Most experiments that claim to show the quantum Zeno paradox fall short, study says

June 5 2013, by Lisa Zyga

(Phys.org) —By their very nature, unstable particles will eventually decay, some faster than others. But according to the quantum Zeno paradox (QZP), an unstable particle that is observed continuously has been said to never decay. Though counterintuitive, this effect has been claimed to show up experimentally in numerous ways. Now in a new study, physicist Peter Toschek at the University of Hamburg in Hamburg, Germany, has argued that most of these experiments do not provide sufficient evidence of the QZP. By identifying the sufficient conditions necessary for proving the QZP, he confirms the validity of the paradox while probing deeper into its origins.

Toschek's paper, "The quantum Zeno paradox: A matter of information," is published in a recent issue of *EPL*.

"The QZP holds for all unstable quantum systems whose transition (or 'decay') is electromagnetically induced," Toschek told *Phys.org*.
.
As he explained, most experiments that have claimed to prove the QZP (or its manifestation, the quantum Zeno effect) rely on measurements of "expectation values," which are group averages that don't provide information on individual objects, in particular on their survival times. Instead, he explains that the outcomes of quantum measurements should represent "eigenvalues," which do provide information on individual quantum objects. He explains that the survival time of a particle can be derived from uninterrupted sequences of the detected eigenvalue of the initial, undecayed state of the quantum system (particle plus radiation

field), provided an individual quantum object is addressed.

For example, in some experiments that use light-irradiated atoms to demonstrate the QZP, a continuous measurement has been approximated by a series of short light pulses irradiating a group of 5,000 unstable atoms. Then the mean decay rate of the atoms has been measured. The results of these experiments show that the mean decay rate decreases when the pulse repetition rate increases, and this finding has been interpreted as evidence of the QZP.

In these experiments, the measurement of the average decay rate of the entire group of atoms generates an expectation value, a classical quantity with a deterministic result—apart from small fluctuations from "projection noise." In contrast, quantum measurements are known to show conditionally random results.

In order to come up with eigenvalues instead of expectation values, Toschek explains that measurements of the decay process should be characterized by individual survival times. Importantly, this condition lies in the definition of the QZP. Further, the effects of each light pulse on the atom should be recorded. In this way, the information on the state of the atom gained by a measurement affects the prediction of the average of results. The results of classical measurements (like those measuring the mean decay rate) are insufficient to demonstrate the QZP because they are indistinguishable from results of other effects, such as spectral line-broadening by radiative saturation of an atomic resonance line.

"So far, wide-spread misconception has claimed the QZP to be the cause of simple phenomena (for example, the 'power broadening' of irradiated atoms), which involve neither quantum measurements nor the Zeno effect (extension of the survival time under measurement)," Toschek said.

While most of the claims for demonstration of the QZP have fallen short of satisfying both the criteria for being "quantum" and "Zeno," a few experiments have met all the requirements and provide sufficient evidence to support the existence of the QZP. So the results of the current paper don't question the validity of the paradox. Rather, they distinguish it from well-understood and unsurprising effects and present an explanation of the paradoxical aspects in terms of the transfer of quantum information.

More information: Peter E. Toschek. "The quantum Zeno paradox: A matter of information." *EPL*, 102 (2013) 20005. DOI: 10.1209/0295-5075/102/20005