Feynman-like diagrams in attosecond science: double excitations and final-state correlation

J. Marcus Dahlström, Thomas Carette and Eva Lindroth

Department of Physics, Stockholm University,
AlbaNova University Center, SE-106 91 Stockholm, Sweden
marcus.dahlstrom@fysik.su.se

We study many-body effects in laser-assisted photoionization by attosecond pulses. Our aim is to implement *diagrammatic perturbation theory* for a solid description of these multi-photon processes that underline most of attosecond metrology. This includes both “streaking” and “rabbit” methods. In order to understand such fundamental processes as the ionization of inner atomic orbitals, it is essential to account for many-body screening effects [1]. Currently, there is a great interest in characterizing the *delay in photoionization* between different ionization channels of atoms using laser-assisted attosecond pulses [2, 3, 4].

These “atomic delays” are directly related to phase-shifts of two-photon matrix elements, as demonstrated in a recent tutorial [5]. Here, we have implemented the Random-Phase Approximation with Exchange (RPAE) that effectively describes the propagation of a single electron–hole pair created by the attosecond pulse, e.g. Fig. 1(a). This has allowed us to quantify the inter-orbital correlation that leads to substantial shifts of the photoionization delays from inner-shell orbitals [6]. Further, by extending our diagrammatic approach, we examine more exotic processes including excitations to additional virtual electron–hole pairs, e.g. Fig. 1(b,c). It may also happen that these virtual electron–hole pairs do not annihilate. In this case two “real” electrons will be ejected from the atom, resulting in double photoionization by so-called shake-off or knock-out mechanisms, respectively. Guided by many-body perturbation diagrams, we present *a simple interpretation for the delay also in laser-assisted double ionization*.

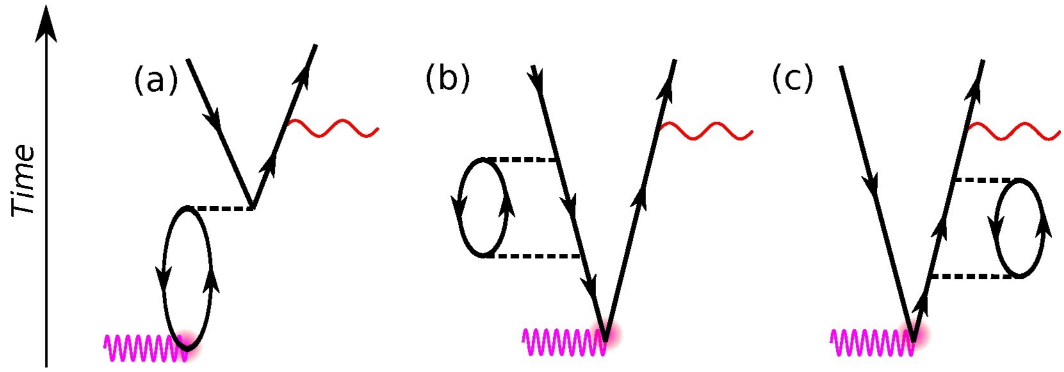

Fig 1. Perturbation diagrams for correlation effects in laser-assisted photoionization. The initial electron–hole pair is created by absorption of an XUV photon (fast wiggle). The ionization process is then probed by ex-change of one IR photon (slow wiggle). Intermediate correlation effects include various **(a)** RPAE diagrams but also virtual electron–hole pairs excited by either **(b)** hole or **(c)** photoelectron.

References:
[1] M.Y. Amusia et al., Atomic photoeffect (Plenum Press, New York, 1990)
[2] M. Schultze et al., Science 328, 1658 (2010).
[3] K. Klünder et al., Phys. Rev. Lett. 106 143002 (2011)
[4] D. Guénot et al., Phys. Rev. A 85, 053424 (2012).
[5] J.M. Dahlström et al., J. Phys. B 45, 183001 (2012).
[6] J.M. Dahlström et al., Phys. Rev. A 86, 061402(R) (2012).