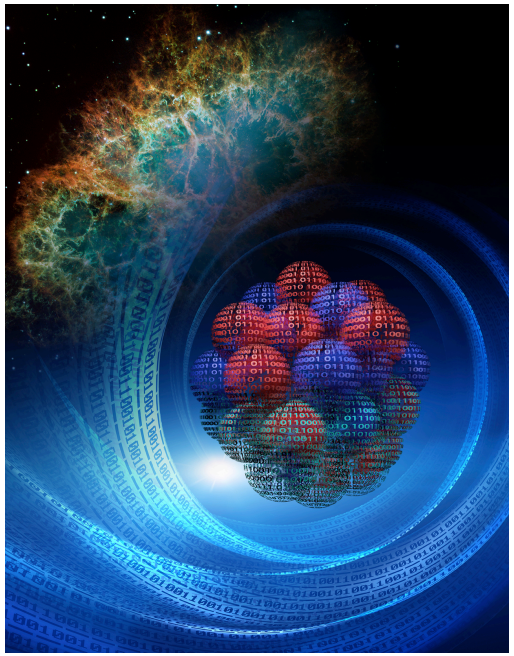
Computing the size of the atomic nucleus calcium-48

Objectives

- Determine the size of the atomic nucleus calcium-48. For the nucleus calcium-48, which consists of 20 protons and 28 neutrons, the neutron distribution extends beyond the proton distribution and thereby sets the actual size of the nucleus
- Ab-initio computation of the neutron and weak-charge distributions of ^{48}Ca based on state-of-the-art optimized chiral effective interactions
- Provide a constraint on the radius of a neutron star
- Provide a critical bridge between state-of-the-art *ab initio* calculations and calculations based on nuclear density functional theory (DFT)

Impact

- Neutron radius will be measured by the CREX (Calcium-Radius EXperiment) at Jefferson Laboratory, and the dipole polarizability is presently being analyzed by the Darmstadt-Osaka collaboration
- The size of the atomic nucleus ^{48}Ca impacts the size of a neutron star
- Knowledge of the neutron skin of atomic nuclei so far mostly based on nuclear DFT
- The atomic nucleus calcium-48 provides a meeting point for ab-initio computations and calculations based on nuclear DFT



Caption: Image connects the first-principles computation of the calcium-48 nucleus with the neutron star at the center of the Crab Nebula. Understanding the neutron distribution of an atomic nucleus allows researchers to constrain the size of a neutron star. These objects differ in size by 18 orders of magnitude.

Image credit: Oak Ridge National Laboratory, U.S. Dept. of Energy; conceptual art by LeJean Hardin and Andy Sproles

Accomplishments

- Computed the size of atomic nucleus ^{48}Ca from first principles
- Extended the reach of reliable ab initio computations to medium-mass nuclei
- Revealed that the neutron skin of calcium-48 is significantly thinner than previously thought, while the related dipole polarizability is consistent with calculations based on nuclear DFT
- Found neutron skin to be independent of the employed chiral effective interactions between the constituent nucleons—protons and neutrons

U.S. DEPARTMENT OF ENERGY | Office of Science

NUCLEI Nuclear Computational Low-Energy Initiative

Reference: G. Hagen *et al.,* Nature Physics (2015), doi:10.1038/nphys3529

Contact: G. Hagen, hageng@ornl.gov