Research

The research in our group is presently focussed on the theoretical understanding of quantum matter. This refers to a very modern development in physics that only started to flourish in recent years. Matter refers here not only to the solids, liquid, gasses, etcetera that we encounter in our daily life but also for instance to the elementary particles described by the standard model of high energy physics. In modern physics all of it is understood as originating in collective behavior of infinities of underlying quantum degrees of freedom.

The central pillar of twentieth century physics was the idea that upon combining large numbers of microscopic quantum things invariably classical physics would emerge in the macroscopic realms as a collective effect. This is in turn characterized by collective modes (like light) that upon semi-classical re-quantization turns into quantum particles (like photons). A crucial insight came from quantum information: "classical" really means that the vacuum state is devoid of entanglement, that property rendering the quantum computer to be potentially supremely better in processing information.

We appear to be in the process of discovering states of matter that are genuinely infinite body entangled in the macroscopic realms. This development rests on new mathematical machinery discovered in string theory called the "holographic duality" that maps the physics of quantum matter on the properties of special black holes in an equivalent gravitational system. This is in turn closely related to the latest progress in quantum gravity where the origin of space and time is associated with the flow of quantum information (the "it from quantum bits" program). On the experimental side evidences are accumulating that genuine quantum matter is realized in the strongly interacting electron systems formed in special solids such as the high Tc superconductors. These have been a mainstay of experimental research in condensed matter laboratories for a long time, motivated by their highly mysterious behaviors. The math of the string theorists meets this physics, indicating that generic new principles are at work in the realms of quantum matter carrying names like "Planckian dissipation", "un-particle physics", "local quantum criticality", etcetera.