## Advanced spectroscopic studies of C-H bond activating enzymes and molecular catalysts

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The ability to activate and functionalize C-H bonds in controlled and sustainable fashion remains one of the holy grails of chemistry. It is here that nature provides much inspiration, with enzymes such as methane monooxygenases enabling the direct and selective oxidation of methane to methanol - utilizing either a copper active site in the particulate form or a dinuclear iron site in the soluble form of the enzyme. Our understanding of the nature of these active sites and their mechanisms has greatly benefited from spectroscopic developments. In the present talk, I will present our groups recent spectroscopic studies on methane monooxygenases. In addition, 2p3d resonant inelastic X-ray scattering (RIXS) spectroscopic development efforts focused on high-valent iron oxo model complexes will be presented. These RIXS studies provide a unique experimental probe of two-state reactivity, enabling the previously elusive spin forbidden triplet to quintet transitions to be experimentally observed and correlated directly to reactivity. Finally, our recent time-resolved X-ray pump-probe studies of Fe(IV)-oxo complexes will be discussed.