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Nondestructive Rydberg-interaction-mediated cooling of neutral atoms

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We propose a protocol for sympathetically cooling neutral atoms without destroying the quantum information stored in their internal states. This is achieved by designing state-insensitive Rydberg interactions between the data-carrying atoms and cold auxiliary atoms. The resulting interactions give rise to an effective phonon coupling, which leads to the transfer of heat from the data atoms to the auxiliary atoms, where the latter can be cooled by conventional methods. This can be used to extend the lifetime of neutral-atom-based quantum storage and can have applications for long quantum computations. The protocol can also be modified to realize state-insensitive interactions between the data and the auxiliary atoms, but tunable and non-trivial interactions among the data atoms, allowing to simultaneously cool the data atoms and simulate a quantum spin-model.