

Through the lens: discovering continuous gravitational waves amplified by microlensing

Non-symmetric rotating neutron stars are prospective sources of quasi-monochromatic (long duration, continuous) gravitational waves. They are yet to be detected as their intrinsic gravitational-wave amplitude is smaller than transient gravitational waves emitted by compact binary systems inspirals of neutron stars and black holes, now routinely detected by the LIGO-Virgo-KAGRA Collaboration network of detectors.

An interesting opportunity to detect continuous waves occurs if a signal is gravitationally microlensed, which means that its waveform is magnified by the gravitational potential of a massive object, positioned near the line of sight between the source and the detector, in a close analogy do the well-known microlensing in the electromagnetic band and temporal increase of the brightness called the Paczyński curve. Detecting this temporal amplification which enhances a weak gravitational wave above the critical threshold will not only lead to the detection of a continuous wave source, but will aid in studying physical properties of the lensing object and the source of a wave, as well as the Galactic population of lensing objects.

This proposal contains preliminary groundwork results towards this goal, involving the examples of the physics of the microlensing phenomenon: the Einstein crossing time (a characteristic time of microlensing related to the mass and distance of the lens), the amplification factor, related to amplification of the signal-to-noise of the signal registered by the detectors, and studies on diffraction or interference patterns in the signal-to-noise evolution in time, which may occur for specific choices of parameters, such as lens mass and duration of the lensing.

In searches for gravitational-wave microlensing, we plan to involve a data analysis method developed by the Polish gravitational-wave researchers (a multi-detector semi-coherent Time-Domain F-statistic method routinely used in the LIGO-Virgo-KAGRA Collaboration searches) on a sequence of time-domain data segments, to produce a gravitational-wave "light curve" of time-varying amplitudes, and combine it with a machine learning implementation for post-processing analysis (deep neural network with convolutional layers to classify the lensed signals rapidly and reliably), and apply it to the current gravitational wave detectors' data (LIGO and Virgo) and simulated data of future detectors, such as the Einstein Telescope which is planned to be built in Europe, and US-based Cosmic Explorer. This research aims at a contribution to scientific goals of these planned detectors.