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Observation of a three-photon bound state QIYU LIANG, SERGIO CANTU, Massachusetts Institute of Technology, ADITYA VENKATRAMANI, Harvard University, TRAVIS NICHOLSON, Massachusetts Institute of Technology, MICHAEL GULLANS, ALEXEY GORSHKOV, Joint Quantum Institute, NIST/University of Maryland, JEFF THOMPSON, Princeton University, CHENG CHIN, University of Chicago, MIKHAIL LUKIN, Harvard University, VLADAN VULETIC, Massachusetts Institute of Technology — Bound states of massive particles, be it in the form of nucleons, atoms or molecules, are ubiquitous, and constitute the bulk of the visible world around us. In contrast, photon-photon interactions are weak and need to be specifically engineered in the form of nonlinear optical media. Here we report the observation of a three-photon bound state inside a quantum nonlinear optical medium. The strong photon-photon interaction is achieved by coupling the light to highly excited, strongly interacting Rydberg states in a cold atomic gas. The photonic trimer, which can be viewed as a quantum soliton, is observed via bunching and a strongly nonlinear phase in the three-photon correlation function of the emerging light. The observations are quantitatively described by an effective field theory of Rydberg-induced photon-photon interactions, and agree with direct numerical simulations. This work paves the way towards the realization, understanding, and control of strongly interacting quantum gases of light.

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