Photoabsorption and photoionization processes involving K-vacancy states of highly ionized iron atoms in high-density astrophysical plasma environments

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The main goal of the present work is to estimate the effects of plasma environment on the photoabsorption and photoionization processes associated with the K-vacancy states in iron ions within the astrophysical context of accretion disks around black holes. In order to do this, relativistic atomic structure calculations have been carried out by considering a time averaged Debye-Hückel potential for both the electron-nucleus and electron-electron interactions. A first sample of results related to the photoabsorption resonances and photoionization cross sections is reported for Li-like iron (Fe XXIV).

Astrophysical context

In the inner-radius region of a black-hole accretion disk, high plasma densities ($\geq 10^{20}$ cm^{-3}) are likely to exist [1]. This would affect all atomic parameters, either by changing the atomic structures and associated rates, or by lowering the ionization potentials, increasing the importance of collisional processes. It is, therefore, imperative that models of X-ray spectra from astrophysical sources include plasma environment effects in the atomic data. Addressing the problem of high-density plasma is important also in modeling other astrophysical media such as the accretion disks of neutron stars, the atmospheres of white dwarfs, and partially ionized outflows from galactic black holes [2]. In these X-ray sources, the plasma density approaches or exceeds the limits of applicability for many of the rates in current atomic databases; thus new atomic calculations tailored for high density plasmas are urgently needed. In this context, the importance of K-shell atomic processes has been appreciated since the launch of X-ray observatories *Chandra* and *XMM-Newton*. In particular, iron K lines emitted by accretion disks around black holes are widely used to investigate Doppler and gravitational effects, as well as to measure the black-hole spin [3]. However, the accuracy of these spin estimates is called into question because the models used to determine those parameters from observations require inexplicably large iron abundances, several times the solar value [4]. The most likely explanation for these iron overabundances is a deficiency in the models, and the main reason might be that current models are inapplicable at densities above 10^{18} cm^{-3}.

Computational approach

Following previous works on the radiative and Auger rates in highly charged iron ions [5-7], we have estimated density effects on the photoabsorption and photoionization parameters associated with the K-vacancy states. For this purpose, fully relativistic multiconfiguration Dirac–Fock (MCDF) computations have been carried out for these species representing the plasma electron–nucleus and electron–electron shieldings with a time-averaged Debye-Hückel potential. In a recent paper [8], we have shown that plasma screening on both these interactions must be taken into account. The calculations were performed by combining the GRASP92 [9] and RATIP [10] codes to obtain the wave functions and the atomic parameters, respectively.

Photoabsorption and photoionization

In the present work, we report some preliminary results obtained concerning the K-shell photoionization cross sections, whereby the direct and resonance contributions are treated separately. The plasma screening effects on the K-threshold, as well as on the continuous cross sections and resonances, are discussed in the particular case of Li-like iron, Fe XXIV.

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