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Rapid Generation of Kilonova Light Curves Using Conditional Variational Autoencoder

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The discovery of the optical counterpart, along with the gravitational waves from GW170817, of the first binary neutron star merger, opened up a new era for multi-messenger astrophysics. The optical counterpart, designated as a kilonova (KN), has immense potential to reveal the nature of compact binary merging systems. Ejecta properties from the merging system provide important information about the total binary mass, the mass ratio, system geometry, and the equation of state of the merging system. In this study, a neural network has been applied to learn the optical light curves of the KN associated with GW170817 using data from Kasen model and we generate the light curves based on different ejecta properties such as lanthanide fraction, ejecta velocity and ejecta mass. For training the autoencoder, we use simulated KN light curves, where each light curve depends on ejecta mass, ejecta velocity and lanthanide fraction of the ejecta. We generated the light curves using our basic autoencoder code, which, as expected, is quite in agreement with the original light curves. Next, in order to verify the model built from the autoencoder, we apply denoising autoencoder to separate the noisy data from the real data. This process establishes the accuracy and robustness of the code. Following this we, develop conditional variational autoencoder (CVAE), which is for generating light curves based on the physical parameter of our choice. This flexibility was absent in the initial stages. Using the conditional variational autoencoder on simulated data and completing the training process, we generate light curves based on physical parameter of our choice. We have verified that, for a physical parameter present in the simulated data, the generated light curve for the same physical parameter is quite accurate with the original input light curve. This confirms that the code can now generate light curves for any random feasible physical parameter with satisfying accuracy. The timeline for generating the light curves using CVAE is very small, due to which this technique has the ability to replace time consuming and resource-draining simulations. Using the CVAE, we can look into the extremum detection limit associated with a KN model. Since there are several other factors that influences the KN, CVAE trained with simulated data from model with more detailed inclusion of physical parameters could give a more insight into the physics of KN. Currently, the CVAE is being trained on a different KN model and test on a separate data from another different model. This allows us to verify the variational aspect of the CVAE and get a more general look into the different KN light curves. The merit of this approach lies in its rapid generation of light curves based on desired parameters and at the same time encompass all the possible light curves related to KN.

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