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Research Result Report
ICRR Inter-University Research Program 2025

Research Subject: Mitigating Noise from Violin Modes in the KAGRA Detector Using Physics-Informed Neural Networks

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Summary of Research Result :

In this project, we propose to develop Physics-Informed Neural Networks (PINNs) to improve the sensitivity of the KAGRA detector. The central idea is to utilize the equations governing the damping and vibrational properties of the suspended mirrors in the KAGRA detector to guide the training and optimization of the PINNs. The initial focus of this project is on developing a PINN-based frameworks to accurately predict the frequency and Q-factor of the violin modes. These parameters are critical for understanding and characterizing the vibrational behavior of the detector mirrors.

Before we apply PINNs on the KAGRA detector, we show a proof of concept of our preliminary study by incorporating the kilonova model as the input to the PINN. In Figure 1, we show that we have successfully predicted kilonova light curves across a range of models.

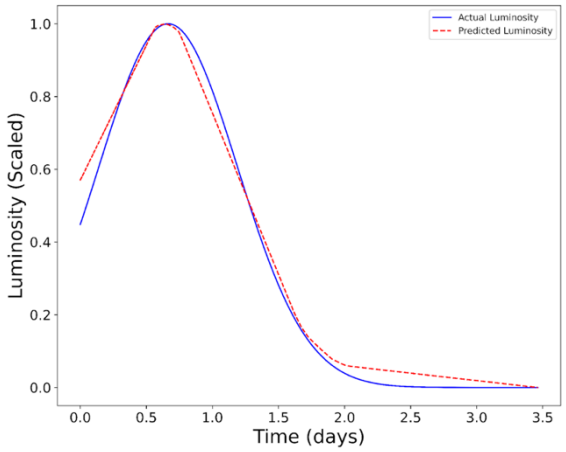

Figure 1: Comparison between a simulated and a PINN-predicted kilonova light curve by modeling radiation transport in kilonovae. The minor mismatch may be attributed to low-performing loss functions which can be corrected with more training and hypertuning the PINN architecture.

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We are now modifying the code for the violin mode. To start with, the PINN will first be trained to predict the frequency and Q-factor of violin modes, with governing equations for these quantities serving as the input differential equations. Hyperparameter tuning and iterative refinement will be conducted to improve the precision of these predictions. Once the initial model is trained, the PINN will be applied to calibration channel data.

In January and February, we visited ICRR to discuss with KAGRA scientists over this topic. As a preliminary study, we can now predict the first harmonic of the violin mode near 180 Hz in the spectrum based on the damping equation by using PINN.

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