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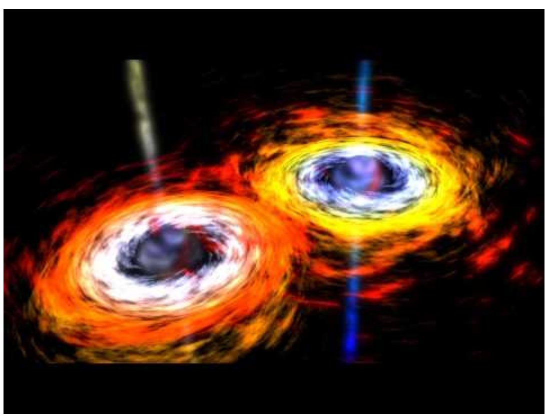
In this issue...

University of Guelph professors use black holes to understand the laws of the universe

Black holes: Inside gravity's relentless pull

Black holes are regions of space where ordinary gravity has become so extreme that it allows nothing to escape - not even light. Gravity's effects are stronger around black holes because they are massive and compact. But what happens to gravity when two black holes merge?

That's what Profs. Luis Lehner and Eric Poisson, theoretical astrophysicists at the University of Guelph, want to find out. As leaders of the Guelph Gravitation Group, they are trying to understand the nature of gravitation in its most extreme manifestations, predicted by Einstein's theory of general relativity. The group includes undergraduate and graduate students, post-doctoral scholars and has close ties with Perimeter Institute.



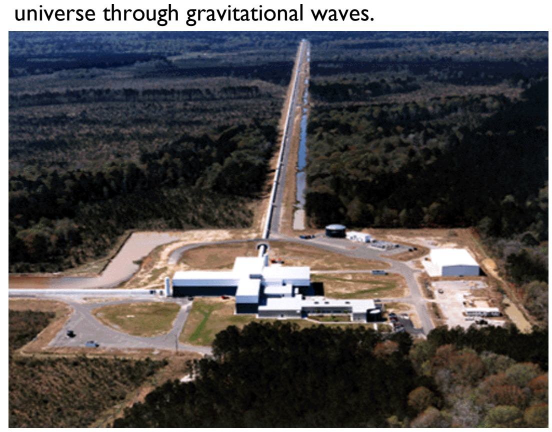
Artist rendition of merging black holes. Credit: Caltech

"I've always found gravity and its effects fascinating," says Lehner. Almost a century ago, Newton's Law of Gravity was superseded by Einstein's, who described gravity as a property of space and time, or 'space-time'. Einstein also predicted that gravitational waves would be produced when huge masses interact with one another. Gravitational waves are small disturbances in the fabric of space-time, like space-time ripples.

Einstein developed a set of equations to describe the interaction of gravitation as a result of space-time being curved by matter and energy. These equations govern all gravitational phenomena, including gravitational waves. However, these equations are complex and solution techniques often involve using assumptions. Two approaches can be used. One is to rely on approximations and develop pen-and-paper techniques to solve the equations. The other is using computer simulations. Poisson uses the pen-and-paper method and Lehner uses computer simulations.

Lehner and Poisson study the different forms gravitational waves can take depending on the sizes of the two black holes merging. Poisson investigates the waves produced when a large black hole merges with a much smaller one. Lehner is interested in the waves that are created by merging two similar-sized black holes. The waves can differ in their frequency, and amplitude over time. One goal is to characterize these waves and the way they change to develop a catalogue to help identify the source.

Such information is key to help in the detection enterprise and crucial in connecting the obtained signals to the source that produced them. Such connection will open a fundamentally new way to scrutinize our universe through gravitational waves.



LIGO Gravitational Wave Detector in Livingston, La (USA). Part of a worldwide network of facilities to detect gravitational waves and open a new window to the universe

Black hole mergers also affect the surrounding matter such as gases and plasma, an effect studied by Lehner in his simulations. This matter emits electromagnetic radiation and neutrinos, which can be detected in addition to the gravitational waves. This is the new era of ``multi-messenger astronomy".

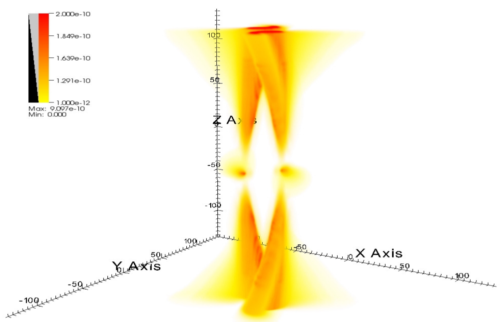
As opposed to electromagnetic waves, gravitational waves propagate through space unscattered thus providing pristine information of the source that produced them….

"Gravitational waves have been predicted to exist for a long time but have never been detected directly. But that will change soon..."

Funding for this research has been provided by NSERC, CIFAR, NSF and Perimeter Institute.

By Katharine Tuerke. Student participant in SPARK (Students Promoting Awareness of Research Knowl-

Poisson studies how a black hole in orbital motion around another object is deformed by the tidal forces exterted by the other body. "This is just like the ocean tides on Earth", says Poisson, "the tidal coupling of black holes can tell us something very specific about their nature through its effect on gravitational waves".

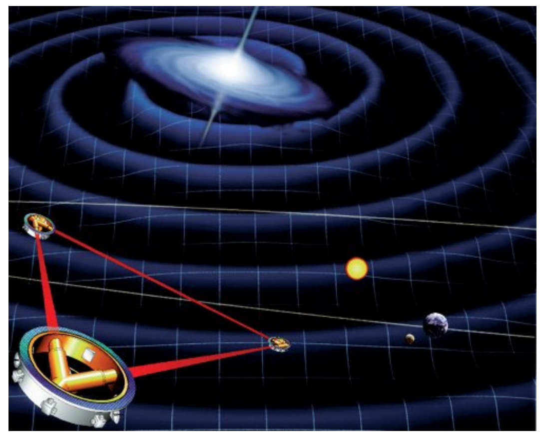


Numerical simulations uncovered dual jets created by the interaction of binary black holes with surrounding plasma.

Black hole mergers are expected to be the most powerful source of gravitational waves in the universe. Unlike electromagnetic radiation (i.e. visible light), gravitational waves are not scattered by intervening objects as they travel though space. That means they carry "pristine" information about the forces and fields that created them. For this reason they are used to give insight into many mysteries of theoretical physics -- including understanding cosmology, super-massive black hole formation and Einstein's theory of relativity.

"Gravitational waves have been predicted to exist for a long time but have never been detected directly. But that will change soon," says Lehner.

Even though these waves are created in galaxies far away, physicists believe that the space-time ripples can be felt here on Earth. The trick is to try and catch the small signal. Current detectors haven't been able to detect these systems yet but Lehner and Poisson says their work, together with that of others, will help change that. A better understanding of the gravitational waves produced by black hole mergers will also guide the development of future detectors.



Artist rendition of the planned LISA detector. A space-based facility targeting gravitational waves produced by supermassive black hole systems.

(from left to right) Ian Vega, Marc Casals, Ryan Massey, Misha Smolkin, Shannon Potter, Peter Zimmerman, Luis Lehner, Ryan Morrisey, Michael Barriault, Eric Poisson. (absent: Chad Hanna and Erik Schnetter)