Quantum goes massive

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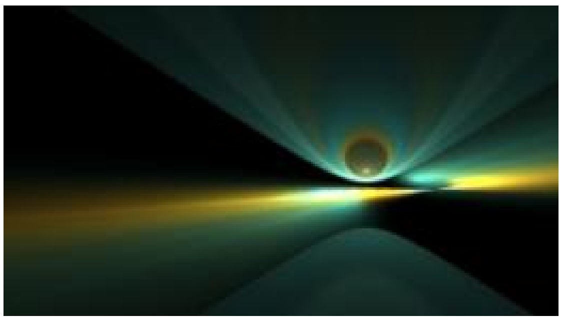

(PhysOrg.com) -- An astrophysics experiment in America has demonstrated how fundamental research in one subject area can have a profound effect on work in another as the instruments used for the Laser Interferometer Gravitational-Wave Observatory (LIGO) pave the way for quantum experiments on a macroscopic scale.

The work is reported in a research article published today, Thursday, 16 July, in New Journal of Physics.

LIGO is a huge experiment, funded mainly by the U.S. National Science Foundation and involving more than 600 astrophysicists worldwide, undertaken to detect gravitational waves and thereby help us monitor space through another valuable set of lenses - gravitational radiation.

By measuring tiny motions of test masses caused by passing gravitational waves, LIGO expects to directly detect this radiation, thought to stem from exotic phenomena in space such as the collisions of neutron stars and black holes, and supernovae.

Laser light is used to monitor relative displacements of interferometer mirrors, which are suspended as pendulums to act as quasi-free test masses. Since the effect of gravitational waves is expected to be very small, LIGO detectors are sensitive enough to measure displacements smaller than one-thousandth the size of a proton for mirrors that are 4 km apart.

In different frequency bands, the sensitivity of the LIGO instruments are limited by noise arising from the quantum nature of the laser light, or by thermal noise arising from the thermal energy of the mirrors. Observing quantum mechanical behaviour of the LIGO mirrors requires reducing the thermal noise, which may be achieved by cooling the interferometer mirrors with techniques similar to laser cooling of atoms. However, the temperature must be brought extremely close to absolute zero (0 Kelvin, or about -273 degrees Celsius).

While absolute zero is impossible to achieve, scientists working on LIGO have used both a frictionless damping force and a magnetic restoring force to cool the mirror oscillator to about 1 millionth of a degree above absolute zero. The frictionless damping force removes energy from the mirror while the restoring force increases the frequency of the oscillator in order to avoid disturbances caused by local ground motion.

While the effort to detect gravitational waves is ongoing, the researchers have now used the LIGO apparatus to observe the oscillations of a 2.7 kg pendulum mode at a level close to its quantum ground state. The results suggest that it should be possible for quantum physicists to use the apparatus to observe quantum mechanical behaviour, such as quantum entanglement, at mass scales previously thought impractical.

While there is still work to go in strengthening the laser and reducing excess noise in the detectors, LIGO scientists Thomas Corbitt and Nergis Mavalvala of the Massachusetts Institute of Technology echo the optimism of the research article, which concludes that "the present work, reaching Microkelvin temperatures, provides evidence that interferometric gravitational wave detectors, designed as sensitive probes of general relativity and astrophysical phenomena, can also become sensitive probes of macroscopic quantum mechanics."

More information: The research paper can be found at http://stacks.iop.org/NJP/11/073032.

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