How hot is Schrodinger's coffee?

August 14 2018

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A new uncertainty relation, linking the precision with which temperature can be measured and quantum mechanics, has been discovered at the University of Exeter.

If you measure the temperature of your coffee with a standard over-the counter thermometer you may find 90°C give or take 0.5°C. The temperature uncertainty in your reading arises because the mercury level in the thermometer fluctuates a little bit, due to microscopic collisions of the mercury atoms.

Things become more interesting when trying to measure the temperature of small objects, such as nanometer devices or single cells. To obtain precise measurements one needs to use tiny nanoscale thermometers made up of just a few atoms.

The team at Exeter has developed a new theoretical framework that allows the characterisation of small-scale thermometers and establishes their ultimate achievable accuracy. It turns out that under certain circumstances the uncertainty in temperature readings are prone to additional fluctuations, which arise because of quantum effects.

Specifically, tiny thermometers can be in a superposition between different temperatures, e.g. 90.5°C and 89.5°C, just like Schrödinger's cat can be in a superposition between being dead and alive.

This research is published in the leading scientific journal *Nature Communications*.

Harry Miller, first author of the paper and from Exeter's Physics and Astronomy department explains: "In addition to thermal noise that is present when making a temperature measurement, the possibility of being in a superposition means that quantum fluctuations influence of how we observe temperature at the nanoscale".

The discovery establishes a new connection between quantum uncertainty, arising from such superposition states, and the accuracy of temperature measurements. In the future this uncertainty relation will be useful for experimentalists to design optimal nanoscale thermometers that take into account the effects of quantum mechanics.

Dr. Janet Anders, co-author of the paper and a Senior Lecturer at the University of Exeter added: "This finding is an important step for extending thermodynamic concepts and laws to the nanoscale, where our macroscopic assumptions break down".

Energy-temperature uncertainty relation in quantum thermodynamics is published in *Nature Communications*.

More information: H. J. D. Miller et al, Energy-temperature uncertainty relation in quantum thermodynamics, *Nature Communications* (2018). DOI: 10.1038/s41467-018-04536-7

Provided by University of Exeter