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Advances in synchrotron-based methods of Mössbauer spectroscopy

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Mössbauer spectroscopy has traditionally been considered the ideal tool to study valence and spin properties of iron and its compounds; however measurements directed at understanding the Earth's interior should be conducted in situ at the relevant conditions of pressure and temperature because spin and valence transitions are generally reversible. The diamond anvil cell provides the means to reach the extreme pressure and temperature conditions of the Earth's interior; however the use of conventional Mössbauer spectroscopy (employing a radioactive source) is restricted by the impracticality of focusing gamma radiation in the laboratory, resulting in long measuring times and poor signal to noise ratios. Nuclear resonance scattering methods have overcome these limitations, and measuring times are sufficiently short that data can also be collected at high temperature in the diamond anvil cell using laser heating. Nuclear inelastic scattering (NIS) enables the determination of elastic wave velocities of relevant iron-containing minerals through direct determination of the partial density of states, and values obtained from measurements in the laser-heated diamond anvil cell can be directly compared with geophysical data obtained from seismology. Nuclear forward scattering (NFS) provides a means to determine hyperfine interactions in iron-containing minerals and their sensitivity to extreme conditions of pressure and temperature, and is particularly useful for identifying electronic structure changes in phases with relatively simple hyperfine interactions. For multiple hyperfine interactions such as found in the Earth's most abundant phase, silicate perovskite, synchrotron Mössbauer source (SMS) measurements enable a nearly unambiguous determination of individual hyperfine interactions, providing critical constraints for the interpretation of valence and spin state changes in iron-containing phases within the Earth's interior. The presentation will showcase recent results obtained from nuclear resonance experiments at ESRF to cutting-edge problems in geophysics.