PAPER • OPEN ACCESS

# Attosecond time delays in $C_{60}$ valence photoemissions at the giant plasmon

To cite this article: T Barillot *et al* 2015 *J. Phys.: Conf. Ser.* **635** 112074



Journal of Physics: Conference Series **635** (2015) 112074 doi:10.1088/1742-6596/635/11/112074

# Attosecond time delays in $C_{60}$ valence photoemissions at the giant plasmon

**T. Barillot*, M. Magrakvelidze†, V. Loriot*, C. Bordas*, P-A. Hervieux[1], M. Gisselbrecht[2], P. Johnsson[2], J. Laksman[2], E. P. Mansson[2], S. Sorensen[2], S. E. Canton[3], J. M. Dahlström[4], G. Dixit[5], M. E. Madjet[6], F. Lépine* [1], H. S. Chakraborty† [2]**

* Institut Lumiére Matière, UMR5306, Université Lyon 1-CNRS, 10 rue Ada Byron, 69622 Villeurbanne cedex, France
† Department of Natural Sciences, D.L. Hubbard Center for Innovation and Entrepreneurship, Northwest Missouri State University, Maryville, Missouri 64468, USA
[1] Institut de Physique et Chimie des Matériaux de Strasbourg, 23 rue du Loess, BP 43, 67034 Strasbourg Cedex 2, France
[2] Department of Physics, Lund University, Box 118, 221 00 Lund, Sweden
[3] Department of Synchrotron Radiation Instrumentation, Lund University, Box 118, 221 00 Lund, Sweden
[4] Department of Physics, Stockholm University, Alba Nova University Centrum, S-106 91, Stockholm, Sweden
[5] Max Born Institute, Max-Born-Strasse 2A, 12489 Berlin, Germany
[6] Qatar Environment and Energy Research Institute, Qatar Foundation, P.O. Box 5825, Doha, Qatar

**Synopsis** We perform time-dependent local density functional calculations of the time delay in $C_{60}$ HOMO and HOMO-1 photoionization at giant plasmon energies. A semiclassical model is used to develop further insights.

Oscillations of the correlated electron density in nanosize systems stimulated by external radiation can quantize, forming many-body quasi-partcle, the plasmon. For nanoclusters, the direct consequence of the plasmon is the formation of a giant resonance in the response spectra that holds promise in optical applications. For the $C_{60}$ molecule, a giant dipole plasmon can be ionized by XUV photons around 20 eV which therefore can serve as a spectral laboratory to study the effects of the collective motions on the emission time delay.

We compute the phases of HOMO and HOMO-1 photoamplitudes of $C_{60}$, using the time-dependent local density approximation (TDLDA) [1] that includes many-particle correlation effects. Previous calculations [2] were improved by including a scheme that angle-integrates the dipole amplitudes to calculate the total phase, whose energy-derivatives gave the Wigner-Smith time delays of emission. A semiclassical description is utilized to interpret some aspects of the result.

Numerical results for HOMO and HOMO-1 delay are presented in Figure 1(a). The comparison with single-particle LDA predictions, that omit correlations, clearly reveals the role of the plasmon to affect the delay. A roughly opposite delay pattern between the growing versus waning part of the plasmon resonance (peaked at 20 eV) is noted.

The complex interaction between the 240 valence electrons of $C_{60}$ and the incident photon can be mimicked without solving the full time-dependent many-body problem, by introducing an effective Hamiltonian. Based on a semi-classical model, we show that the plasmon acts as a screening effect that modifies the phase of the electron wavepacket. It induces a local variation of the angular distribution which is accompanied by a variation of the photoemission delays on the attosecond timescale.

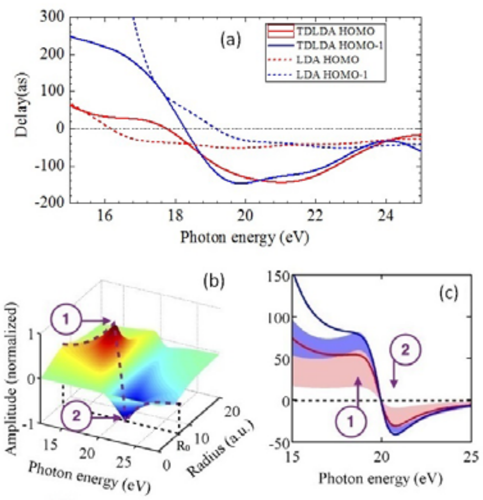


**Figure 1.** (a) TDLDA and LDA delays for HOMO and HOMO-1 emissions. (b) Real part of the screening potential. (c) Delays from semi-classical model.

This work was supported by NSF (USA) and ANR-10-BLAN-0428-01 “MUSES”.

## References

[1] M. Madjet *et al* 2010 *Phys. Rev. A* **81** 013202
[2] T. Barillot *et al* 2015 *Phys. Rev. A (accepted)*

E-mail: franck.lepine@univ-lyon1.fr