GRB 211211A: The Case for an Engine-powered over r-process-powered Blue Kilonova

Hamid Hamidani[1], **Masaomi Tanaka**[1], **Shigeo S. Kimura**[1,2], **Gavin P. Lamb**[3], **and Kyohei Kawaguchi**[4,5]

[1] *Astronomical Institute, Graduate School of Science, Tohoku University, Sendai 980-8578, Japan; Email: hhamidani@astr.tohoku.ac.jp*
[2] *Frontier Research Institute for Interdisciplinary Sciences, Tohoku University, Sendai 980-8578, Japan*
[3] *Astrophysics Research Institute, Liverpool John Moores University, Liverpool Science Park IC2, 146 Brownlow Hill, Liverpool, L3 5RF, UK*
[4] *Max Planck Institute for Gravitational Physics (Albert Einstein Institute), Am Mühlenberg 1, Potsdam-Golm, 14476, Germany*
[5] *Center of Gravitational Physics and Quantum Information, Yukawa Institute for Theoretical Physics, Kyoto University, Kyoto, 606-8502, Japan*

Abstract: The recent Gamma-Ray Burst (GRB) GRB211211A provides the earliest data of a kilonova (KN) event (~5 h), displaying bright ($\sim 10^{42}$ erg s^{-1}) and blue early emission. Previously, this KN has been explained using simplistic multi-component fitting methods. Here, in order to understand the physical origin of the KN emission in GRB~211211A, we employ an analytic multi-zone model for r-process powered KN. We find that r-process powered KN models alone cannot explain the fast temporal evolution and the spectral energy distribution (SED) of the observed emission. We propose an alternative scenario involving early contributions from the GRB central engine via a late low-power jet, consistent with plateau emission in short GRBs and GeV emission detected by Fermi-LAT at $\sim 10^4$ s after GRB 211211A. Such late central engine activity, with an energy budget of ~ a few % of that of the prompt jet, combined with a single red-KN ejecta component, can naturally explain the light curve and SED of the observed emission. This supports claims that late low-power engine activity after prompt emission may be common.

Observations:

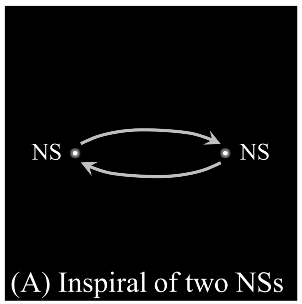
In 2021, GRB211211A was discovered, and follow-up observations revealed a bright KN emission. Observations provided KN data as early as ~5 hours after the explosion, making it the earliest observed KN to date. There were two issues with this KN: **(i) the early data showed a very bright emission with a fast temporal evolution** [1], and **(ii) the early KN was too blue in color** [1,2]. Although this data could be fitted with simplistic r-process-powered KN models, we revisited it using more realistic modeling.

Method & Results:

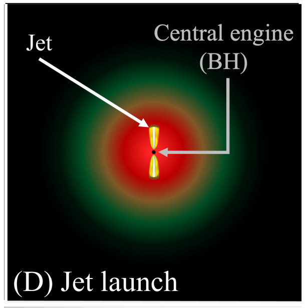
We present an analytic model of the r-process-powered KN emission. We show that a characteristic feature of the r-process-powered KN model is its slow temporal evolution (with an index of -0.3) at early times. This makes it challenging to explain the fast temporal evolution of this event using the r-process alone. Additionally, we modeled the cooling emission from late engine activity [3,4]. **We found that combining engine-powered cooling emission at early times with late r-process-powered emission at later times can explain all the observed data**, including the time evolution, spectral energy distribution (SED), and the GeV emission detected by Fermi at ~10,000 seconds after the GRB [5].

