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From trilobite molecules to tight-binding models

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When a Rydberg atom and a ground state "perturber"atom encounter one another in an ultracold gas, they interact via an oscillatory potential mediated by the scattering of the Rydberg electron off of the perturber. Sufficiently deep wells form in the oscillations of this potential that the perturber becomes trapped, binding the two atoms together into a molecule. This unusual mechanism is also able to bind several atoms together into trimers, tetramers, and even larger clusters. As the number of perturbers increases, it becomes impractical to describe this system within the framework of molecular physics, inviting a turn to the language of solid-state physics. In this talk, I will investigate how a dense environment of immobile perturbers modifies the spectrum of the Rydberg electron, which would otherwise be highly degenerate due to the SO(4) symmetry of the Kepler problem. I will show that this degeneracy leads to an exact mapping - familiar from supersymmetric quantum mechanics - between the perturbed Rydberg states and the states of a particle in a tight-binding lattice. The confluence of the infinite-ranged Coulomb potential and the zero-range electron-atom potentials leads to a plethora of possible lattice parameters. Using this mapping, I demonstrate how to realize a thermodynamic limit in the Rydberg electron and, as a result, the localization of the Rydberg electron in a disordered lattice.

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