In a neutron-rich tin nucleus, electromagnetism can win over the strong force

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The atomic nucleus offers a unique opportunity to study the competition between three of the four fundamental forces known to exist in nature, the strong nuclear interaction, the electromagnetic interaction and the weak nuclear interaction. Only the much weaker gravitational force is irrelevant for the description of nuclear properties. Although in general the decay of an excited nuclear state follows the hierarchy of these forces, there are sometimes exceptions.

In a recent experiment performed at the Radioactive Isotope Beam Factory at RIKEN, an international collaboration with scientists from eleven countries, led by scientists of the Instituto de Estructura de la Materia, CSIC (Spain) and the RIKEN Nishina Center (Japan), made a very surprising observation: High-energy gamma rays—which are mediated by the electromagnetic force—are emitted in the decay of a certain excited nucleus—tin 133, in competition with neutron emission, the decay mode mediated by the strong nuclear force. This is despite the fact that the neutron emission was expected to be orders of magnitude faster since the force is much stronger.

The discovery, published in *Physical Review Letters*, was made using the neutron-rich nucleus 133Sn, which consists of a single neutron coupled to the doubly-magic nucleus 132Sn, a nuclei that is very stable due to its doubly-magic status. The nuclei were produced knocking out a neutron from a slightly heavier nucleus, 134Sn, at relativistic energies. The gamma radiation emitted in the decay of its excited states was detected using the gamma ray spectrometer DALI2.

According to Pieter Doornenbal of the Nishina Center, "This was quite surprising as we would expect neutron emission to be much faster. We believe that the ability of electromagnetic decay to successfully compete with neutron emission is due to to nuclear structure effects, one of the ingredients of Fermi's golden rule describing the probability of a certain decay process to occur."

The RIBF results suggest that structure effects, which are commonly neglected in the evaluation of neutron-emission probabilities in calculations of global beta-decay properties for astrophysical simulations, are much more important than generally assumed, in particular in the region "south-east" of 132Sn, where nuclei are very neutron-rich.

According to Doornenbal, "One of the significances of this finding is that it could help us gain a better understanding of nuclear synthesis of the elements in our Universe—in other words, how our Universe came to have the nuclei that it does. Nearly half the heavy elements beyond iron are believed to be made by what is known as the r process, which takes place in supernovae. Neutron emission is usually emitted from calculations on the decay of neutron-rich nuclei, because it is not considered to play an important role. But our work shows that this may need to be reconsidered, and that our understanding of how nuclei are produced by the r process may need to be revised."

More information: V. Vaquero et al. Gamma Decay of Unbound Neutron-Hole States in, *Physical Review Letters* (2017). DOI: 10.1103/PhysRevLett.118.202502

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