Non-relativistic spin splitting above and below the Fermi level in a g-wave altermagnet

Nicholas Dale[1,2], Omar A. Ashour[1,2,3], Marc Vila[1,2], Resham B. Regmi[5,6], Justin Fox[1,2,4], Cameron W. Johnson[2], Alexei Fedorov[7], Alexander Stibor[2], Nirmal J. Ghimire[5,6], and Sinéad M. Griffin[1,2]

[1]*Materials Sciences Division, Lawrence Berkeley National Lab, 1 Cyclotron Road, Berkeley, CA 94720, USA*
[2]*Molecular Foundry, Lawrence Berkeley National Lab, 1 Cyclotron Road, Berkeley, CA 94720, USA*
[3]*Department of Physics, University of California, Berkeley, CA 94720, USA*
[4]*Department of Physics, Carnegie Mellon University, Pittsburgh, PA 15213, USA*
[5]*Department of Physics and Astronomy, University of Notre Dame, Notre Dame, IN 46556, USA*
[6]*Stravropoulos Center for Complex Quantum Matter, University of Notre Dame, Notre Dame, IN 46556, USA*
[7]*Advanced Light Source, Lawrence Berkeley National Lab, 1 Cyclotron Road, Berkeley, CA 94720, USA*

Nonrelativistic spin splitting (NRSS) challenges conventional wisdom about antiferromagnets by allowing spin-split electronic bands even in collinear orders with zero net magnetization. This sub-class of antiferromagnets, recently dubbed "altermagnets," enforces distinctive spin textures via spin-group symmetries in the crystal. However, direct experimental evidence for such symmetry-driven magnetism remains scarce. Here, we combine first-principles calculations, symmetry analysis, and two spin-resolved spectroscopies—angle-resolved photoemission (spin-ARPES) and our newly developed spin- and angle-resolved electron reflection spectroscopy (spin-ARRES)—to achieve the first complete momentum-resolved mapping of NRSS in $CoNb_4Se_8$. By probing both the occupied (spin-ARPES) and unoccupied (spin-ARRES) electronic states in a single experiment, we uncover a momentum-dependent spin splitting that switches sign under sixfold rotations and persists far above and below the Fermi level. Crucially, the observed collapse of NRSS near the Néel temperature confirms a genuine magnetic phase transition. Our work demonstrates, for the first time, the combined power of spin-ARPES and spin-ARRES in capturing the full spin texture across an extended energy range, positioning $CoNb_4Se_8$ as a prototype for exploring spin-group-based phenomena.

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Figure 1. Direct Probes of NRSS in $CoNb_4Se_8$. (**a**) Magnetic structure of $CoNb_4Se_8$ along the b-axis. (**b,c**) spin-ARPES probes alternating spin-texture in occupied states. (**d,e**) spin-ARRES probes alternating spin-texture in unoccupied states