# Multimessenger Astronomy with analysis of gravitational waves and neutrinos using multivariate statistical methods

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## Introduction

The detection of Gravitational Waves from the merger of astrophysical objects into a binary system was a significant milestone in multimessenger astronomy. This opened up new perspectives for observing the universe, ushering in an era in which astronomers can explore cosmic events in ways that were previously inaccessible. The detection of the gravitational wave, event GW170817, ushered in multimessenger astronomy. (FERREIRA, 2022). From this perspective, the present work aims to analyze two specific events, namely gravitational waves and neutrinos.

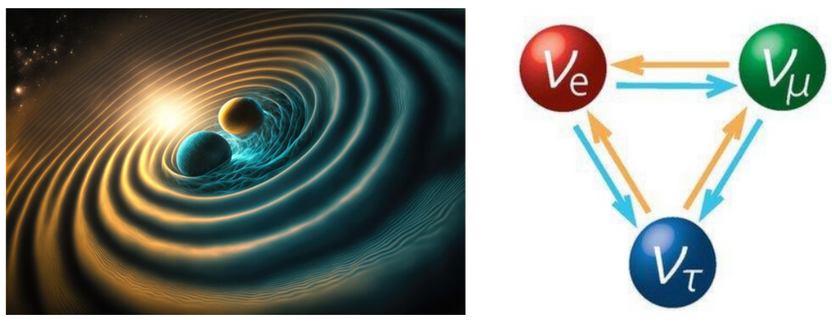


Figure 1. The right is a representation of a binary system producing gravitational waves. And on the right the representation of the 3 types of neutrinos.

## Research objectives

The objective of this research is to analyze the coincidences of the observed data of neutrinos and Gravitational Waves. The simultaneous detection of gravitational waves and high-energy neutrinos can contribute to further ongoing research on related topics, better understanding the origin of supernovae and black holes. We can help each other better understand the nature of dark matter and dark energy, and even develop new technologies to detect and study high-energy neutrinos and gravitational waves.

## Methodology

Multivariate statistics main objective is to analyze data sets that involve several interrelated variables. It seeks to identify patterns, relationships and underlying structures in the data, allowing a deeper and more comprehensive understanding of the phenomenon studied. In this sense, we seek to analyze the correlation between the two messengers, neutrinos and GW. GW were observed for the first time in 2015, by the Laser Interferometer Gravitational-Wave Observatory (LIGO). The interferometry technique used is based on the Michelson interferometer.

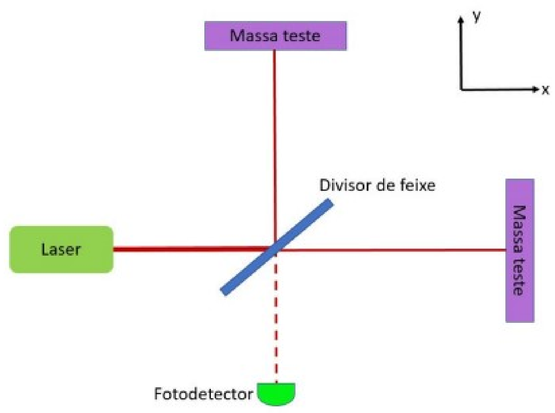


Figure 2. Representation of the Michelson interferometer.


Figure 3. LIGO-Livingston and LIGO-Hanford Observatory in the USA.

Two other interferometers that make up the gravitational wave detectors are Virgo in Italy and KAGRA in Japan. Together they are called LVK. (FERREIRA, 2022)

The KM3Net-ARCA project is dedicated to the search for High Energy Neutrinos (HEN). Astroparticle Research with Cosmic Abyss (ARCA) has good resolution, which makes it possible to study the cosmic flux of neutrinos, providing essential data on their origin, energy spectrum and flavor composition.

Neutrino detection in ARCA is based on the Cherenkov light detection principle.

