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How Strongly Gravitating Systems Create Heavy Elements

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The era of gravitational-wave and multi-messenger astronomy sheds light on the astrophysics of black holes and neutron star binaries and also allows for unique probes of fundamental physics. I will discuss recent results on how neutron-star mergers and other strongly gravitating systems of prime interest in time-domain astronomy, such as collapsars, give rise to the formation of heavy elements in the universe. In particular, I will discuss simulation results at the interface of numerical relativity, neutrino physics (including oscillations), and nuclear physics, and highlight their implications for multi-messenger astrophysics and chemical evolution of galaxies.