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MEASUREMENTS OF THE QUANTUM GEOMETRIC TENSOR IN SOLIDS

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Why?

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Measurements of the quantum geometric tensor in solids

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Abstract

Understanding the geometric properties of quantum states and their implications in fundamental physical phenomena is a core aspect of contemporary physics. The quantum geometric tensor (QGT) is a central physical object in this regard, encoding complete information about the geometry of the quantum state. The imaginary part of the QGT is the well-known Berry curvature, which plays an integral role in the topological magnetoelectric and optoelectronic phenomena. The real part of the QGT is the quantum metric, whose importance has come to prominence recently, giving rise to a new set of quantum geometric phenomena such as anomalous Landau levels, flat band superfluidity, excitonic Lamb shifts and nonlinear Hall effect. Despite the central importance of the QGT, its experimental measurements have been restricted only to artificial two-level systems. Here, we develop a framework to measure the QGT in crystalline solids using polarization-, spin- and angle-resolved photoemission spectroscopy. Using this framework, we demonstrate the effective reconstruction of the QGT in the kagome metal CoSn, which hosts topological flat bands. Establishing this momentum- and energy-resolved spectroscopic probe of the QGT is poised to significantly advance our understanding of quantum geometric responses in a wide range of crystalline systems.

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- experimental measurements of the QGT restricted
- new framework in crystalline solids: polarization-, spin- and angle-resolved photoemission spectroscopy

- usually we study the quantum geometry of electrons by (theoretically) e.g. looking at the electronic bandstructure

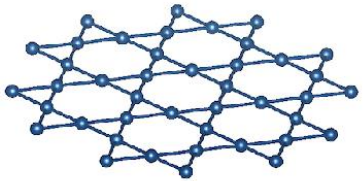
for a real system, the two band approximation is true between pairs of bands

Two-band approximation

Band curvature measurements

band curvature analysis, also given by angular-resolved photoemission spectroscopy

Quantum geometry in solids



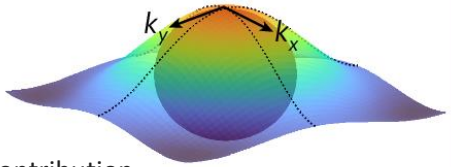
Spin-resolved CD-ARPES

angular-resolved photoemission spectroscopy

Two-band approximation

a

BDW



band contribution to the momentum-resolved Drude weight or BDW in metallic systems

$\mathrm{Re}\,[q_{ij}^n]$

effective electron density contributing to conductivity

Quasi-QGT

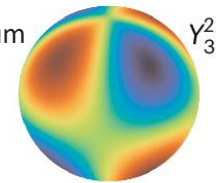
$$q_{ij}^n = \sum_{m \neq n} \frac{\langle u_n | \partial_{k_i} H | u_m \rangle \langle u_m | \partial_{k_j} H | u_n \rangle}{E_m - E_n}$$

$\mathrm{Im}\,[q_{ij}^n]$

b

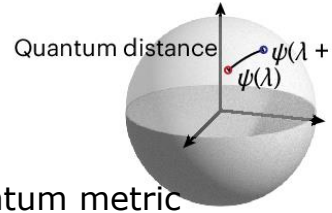
orbital angular momentum

OAM



c

QM



quantum metric

e.g. as seen in (nonlinear) Hall effect

$\mathrm{Re}\,[Q_{ij}^n]$

QGT

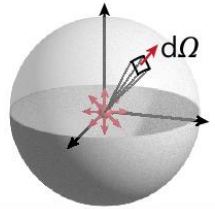
$$Q_{ij}^n = \sum_{m \neq n} \frac{\langle u_n | \partial_{k_i} H | u_m \rangle \langle u_m | \partial_{k_j} H | u_n \rangle}{(E_m - E_n)^2}$$

$\mathrm{Im}\,[Q_{ij}^n]$

d

Berry phase

BC

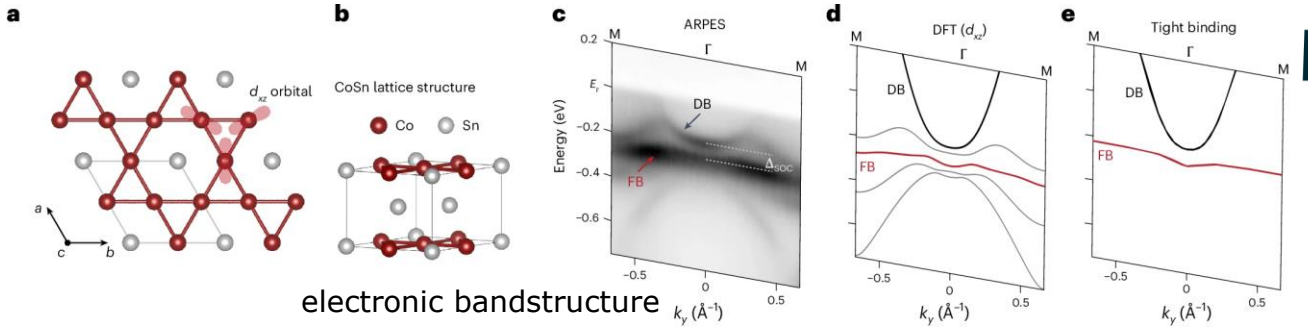


The quasi-QGT with well-defined physical meanings (BDW and OAM) complements the QGT (QM and BC) for the description of the intrinsic geometric properties of the Bloch electrons

key findings

- Kagome metal CoSn

bandstructure of d_{xz} Dirac band



electronic bandstructure