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Ultra-fast structural dynamics in materials at extreme conditions

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Planetary science is witnessing a revolution with the discovery of hundreds of extra-solar planets orbiting nearby stars [1]. Characterising such astrophysical objects requires the knowledge of physical properties of their main constituents at multi-Mbar pressures and few-eV temperatures (1 eV = 10 605 K). The precondition is the establishment of phase diagrams of these materials, in order to identify and characterize structural changes, phase transitions, metallization, and dissociation processes. Physical and chemical changes induced by the application of high pressures and temperatures can occur in a wide range of different time scales, thus capturing their nature and underlying mechanisms requires the use of adapted tools, capable to catch happening phenomena in static and dynamic regimes. Also, it was shown that materials structural response to pressure increase might be different under static or dynamic compression loads i.e. [2].
Since the opening in 2019, HED Instrument at the European XFEL has persistently upgraded and today offers standard platforms for static and dynamic compression studies, at timescales spreading between minutes and seconds to micro- or nanoseconds. X-ray diffraction and emission spectroscopy are routinely coupled to diamond anvil cells (static and dynamic, dDAC) in a different range of sample environments. Relevant studies comprehend the synthesis of metastable iron hydrides, phase diagram of water, dynamic compression of high-Z compressible gases like Krypton, the spin states and electronic transitions in iron sulfates, carbonates, and melts and many more. Shock-compression will be also available by the end of 2022 and will be coupled initially to x-ray diffraction and large area detectors. The presentation will focus on our most recent and interesting results. An outlook towards the future will elucidate ongoing projects and expected outcome.

[1] Mayor, M. and Queloz, D. A Jupiter-mass companion to a solar-type star. Nature 1995, 378, 355–9.
[2] Pépin, C. M. et al. Kinetics and structural changes in dynamically compressed bismuth. Phys. Rev. B 2019, 100, 060101

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