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Neutron Star Mergers as Sites of Heavy Element Synthesis

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Almost three years ago, the LIGO/Virgo gravitational wave observatories detected the first binary neutron star merger event (GW170817), a discovery followed by the most ambitious electromagnetic (EM) follow-up campaign ever conducted. Within 11 hours, a bright but rapidly fading thermal optical counterpart was discovered in the galaxy NGC 4993 at a distance of only 130 Million light years. The properties of the optical transient match remarkably well predictions for "kilonova" emission powered by the radioactive decay of heavy nuclei synthesized in the expanding merger ejecta by rapid neutron capture nucleosynthesis (r-process). The rapid spectral evolution of the kilonova emission to near-infrared wavelengths demonstrates that a portion of the ejecta contains heavy lanthanide nuclei, while other features of the light curve and possible spectral features suggest the joint synthesis of lighter r-process elements. I will describe our understanding of the sources of neutron-rich ejecta in neutron star mergers and the sensitivity of their properties (and the resulting kilonova signal) to the lifetime of the neutron star remnant. I will describe how multi-messenger observations of GW170817 and future mergers constrain the astrophysical origin of the r-process and the properties of neutron stars (particularly their uncertain radii and maximum mass, which are determined by the equation of state of nuclear matter). Time permitting, I will overview new results from LIGO's ongoing O3 run and preview the upcoming era of multi-messenger astronomy, once Advanced LIGO/Virgo reach design sensitivity and a neutron star merger is detected every few weeks.