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Atomic Cascade Computations for Astro and Plasma Physics

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Synopsis
Atomic cascades occur frequently in Nature and have therefore been tudied in different fields of physics and elsewhere, from precision measurements to the modeling of astrophysical spectra, and up to aterials research. We here discuss a classification of atomic cascades and shall demonstrate how such cascade processes can be readily modeled within the framework of JAC, the Jena Atomic Calculator.

Atomic cascades occur frequently in Nature owing to the interaction of matter with particles and light. They typically refer to a stepwise modification in the (electronic) structure of atoms and ions and are often "caused" by either the excitation of inner-shell electrons due to photon, electron, or proton impact, or by the capture of electron(s) into Rydberg orbitals. If, for instance, an atom or ion is initially excited into the continuum of the next higher (or even a several times higher) charge state, it will stabilize itself via various decay rocesses towards some ground configuration, a process that is typically
seen in the observed photon, electron or ion spectra. In astrophysics, for example, much of the information about distant stars originates from
the photon emission of particular atoms or ions at well-defined wavelengths, and may help reveal the temperature, density and chemical composition of these objects, Figure 1 displays selected needs for modeling atomic cascades in different field of physics [1,2]. In practice, most of these (atomic) cascades exhibit a rather high complexity, even if just the dominant decay pathes are to be taken into account. This complexity arises first of all from the large number of decay paths that a (manyparticle) quantum system may take. To systematically model such cascades, we have expanded JAC, the Jena Atomic Calculator [3,4], that supports the calculation of different atomic shell structures and processes. To model the excitation and subsequent decay of atoms and ions, we have classified and implemented a number of atomic cascade schemes within the framework of JAC. Moreover, this implementation is based on a clear distinction between (so-called) cascade computations, to first generate all of the necessary transition data, and subsequent simulations in order to properly combine these data and compare them with experiment.

Figure 1. Needs for modeling of atomic cascades in different field of physics.

References

[1] Fritzsche S, Palmeri P and Schippers S 2021 Symmetry 13 520
[2] Fritzsche S et al 2024 Eur. J. Phys. D78 75
[3] Fritzsche S 2019 Comp. Phys. Commun. 240 1
[4] JAC: https://github.com/OpenJAC/JAC.jl

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