Latest news from the McGill Space Institute

Merging Neutron Stars in X-rays and Gravitational Waves

Why this is important

The detection of X-rays from this gravitational wave event directly confirms that short gamma-ray bursts are produced in neutron star-neutron star mergers. Modeling of X-ray observations show that this is the first off-axis short gamma-ray burst ever detected. Detecting light (e.g. X-rays) from a gravitational wave event ushers in the long-awaited dawn of 'multi-messenger' astronomy, where both light and gravitational waves from a source can be studied together.

Prof. Daryl Haggard *is an Assistant Professor of Physics at McGill University in the McGill Space Institute. She studies the Galactic center and Sgr A*, electromagnetic counterparts to gravitational wave sources, accreting compact objects, supermassive black holes and their host galaxies, and multi-wavelength and time domain surveys.*

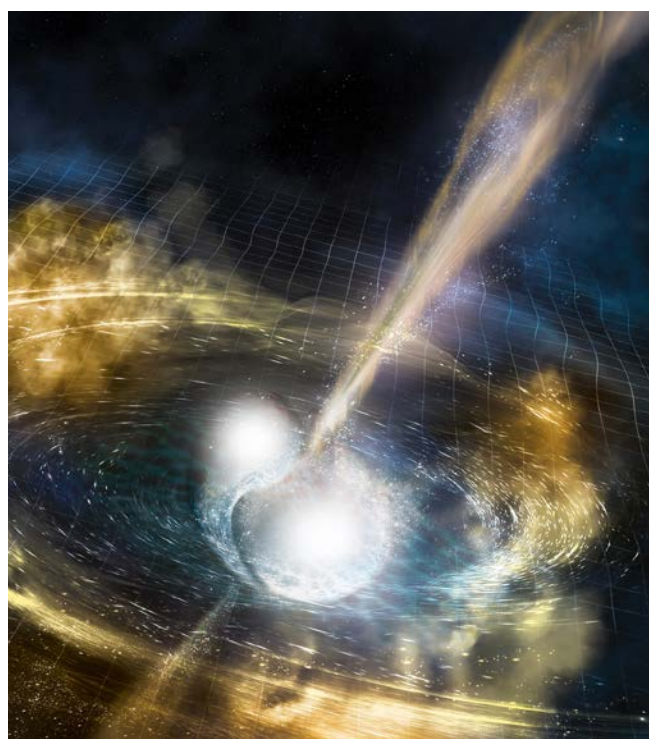
On the morning of August 17, 2017, MSI Professor Daryl Haggard was in her office when she received some exciting news — that LIGO (the Laser Interferometer Gravitational-Wave Observatory) had seen a new gravitational wave signal, ripples in spacetime made in the last seconds of the merger of massive, compact objects.

Attempts to observe an electromagnetic counterpart (a signal in some form of light) of the four previous mergers detected since LIGO came on line in 2015 had come up short, but those four mergers were pairs of black holes and were not expected to give off any light.

This time was different. Instead of colliding black holes, data from the fifth signal detected by LIGO pointed to a pair of merging neutron stars. Neutron stars, the corpses of massive stars, are extreme objects. They are about twice the mass of the Sun and about the size of the island of Montreal, making them incredibly dense.

The question that Haggard and her collaborators, including MSI postdocs Mel Nynka and John Ruan, had that August morning was: did they have enough evidence to "trigger" the space-based Chandra X-ray observatory to search for an X-ray signal from the gravitational wave source?

In the weeks that followed, "there was a world-wide collaboration of astronomers searching for electromagnetic emission from the neutron star merger, from those detecting neutrinos in the South Pole to astronomers using the



» Artist's impression of a neutron star-neutron star merger. National Science Foundation/LIGO/Sonoma State University/A. Simonnet

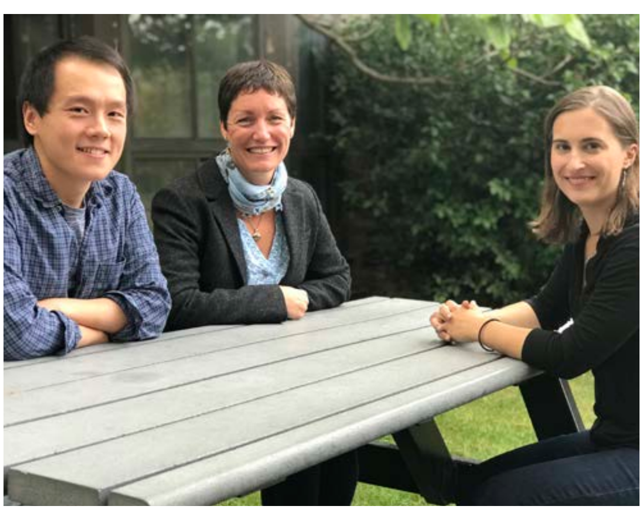
Hubble telescope to space-based gamma ray observatories," said Nynka, "It was both humbling and exciting to be a part of such an enthusiastic, global collection of scientists."

By August 19, observations detecting the merger in gamma-rays and visible light had pinpointed the location of the merger, giving Haggard's team enough information to initiate their Chandra observations. At first, their results were the same as those for previous studies of merging black holes — a non-detection in X-rays. However, observations taken 15 days later show a distinct X-ray source at the location of the merger.

"This was entirely unexpected," said Ruan, "our modeling [of the X-ray observations] showed that it is due to the jet from the gamma-ray burst produced in the neutron star-neutron star merger being off-axis (i.e. pointed away from the Earth)." This was the first confirmation that the cosmic explosions known as short gamma-ray bursts are the product of neutron star mergers and the first detection of an off-axis gamma-ray burst.

Haggard notes that "observations at other wavelengths also showed us that this merger led to a so-called kilonova. These explosions are crucial for making elements heavier than iron, like platinum, gold, silver, which make up almost half of our periodic table. So we've connected together gravitational waves, gamma-ray bursts, off-axis jets, and kilonova explosions, all in one exciting detection. That just doesn't happen every day."

Haggard's team is eagerly awaiting further observations in December, when the Chandra X-ray Observatory's orbit puts the location of the merger far enough away from the sun to safely observe it again. How the X-rays observed from the energetic jet change over time will give her team the additional pieces of information needed to understand the details of the merger and how the jet interacts with its surroundings.



Haggard, D., **Nynka, M.**, **Ruan, J. J.**, et al. 2017, *A Deep Chandra X-Ray Study of Neutron Star Coalescence GW170817*, ApJL, 848, L25

« from left to right: John Ruan, Daryl Haggard and Mel Nynka.

2017 Nobel Laureate Rai Weiss visits

Rai Weiss, professor emeritus at MIT, visited the McGill physics department in March of 2017 to give a public and scientific Anna I. McPherson Lecture about his work planning, developing and then making the first discoveries of black hole mergers in gravitational waves with LIGO. During his visit, he met with students from the MSI and the physics department.

Weiss along with Barry Barish, and Kip Thorne won the 2017 Nobel Prize in Physics "for decisive contributions to the LIGO detector and the observation of gravitational waves."