New states of electronic matter created under moderate non-equilibrium conditions

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The focus in the study of some representative model complex systems has recently started to shift from thermodynamic equilibrium to new emergent non-equilibrium states. This has been stimulated by some recent discoveries of unusual hidden states in a few diverse materials revealed in photoexcitation experiments. The rapid development of new techniques which allow investigations of elementary electronic, spin and lattice structural excitations on short timescales have opened up the possibility of investigating such states in detail. However, the properties of such new emergent states created out of equilibrium are still relatively mysterious, and their relation to equilibrium states is often unclear. The problem, even with state of the art techniques is that the hidden emergent states may be quite delicate, or short lived, and a detailed structure cannot be easily ascertained. Here metastable states come to the rescue: if their lifetime is sufficiently long, their intricate structure can be investigated in detail using static high resolution techniques. An excellent example of a material in which the interplay of electronic, spin and lattice degrees of freedom lead to a plethora of equilibrium and non-equilibrium electronically ordered states is the layered quasi-2D quantum spin liquid candidate material 1T-TaS_2, whose electronic states are hard to distinguish spectroscopically, but are revealed in great detail with femtosecond-excited scanning tunneling microscopy. I will also present new experimental data on a high density amorphous electronic state created under warm dense matter conditions, which is meta stable at low temperatures. The experiments open the way to understanding the mechanisms for the creation of new states of matter under highly non-equilibrium conditions.