Dynamics in the Atomic Zoo

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At the atomic scale the constituent atoms and crystal structure are the most important fundamental factors that determine the physical properties of the material. Bonding between adjacent atoms is responsible for spin correlations in addition to determining the transport properties of electrons and vibrational modes. Correlated electron systems are a well-studied subset of materials where the further interplay of charge, spin, and vibration leads to exotic electronic properties, most famously, superconductivity. The variety, of interactions and complexity of large crystal structures makes experimental and theoretical study of these materials challenging.

The scanning tunneling microscope (STM) provides the ability to examine surfaces with atomic resolution, and to interrogate electronic wavefunctions with incredible energy resolution. This has made it an invaluable tool in materials science, particularly for the study of quantum materials with electronic correlations. Developed concurrently with STMs, ultrafast lasers have allowed observations on timescales approaching those of the atomic interaction mechanisms at work in correlated materials. Dynamics provide a much more sensitive test for theory describing correlated materials than do static measurements. Optical measurements, however, are limited to few-nanometer resolution at best.

The ultimate experimental tool would combine atomic resolution with ultrafast time resolution. The realization of practical ultrafast STMs has been a long process. Now, largely because of the pioneering work of Canadian researchers, ultrafast STMs are a reality. The historical development of ultrafast STM and recent results will be presented. The implications for future research will be discussed, with a particular focus on the facilities now being developed at the University of Manitoba.