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Impact of internal-conversion X-rays and nuclear isomers on X-ray and gamma ray emission from neutron-rich ejecta in a binary compact-star merger

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In the gravitational wave event GW170817, observed in 2017, electromagnetic counterparts were identified in a wide range of wavelengths from radio to gamma rays for the first time. A kilonova (AT2017gfo) was detected in visible and infrared bands and powered by the radioactive-decay heat of neutron-rich nuclei synthesized via the rapid neutron-capture process (r-process). Furthermore, heavy elements such as Sr and Te, whose production is theoretically expected via the r-process during a binary neutron star merger, were observationally confirmed by identifying infrared spectral lines. The optical and infrared light curves and spectral evolution strongly suggest the synthesis of lanthanides ($Z = 57$–71). However, the observational confirmation of third-peak nuclei ($Z \sim 80$), which are also theoretically expected to form, remains elusive. In this study, we calculate the time evolution of nuclear gamma-ray and internal-conversion X-ray fluxes originating from the decay of neutron-rich nuclei synthesized via the r-process in gas ejected during compact star mergers.

Employed with the same spherical symmetric, constant-velocity expansion model for the ejecta from a binary compact-star merger and nuclear reaction network as our previous work (Terada et al. 2022), we estimate the time evolution of temperature, density, and chemical composition in the ejecta, with the electron fraction (Y_e) as a parameter. We focus on internal-conversion X-rays and nuclear gamma rays, comprehensively considering the effects of nuclear isomers and internal-conversion X-rays, which have been understudied or unexamined in the past. We focus on the epoch within approximately one month after the merger. Our findings are as follows:
(1) We identify the flux enhancement below approximately 100 keV due to internal-conversion X-rays, particularly over one-order-of-magnitudes increase below the 60–70 keV range;
(2) Plenty of internal-conversion X-ray lines are emitted with high fluxes from the ejecta with high neutron excess $Y_e \leq 0.20$;

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