Goldschmidt 2024 Abstract
https://doi.org/10.46427/gold2024.22420

Mineralogy of Large Terrestrial Exoplanets

THOMAS DUFFY

Princeton University

Presenting Author: duffy@princeton.edu

Large rocky exoplanets up to ~10 times the mass of the Earth are a novel type of planet not represented in our solar system. The pressure at the core-mantle boundary of such planets can be as high as 1.3 terapascals, an order of magnitude larger than found at Earth's core-mantle boundary. The interior mineralogy and phase transitions of a planet can strongly influence its dynamic behavior, heat flow, and thermal evolution. Theoretical studies have predicted phase transitions and new crystal structures for silicates and oxides at the pressures of the deep interior of rocky exoplanets. However, the predicted pressures of these transitions are often beyond the limits of static high-pressure devices such as diamond anvil cells.

There are two ways around this limitation. The first involves the use of analog materials such as germanates and fluorides which may undergo similar phase transitions as silicates, but at substantially lower pressures. Our experiments on Mg_2GeO_4 in the laser heated diamond cell up to ~200 GPa have revealed the formation of the Th_3P_4-type phase as predicted by theory. This is the first known phase in which Ge is in 8-fold coordination with oxygen.

The second approach uses laser-based dynamic compression techniques at national user facilities which can reach up to TPa pressures with compression timescales of order 10-30 nanoseconds. Atomic-level structural information can be obtained from nanosecond pulsed X-ray diffraction while the sample is at peak compression. Using this method, we have determined high-pressure phases in a range of materials relevant to exoplanetary mantles including Mg_2SiO_4, (Mg,Fe)O, Fe_3O_4, Fe_2O_3, and GeO_2. Using this new data, we have constructed models for the interior mineralogy of exoplanets for different Mg/Si contents. Overall, this work expands understanding of ultra-high-pressure phase transitions, providing a test of theoretical calculations and yielding an improved basis for modeling the structure, dynamics, and evolution of exoplanetary interiors.