Conclusion:

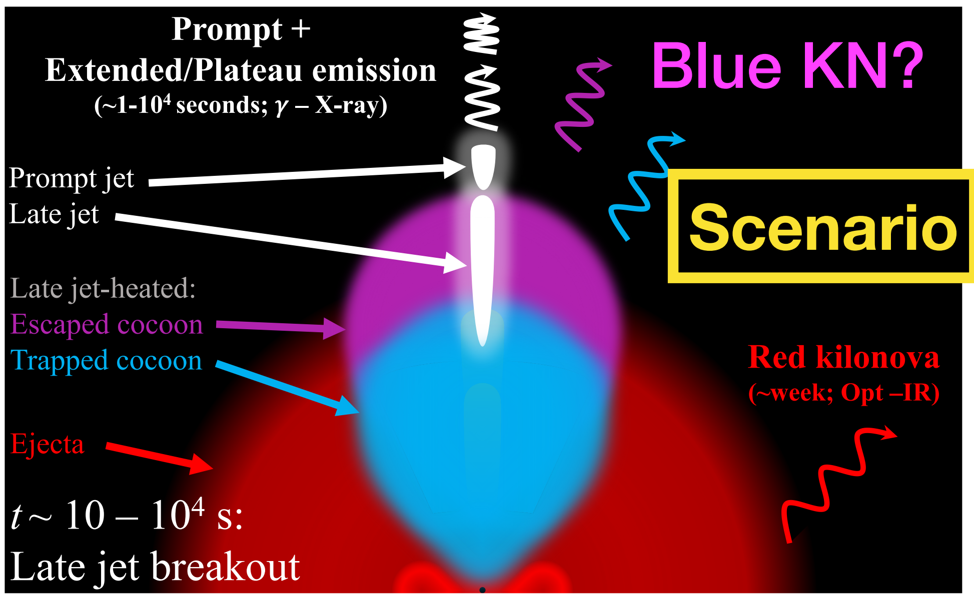
With GRB211211A providing the earliest data of a KN emission, we found that the early KN emission, the so-called "blue KN," is too bright, too blue, and evolves too rapidly in time to be explained by an r-process-powered KN model alone. Instead, we show that an engine-powered KN model (with a timescale of ~hours [3]), combined with a typical r-process-powered KN, can explain all the observed data across all wavelengths and epochs, as well as the GeV emission detected by Fermi [4,5].

