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r-process nucleosynthesis in compact object mergers

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Thirty years after both the light and neutrino emission was observed from SN1987A, the neutron star merger event GW170817 demonstrated the power of new tools in multi-messenger astronomy. Since LIGO/VIRGO gravitational wave detection enables identification and pointed electromagnetic follow-up of merger events, new insights into these rare and interesting systems can be gained. The observations of the GW170817 electromagnetic counterpart suggested the production of heavy elements via the rapid neutron capture process (r process) due to the light curve compatibility with the presence of high opacity elements such as the lanthanides. However lanthanide production in r-process nucleosynthesis is subject to large uncertainties from nuclear physics and astrophysics unknowns. For instance the rare-earth abundance peak, a feature of enhanced lanthanide production at A~164 seen in the solar r-process residuals, is not robustly produced in r-process calculations when nuclear physics inputs are varied. Nuclear and astrophysics uncertainties also make it difficult to know if merger events are responsible for populating the heaviest observed nuclei, the actinides. An r process which reaches the actinides is also likely to host fission, which is largely experimentally uncharted for neutron-rich nuclei, further compounding the difficulty in predicting the nucleosynthetic outcome in merger events. Here we will review what can be gleaned regarding heavy element production from this merger event with an emphasis on how nuclear physics unknowns can affect such conclusions. We will discuss a potential direct signature of actinide production in merger environments as well as the potential for future experimental and theoretical efforts to refine our knowledge of fission in the r process. The question of where nature primarily produces the heavy elements can only be answered through such collaborative efforts between experiment, theory, and observation.

Keywords

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