Scientists help define structure of exoplanets

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Using models similar to those used in weapons research, scientists may soon know more about exoplanets, those objects beyond the realm of our solar system.

In a new study, Lawrence Livermore National Laboratory scientists and collaborators came up with new methods for deriving and testing the equation of state (EOS) of matter in exoplanets and figured out the mass-radius and mass-pressure relations for materials relevant to planetary interiors.

Astronomers started detecting exoplanets 18 years ago and more than 700 have been found so far, the vast majority within the last two years. Interest is now growing in the structure and atmospheres of these worlds.

New equation-of-state work helps interpret the structure of exoplanets. As there is a minimal amount of data in each exoplanet observation, interpretation of their composition and structure depends largely on comparing their mass and radius with the composition expected given the distance from their parent star. The makeup implies a mass-radius relation, which relies heavily on EOS calculated from electronic structure theory and measured experimentally on Earth.

In the new research, lead Laboratory scientist Damian Swift, along with LLNL colleagues Jon Eggert, Damien Hicks, Sebastien Hamel, Kyle Caspersen, Eric Schwegler and Rip Collins, compared their modeling results with the observed masses and radii of exoplanets. Their results broadly support recent assumptions about the structures of exoplanets but can now take advantage of the accurate EOS models and data produced at Livermore.

"Current theoretical techniques for calculating electronic structures can predict EOS relevant to planetary interiors," Swift said. "But we still need experimental validation of these calculations; something that can now be done at the National Ignition Facility (NIF)."

LLNL's National Ignition Facility is the world's largest laser designed to perform research on national security, fusion experimentation and basic science, such as astrophysics.

The team made specific predictions for notable exoplanets having earth-like, rocky, icy compositions, with planetary center pressures ranging from 8 to 19,000 Mbar (8 million to 1.9 billion atmospheres of pressure).

"We have a project to measure material properties up to billions of atmospheres on NIF. We will eventually exceed the highest pressures investigated in the very small number of previous experiments using underground nuclear tests, which reached far above pressures that can be explored with other techniques currently available," Swift said.

Placing constraints on the structure of exoplanets requires accurate information about the compressibility of relevant compositions of matter, including iron alloys, silicates, and ices, under extreme conditions of pressure and temperature.

"This sets the record straight and presents a survey of exoplanet structure information using material properties generated for, and validated using, experimental capabilities at the national labs," Swift said.

More information: The research recently appeared in *The*

Astrophysical Journal (*APJ*, 744:59, 2012).

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