Physicists develop model that pushes limits of quantum theory, relativity

August 3 2010

All of the matter in the universe -- everything we see, feel and smell -- has a certain predictable structure, thanks to the tiny electrons spinning around their atomic nuclei in a series of concentric shells or atomic levels. A fundamental tenet of this orderly structure is that no two electrons can occupy the same atomic level (quantum state) at the same time—a principle called the Pauli exclusion principle, which is based on Albert Einstein's theory of relativity and quantum theory.

However, a team of Syracuse University physicists recently developed a new theoretical model to explain how the Pauli exclusion principle can be violated and how, under certain rare conditions, more than one electron can simultaneously occupy the same quantum state.

Their model, published July 26 in *Physical Review Letters* (vol. 105) may help explain how matter behaves at the edges of black holes and contribute to the ongoing scientific quest for a unified theory of quantum gravity. Physical Review Letters is a publication of the prestigious American Physical Society.

"Transitions of electrons from one atomic shell to another that violate the Pauli principle challenge the foundations of physics," says A.P. Balachandran, the J.D. Steele Professor of Physics in SU's College of Arts and Sciences. "For this reason, there is strong experimental interest in looking for such transitions. Until now, there were few viable models able to explain how such transitions can occur. Our theory provides such a model."

Balachandran is the lead author on the paper with Ph.D. candidates Anosh Joseph and Pramod Padmanabhan.

The orderly way in which electrons fill up atomic levels provides stability and structure to matter, as well as dictates the chemical properties of elements on the Periodic Table. Underlying this stability is the ability to pinpoint the location of objects (electrons, protons and neutrons) almost exactly in space and time. The new model posits that at the level where quantum gravity is significant, this picture of space-time continuum breaks down, deeply affecting the rotational symmetry of the atoms and triggering electron transitions (movement from one shell to another) that violate the Pauli principle.

"The Pauli principle is not obeyed in the model we built," Balachandran says. "We then used existing experimental evidence to put limits on when these violations in transitions can occur."

According to the model, violations of the Pauli principle would theoretically occur in nature in a time span that is longer than the age of the universe—or less frequently than once in the proverbial "blue moon."

"Though this effect is small, scientists are using high-precision instruments to try to observe the effect," Balachandran says. "If found, it will profoundly affect the foundations of the current fundamental physical theories. "

"Additionally, chemistry and biology in a world where such violations occur will be dramatically different," adds co-author Padmanabhan.

The fact that the Pauli principle can be violated may also help explain how matter behaves at the edge of black holes, Joseph says: "While we don't know what happens to matter in a black hole, our model may give hints about how matter behaves as atoms collapse from the gravitational pull of black holes."

More information: prl.aps.org/abstract/PRL/v105/i5/e051601

Provided by Syracuse University