Impacts of isomers on a light curve of a kilonova associated with newtron star mergers

S. Fujimoto[1] and M. Hashimoto[2]

[1]National Institute of Technology, Kumamoto College, Kumamoto 861-1102, Japan
[2]Department of Physics, Kyushu University, Fukuoka 819-0395, Japan

Primary heating sources of a kilonova associated with neutron star mergers are unstable nuclei whose mass numbers are around 120-140 and decay to second-peak nuclei [1]. Among these unstable nuclei, there exist nuclei whose isomer, or a quasi-stable state of the nuclei, has a branch of the β-decay to their daughter nuclei and a β-decay half-life very different from that of their ground state. If such nuclei excite to their isomer during the ejection from neutron star mergers, a light curve of the kilonova is likely to change due to large change of the half-lives of the nuclei via the isomer.

In the present study, we have investigated impacts of isomers on the light curve of a kilonova from neutron star mergers. Taking into accounts of isomers of nine nuclei, or ^{121,125,123,127}Sn, ^{128,129}Sb, ^{129,131}Te, ^{134}I, we calculated evolution of abundances of ejecta from the neutron star mergers and of energy generation rates, $\dot{\epsilon}_{\rm nuc}$, inside the ejecta. We note that the β-decay half-live of the isomers of the nine nuclei is different from that of the ground state by orders of magnitude. We have adopted a simplified dynamical model of the ejecta, which is uniformly expanded with a constant velocity [2]. The model has four parameters, or the mass of the ejecta, $M_{\rm ej}$, the expansion velocity $v_{\rm ex}$, and the electron fraction, Y_e, and entropy per baryon, s, at a temperature of 9×10^9K. We have performed the calculations for two cases; (a) the nine nuclei are assumed to be always stayed in their ground state and (b) in their isometric state and for parameters of $Y_e = 0.1, 0.15, 0.2, 0.25, 0.3$ and $v_{\rm ex}/c = 0.05, 0.1, 0.2$ with fixed parameters $M_{\rm ej} = 0.03 M_\odot$ and $s = 10 k_B$, where c is the speed of light and k_B the Boltzmann constant.

We found that $\dot{\epsilon}_{\rm nuc}$ between a few hours and a few days decrease in the ejecta with $Y_e = 0.2 - 0.3$ for case (b) compared with those for case (a) due to the decreases of the nine nuclei, which are abundantly produced. In particular, the decrease in $\dot{\epsilon}_{\rm nuc}$ is prominent for the $Y_e = 0.25$ ejecta, which possibly corresponds to an early, blue component of a kilonova observed in GW180718. For slower ejecta, the decreases in $\dot{\epsilon}_{\rm nuc}$ are larger. We also find that faster and heavier ejecta are required to fit an light curve of the kilonova observed in GW170817 for case (b) if we assume the ejecta has Y_e of 0.25.

[1] B. Metzger et al. MNRAS 406, 2650 (2010).
[2] S. Rosswog et al. Classical and Quantum Gravity 34, id104001 (2017).