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**Microwave quantum logic spectroscopy and control of molecular ions** MOLU SHI, PETER HERSKIND, ISAAC CHUANG, MIT-Harvard Center for Ultracold Atoms, Department of Physics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA — A general method for rotational microwave spectroscopy and control of polar molecular ions is considered, which combines several techniques developed for quantum information processing with both neutral atoms and atomic ions. Our method makes use of spatially varying AC Stark shifts, induced by far off-resonant, focused laser beams to achieve an effective coupling between the rotational state of a molecular ion and the electronic state of an atomic ion. In this setting, the atomic ion is used for read-out of the molecular ion state, in a manner analogous to quantum logic spectroscopy based on Raman transitions. Key to this approach is that it is compatible with the use of microwave fields in the spectroscopy, which avoids the need for technically challenging Raman lasers. In addition to high-precision spectroscopy, the techniques outlined here allow for rotational ground state cooling, and form the basis for quantum information processing with polar molecular ions. All elements of our proposal can be realized with currently available technology.

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