Longstanding mystery of matter and antimatter may be solved

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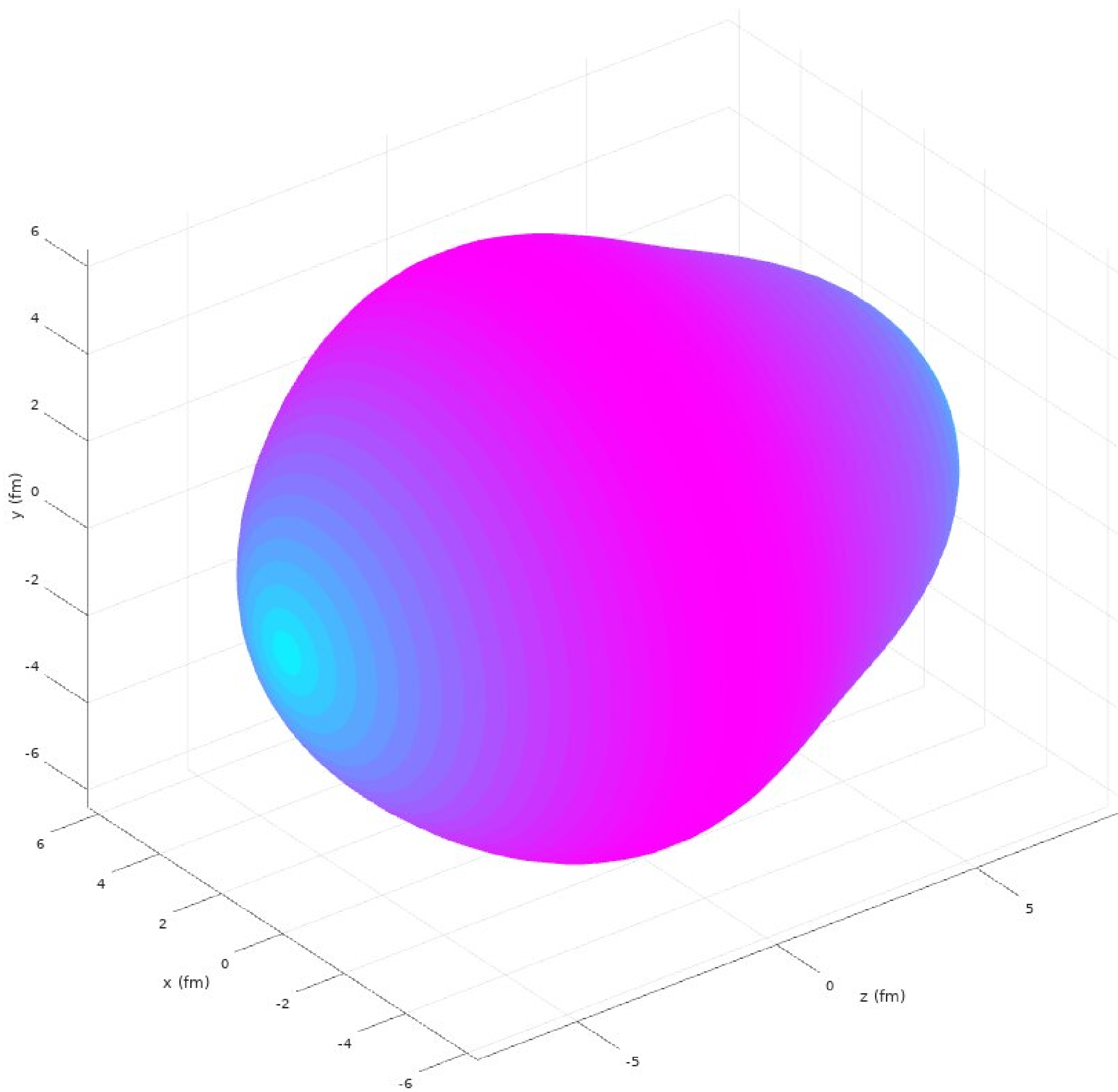

Thorium-228. Credit: University of the West of Scotland

An element which could hold the key to the long-standing mystery around why there is much more matter than antimatter in our Universe has been discovered by a University of the West of Scotland (UWS)-led team of physicists.

