

Interplay between Relativistic Spin-Momentum Locking and Breaking of Inversion Symmetry

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We investigate the interplay between relativistic spin-momentum locking¹ arising from altermagnetism and various forms of inversion symmetry breaking. Depending on the specific symmetry breaking, this can give rise to Rashba-type spin-orbit coupling, Weyl-type spin-orbit coupling, or the coexistence of two distinct spin-momentum lockings. We focus on the altermagnetic Ca_2RuO_4 as a testbed material. Our results reproduce the experimentally observed ground state, which is an A-centered magnetic order with the Néel vector aligned along the b -axis, hosting spin cantings along the a - and c -axes but without weak ferromagnetism. Ca_2RuO_4 exhibits relativistic spin-momentum locking, with different even-parity wave orders for each of the three spin components. Under ferroelectric- and antiferroelectric-like distortions, there are no qualitative changes in the symmetries of the non-relativistic spin-momentum locking and in the weak ferromagnetism. However, we observe the rise of Rashba- or Weyl-type spin-orbit coupling; both types preserve the vanishing magnetization. Using numerical and analytical models, we investigate which nodal planes persist when inversion symmetry is broken in the relativistic case. We find that, in general, the spin-momentum locking of the spin component parallel to the electric field survives in the presence of Rashba coupling. The spin-momentum lockings of the other components adopt a p -wave character in the Rashba case. In contrast, Weyl-type spin-orbit coupling disrupts all nodal planes, leaving only nodal lines. Finally, to simulate stripe phases, we investigate a modulated electric field introducing atomic shifts on a single layer of the Ca_2RuO_4 unit cell. This produces a magnetic phase transition to an exotic altermagnetic state with two non-relativistic spin-momentum lockings hosting weak ferromagnetism. Our results provide a comprehensive analysis of altermagnets with broken inversion symmetry under relativistic effects².

References:

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- [2] A. Fakhredine, G. Cuono, J. Skolimowski, S. Picozzi, and C. Autieri. In manuscript