Radiative Transfer Simulations of Neutron Star Mergers: Toward Multi-Messenger Astronomy

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Next-generation gravitational-wave telescopes, such as Advanced LIGO, Advanced Virgo, and KAGRA, are expected to directly detect gravitational waves from neutron star (NS) mergers within about 200 Mpc. However, the accuracy of positional localization with gravitational-wave telescopes is only about 10−100 deg^2. Therefore, to fully understand the nature of the gravitational-wave sources, it is extremely important to identify electromagnetic wave counterparts.

Optical/infrared emission powered by radioactive decay of r-process nuclei synthesized in the NS merger is one of the most promising counterparts. However, detailed theoretical prediction was difficult due to our poor understanding of photon transfer in the NS merger ejecta. We succeeded in radiative transfer simulations of NS merger including detailed r-process elements for the first time (Figure 1, [1]) using Cray XC30 supercomputer (ATERUI) at Center for Computational Astrophysics (CfCA), NAOJ.

We show that the optical/infrared emission is fainter than previously expected by a factor of 10. However, this emission is, in fact, detectable with 4−8 m class telescopes (Figure 2). We also performed radiative transfer simulations for the merger of black hole (BH) and NS [2]. We showed that the observed brightness of BH-NS mergers can be comparable to or even higher than that of NS-NS mergers. In addition, we find that the emission from BH-NS mergers tends to be bluer than that from NS-NS mergers. Thanks to these properties, we might be able to distinguish BH-NS merger events from NS-NS merger events by multi-band observations.

Based on these results, we can determine the efficient observing strategy to search for the electromagnetic counterparts. Our simulations are one of the first steps toward a new field of astronomy – "multi-messenger astronomy" which combines observations of electromagnetic waves and gravitational waves.

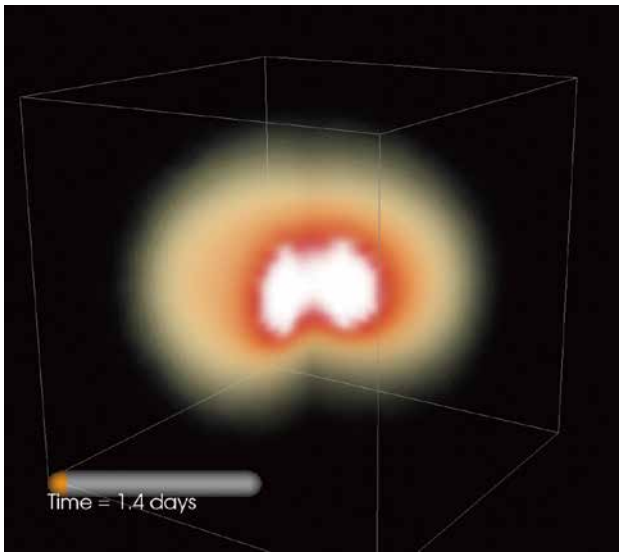

Figure 1: Snapshot of the radiative transfer simulation of NS mergers.

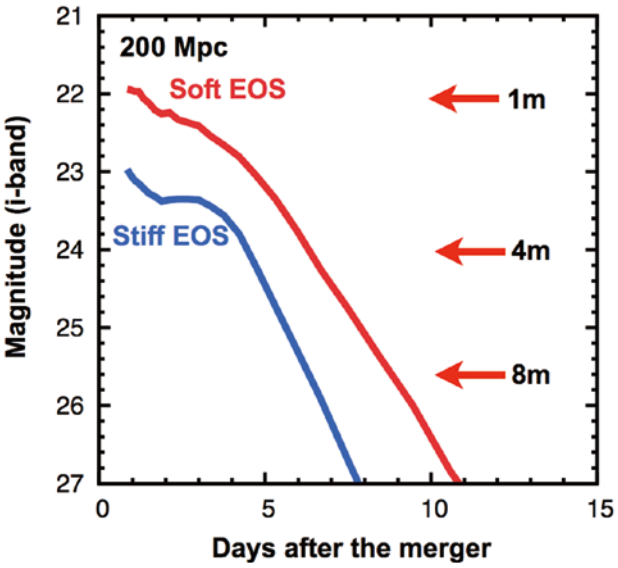

Figure 2: Expected *i*-band light curves of NS-NS mergers at 200 Mpc. Red and blue lines show the models with different equation of states.

References

[1] Tanaka, M., Hotokezaka, K.: 2013, *ApJ*, **775**, 113.
[2] Tanaka, M., et al.: 2014, *ApJ*, **780**, 31.