Multi-messenger insights into merger physics: GW170817 and beyond

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Abstract

With the first gravitational wave detection on September 2015 and the forthcoming new developments of gravitational interferometers, neutrino detectors, as well as ground- and space-based telescopes, a golden era of multi-messenger astronomy is approaching. Multi-messenger observations enable us to obtain a more complete phenomenological picture of several astrophysical phenomena. The most beautiful example so far is represented by the binary neutron star merger detected on August 17th, 2017 by the gravitational wave detector network (formed by Advanced LIGO and Advanced Virgo) and by several telescopes covering the whole electromagnetic spectrum. Multi-messenger observations of this source have enabled us to make huge steps forward in our knowledge of merging neutron star binary systems and their connection with short gamma ray bursts and with the Universe chemical enrichment of heavy elements. Many other open questions will be tackled in the next years given the realistic possibility to obtain multi-messenger observations for a large number of such systems with the present and future instrumentations. In this talk I will summarize some of the main results obtained for GW170817 and the multi-messenger observations future perspectives.

Introduction

The last generation of modified Michelson interferometers as Advanced LIGO (Harry and LIGO Scientific Collaboration, 2010) and Advanced Virgo (Acernese et al. 2015) have enable to open a new observational window in the Universe and the expected gravitational waves (GWs) from cosmic events have been detected. Ground-based interferometers are sensitive to high-frequency GWs at which sources as compact binary coalescences, core collapsing massive stars and bursting neutron stars are expected to emit. So far, only compact binary coalescences have been detected and up to the 14th of August 2017, five stellar-mass black hole binary mergers have been confirmed (Figure 1).

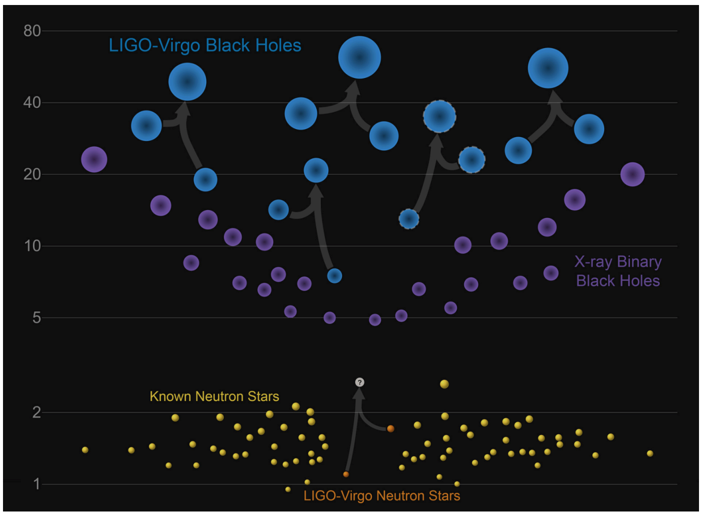

Figure 1 The y-axis shows the masses (in solar mass unit) of the black holes (blue) and neutron stars (orange) in the merging binary systems detected up to August 2017 with Advanced LIGO and Advanced Virgo, compared with the previous known BH and NS masses (violet and yellow). Credit: LIGO/Virgo

On August 17th, 2017 the GW detector network composed by Advanced LIGO and Advanced Virgo discovered for the first time a GW signal consistent with a binary neutron star merger. The event, GW 170817, was also the first gravitational wave source detected in the electromagnetic spectrum, marking an important milestone in the multi-messenger astronomy. Indeed, 1.7s after the merger time a short gamma-ray burst was detected by the INTEGRAL and Fermi satellites (Abbott et al. 2017a, Fig. 2). About 11 hours after, an optical counterpart was found as the only interesting bright transient within all the galaxies contained in the sky error box provided by the GW detector triangulation and at the distance inferred from the gravitational waveform of 40^{+8}_{-14} Mpc (Abbott et al. 2017b). The transient was hosted within a lenticular galaxy, NGC4993, at z=0.009 (~40 Mpc) and it showed the expected behavior from a blue-red kilonova source. After 9 and days since the merger epoch, an X-ray and radio counterparts were found, respectively and identified with the afterglow of the short GRB 170817 viewed off-axis.

