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Atomic data and opacity calculations in niobium and silver ions for kilonova spectral analyses

Sirine Ben Nasr[1] Helena Carvajal Gallego[1], Jérome Deprince[1], Patrick Palmeri[1], Pascal Quinet[1,2]

[1]*Atomic physics and Astrophysics, Mons university – UMONS, B-7000 Mons, Belgium*
[2]*Atomic physics and Astrophysics, Mons university IPNAS, Université de Liège, Sart Tilman, B-4000 Liège, Belgium – UMONS, B-7000 Mons, Belgium*

Neutron star (NS) mergers are at the origin of gravitational waves (GW) detected by LIGO/Virgo interferometers. Such events produce a large amount of elements heavier than iron by a rapid neutron capture (r-process) nucleosynthesis. Among these elements, those belonging to the fifth row of the periodic table, in particular from Zr ($Z = 40$) and Cd ($Z = 48$), are the greatest contributors to the opacity affecting the kilonovae, after the lanthanides and actinides. In the present work, new atomic structures and radiative parameters (wavelengths and oscillator strengths) are reported for a large number of spectral lines in two selected elements, namely Nb ($Z = 41$) and Ag ($Z = 47$) from neutral to triply ionized states. These results were obtained through large-scale atomic structure calculations using the pseudo-relativistic Hartree–Fock method implemented in Cowan code. The results obtained were used to calculate the expansion opacities characterizing the kilonova signal observed resulting from the collision of two NS, for typical conditions corresponding to time after the merger $t = 1$ day, the temperature in the ejecta $T \leq 15000$ K, and a density of $\rho = 10^{-13}$ g.cm^{-3} . Comparisons with previously published experimental and theoretical studies have shown a good agreement. In terms of quantity and quality, the results presented in this work are the most complete currently available, concerning the atomic data and monochromatic opacities for niobium and silver and are useful for astrophysicists to interpret kilonova spectra.

Presenting Author Email Address: *sirinamarouan@gmail.com*