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Identifying r-process Elements in Kilonova Infrared Spectra

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Binary Neutron Star mergers are a promising site for the nucleosynthesis of heavy elements via the r-process. This has been observationally confirmed with the detection of the kilonova AT2017gfo and the investigation of its light curves and spectra. While much work has been done to decode AT2017gfo signatures, the specific identifications of elements responsible for each spectral feature is still challenging, particularly in the infrared range. In our study (Rahmouni et al. 2024, arXiv:2412.14597), we conducted a systematic selection of heavy elements most likely to exhibit strong transitions in the infrared range, using their experimentally calibrated energy levels. Our analysis reveals that most elements with strong absorption lines are lanthanides (Z=57-71) and actinides (Z=89-103). This is due to their complex atomic structures with many low-lying energy levels, resulting in strong infrared lines. Previous studies (Domoto et al. 2022, ApJ 939, 8) have shown that La III and Ce III account for the absorption features at λ ~ 12,000 - 15,000 Å. While our results support these findings, we further identify Gd III as the next most promising species. Due to its unique atomic structure involving the half-filled 4f and the outer 5d orbitals, Gd III has one of the lowest-lying energy levels, between which relatively strong transitions occur. By performing radiative transfer simulations, we confirm that Gd III affect the feature at λ ~ 12,000 Å previously attributed to La III. Future space-based time-series observations of kilonova spectra will allow the identification of Gd III lines.

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