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Plasma
Physics

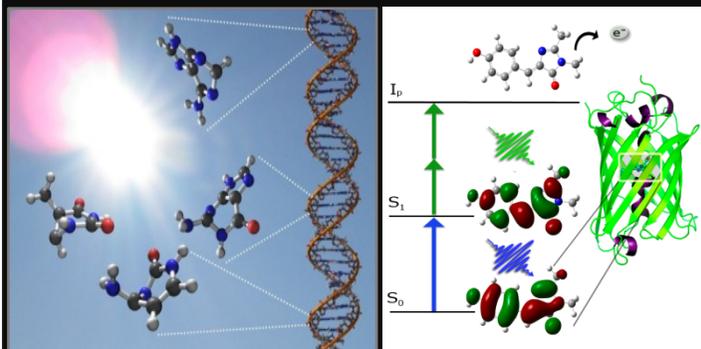
Jason
Greenwood



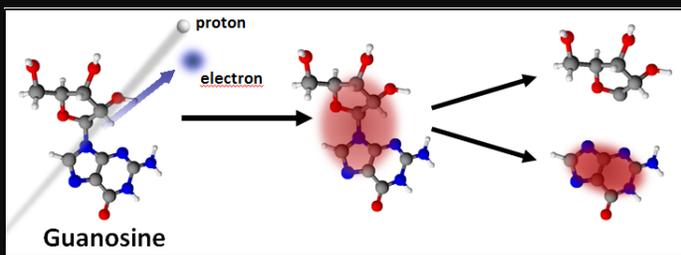
Ian
Williams

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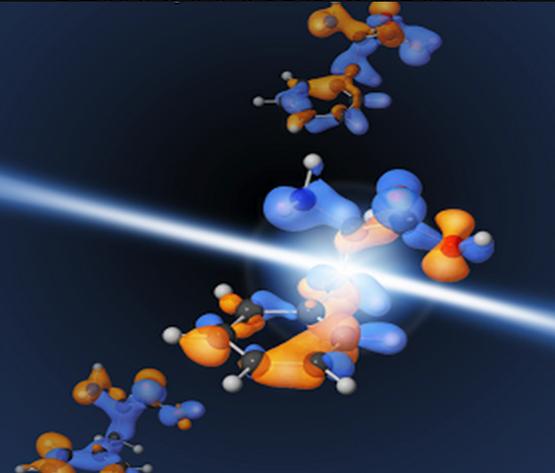
Ultrafast Biomolecular Processes



Many biological processes are initiated by ultrafast interactions of radiation with molecular building blocks like proteins and DNA. In our experiments we stimulate these molecules using particles such as protons or ultrashort light pulses and observe ions and fragments produced from the interaction. From our results we gain an understanding of how DNA protects itself from ultraviolet irradiation and how it is damaged in radiotherapy cancer treatment. We have also learned the mechanisms by which proteins used to image cells (such as the green fluorescent protein) emit visible light when exposed to ultraviolet radiation.



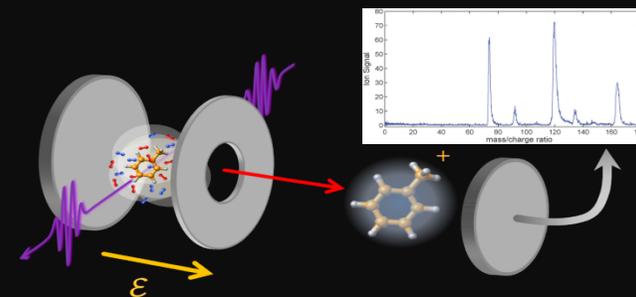
www.ultrafastbelfast.com
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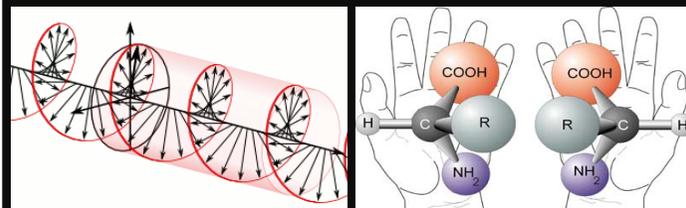
Electrons are the “glue” holding matter together and the carriers of electrical signals in our bodies and technological devices. By using the shortest laser pulses ever produced as ultrafast strobe lighting, we have made the first observations of electrons moving in matter. In effect we have created an electron movie, with each frame lasting attoseconds (billion billionths of a second).



