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Dynamical shell structure from Rydberg impurities in a many-body environment[1] JOHN SOUS, University of British Columbia, ITAMP, Harvard University, THOMAS KILLIAN, Rice University, HOSSEIN SADEGHPOUR, ITAMP, EUGENE DEMLER, Harvard University, RICHARD SCHMIDT, Max-Planck-Institute of Quantum Optics, Munich Center for Quantum Science and Technology — We consider a Rydberg impurity in a single-component Fermi gas. The Rydberg electron of the impurity induces a giant potential for the bath particles. We develop a theoretical approach to predict the full absorption line shape of Rydberg molecules composed of an impurity and bath particles, including dressing effects by low-energy excitations of the fermionic environment. We find striking differences in the dynamics of fermions and bosons arising from the interplay of molecule formation, scattering physics and quantum statistics. Analyzing the full spectral absorption line shape we demonstrate that the dynamics is governed by states that exhibit a shell structure similar to that found in nuclear physics. We study the evolution with increasing density from the few-body limit with resolved molecular spectral lines to the many-body limit with a profile representing a giant Fermi superpolaronic state in which a large number of fermions bind to the Rydberg impurity. A compression of the superpolaronic spectrum allows Rydberg impurities to serve as an in-situ sensor of local density fluctuations. We further discuss the orthogonality catastrophe in the new setting of giant impurity excitations far from equilibrium.

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