What Neutron Stars are Made of

Andrew Steiner wins the department's fourth NSF CAREER grant in five years

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When massive stars die, some leave descendants that are extremely cold and dense. Assistant Professor Andrew W. Steiner's interest in getting to the core—literally—of these objects has earned him a CAREER Grant from the National Science Foundation: the fourth for UT Physics in five years.

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When a star with a mass eight to 20 times that of the sun explodes in a core-collapse supernova, it leaves behind a neutron star with the mass of the sun and a 15-mile diameter. These stars are an excellent lab for astrophysicists because their cores are subject to a powerful gravitational force: one that compresses matter to densities a *thousand trillion times* that of water. Scientists like Steiner want to know if that pressure forces the core's resident neutrons and protons to transform into exotic particles. They also study neutron stars to understand the broader nature of ultra-dense matter.

"On the astronomy side this is important because it really dictates how neutron stars evolve," Steiner said. "It's hard to say what they're going to do if you don't know what they're made of. On the nuclear physics side this is important because very dense, very cold matter is almost impossible to produce in the laboratory."

To explore these questions, Steiner will combine existing models of strongly-interacting matter with new calculations of nuclear structure. From there, he and his students and postdoc will construct state-of-the-art computational models of the neutron star crust and core. They will then calibrate those models with nuclear data and compare them to neutron star cooling, mass, and radius observations.

Steiner explained that some of this nuclear data is currently available, but more is expected from increasingly sophisticated sources such as NASA's Neutron star Interior Composition Explorer (NICER). SpaceX will launch this payload to the International Space Station in early 2017 to study neutron stars through soft X-ray timing. In another five years or so, the Facility for Rare Isotope Beams (FRIB) at Michigan State will provide intense beams of rare isotopes for nuclear studies.

Steiner said that models of the neutron crust and core are continually being developed and he hopes "to be on sort of the cutting edge of those."

The real goal, he added, is to learn the composition of neutron stars.

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Students will have the opportunity to be part of that quest, through both the research itself and expanded educational components including a Studio Physics course and a web-based visualization of neutron stars. The $425,000 grant, titled “The Composition of Dense Matter and Observations of Neutron Stars,” begins July 1 and is estimated to conclude June 30, 2021.

The Faculty Early Career Development (CAREER) Program offers the National Science Foundation's most prestigious awards in support of junior faculty who exemplify the role of teacher-scholars through outstanding research, excellent education, and the integration of education and research within the context of the mission of their organizations. Steiner is the latest of the physics faculty at Tennessee to win the honor. Norman Mannella (2012), Jaan Mannik (2013), and Haidong Zhou (2014) are all CAREER award recipients.

Steiner said UT’s Physics Department has been very successful in hiring good faculty, and “one of the ways you can tell is because we have so many of our young faculty with these kinds of awards.”

As Department Head Hanno Weitering said, “Indeed, this is a very exciting time for the department. We have recruited eight assistant and two full professors in the past five years, in addition to several full time lecturers and staff personnel. Young people like Andrew bring lots of energy and new ideas to the department, which not only boosts our research enterprise, but also reshapes the way we teach and advise our students. The remarkable success rate in winning these highly prestigious CAREER awards has not gone unnoticed with the College and UT’s central administration and bodes well for the future of the department.”

Steiner earned a Ph.D. from the State University of New York at Stony Brook in 2002. Prior to joining the UT faculty in January 2015, he held postdoctoral positions at the University of Minnesota, Los Alamos National Laboratory, and Michigan State University and was a Research Assistant Professor at the University of Washington Institute for Nuclear Theory.

More information online:

- **Andrew W. Steiner’s NSF CAREER Grant (http://www.nsf.gov/awardsearch/showAward?AWD_ID=1554876)**
- **Dr. Steiner’s Website (http://web.utk.edu/~asteine1/)**