Trace Detection of Organic Compounds



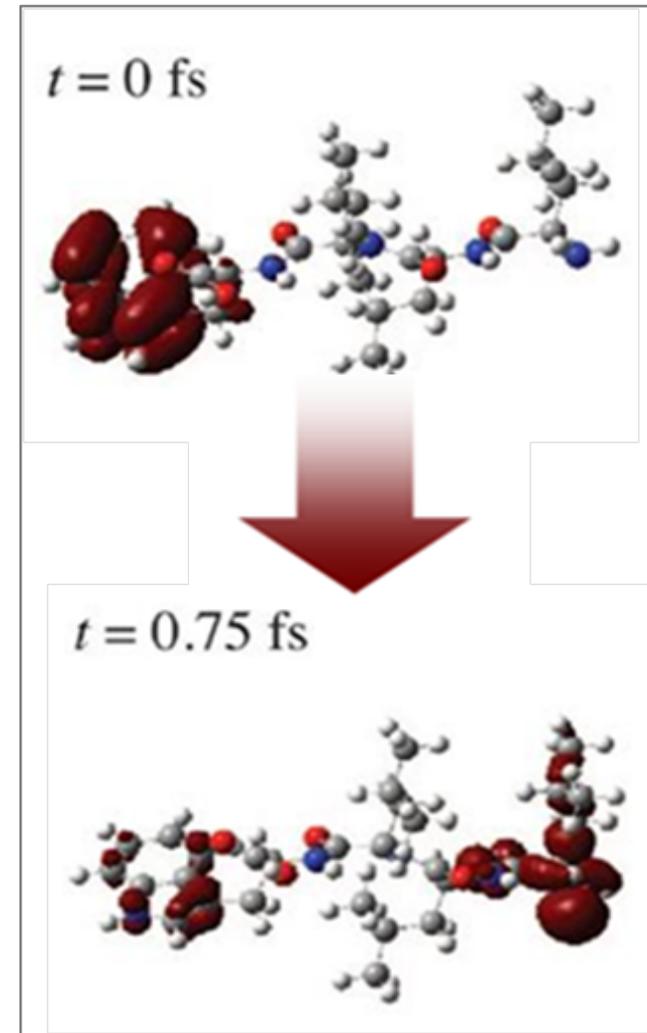
Mass spectrometry is currently the most sensitive chemical analysis technique. It removes (ionises) electrons from molecules so they can be identified by their mass. We are currently using intense, short pulse lasers to more efficiently ionise molecules so that even higher detection sensitivities can be achieved. These studies could lead to applications in analysis of human breath, blood and tissue samples for the diagnosis of disease and testing the efficacy of treatments.



Life on Earth is unique in that its building blocks exhibit a distinct handedness or chirality. Proteins in our body are left handed while none have the right handed configuration. Using intense laser pulses which are polarised with a rotating electric field in combination with mass spectrometry, we are seeking a more sensitive way of identifying different chiral molecules.

