# The first cutting-edge simulation of the warm dense electron gas

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An international team of scientists from Los Alamos National Laboratory, Imperial College London (IC), and Kiel University (CAU), headed by Professor Michael Bonitz of the Institute of Theoretical Physics and Astrophysics at CAU and Professor Matthew Foulkes of the Department of Physics at IC, has achieved a major breakthrough in the description of warm dense matter – one of the most active frontiers in plasma physics and material science. This exotic state of matter is characterized by the simultaneous presence of strong quantum effects, thermal excitations, and strong interaction effects, and differs completely from the usual solid, liquid, gas and plasma states commonly found on Earth. A full understanding of the interplay of these three effects has been lacking until now. The tri-national team of scientists published their research findings in the current edition of *Physical Review Letters*.

With its temperature from ten to ten thousand times room temperature and its density anywhere between one and a few thousand times warm dense matter is completely different from normal solids you can find on earth. These extreme conditions exist within astrophysical objects such as planet cores and white dwarf atmospheres. "An improved understanding of warm dense matter will be the key to answering fundamental questions in astrophysics. For example, it will help to determine the age of galaxies", explains Bonitz.

It is now possible to create warm dense matter routinely in the lab by exciting solids with powerful lasers. The warm dense conditions last for only a few microseconds, but this is long enough to allow measurements to be made and the new data has sparked an explosion of activity in the field. In particular, researchers need to overcome the challenges arising from this extreme state of matter in order to master inertial confinement fusion, which is considered the most promising source of energy in the future.

Until now, a theoretical description of warm dense matter has required crude approximations of the underlying physics. Exact simulation methods have been developed, but they were restricted to small model systems containing only a few particles in a limited parameter range. The research teams around Bonitz and Foulkes overcame these obstacles by using three complementary simulation techniques recently developed in Kiel and London, in combination with a novel approach to remove the errors that arise from the limited size of the systems simulated. This allowed them to obtain the first accurate thermodynamic results for the electron component in warm dense matter. Their simulations required an enormous amount of computer resources and would have taken about 200 years if carried out on a single desktop computer.

"Our results will constitute the basis of future warm dense matter research", says Bonitz.

**More information:** Tobias Dornheim et al. Quantum Monte Carlo Simulation of the Warm Dense Electron Gas in the Thermodynamic Limit, *Physical Review Letters* (2016). DOI: 10.1103/PhysRevLett.117.156403

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