LIGO, Virgo, KAGRA, and beyond: Ground-based Gravitational Wave Observatories

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The network of ground-based gravitational-wave (GW) detectors is in transition from the phase of the initial discovery to one of production astrophysics. The necessity of the tight collaboration of Virgo and LIGO was seen well before detections – in the early 2000's – but significant evolution in the detectors and above all in the sociology of the Collaborations was required to bring the two organizations into a coherent team. That evolution did enable the second generation of detectors and ultimately that first detection in September 2015.

A second phase of the ground-based network was abruptly introduced by the observation of the first binary neutron star in 2017. While there had been memoranda of understanding with the EM and particle observers in place, with followup observations for the binary black hole events seen in the O1 and O2 data sets, the confirmation of an optical counterpart some 10 hours after the GW event introduced a crash course in coordination and joint scientific endeavor. This brought to light (no pun intended) the significant differences in the collaboration models between EM/particle astronomers.

Now that Virgo and LIGO are sharing triggers with all interested parties some of the difficulties in the followup of GW170817 are resolved, but a discussion of the advantages of collaboration between EM observers and of EM and GW observers working closely together can still result in a greater scientific harvest from future multi-messenger events. We will find ourselves once again making up the rules as we go for the next such event. Separately, the tension created by the LIGO/Virgo proprietary period remains.

The ground-based GW network will soon grow to include the Japanese KAGRA detector, and then in the mid-2020's the third LIGO detector located in India. The GW Collaborations are planning to continue to work together, combining data sets and coordinating observations and upgrades. Further in the future, the Einstein Telescope and Cosmic Explorer concepts for third generation ground-based GW detectors are targeting the 2030's for operation, and the number of GW signals will be counted in the millions. A mode to capitalize on the rich data set, and joint GW-EM-particle data sets, should be a focus over the coming decade to ensure communication, computation, and collaboration all can best exploit the possibilities in those data.