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Probing emergent phenomena through large-scale atom manipulation

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The magnetic and electronic properties of materials often find their origin in basic atomic-scale interactions. Yet, due to the large number of atoms involved, many phenomena can be very difficult to predict: we call these 'emergent'. The ability to build structures atom-by-atom by means of scanning tunneling microscopy (STM) may provide an excellent platform to explore emergence as a function of system size. For example, by properly tuning the anisotropy of magnetic atoms a thin insulator, we have been able to engineer finite spin chains hosting spin waves (1) as well as the beginnings of a quantum phase transition at a critical magnetic field (2). Unfortunately, the maximum size of such assembled structures is often limited due to e.g. crystal impurity, crystal strain, and general uncontrollability of the STM tip shape, hampering the reliability with which atoms can be manipulated. In this talk, I will demonstrate how atomic assembly can be enhanced dramatically by switching to manipulation of atomic vacancies, rather than adatoms, on a chlorine-terminated copper surface. The resulting structures, comprising thousands of vacancies positioned on an exactly defined grid, are found to be stable at temperatures up to 77 K. We use this new technique to construct two-dimensional quasi-crystals of various size and atomic spacing, and investigate their collective electronic properties through local tunneling spectroscopy.

1. Imaging of spin waves in atomically designed nano magnets, A. Spinelli et al., Nature Materials 13, 782 (2014)
2. Atomic spin chain realization of a model for quantum criticality, R. Toskovic et al., Nature Physics (2016), in print