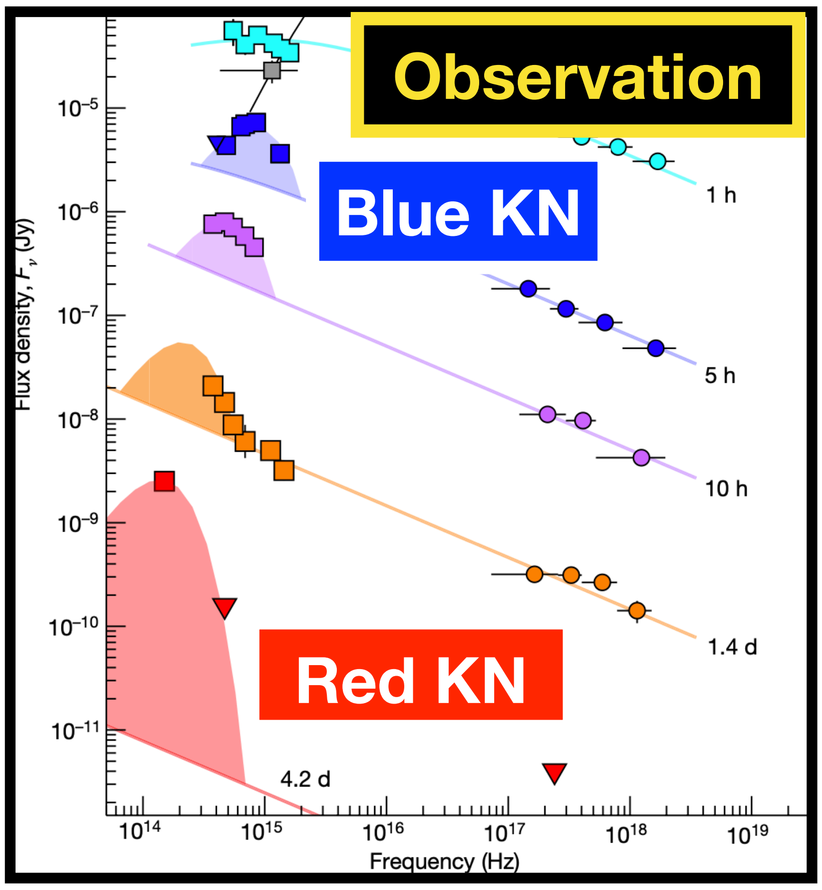


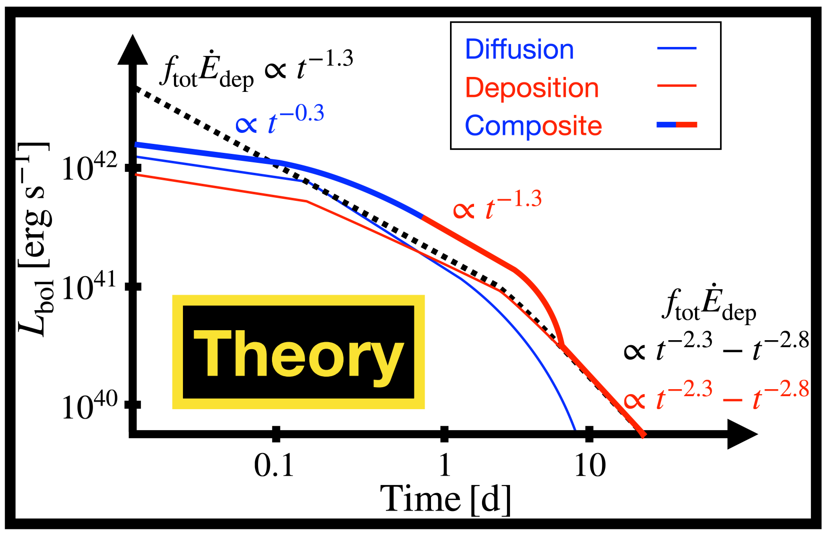
(A) Inspiral of two NSs

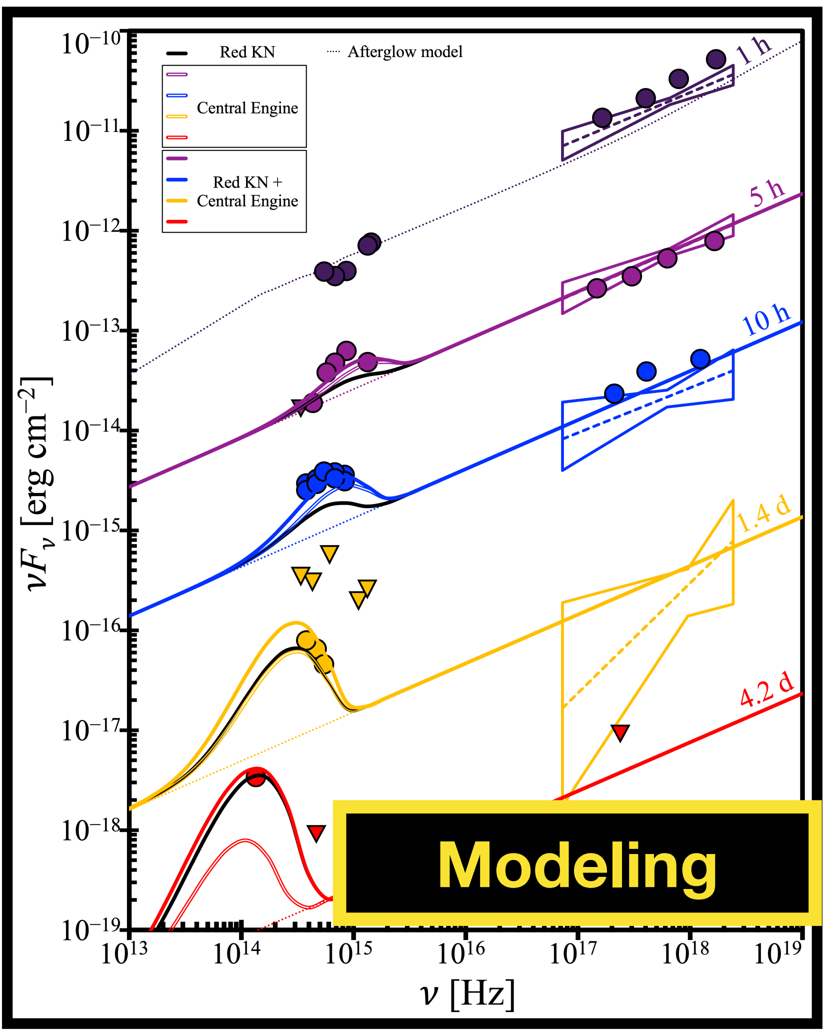


(D) Jet launch









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