Abstract

The discovery of the first gravitational wave in 2015 marked the beginning of the era of gravitational-wave astronomy. The newly opened window on the Universe allowed us to observe the outer space around us from a completely new perspective. Gravity, the fundamental force in the Universe, has become a valuable source of information on the dynamic processes occurring in space. Space-time undergoes dramatic changes during violent phenomena such as merging black holes or neutron stars as well as supernova explosions. The gravitational wave's propagation distorts the space it passes through. Though the effect diminishes as the wave travels away from the source, the power emitted by dramatic events such as merging black holes exceeds the electromagnetic emission of all stars in the observed Universe!

Detection of such subtle phenomena as gravitational waves requires extremely precise equipment. The instruments that enable the registration of these signals are laser interferometric detectors built within the Advanced LIGO and Advanced Virgo projects. However, the use of extremely sensitive tools that can register gravitational waves does not equal actual detection. This signal is buried deeply in the noise, which at this level is generated practically through everything: the detector itself, human activity such as planes and cars, seismic activity, or atmospheric conditions. Therefore, gravitational wave detection requires the application of a sophisticated analysis of data collected by detectors. Methods such as machine learning, a branch of artificial intelligence that revolutionized computational capabilities in the twenty-first century, appear to be an ideal candidates.

Work on this thesis began in the autumn of 2017, at the dawn of machine learning applications in gravitational-wave astronomy. As a result, the thesis addresses scientific issues that were previously unstudied or studied only to a limited extent. In general, the thesis fits perfectly into the larger picture of extensive research on how machine learning can be used in gravitational-wave astronomy and what it can give us in return. In my thesis, I investigate the potential of machine learning as a novel method of detecting gravitational waves defined in terms of anomalies in the data. In addition, I discuss the use of machine learning in the search of yet undetected signals emitted during supernova explosions and by non-axisymmetric neutron stars. I am also looking into the idea of reconstructing fundamental theoretical equations describing the physics of neutron stars based on what we can observe.

The ongoing and future LIGO-Virgo-KAGRA observing runs are expected to yield more observations of both known and unknown signals. I hope that this dissertation will make a significant contribution to the development of modern methods for studying gravitational waves.