Quantum Fluids of Light: from warm atomic vapors to cold Rydberg gases

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In the paraxial approximation, light propagating through atomic media acquires an effective mass and tunable photon-photon interactions, enabling fluid-like behavior. Recent experiments in warm atomic vapors have revealed the quasiparticle excitation spectrum, photon precondensation, dispersive shock waves, vortex generation, and Sakharov oscillations following interaction quenches.

While warm atomic vapors provide only moderate photon-photon interaction strengths, Rydberg electromagnetically induced transparency in cold atomic gases enables interactions enhanced by several orders of magnitude through the combined effects of slow light and cooperative atomic responses. This regime provides a promising platform for exploring strongly correlated states of light, where a full quantum-field description is required. Moreover, the nonlocal and long-range nature of Rydberg-mediated photon-photon interactions enables photonic analogs of modulation instability, crystallization, and quantum droplets.

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