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FINALIST: Quantum Hall Physics with Photons[1]

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Can quantum materials be made of light? This exciting possibility requires two primary ingredients, photons that behave like massive particles and strong interactions between those photons. We describe our realization of these ingredients and our initial explorations of the resulting system. First, we develop a synthetic magnetic field for harmonically trapped photons and observe the formation of a Landau level. This enables investigation into three distinct topological characteristics of a photonic integer quantum Hall system. Next, we turn photons into strongly-interacting cavity Rydberg polaritons, quasiparticles which inherit their motional dynamics from the optical cavity and gain strong interactions from Rydberg excitations of a cold Rubidium gas. Granting these polaritons access to a degenerate Landau level of cavity states allows them to move, collide, and order themselves into topologically nontrivial material states. Observations of strong correlations in both real space and angular momentum space certify the creation and detection of a photonic Laughlin state, a ground state of a fractional quantum Hall system. Developing synthetic quantum materials out of light provides fundamentally new experimental capabilities and opportunities and here establishes quantum many-body optics as a direct route towards breakthroughs in understanding topological order and strongly correlated materials.

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