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Can angle-resolved x-ray measurements help determine small level splittings in highly charged ions ?

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Synopsis The angular distribution and photon-photon angular correlation have been studied for x-ray emissions from two-step radiative cascades that proceed via two or more overlapping intermediate resonances. From this study, we suggest that accurate angle-resolved measurements of the x-ray emissions may serve as a tool for determining small level splittings in excited highly-charged ions.

During the last decades, the angular distribution and angle-resolved polarization of the characteristic x-ray emission from highly charged ions (HCI) have been studied extensively. Compared to the total decay rates of these ions, such angle-resolved properties were found to be more sensitive to subtle effects in the electron-photon and electron-electron interactions and, hence, helped provide new insight into the struture and dynamics of HCI.

Until the present, however, almost all experimental and theoretical investigations upon the angular distributions of HCI were performed for x-ray emissions from well-isolated fine-structure levels. In contrast, little attention was paid to radiative cascades that proceed via two or more overlapping intermediate resonances. When compared with well-isolated levels, such x-ray cascades are typically affected by spin-spin or spin-orbit interactions that may lead to a depolarization in the magnetic sublevel population of the intermediate levels. Such a depolarization can be seen in angle-resolved measurements of the associated x-ray emissions.

In order to explore these depolarizaton phenomena, expressions were derived for the angular distribution of 1st- and 2nd-step photons and the photon-photon angular correlation. In particular, we considered the radiative cascade

$$
\begin{aligned}
& 1s2p^2 \;\; J_i = 1/2, 3/2 \\
& \longrightarrow \quad \gamma_1 \; + \left\{ \begin{array}{l} 1s2s2p \;\; J = 1/2 \\ 1s2s2p \;\; J' = 3/2 \end{array} \right\} \\
& \longrightarrow \quad \gamma_1 \; + \; \gamma_2 \; + \; 1s^2 2s \;\; J_f = 1/2 \qquad (1)
\end{aligned}
$$

of lithium-like ions, which possess a simple level structure and are known to exhibit a level crossing of the two intermediate levels between $74 \le Z \le 79$ [1]. For W^{71+} ions, for example, Fig. 1 displays the angular distribution of the second-step photon γ_2 for four different intermediate level-splittings (in a.u.), if initially the $J_i = 3/2$ level has the alignment $\mathcal{A}_2 = 1.0$. As seen from this figure, a quite remarkable effect of the level-splitting is found for the angular distribution for small level splittings.

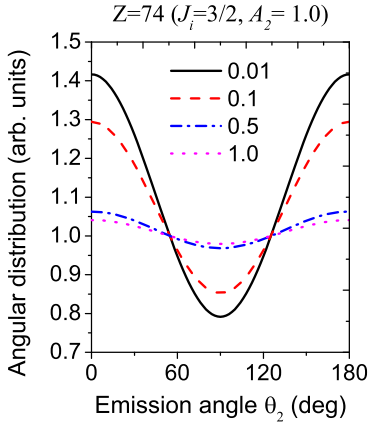

Figure 1. Angular distribution of the second-step photon emissions from the two-step radiative cascade (1). See text for further discussions.

Because of this strong dependence of the angular distribution upon the level-splitting of overlapping resonances, we suggest that accurate measurements of x-ray angular emissions may serve as a tool to determine small level splittings in highly charged ions [1]. Such measurements will be feasible with present-day x-ray detectors.

References

[1] Z. W. Wu *et al* 2014 *Phys. Rev. A* **90** 052515

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