Ultrafast Charge Transfer

- Electron (charge) movement critical in natural and synthetic systems for electrical conduction and initiate chemical reactions.
- To initiate charge transfer the electrons have to be disturbed from equilibrium, e.g. by
 - Photon absorption
 - Interaction with an energetic particle
- As electrons are light their movements are very fast and if instantaneously excited then the motion can be coherent



F. Remacle and R.D. Levine
PNAS **103**, 6793 (2006).

Amino acids

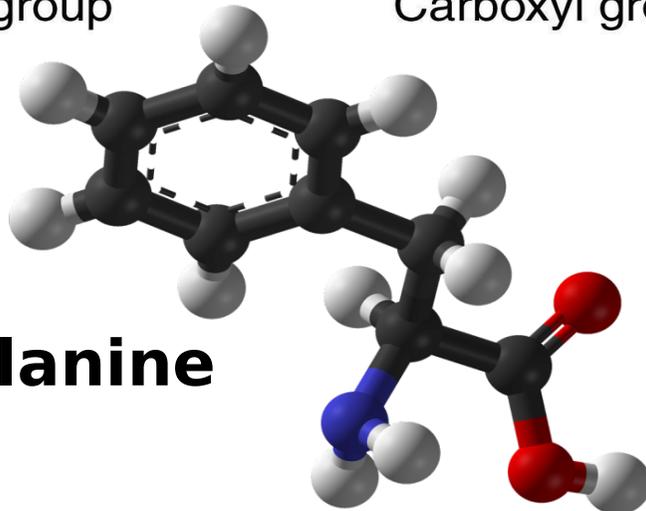
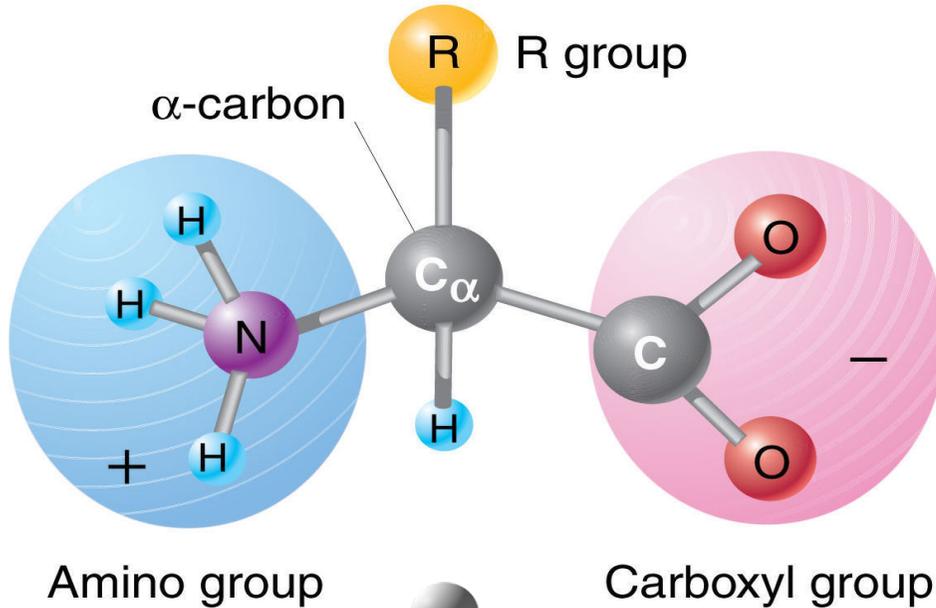
https://www.mun.ca/biology/scarr/iGen3_06-01.html

AMINO ACIDS are the basic structural unit of all proteins.

