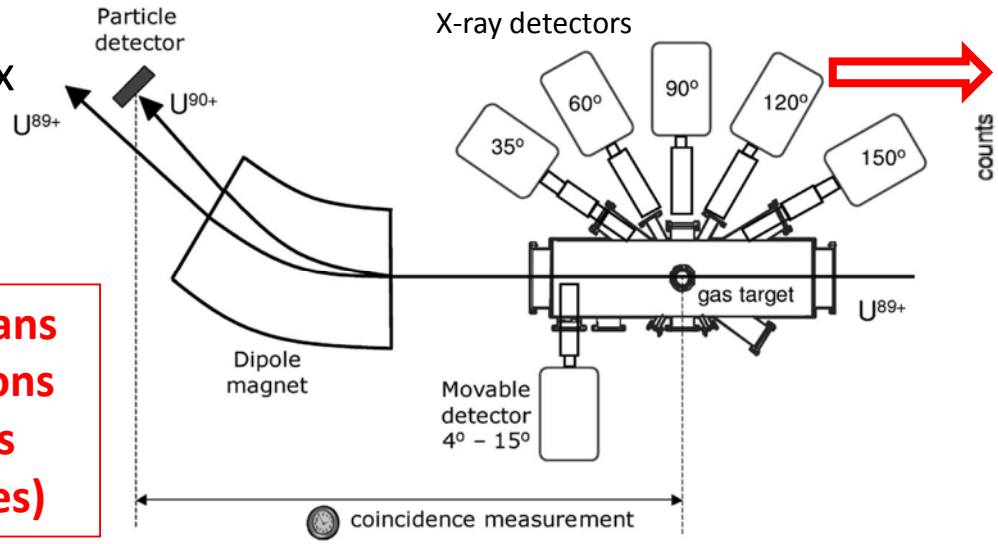
Processus de collision d'ions mutlichargés (forte perturbation coulombienne) à regime relativiste et non-relativiste



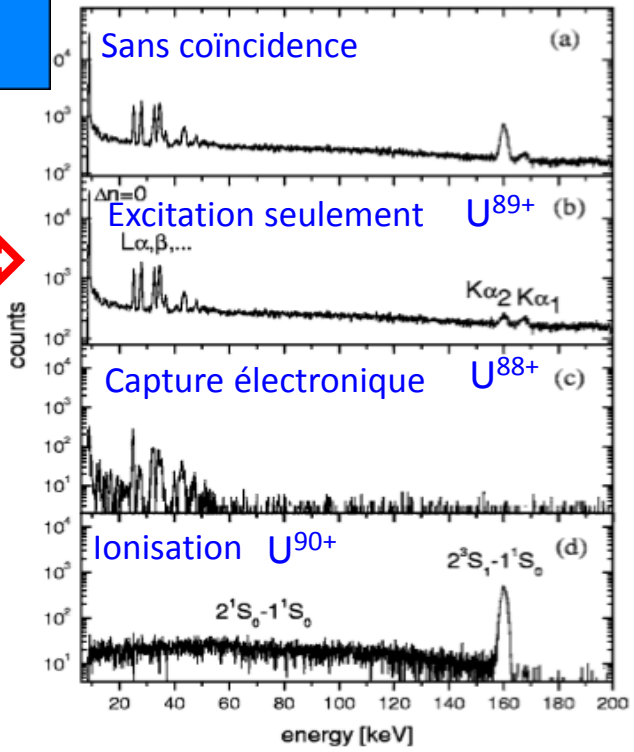
Processus fondamentaux collisions



Collisions d'intêret astrophysique



Collisions dans des conditions contrôlées (laboratoires)



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Practical informations:

➔ thrusday aftenoon

➔ in French or English

➔ oral exam with presentation of a short publication (letter)