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Chiral ground-state currents of interacting photons in a synthetic magnetic field

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The intriguing many-body phases of quantum matter arise from the interplay of particle interactions, spatial symmetries, and external fields. Generating these phases in an engineered system could provide deeper insight into their nature. Using superconducting qubits, we simultaneously realize synthetic magnetic fields and strong particle interactions, which are among the essential elements for studying quantum magnetism and fractional quantum Hall phenomena. The artificial magnetic fields are synthesized by sinusoidally modulating the qubit couplings. In a closed loop formed by the three qubits, we observe the directional circulation of photons, a signature of broken time-reversal symmetry. We demonstrate strong interactions through the creation of photon vacancies, or 'holes', which circulate in the opposite direction. The combination of these key elements results in chiral groundstate currents, the first direct measurement of persistent currents in low-lying eigenstates of strongly interacting bosons. Our work introduces an experimental platform for engineering quantum phases of strongly interacting photons.