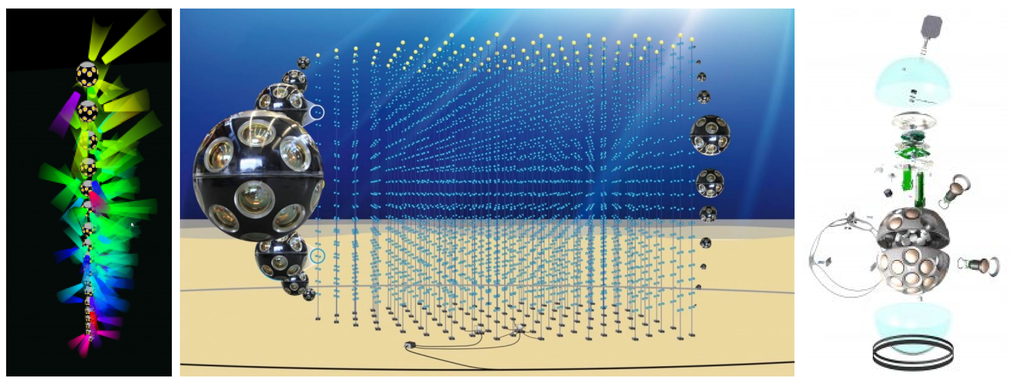

Figure 4. Representation of the light cone and representation of the ARCA construction with the installation of optical modules.

## Expected results

The simultaneous detection of gravitational waves and neutrinos could provide crucial information about extreme cosmic events such as black hole mergers, neutron star collisions or supernovae. The coincidence of records of these two phenomena can offer a more complete and detailed view of these events, with neutrinos and gravitational waves originating from the same source.

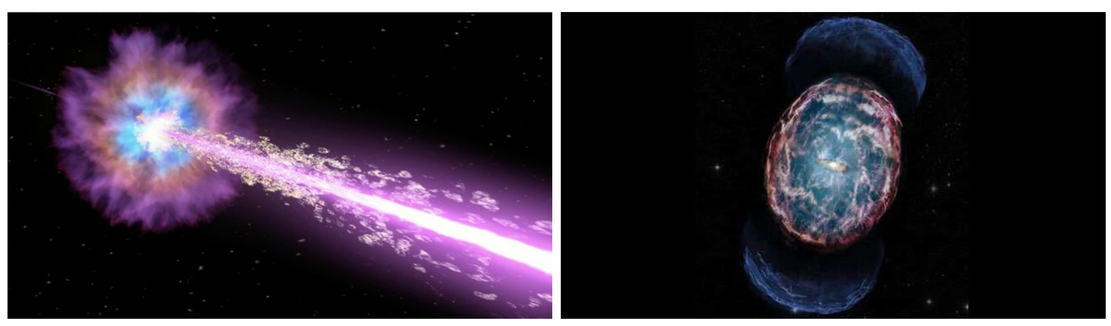

Figure 5. Gamma ray bursts and Kilonova. Examples of common neutrino and GW sources.

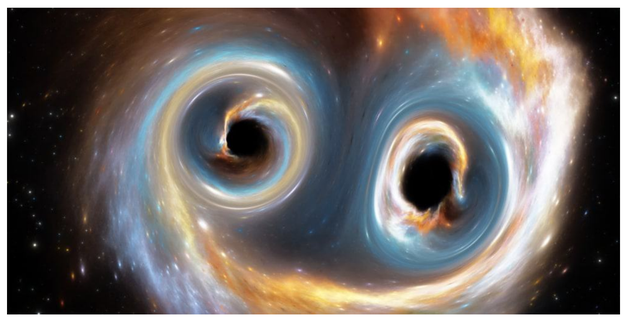

Figure 6. Binary system of compact objects. Examples of common neutrino and GW sources.

Gravitational Waves and High Energy Neutrinos (HEN) can provide information not observed until now, through photons. Due to the low interaction of gravitational waves and HENs, with larger and more sensitive instruments, a greater volume of data and better data processing are expected, thus a possible correlation between the two messengers.

## References

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## Acknowledgements

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## Collaboration