Scientists show quantum systems could flout physics law

June 2 2008

Scientists in the Weizmann Institute's Faculty of Chemistry, together with colleagues in Germany, have made a startling prediction: Simply 'taking the temperature' of certain quantum systems at frequent intervals might cause them to disobey a hard and fast rule of thermodynamics.

Thermodynamics tell us that the interaction between a large heat source (a heat bath) and an ensemble of much smaller systems must bring them – at least on average – progressively closer to thermal equilibrium.

Now Prof. Gershon Kurizki, Dr. Noam Erez and doctoral student Goren Gordon of the Chemical Physics Department, in collaboration with Dr. Mathias Nest of Potsdam University, Germany, have shown that ensembles of quantum systems in thermal contact with a heat bath could present a drastic departure from this allegedly universal trend, a prediction they recently reported in *Nature*.

With complete disregard for this physical rule, the ensemble may, remarkably, heat up even when it is hotter than the bath or cool down when it is colder. The scientists showed that if the energy of these systems is measured repeatedly, both systems and bath will undergo temperature increase or decrease, and this change depends only on the rate of measurement – not on the actual results of these measurements.

How can these effects of quantum measurements be explained? As opposed to classical measurement, which may be completely nonintrusive, measuring quantum systems decouples them from their heat bath. This decoupling, followed by recoupling of the two when measurement ceases, introduces energy (at the expense of the measuring apparatus) into the systems and the bath alike, and thus heats them up. When this happens over a very short time interval, the systems cannot be discriminated from the bath.

For longer time intervals, the systems and bath start exchanging energy as coupled oscillators (analogous to connected springs). This energy exchange will cause the quantum systems to lose energy to the bath, thus lowering the temperature of the ensembles. Depending on whether the measurements are repeated at short or long intervals, it should be possible to heat up or cool down the systems.

The predicted effects may be the key to developing novel heating and cooling schemes for atomic, molecular and solid-state devices. Such schemes might allow ultrafast temperature control by optical measurements performed at an extremely high rate.

Source: Weizmann Institute of Science