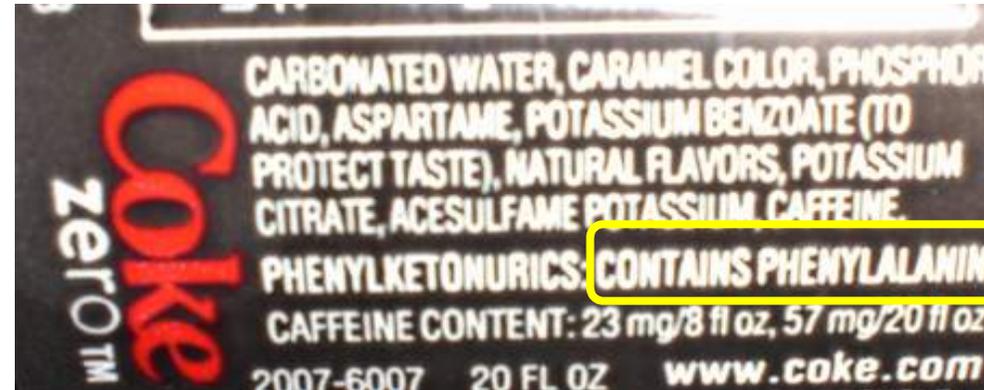
A single amino acid always has:

- an amino group **-NH₂**,
- a carboxyl group **-COOH**
- a hydrogen **-H**
- a side chain **-R**

