The astrophysical sources of gravitational waves

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Abstract

The discovery of the electromagnetic counterparts to the binary neutron star merger GW170817 has opened the era of gravitational wave+electromagnetic (GW+EM) multi-messenger astronomy. Exploiting this breakthrough requires increasing samples to explore the diversity of kilonova behaviour and provide more stringent constraints on the Hubble constant, and tests of fundamental physics. LSST can play a key role in this field in the 2020s, when the gravitational wave detector network is expected to detect higher rates of merger events involving neutron stars ($\sim$10s per year) out to distances of several hundred Mpc. Our quintuplet want to study and identify the likely faint and rapidly fading electromagnetic counterparts of the hundreds of GW events expected by the 2nd generation GW detector network at full sensitivity. This program requires LSST to operate in synergy with other multi-wavelength facilities, which we expect to be available for our team (GRAWITA: http://www.grawita.inaf.it/).

1 Quintuplet Information 2018

Silvia Piranomonte(P.I.), Enzo Brocato, Giovanni Piano, Giulia Stratta

2 Quintuplet Information 2019

Silvia Piranomonte (P.I.), Enzo Brocato, Alessandro Ursi, Guillermo Rodriguez, PhD Student (to enlist)

3 Scientific Collaborations:

1. Transients and Variable Stars Science Collaboration (TVS collaboration)
2. subgroup Multi Wavelength Characterization (now also incorporates the gravitational Waves subgroup)

4 Scientific Activity

Our main scientific activities are:

1) Start a solid multi-messenger approach to study the GW sources with the aim of shedding light on compact object formation and evolution on statistical basis and exploit the direct availability of full LSST data to select specific EM counterparts of GW detections for spectroscopic multi-wavelength campaigns with optical facilities (LBT, VLT, SRT, E-ELT, etc). This will lead to new fundamental steps on several science goals like final source identification, nature of GW events, host galaxy properties and source physics.

2) Take advantage of the LSST capabilities in order to provide the key low energy counterparts to the γ-ray emission from the most extreme phenomena in both Galactic and extragalactic sources, bringing crucial information about their environment and physical mechanisms. AGILE and Fermi have provided a wealth of data for several classes of sources, but the simultaneous optical data are only rarely available, due to the late follow-up observations and the difficulty to match the wide sky coverage currently available in γ-rays. LSST, operating in the timeframe of present or future gamma-ray missions, will allow us to overcome these issues for a variety of classes of sources, including: Galactic transients and binaries; blazars (optical flares and long-term monitoring); GRBs; GW source counterparts; exotic transients (TDE).

3) In the framework of the Memorandum of Understanding (MoU) signed between INAF and LIGO and Virgo Collaboration (hereinafter LVC) started on 2014, the proposers are already operative in organizing and coordinating follow-up observational campaigns of GW sources using the following ground- and space-based telescopes through existing collaborations and agreements, in the context of a large international consortium. During the second observational GRAWITA had an very important role with the spectacular detection of the first EM counterpart of a GW event originated by the coalescence of a binary neutron star system (GW 170817) (Abbott et al. 2017) which marked the dawn of a new era for multi-messenger and time-domain astronomy. A world-wide extensive observing campaign was carried out to follow-up and study this source, with the forefront participation of our team (GRAWITA) and international collaborators. Our unique optical and near-infrared dataset provided the first compelling observational evidence for the existence of "kilonovae", transient sources powered by radioactive decay of heavy elements resulting from the r-process nucleosynthesis of ejected neutron star matter (Pian et al. 2017; Tanvir et al. 2017).

The following facilities have been used during the first observational runs of LVC and are planned to be used in the future during the LSST era: in the visible frequency range VST, VLT inside the ENGRAVE collaboration, REM at ESO, LBT, TNG, NOT, NTE@NOT, SOXS@NTT and national telescopes as the 1.82m in Asiago, 1.52m in Loiano, 0.9m in Campo Imperatore, plus collaborations with HST observatory, and in the Near-IR with VISTA; 64mt SRT in Cagliari and 2x32m radio telescopes in Medicina and Noto, the 6x22m antennas of the ATCA radio telescope in Australia at radio frequencies. In the high-energy domain, we work with space-based observatories AGILE, INTEGRAL, Fermi, Swift, XMM-Newton and Chandra and ground-based facilities as MAGIC. Collaborations with future telescopes as the Cerenkov telescopes ASTRI and CTA, the radio array SKA and the optical/IR telescope E-ELT are planned in the future. All these facilities could work in synergy with LSST to characterize the GW sources.

5 Scientific activity of the quintuplet

- LSST Cadence Hackaton attendance where we proposed the project ?ToO afraid?? to evaluate the impact of implementing a Target of Opportunity program (ToO) in LSST, specifically focused on the follow-up of gravitational wave events. The strategy started with a simulation which covered $\geq 90\%$ of the GW skymap, scanning two or more times in one or two filters with a short separation using the criteria of rising lightcurve within 12 hours. We worked on a possible strategy optimization using GW information (distance, binary parameters, see Salafia+17) & other criteria (e.g. crowded fields, numbers of galaxies)
- work on LSST White Paper ?Target of Opportunity Observations of Gravitational Wave Events with LSST where we proposed comprehensive target-of-opportunity (ToOs) strategies for follow-up of gravitational-wave sources that will make LSST the premiere machine for discovery and early characterization for neutron star mergers and other gravitational-wave sources.
- review of all white papers presented by the entire TVS-LSST community

6 Scientific and technical deliverables

please list the papers/proposals/documents and/or the technical deliverables in which you have been involved during the last year, if any.

1. Target of Opportunity Observations of Gravitational Wave Events with LSST, LSST white paper
2. "ToO afraid?", LSST Hackaton project (O. Salafia, S. Piranomonte, E. Neilsen, F. Riesco))

7 Other information

Any other information concerning your scientific activity (meetings, zoom/skype).

1. *Regular activity in teleconferences both general (TVS) and specific (transients)*
2. *participation to meetings (hackaton NY)*
3. *organization and participation to italian LSST meeting on transient and variables in Napoli*
4. *organization and participation to italian LSST meeting in Palermo*
5. *leading of the transient teams of LSST - Italy*
6. *review of all WHITE PAPERS presented by the entire TVS-LSST community*
7. *management of the LSST-Italy budget*

8 References

Abbott et al. 2017, PRL, 119, 161101 Pian et al. 2017, Nature, 551, 67; Tanvir et al. 2017, ApJ, 848, L27; Salafia et al. 2017, ApJ, 846, 62