Implementation of an Integrated Machine Learning Pipeline for LIGO Continuous Gravitational Wave Searches

Thiagarajan, Harini (School: North Creek High School)
Yalla, Vishal (School: North Creek High School)

Continuous gravitational waves (CW) are long-lasting, monochromatic gravitational waves (GW), produced by persistent quadrupolar variations of dense matter resulting from rapidly spinning asymmetric neutron stars. Among the most promising targets for LIGO, CWs still remain unobserved, largely due to the presence of spectral noise artifacts and substantial computational complexity associated with detection. The development of an efficacious analysis method is crucial to increase detection chances, this study investigates the assimilation of machine learning (ML) as an alternative to deterministic methods for spectral noise classification and reduced computational CW search complexity. The scope of the analysis includes detector characterization (DetChar) activities at LIGO – key for enabling higher detector sensitivity and confirmation of GW candidates. First, a convolutional neural network (CNN) trained on over 50,000 O4 Fscan samples serves to flag line artifacts under an Amplitude Spectral Density (ASD) vs. Frequency representation, conquering the currently human-vetted process. With an accuracy rate of over 90.2% and a false positive rate of under 6.65%, the automated CNN approach saves a multitude of human labor hours. Second, a Physics-Informed Neural Network (PINN) was constructed to approximate computationally expensive matched filtered searches and was numerically trained on a curated synthetic dataset formulated on CW physics. Both contribute towards the first end-to-end CW ML pipeline with ongoing componentized implementation within the larger DetChar pipeline and demonstrated progress towards the first detection of a CW. A detection would unravel neutron star astrophysics and deepen understanding of dark matter, primordial black holes, and exotic particles.