Abstract for the general public

Gravitational-wave astrophysics is a new, expanding branch of astronomy, with a number of breakthrough discoveries on the nature of compact objects: black holes and neutron stars. Tens of registered GW detections are now used in mainstream studies on the dense matter equation of state, stellar evolution, cosmology, and tests of theories of gravity (to list just a few).

The steadily-improving Advanced Era ("2nd generation") LIGO and Virgo global network of detectors will soon be expanded by the Japanese KAGRA, providing not tens, but hundreds and thousands of binary systems' detections per observing run. Other classes of gravitational-wave signals await their discovery, for example long-lasting ("continuous") waves emitted by rotating, non-axisymmetric neutron stars. A discovery of such a signal would allow us to study elastic, magnetic and superfluid properties of matter in conditions very different from those occurring in binary systems' mergers, as well as to carry out additional tests of theories of gravity, perform detectors' calibration and allow for repeatable studies. Other persistent sources are inspirals of light compact binaries, like the hypothetical primordial BHs, post-merger hot remnant neutron-stars, scalar boson clouds surrounding spinning black holes, dark photon dark matter interacting with the detectors. Detection of a continuous gravitational wave would open a new chapter in gravitational-wave astronomy.

In addition, future "3rd generation" terrestrial detectors, notably the US-based Cosmic Explorer and the European-based Einstein Telescope, are currently being designed. Their planned one order-of-magnitude increase in sensitivity will yield literally *millions* of detections per year, some of which will belong to new classes of gravitational waves. Events will routinely overlap in sky positions and in time, and their observed duration will be tens of hours or days, and not seconds like now, because the sensitivity window will extend down to 1 Hz instead of tens of Hz now. "Transient signals" of inspiral and mergers of neutron stars observed today will therefore appear much more like continuous waves, when registered by the Einstein Telescope. Broadening of the sensitivity window towards lower frequencies will open new possibilities to study never-before seen sources, like very massive black holes systems, or a population of slowly-spinning neutron stars.

In order to take steps in advance and use the current "calm before the storm" period, we want to prepare for the incoming richness of the future. The potential for groundbreaking discoveries is motivating this project, devised to explore and prepare efficient methods to deal with the multitude and complexity of future data. We will implement not only quantitatively, but *qualitatively*-different solutions, motivated by astrophysical simulations and the progress in computational methods. The gravitational-wave data analysis methods developed at the Nicolaus Astronomical Copernicus Center and by the LIGO-Virgo-KAGRA data analysis group will be improved by machine learning techniques and applied to various gravitational signals, like long inspirals of binary systems, to be later used on the data of the LIGO-Virgo-KAGRA and the Einstein Telescope detectors.

Specifically, we will implement machine-learning enhancements to the continuous-wave search pipeline, developed in our group, in order to exploit characteristic features of the signals and improve detection of weak signals with complicated morphology (for example, with wandering frequency, not strictly continuous signals), use machine learning denoising techniques to distinguish true astrophysical signals from instrumental artifacts, automatically estimate their parameters, and perform rapid verification supplemented by information on the signals' shape. These improvements will be supported by astrophysical simulations of neutron-star models with specific dense-matter features, in order to establish ranges of signal-to-noise, measurement errors and number of detections needed to prove or disprove specific features: e.g. elastic properties, tidal effects, modes of oscillation, or existence of dense-matter phase transitions. We will perform both detailed numerical-relativity simulations, and data analyses of simulated future data sets to assess the requirements needed by future detectors, such as the planned Einstein Telescope.