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Nuclear Magnetic Resonance in Correlated Quantum Materials: from Frustrated Magnets to Plutonium

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In condensed matter physics, designing and understanding quantum materials has been the key to searching for emergent behavior and phases of matter and opening a pathway to use them for energy relevant technologies [1]. In the context of correlated quantum materials often hosting 4f and 5f electrons [2,3], a variety of intriguing physical phenomena appear and attract great attention due to an interplay of the interaction between electrons and a competition between their itinerant and localized nature [4]. In this talk, we will highlight our recent advances in the microscopic understanding of quantum materials primarily based on lanthanide (4f) and actinide (5f) elements using nuclear magnetic resonance (NMR) and quadrupole resonance (NQR) spectroscopy combined with other characterization techniques.
First, we will focus on a few lanthanide materials that have either geometrical frustrations (such as in triangular and kagome lattices) or a dimensional reduction and show a hybridization of 4f-electron moments with conduction electrons [5,6]. Ligand site NMR/NQR will be used to probe the magnetic Ce/Yb ions through (transferred) hyperfine couplings at the ligand sites. Examples will be given as to how NMR can be used to unveil important quantities, ranging from energy scales of hybridization and spin fluctuations to order parameter. Then, we will move to other systems of interest in actinide materials, particularly focusing on plutonium-based materials [4]. Direct actinide (239Pu) NMR as well as ligand site (11B, 13C) NMR are performed in some representative systems, such as insulating PuO2 [7] and PuB4 [8,9] or metallic Pu2C3 [10]. We will show how these techniques can provide unique insight into the electronic and structural details of Pu materials, including electronic correlations and cryogenic accumulation of self-irradiation damage as well as its partial healing by annealing.

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