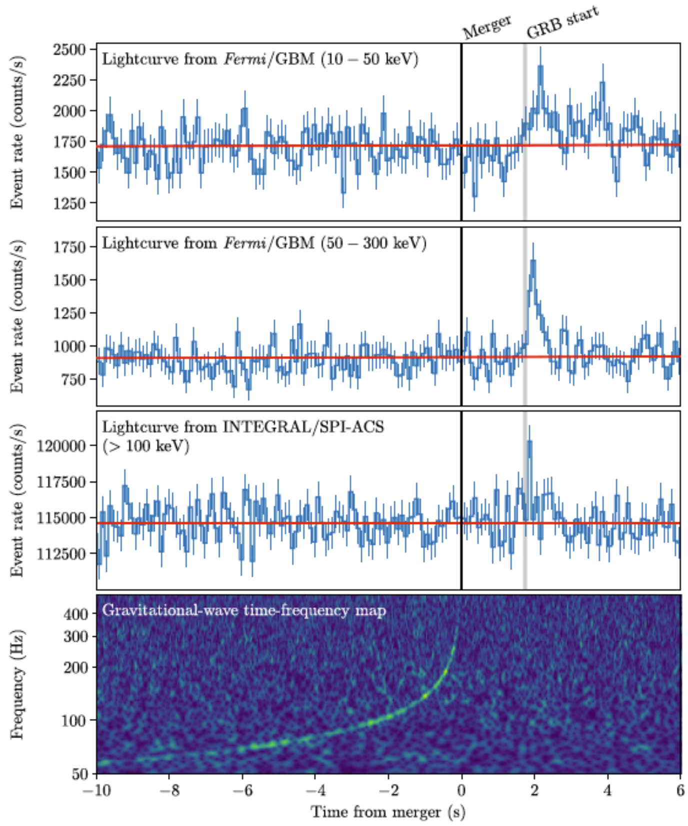

Figure 2 The GW 170817 signal evolution with time (bottom) and the light curve of the short GRB 170817A (top), plotted on the same temporal scale (from Abbott et al. 2017a)

Multi-messenger studies of GW170817

Multi-messenger observations are powerful tools in astronomy since enable us to obtain a more complete phenomenological picture of several astrophysical phenomena and to increase statistical confidence in assessing the astrophysical origin of low signal to noise ratio events. The most beautiful example so far is represented by the binary neutron star merger GW170817. Multi-messenger observations of this source have enabled us to make huge steps forward in our knowledge of merging neutron star binary systems.

In this talk I will review some examples of the huge and still growing amount of results that are obtained from the combination of the gravitational wave data with the information from the electromagnetic counterpart.

Future perspectives

The second generation GW detector network is planned to be completed by 2024 with five second generation interferometers with comparable sensitivity. By the end of the 2020s third generation GW detectors as the Einstein Telescope (EU, Punturo et al. 2010) and the Cosmic Explorer (USA), are planned to be operative and to improve the sensitivity of the second generation by one order of magnitude, thus significantly boosting the present BNS merger rate up to more than one per day. By that time, GRBs are among the most promising electromagnetic counterpart given their intrinsic brightness and future mission dedicated to GRB detections, as the THESEUS (*Transient High Energy Sky and Early Universe Surveyor*, Amati et al. 2018, Stratta et al. 2018), as well as neutrino detectors, currently upgrading to multi km^3 telescopes, will pave the way for a golden era of multi-messenger astronomy.

Bibliography

Harry, LIGO Scientific Collaboration, Classical and Quantum Gravity 27 (2010) 084006.

Acernese et al., Classical and Quantum Gravity 32 (2015) 024001.

Abbott et al. 2017a *Gravitational Waves and Gamma-Rays from a Binary Neutron Star Merger: GW170817 and GRB 170817A,* ApJL, 848, L13

Abbott et al. 2017b *GW170817: Observation of Gravitational Waves from a Binary Neutron Star Inspiral*, PRL 119, 161101

Amati et al. 2018, *The THESEUS space mission concept: science case, design and expected performances*, AdSpR, 62, 191

Stratta et al. 2018, *THESEUS: a key space mission concept for Multi-Messenger Astrophysics,* ASPR, in press

Punturo et al. 2010 Classical and Quantum Gravity 27 (2010) 194002.