Radiative decay parameters for spectral lines in lanthanide ions of interest for the study of kilonovae in their nebular phase

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Most heavy elements have a fairly complex atomic structure, in particular the lanthanides (Z = 57 – 71) and the actinides (Z = 89 – 103) which present electronic configurations in which the 4f or 5f subshell is partially filled, giving rise to numerous energy levels and therefore many possible radiative transitions between these energy levels. Consequently, in the kilonova phostospheric phase, i.e. in the first few days after a neutron star merger (NSM), the spectrum is greatly affected by a significant opacity due to the absorption of light by millions of allowed electric dipole transitions (E1) belonging to the different heavy ions present in the ejecta [1].

At later times, as the NSM ejecta continues to expand, temperatures and densities decrease rapidly, leading to non-local thermodynamic equilibrium (NLTE) conditions in which the kilonova is considered to be in the nebular phase. This has the consequence that the spectrum is then emission line dominated, unlike the quasi-blackbody continuum spectrum observed in the phostospheric phase. Moreover, the infrared nebular phase kilonova spectrum detected by the *Spitzer Space Telescope* was assumed to contain forbidden lines of magnetic dipole (M1) and electric quadrupole (E2) types [2] The key role of such forbidden transitions in kilonova modeling was also underlined by Gillanders *et al*. [3] who showed how the inclusion of M1 and E2 lines of heavy elements could lead to the identification of elemental signatures through radiative transfer calculations, while emphasizing the lack of accurate atomic data available for these lines in order to perform reliable kilonova spectral analyses.

The main goal of the present work is to provide new radiative decay rates corresponding to forbidden lines in lanthanide ions. To do so, two computational approaches are used, namely the pseudo-relativistic Hartree-Fock (HFR) method [4] and the fully relativistic Multiconfiguration Dirac-Hartree-Fock (MCDHF) method [5]. New transition probabilities for M1 and E2 lines within the ground configurations of Pr III, Nd III and Er III will be reported at the conference. Astrophysical implications will also be discussed in the context of spectral investigations of kilonovae in their nebular phase.

References

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