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IRON UNDER EXTREME CONDITIONS

Journey to the core of the Earth

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The composition of the Earth's core is not exactly known. Its precise determination is hindered by the complexity of the experiments that could probe it. New measurements of the properties of liquid iron under temperatures and pressures close to those at the Earth's core — 116 GPa and 4350 K — reported by Yasuhiro Kuwayama, Yoichi Nakajima, Kei Hirose and colleagues in *Physical Review Letters* shed new light on this matter.

Iron is the main element in the Earth's core, but we know it's not the only one. "The determination of the composition of the Earth's core is one of the most important topics in Earth science since Francis Birch proposed that it may be lighter than pure iron in 1952," notes Kuwayama. The properties of the core that can be directly probed are the density and longitudinal sound velocity, which are derived from seismic data. Comparing these values with those for pure iron under similar conditions is key to determining the core's composition and behaviour.

Credit: Kei Hirose, the University of Tokyo

However, the determination of the density of liquid iron at extreme temperatures and pressures is challenging. First, it requires the maintenance of high pressure and high temperature simultaneously, for sufficient time for the measurements to be taken. Second, determining the density of a disordered material under extreme conditions is far from trivial as the existing analytical methods have high uncertainty. Third, the measurements require a very brilliant and focused X-ray beam.

"To measure liquid samples, which produce a weaker signal than solid samples, over the past two decades we have developed a very brilliant and highly focused X-ray source at the SPring-8 synchrotron light source in Japan, optimized for high-pressure experiments," explains Kuwayama. The researchers used static compression in a laser-heated diamond anvil cell for the experiments and introduced a new method to analyse diffuse X-ray scattering in a liquid to extract the density of the iron from the data. This allowed them to determine that the Earth's outer core is ~8% less dense than pure iron.

"Our results also show that oxygen concentration in the outer core is less than 3.8 wt%," adds Kuwayama. "It has been repeatedly suggested that oxygen is a main core light element, but these results indicate that the core includes other impurity elements." The amount and species of impurities determine the physical properties of the core, such as viscosity and thermal and electrical conductivity, and can provide information on the origin and evolution of the Earth.

This new analytic procedure to extract the density of a liquid from its X-ray scattering signal can be used for any material, opening up new research directions. "The technical and analytical techniques we developed for liquid materials are applicable also to melted rocks, magmas," concludes Kuwayama. "We are now planning to apply these techniques to the study of melted rocks to understand the nature of magmas in the deep Earth."

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