Quantum Spin Nematic Phase in a Square-lattice Iridate

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Spin nematic (SN) is a magnetic analog of classical liquid crystals, a fourth state of matter exhibiting characteristics of both liquid and solid [1, 2]. Particularly intriguing is a valence-bond SN, in which spins are quantum entangled to form a multi-polar order without breaking time-reversal symmetry, but its unambiguous experimental realization remains elusive. In this talk, I will discuss on our recent discovery of a SN phase in the square-lattice iridate Sr_2IrO_4, which approximately realizes a pseudospin one-half Heisenberg antiferromagnet (AF) in the strong spin-orbit coupling limit [3]. Upon cooling, the transition into the SN phase at T_C~263 K is marked by a divergence in the static spin quadrupole susceptibility extracted from our Raman spectra, and concomitant emergence of a collective mode associated with the spontaneous breaking of rotational symmetries. The quadrupolar order persists in the antiferromagnetic (AF) phase below T_N~230 K, and becomes directly observable through its interference with the AF order in resonant x-ray diffraction, which allows us to uniquely determine its spatial structure. Further, we find using resonant inelastic x-ray scattering a complete breakdown of coherent magnon excitations at short-wavelength scales, suggesting a resonating-valence-bond-like quantum entanglement in the AF state. Taken together, our results reveal a quantum order underlying the Neel AF that is widely believed to be intimately connected to the mechanism of high temperature superconductivity [4].

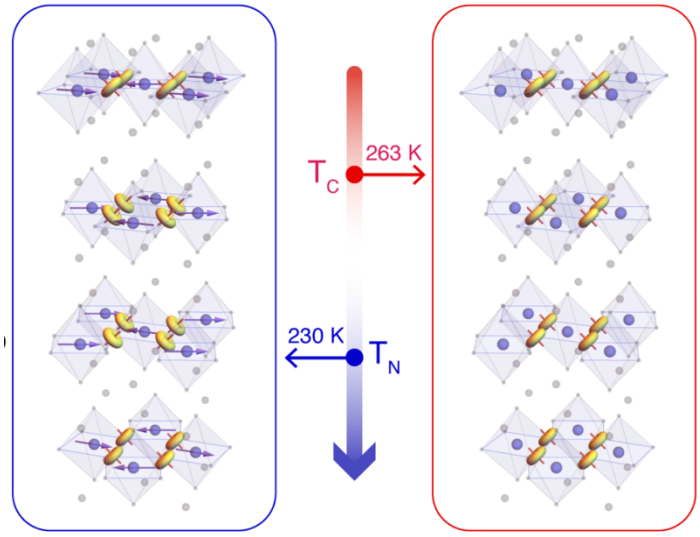

Figure 1**:** A schematic of the Neel AF and SN orders overlaid on the crystal structure of Sr_2IrO_4.

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3. J. Bertinshaw, Y. K. Kim, G. Khaliullin, and B. J. Kim, Annu. Rev. Condens. Matter Phys. 10, 315–336 (2019).
4. H. Kim et al., Nature (in press).