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**Symmetry-protected collisions between strongly interacting photons** TRAVIS NICHOLSON, Massachusetts Institute of Technology, JEFF THOMPSON[1], Harvard University, QIYU LIANG, SERGIO CANTU, Massachusetts Institute of Technology, ADITYA VENKATRAMANI, SOONWON CHOI, Harvard University, DANIEL VISCOR, THOMAS POHL, Max Planck Institute for the Physics of Complex Systems, MIKHAIL LUKIN, Harvard University, VLADAN VULETIC, Massachusetts Institute of Technology — Realizing robust quantum phenomena in strongly interacting systems is one of the central challenges in modern physical science. Here, using coherent coupling between light and Rydberg excitations in an ultracold atomic gas, we demonstrate a controlled and coherent state exchange collision between two strongly interacting photons. The collision is accompanied by a $\pi/2$ phase shift, which is robust in that the value of the shift is determined by the interaction symmetry rather than the precise experimental parameters, and in that it occurs under conditions where photon absorption is minimal. The measured phase shift of $0.48(3)\pi$ is in excellent agreement with a theoretical model. These observations open a route to realizing robust single-photon switches and all-optical quantum logic gates, and to exploring novel quantum many-body phenomena with strongly interacting photons.

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