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High-pressure dynamic compression experiments for planetary science

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The study of planetary interiors is a key to provide a unified framework about planets' formation, evolution and structure. Today this purpose acquires new significance because of the active discovery of extrasolar planets. Planets of our Solar System are thus studied for both their specific interest and their role as better-known prototypes for classification and modelling of exoplanets. A major issue for this kind of study is represented by the substantial impossibility to directly probe the planets interiors. While the internal structure of our Earth can be inferred by means of analysis of seismic waves, for the other solar planets probing is limited to the surface (Mars) or even to a fly-by in the upper atmosphere (giant planets). In the last case, the only data in our possession are measurements of mass, magnetic and gravitational field, luminosity, radii etc. Therefore, a model is needed to couple these observables in a self-consistent way with the interior structure and dynamics. In this context, an accurate modelling requires a precise knowledge of structural and transport properties of some key materials (e.g. iron and silicates for the Earth or water, ammonia, methane mixtures for icy giants). Exemplary essential inputs are equation-of-states, phase transitions, electrical and thermal conductivities, etc. These properties at regimes typical of planetary interiors (few Mbar, few 1000 K) can today be measured in long pulse (ns) laser driven shock experiments [1-3 as examples]. While up to recently this research was lacking a pertinent microscopic probe, the advent of extremely brilliant and temporally short x-ray sources from XFEL has opened new exciting perspectives [4]. Typically, it allows high-quality in-situ x-ray diffraction (XRD) measurements, which promoted the investigation of phase transitions at high pressures. Obtaining XRD measurement on shocked samples also contributes to shed light into the kinetics of phase transitions at the nanosecond temporal scales, which is useful for understanding kinetic aspects and meteoritical impacts. In addition, the occurrence of metastable states along the shock path as a function of the duration of peak conditions is a major issue for better understanding the general relevance of dynamic compression studies for geophysics and planetology [5]. In this talk we will present recent results we obtained on the characterization of key materials for planetary science such as silicates, water, ammonia and CHNO mixtures using both optical and XRD techniques.

References

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