Thesis abstract Pierre-Alexandre Duvergne :

Multi-Messenger astronomy, localisation of transient sources of gravitational waves and optical follow-ups of gravitational wave candidates.

Multi-messenger astronomy (MMA) aims at combining the information provided by different physical signals. MMA was launched on August, 17th 2017 via the joint detection of a gravitational wave (GW) by the LIGO and Virgo detectors and in the electromagnetic regime over the whole spectrum. This was emitted by a binary neutron stars merger, located at 40 Mpc. The gamma ray burst (GRB) was the first counterpart detected by the GBM instrument of the Fermi satellite less than two seconds after the GW alert. After 11h, the optical counterpart, the so-called kilonova, was discovered by the Swope telescope. Few weeks later, the X-ray and radio signals were discovered by the Chandra and VLA instruments respectively.

This event started the GW-based MMA, and led to the creation of the GRANDMA network of telescopes. The main goals of the network are:

- Dealing with the GW alerts
- Optical follow-up
- Candidate counterpart characterisation
- Astrophysical interpretation.

The GRANDMA infrastructure development involved the creation of a photometry pipeline called Muphoten, able to create homogeneous datasets, despite the instrument's heterogeneity. Muphoten was developed via the use of images produced during the follow-up of the supernova SN2018cow by various telescopes, including some GRANDMA instruments.

The network was heavily involved in the optical follow-up of the GW alerts produced during the O3 observing run. GRANDMA followed 49 of the 53 alerts publicly distributed by LIGO and Virgo, however, no counterpart was discovered neither by GRANDMA nor by any other group. Despite the non-detection, the campaign demonstrated the network's ability to follow rapidly evolving optical transients.

In order to prepare for the upcoming O4, two campaigns were set up. The first one consisted in the follow-up of 12 alerts produced by the ZTF survey. It allowed GRANDMA's ability to characterise and classify the observed transients. This was done based only on photometric data, which is one of the major constraints imposed by the GW optical follow-up. Moreover, Muphoten along with another independant photometry pipeline were used to produce the datasets used for the analysis. The use of two independent codes allowed us to evaluate whether one of the analyses was biased. It turned out that the results produced by Muhoten and STDpipe were compatible.

The second campaign consisted in the follow-up of Swift satellite GRB alerts to find optical counterpart to the gamma emission, the so-called afterglow. The analysis is still ongoing for these observations.

On the other hand, detecting electromagnetic counterpart to GW events requires that reliable information produced by the LIGO Virgo detector are rapidly distributed. In particular, on of the most important for GRANDMA is the source spatial localisation. The latter is given by the Bayestar algorithm whose accuracy has been tested. This was done with a percentile-percentile test that evaluates whether the analysis is biased. A first round of compact binary coalescence simulations allowed to identify a hard-coded parameter ξ as particularly sensitive for sky-localisation. It can lead to an overestimation of the localisation

uncertainties, that would result into a oversized area to cover with the electromagnetic follow-u instruments.

Additional simulations, including an end-to-end online analysis with PyCBC Live, were performed to find why ξ was necessary to implement. Based on these, it is suspected that ξ compensate or the difference between the source parameters and the simulated waveform parameters used for the localisation.