PHD SECOND YEAR ANNUAL REPORT – CARLO GUIDI

RELATORE: MAURO TAIUTI – CORRELATORE: MARCO ANGHINOLFI

During the second year of the PhD in Physics my work took place on several fronts:

1) Application to the real data of the acoustic positioning system for the KM3NeT submarine cosmic neutrino detector and related problems investigations.
2) Analysis of KM3NeT Raw acoustic data in order to find and classify cetaceans' sounds
3) Analysis of Killer Whales' sounds recorded in Genova port during December 2019
4) Course attendance and related study in view of the associated exam tests

Furthermore, during the month of January and part of February I worked at the CPPM of Marseille as part of the co-tutorship with the French university.

1)

KM3NeT is an underwater neutrino telescope located at two different sites in the Mediterranean Sea, one in France (ORCA, at 2500 m depth), offshore the coast of Toulon, and one in Italy, offshore Capo Passero (ARCA, at 3500m depth). The detectors will consist of several hundreds Detection Units (DUs) installed at the seabed at high depths. A Detection Unit is a vertical structure with Digital Optical Modules (DOMs) attached. Each DOM is equipped with photomultipliers to detect Cherenkov light and a piezo sensor for acoustic signals detection.
The simulations carried out during the first year of the PhD have shown that it is possible to set up an efficient acoustic system to reconstruct the position of all the elements of the system. Three emitters are used and the position of each piezoelectric sensor is calculated independently. During the second year, the system was applied to real data with very good results. These results were compared with the marine weather conditions recorded in situ, obtaining a very good agreement. A string stretching phenomenon was also found, consistent with what the theory predicted. The Acoustic Positioning System has been made public to the entire collaboration and it is now usable to calculate the position of each element of the system.

2)

Raw acoustic data from KM3NeT hydrophones were analyzed in order to find possible emissions of cetacean clicks. In particular, raw acoustic data was continuously saved during the month of April 2020. This made it possible to have a large amount of data to analyse. Initially, the data, in binary format, was downloaded, converted into audio files and visualized by eye (amplitude vs time and spectrogram plots) in order to quickly identify the possible presence of cetacean clicks. Clicks of striped dolphins and sperm whales were observed in this way.
At this point a click detector has been implemented, through which it is possible to automatically analyse the binary files in search of cetacean clicks. This program considers empirical thresholds both for the amplitude of the signal (the Signal to Noise Ratio is considered) and for the frequency characteristics of the animals' clicks. Furthermore, in order to recognize the different species and avoid false positives, the typical Inter Click Intervals (ICIs) found in the literature are also considered.
The system is still under development and needs to be improved, but it has begun to give good results, demonstrating the presence of numerous cetaceans in the experiment area.
At the same time, the work of synchronizing the acoustic files of the different hydrophones began, in order to identify the coincidences and, through the cross correlation, calculate the delay time between the different hydrophones for the reception of the cetacean clicks. At the moment only three hydrophones are functional and therefore it is not yet possible to realize a reliable tracking system. In the future, starting in

2021, the number of hydrophones in the water will increase and it will be possible to implement a system to track the movement of cetaceans, especially sperm whales.

3)

During December 2019 four killer whales and a cub were observed inside the commercial port of Genoa Pra. The INFN researchers, in synergy with those of the Genoa Aquarium, carried out various acoustic measurements in situ, accompanied by the Coast Guard. During these data taking, many sounds emitted by the killer whales were collected and a catalog was compiled and published on a public page of the INFN:

https://wiki.ge.infn.it/acoustics/index.php?title=Acoustic_studies_of_the_killer_whale_(Orcinus_orca)_pod_in_Genoa

In addition, Nauta Scientific and the Tethys institute have positioned a fixed hydrophone on the seabed, at a depth of about 10 m, which continuously recorded the sounds of killer whales for a few days. These data were made available and analyzed. A classification of the sounds of the killer whales and a statistical analysis was carried out. The sounds have been divided into three categories (simple sounds, compound sounds and patterns) based on the complexity of the emissions. Furthermore, a value has been assigned to each acoustic file which indicates the number of orcas emissions present in that file. In this way it was possible to understand how frequently the orcas emit sounds and how long the "conversations" on average last. The periods in which no sounds were detected correspond consistently with the periods in which the killer whales were seen by eye moving away from the coast in search of food.

4)

Attended courses:

- High energy astrophysics: an introduction (Fabrizio Tavecchio)

Passed exams:

- High energy astrophysics: an introduction (Fabrizio Tavecchio)

Partecipation at remote shift for ANTARES and KM3NeT (27 May 2020 – 4 Jun 2020)

Partecipation at conferences and workshops:

- Talk at KM3NeT Collaboration meeting in Genova, Italy (10-14 February 2020)
- Talk at KM3NeT Online Collaboration meeting (2-12 June 2020)