Topological and chiral phonons: theory, prediction and detection

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In solids, lattice vibrations—phonons at the terahertz scale—play a crucial role in thermal conductivity, transport properties, and phenomena like structural phase transitions and conventional superconductivity. However, their zero spin and electrical neutrality make phonons difficult to manipulate, limiting their control in physical processes. Recently, introducing *topological* and *chiral* degrees of freedom into the phonon spectrum has provided a new "control handle" for phonons, offering fresh insights into their influence on heat conduction, superconductivity, and other fundamental phenomena.

In the first half, I will discuss classifications and diagnostic methods for topological phonons, along with material predictions and experimental validations 1—including FeSi (the first topological phonon material) and BaPtGe (hosting Weyl phonons with the highest Chern numbers). The second half will cover chiral phonons: their definition, distinctions from topological phonons, and experimental detection 2. Examples include chiral phonons in systems with nonsymmorphic symmetries (e.g., α-HgS and Te), spin-phonon-induced chiral phonons in $Co_3Sn_2S_2$, and the interplay between Weyl and chiral phonons (see Figure).

[1] Zhang, et al., PRL, 120, 016401 (2018); PRL, 121, 035302 (2018); PRB, 102 , 125148 (2020); PRB, 103, 184301 (2021); PRL, 123, 245302 (2019)

[2] Zhang, et al., PRB , 4, L012024 (2022) ; Nat. Phys. , 19, 142-142 (2023); Nano Lett., 23, 7561–7567 (2023); arXiv:2411.03754 (2024); arXiv:2410.21775 (2024)

Figure 1. Relationship between topological phonons and chiral phonons