The UWS and University of Strathclyde academics have discovered, in research published in the journal *Nature Physics*, that one of the isotopes of the element thorium possesses the most pear-shaped nucleus yet to be discovered. Nuclei similar to thorium-228 may now be able to be used to perform new tests to try find the answer to the mystery surrounding matter and antimatter.

UWS's Dr. David O'Donnell, who led the project, said: "Our research shows that, with good ideas, world-leading nuclear physics experiments can be performed in university laboratories.

"This work augments the experiments which nuclear physicists at UWS are leading at large experimental facilities around the world. Being able to perform experiments like this one provides excellent training for our students."

Physics explains that the Universe is composed of fundamental particles such as the electrons which are found in every atom. The Standard Model, the best theory physicists have to describe the sub-atomic properties of all the matter in the Universe, predicts that each fundamental particle can have a similar antiparticle. Collectively the antiparticles, which are almost identical to their matter counterparts except they carry opposite charge, are known as antimatter.

According to the Standard Model, matter and antimatter should have been created in equal quantities at the time of the Big Bang—yet our

Universe is made almost entirely of matter.

In theory, an electric dipole moment (EDM) could allow matter and antimatter to decay at different rates, providing an explanation for the asymmetry in matter and antimatter in our universe.

Pear-shaped nuclei have been proposed as ideal physical systems in which to look for the existence of an EDM in a fundamental particle such as an electron. The pear shape means that the nucleus generates an EDM by having the protons and neutrons distributed non-uniformly throughout the nuclear volume.

Through experiments conducted in laboratories at UWS's Paisley Campus, researchers have found that the nuclei in thorium-228 atoms have the most pronounced pear shape to be discovered so far. As a result, nuclei like thorium-228 have been identified as ideal candidates to search for the existence of an EDM.

The research team was made up of Dr. O'Donnell, Dr. Michael Bowry, Dr. Bondili Sreenivasa Nara Singh, Professor Marcus Scheck, Professor John F Smith and Dr. Pietro Spagnoletti from UWS's School of Computing, Engineering and Physical Sciences; and the University of Strathclyde's Professor Dino Jaroszynski, and Ph.D. students Majid Chishti and Giorgio Battaglia.

Professor Dino Jaroszynski, Director of the Scottish Centre for the Application of Plasma-based Accelerators (SCAPA) at the University of Strathclyde, said: "This collaborative effort, which draws on the expertise of a diverse group of scientists, is an excellent example of how working together can lead to a major breakthrough. It highlights the collaborative spirit within the Scottish physics community fostered by the Scottish University Physics Alliance (SUPA) and lays the groundwork for our collaborative experiments at SCAPA."

The experiments began with a sample of thorium-232, which has a half-life of 14 billion years, meaning it decays very slowly. The decay chain of this nucleus creates excited quantum mechanical states of the nucleus thorium-228. Such states decay within nanoseconds of being created, by emitting gamma rays.

Dr. O'Donnell and his team used highly sensitive state-of-the-art scintillator detectors to detect these ultra-rare and fast decays. With careful configuration of detectors and signal-processing electronics, the research team have been able to precisely measure the lifetime of the excited quantum states, with an accuracy of two trillionths of a second. The shorter the lifetime of the quantum state the more pronounced the pear shape of the thorium-228 nucleus—giving researchers a better chance of finding an EDM.

More information: M. M. R. Chishti et al. Direct measurement of the intrinsic electric dipole moment in pear-shaped thorium-228, *Nature Physics* (2020). DOI: 10.1038/s41567-020-0899-4

Provided by University of the West of Scotland