W57a Cocoon emission in neutron star mergers

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In the gravitational wave event GW170817, there was a ∼10 hours gap before electromagnetic (EM) observations, without detection of the cocoon. The cocoon is heated by a short gamma-ray burst (sGRB) jet propagating through the ejecta of a Neutron Star (NS) merger, and a part of the cocoon escapes the ejecta with an opening angle of 20°–30°. Here we model the cocoon and calculate its EM emission. Our 2D hydrodynamic simulations suggest that the density and energy distributions, after entering homologous expansion, are well-fitted with power-law functions, in each of the relativistic and non-relativistic parts of the escaped cocoon. Modeling these features, we calculate the cooling emission analytically. We find that the cocoon outshines the r-process kilonova/macronova at early times (10–1000 s), peaking at UV bands. The relativistic velocity of the cocoon's photosphere is measurable with instruments such as Swift, ULTRASAT and LSST. We also imply that energetic cocoons, including failed jets, might be detected as X-ray flashes. Our model clarifies the physics and parameter dependence, covering a wide variety of central engines and ejecta of NS mergers and sGRBs in the multi-messenger era.