Large scale computation of atomic data in heavy elements for kilonova modeling

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The production of elements heavier than iron in the Universe still remains an unsolved mystery. About half of them are thought to be produced by the astrophysical r-process (rapid neutron-capture process) [1], for which one of the most promising production sites are neutron star mergers (NSMs) [2]. In August 2017, gravitational waves produced by a NSM were detected for the first time by the LIGO detectors (event GW170817) [3], and the observation of its electromagnetic counterpart, the kilonova (KN) AT2017gfo, suggested the presence of heavy elements in the KN ejecta [4]. The luminosity and spectra of such KN emission depend significantly on the ejecta opacity, which is thought to be dominated by millions of lines from the heavy elements produced by r-process, in particular f-shell elements, *i.e.* lanthanides and actinides [5]. Atomic data and opacities for these elements are thus sorely needed to model and interpret KN light curves and spectra.

In this context, the present work consists in a large-scale computation of atomic data and opacities for all heavy elements with $Z \geq 20$, with a special effort on lanthanides and actinides, and for a grid of typical KN ejecta conditions (temperature and density) between one day and one week after the merger (corresponding to the photospheric phase of the KN ejecta, for which the local thermodynamical equilibrium -LTE- is thought to be valid). In order to do so, we used the pseudo-relativistic Hartree-Fock (HFR) method as implemented in the Cowan's codes [6], in which the choice of the configuration interaction model is of crucial importance [7].

In this talk, our HFR atomic data and opacities for all heavy elements will be presented (with a special focus on lanthanides and actinides), as well as some comparisons with previous works. Besides, we will also discuss the contribution of each element to the total KN ejecta opacity for several NSM models [8] based on their Planck mean opacities and elemental abundances deduced from NSM simulations. The impact of considering such atomic-physics based opacity data instead of typical approximation formulae [5] for the determination of the total KN ejecta opacity will also be discussed. This work is presented in our recently-accepted paper [9]. A dedicated database with all the atomic data and opacities that we computed in this work has been created and is available online [10].

References

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