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Inside Neptune with laser shock compression: melting of silica and properties of metallic and superionic water

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Dynamic compression experiments now allow us to recreate planetary interior conditions in the laboratory, providing valuable data on material properties at unprecedented conditions. These data are of paramount importance to build confidence in numerical simulation methods and establish new planetary structure and evolution models. We will present new results on the optical properties and equation of state (pressure, density, temperature) of warm dense water and silica at extreme conditions of pressure and temperature directly relevant to the deep interiors of Uranus, Neptune and giant exoplanets. Laser shock compression of water starting from ice VII (ρ_0=1.6 g/cc) obtained by coupling static and dynamic compression reached 3.6g/cc at 3 Mbar. We obtained evidence for the transition to the superionic phase near 1 Mbar and to the dense metallic liquid at 2 Mbar . The optical properties of water were determined in the whole pressure range under investigation. The EOS data in the conducting liquid state provide a stringent test on recent ab-initio simulations. As superionic ices could dominate the deep interior or giant icy planets and exoplanets, the new conductivity and equation of state experimental benchmark provide basis for improved modeling of the internal structure and magnetic field generation. In addition, the new data on warm dense silica along the Hugoniot of fused silica, quartz and stishovite document the melting line to 5 Mbar and show that silica is likely solid in the core of Uranus and Neptune but could contribute to magnetic field generation in large rocky super-Earth [1]. Prepared by LLNL under Contract DE-AC52-07NA27344.

[1] Millot et al., Shock compression of stishovite and melting of silica at planetary interior conditions, Science, 347, 418-420 (2015). DOI:10.1126/science.1261507