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Studying waves over astronomical distances

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Tiny pulses of light one billionth of a second apart, travelling further than from the Earth to Sun, were used in an exquisitely sensitive experiment at The University of Auckland to explore fundamental interactions between light and sound.

The research, led by Associate Professor Stéphane Coen from the Department of Physics, examined the behaviour of solitons.

Solitons are solitary waves which maintain their shape in contrast, for instance, to waves hitting the shore which break and fragment. They are found in a wide range of situations, and learning more about them will help physicists understand many phenomena in the natural world.

Solitons were first seen in shipping canals, in which a boat coming to a sudden stop gave rise to a single large propagating wave. They also describe tsunamis – waves which travel unabated across entire oceans – and appear in both scorching hot nuclear fusion plasmas and ultracold gases.

In addition, solitons exist in microscopic glass rings, new devices used by scientists to generate frequency combs. These are a type of light source used to make extremely accurate measurements and which underpinned a Nobel Prize in 2005.

The University of Auckland work examined how two solitons in the same system affect one another. It reports the weakest interaction ever measured between solitons, and has been published in the journal *Nature*

Photonics.

"This was beautifully sensitive work, and tests our understanding of the fundamental properties of nature," says Head of Department of Physics Professor Richard Easther.

The experiment was done using a loop of fibre optic cable. Two pulses (solitons) of laser light were fired into the loop one billionth of a second apart, and allowed to continue travelling until one was found to have an influence on the other.

It wasn't until the pulses had travelled 150 million kilometres – the distance from the Earth to the Sun – that an effect was observed. The gap separating the pulses changed by a billionth of a billionth of a second for every roundtrip in the 100 metre-long loop.

As it travelled, the first pulse created an ultrasound wave in the fibre that disturbed the path of the second, detected as a change in its velocity. The effect was so tiny that it could only be observed after the pulses had travelled astronomical distances.

This was the first time an experimental apparatus had been built that allowed such weak interactions to occur and to be observed.

The work was done by University of Auckland physicists Associate Professor Stéphane Coen, Dr Stuart Murdoch, Dr Miro Erkintalo, and PhD student Jae Jang. It was supported by a Marsden grant of The Royal Society of New Zealand awarded to Associate Professor Coen and colleagues in 2011.

The paper, titled "Ultra-weak long-range interactions of solitons observed over astronomical distances" has been published online ahead of print on the *Nature Photonics* website.

The researchers are now looking to extend this work, and take advantage of their new understanding to facilitate the use of solitons in communications applications.

More information: Ultra-weak long-range interactions of solitons observed over astronomical distances, DOI: 10.1038/nphoton.2013.157

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