The aim of the proposed research is to advance the theoretical understanding of complexity in strongly correlated materials with several interrelated degrees of freedom. Strong local Coulomb interactions between electrons are responsible for their localization. Therefore, the physical properties are driven not by high energy processes which depend on these strong interactions but rather by effective interactions which are unknown in some cases while in some others their complexity prevents simple insights into the nature of realized ground states. These problems are very challenging as novel ground states with unexpected properties may emerge. For instance, antiferromagnetic states could contain ferromagnetic chains or planes, or islands of unexpected spin and orbital order may be triggered by defect states. In some cases disordered states in form of a quantum liquid (spin, orbital or joined spin-and-orbital) may be expected. Knowledge of possible ground states is of importance for future controlled synthesis of strongly correlated materials.

Proposed studies of excited states are at least of equal if not higher importance. Their evolution with changing system parameters is responsible for the physical properties at finite temperature as well as for observed phase transitions. It is challenging to investigate to what extent the states realized in so complex systems follow classical expectations and which concepts should be radically revised to come closer to a realistic description of quantum complex systems.

We plan to study both homogenous transition metal oxides and systems with lowered symmetry due to interfaces or defect states. Research will concentrate on exploring modifications of spin and orbital order in such situation and studying their possible implications on the overall physical properties. Such studies may be important from the point of view of possible future applications of quantum materials in electronic devices.