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Chiral edge modes and crystalline phases in atomic synthetic ladders

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Cold atomic gases endowed with a synthetic dimension are emerging as an ideal platform to address the interplay between interactions and static gauge fields. A fundamental question is whether these setups can give access to pristine two-dimensional phenomena, such as the fractional quantum Hall effect, and how. We show that unambiguous signatures of Laughlin-like states can be observed and characterized in synthetic ladders, thus being related to an unconventional fractional quantum Hall effect in the thin-torus limit. In particular we demonstrate the existence of a hierarchy of fractional insulating and conducting states, showing that the gapped states are characterized by density and magnetic order, whereas the gapless phases can support helical modes. Our analysis provides a guideline towards the observability and understanding of strongly correlated states of matter in synthetic ladders.

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