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Spin Group Theory and Unconventional Magnetism

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The physical properties in magnetic-ordered materials were ultimately believed to rely on the symmetry theory of magnetic groups. Recently, it has come to light that a more comprehensive group, known as spin group, which combines separate spin and spatial operations, is necessary to fully characterize the geometry and underlying properties of magnetic-ordered materials such as altermagnets. In this talk, we introduce recent developments in spin group theory, including an extensive enumeration of over 100000 spin space groups (SSGs) and their irreducible co-representations in momentum space, leading to more energy degeneracies that are disallowed by magnetic groups [1,2]. We further present the applications of spin groups in several aspects: (i) Based on whether the net spin magnetization is constrained to zero by SSG, we establish a stringent classification of the ferromagnetism-antiferromagnetism dichotomy and introduce an oriented SSG description that unifies the SSG and magnetic space group frameworks to reveal the symmetry-breaking pathway induced by spin-orbit coupling [3]. (ii) We propose a SSG-guided framework that systematically generates realistic magnetic configurations without requiring any experimental input, providing an efficient strategy for large-scale prediction [4]. (iii) Spin group theory triggers the emergence of “unconventional magnets”, which simultaneously exhibit antiferromagnetic configurations while displaying properties reminiscent of ferromagnets. [5,6] We also introduce a homemade online program, FINDSPINGROUP (https://findspingroup.com/) [7], which is applied to diagnose the symmetry classification of magnetic materials and related properties.

References:

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