These are all joined to a central carbon atom **C_α**

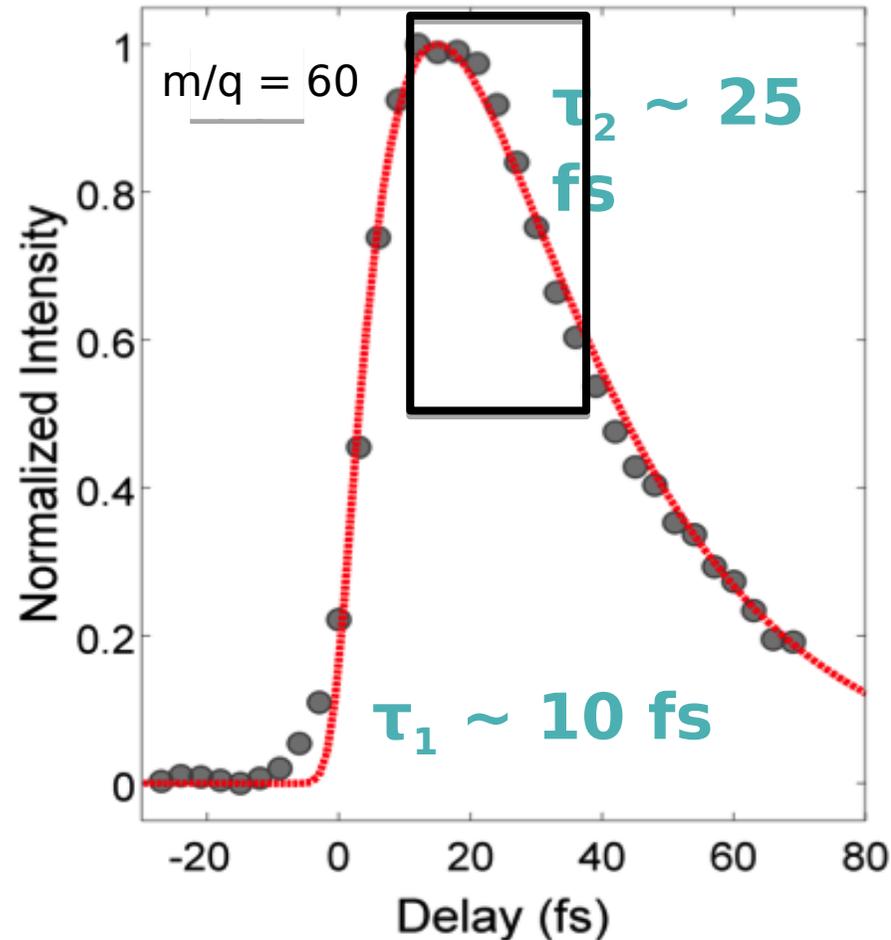


Phenylalanine



Mechanism II: Ionization by Probe

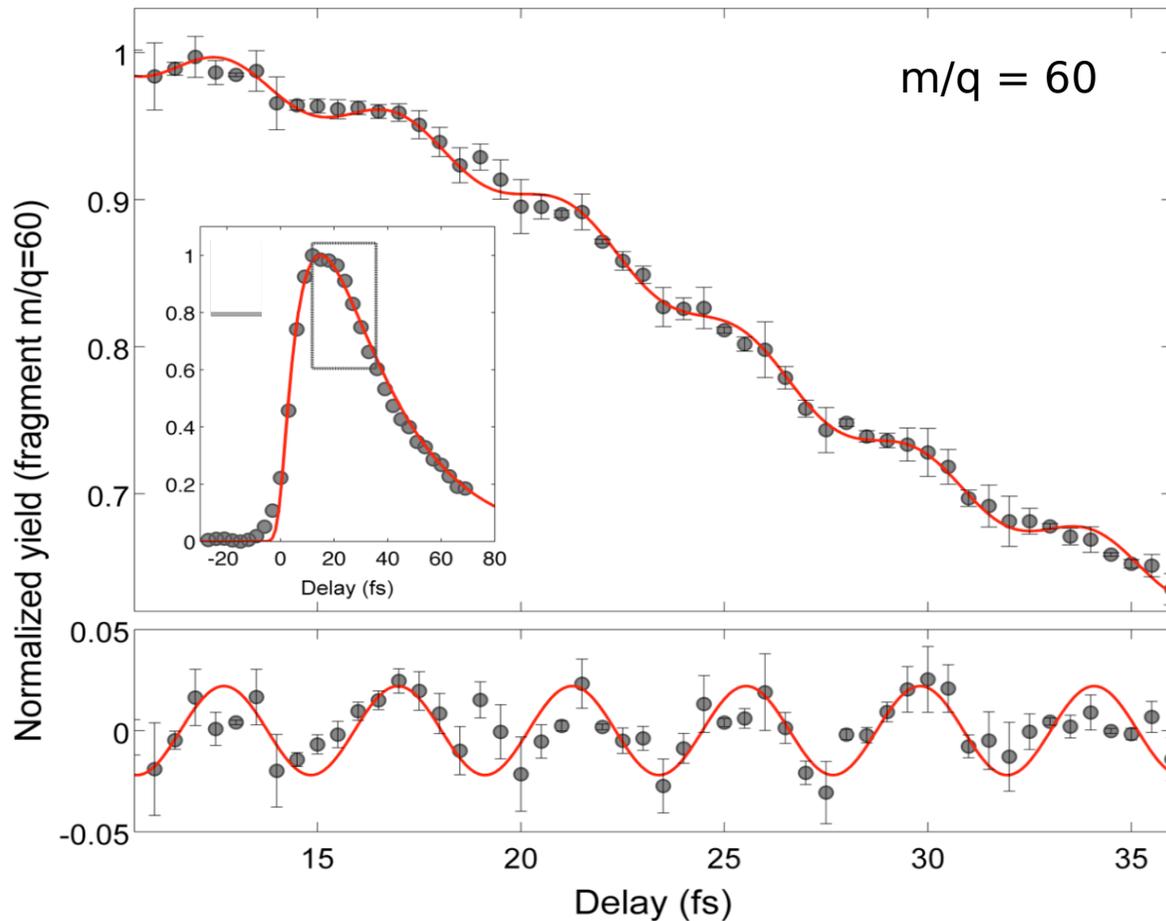
Doubly charged Immonium Ion



Process measured only for
XUV > 17 eV

Due to ionization of sub-
valence electrons

Fast modulation of the dication yield



Increased the resolution of the measurements from 3fs to 500 as.

Fast modulation of the dication yield indicating a purely electronic process!

Period

≈ 4 fs \ll Vibrational motion

***F. Calegari et al.,
Science 346, 336
(2014)***

A&M Data Requirements

- Absorption spectra in UV
 - Potential Energy surfaces
 - Excitation energies
 - Ionisation potentials
- for complex organics