A Deep CFHT Optical Search for a Counterpart to the Possible Neutron Star – Black Hole Merger

The first detection of a merger between two neutron stars in both gravitational waves and light thrilled astronomers across the international community in late 2017. Now, an even more exotic merger and another first may have occurred: the merging of a neutron star and a black hole.

As they perform their final dance and spiral towards each other, a neutron star and black hole produce gravitational waves – ripples in the fabric of spacetime itself – which can be detected by specially designed detectors such as LIGO and Virgo. At the same time, the neutron star is shredded into free neutrons which then rapidly combine to form the heaviest elements in the Universe, including gold, platinum, and uranium. These elements shine in visible and infrared light in a rapidly-evolving 'kilonova', and astronomers with conventional telescopes can then join in.

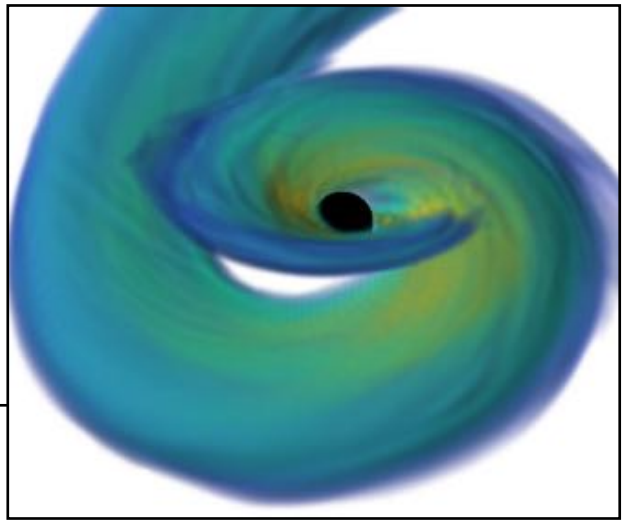
On 14 August 2019, the LIGO and Virgo detectors found an extremely strong gravitational wave signal which was potentially produced by the merger of a neutron star and black hole, now named GW190814. Nick Vieira, Dr. John Ruan, Prof. Daryl Haggard of McGill University, and Prof. Maria Drout of University of Toronto, led an imaging campaign to search for a kilonova counterpart to GW190814 in visible/infrared light with the Canada-France-Hawaii Telescope (CFHT). These CFHT observations were among the deepest and most valuable of those reported by the dozens of teams across the world who engaged in similar campaigns. This Canadian-led team did not detect any such counterpart, nor did any other teams. However, their deep CFHT imaging campaign allowed them to place the tightest constraint to-date on the mass of the neutron star which was consumed by the black hole. They found that at least 97% of a standard neutron star must have been immediately swallowed by the black hole, or, the lighter object must itself have been a black hole. LIGO/Virgo announced in June 2020 that the mass of the lighter object makes it either the heaviest neutron star or lightest black hole ever detected, adding to the mystery of this exciting new system and highlighting the value of the CFHT observations.

These observations reiterated the ability of the CFHT, led by a Canadian collaboration, to play a leading role in 'multi-messenger' astronomy. In the future, the team will employ CFHT, Gemini, and other observatories to search for counterparts to exciting new gravitational wave events, with an eye toward making the first multi-messenger detection of the merger between a neutron star and black hole, when it occurs.

Nick Vieira *is a M.Sc. student working under the supervision of* ***Prof. Daryl Haggard*** *and* ***Dr. John Ruan*** *at the McGill Space Institute. He works on visible/infrared follow-up of gravitational wave sources.*

Why this is important

The 'multi-messenger' detection of a merger between a neutron star and a black hole in both gravitational waves and light would be the first direct proof that such a system exists, and the insights gained by combining these messengers greatly exceeds those gained by using either messenger alone.



Top right: Canada-France-Hawaii Telescope (Credit: (c) Jean-Charles Cuillandre)
Bottom right: Merger simulation [Source: Foucart+17, https://arxiv.org/pdf/1611.01159.pdf]