A New Era of Multi-Messenger Astronomy

Courtney Klein

For as long as humans have roamed the earth, we have looked up to the sky and used our eyes to understand the universe. But as of September 14, 2015, we have opened our senses to something new. Like a deaf child hearing their first sound, we have detected our first gravitational wave, sensing the universe in an entirely new way.

The search for gravitational waves was sparked by Albert Einstein in 1916. In his general theory of relativity, Einstein showed that massive, accelerating objects should create a disruption in space-time that would radiate out as waves that travel through the universe at the speed of light. In the 1970s many scientists proposed different instruments they thought could detect these waves and in 1979 the National Science Foundation (NSF) funded Caltech and MIT’s Laser Interferometer [1]. They built the Laser Interferometer Gravitational-Wave Observatory (LIGO) with the confidence that, although the technology was not yet sensitive enough, one day it would catch up with the theory. That sensitivity came after the much anticipated Advanced LIGO installation. The two observatories in Hanford, Washington and Livingston, Louisiana began operation with the new system and in that same year they had their first detection [1].

The detection of gravitational waves has sparked a new era in multi-messenger astronomy. Multi-Messenger astronomy is the use of different types of signals to interpret one event. We can use the light or electromagnetic radiation collected from telescopes and combine it with our detection of gravitational waves to, in a sense, see and hear cosmological events. The first example of this occurring was on August 17th, 2017 when two merging neutron stars, as shown in Figure 1, were observed. This event, known lovingly as GW170817, is now the most observed event in the

Figure 1.
An artist’s rendition of two neutron stars colliding along with their emitted gravitational waves. [2]

Figure 2
This sky map shows the regions in which each detection originated. GW170817 and GW 170814 are the smaller regions due to the addition of Virgo, an Interferometer in Italy. [1]
Within seconds of the gravitational wave detection, the Fermi Gamma-ray Telescope detected gamma-rays from the same section of the sky, shown in Figure 2. The event was also observed in X-ray, ultraviolet, optical, and radio wavelengths with observatories including Hubble Space Telescope, Gemini Observatory, and the European Very Large Telescope [1].

Similar to the ability of electromagnetic telescopes to observe a specific section of the spectrum, so too are these Laser Interferometers limited to certain frequencies. To observe a new section of the gravitational wave spectrum, scientists have brought observatories to an entirely new scale. Planned for 2034, scientists hope to launch LISA, the Laser Interferometer Space Antenna. LISA will follow earth, as shown in Figure 3, and rotate once per orbit. Its arms will reach out 2.5 million km each and it will be able to detect frequencies between 3 mHz to 30 mHz, which significantly surpasses the sensitivity limit of 1 Hz on the ground [4][5].

Astronomers are learning new things everyday as they study the data put forth by the gravitational wave observatories along with all other telescopes. Every answer we get sparks tens of new questions and we are learning just how much we do not understand about the universe. Astronomy has always been driven by pure curiosity and as interest spikes, this new era of astronomy will thrive.

References: