Popular science account of

Antiferromagnetic long-range order in dissipative Rydberg lattices

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Simulating collectively interacting quantum systems such as atoms on a classical computer is a challenging task since the required memory to store the atomic state of the system grows exponentially with the number of atoms N. Richard Feynman therefore proposed in his 1981 lecture 'Simulating physics with computers' that to overcome this problem, instead of using a classical computer, one should employ 'quantum simulators' that operate according to the laws of quantum mechanics. Using quantum simulators, one could manipulate and engineer the interaction between those particles such as to mimick the physical system one wants to simulate.

In our research, we aim to understand how collective phenomena could be exploited to manipulate light by sending it through a cold Rydberg gas. Beside the fundamental interest of such processes, we hope that the insights gained in this way will pave the way for new information technologies where photons are used to store, process and communicate information on the quantum level.

In our project we are investigating ultracold gases of dilute collections of atoms that are trapped and cooled by lasers to extremely low temperatures near the absolute zero of the temperature scale (-273.15 ^{0}C). When such atoms are excited to high-lying energy states - so-called Rydberg states – they interact very strongly, which altogether yields a unique platform for studying complex many-body phenomena in the "quantum world".

Currently, we are investigating regular lattices of such Rydberg atoms driven by coherent laser excitation which leads to a strong decay of the excited state due to spontaneous emission. In particular, we are looking for the self-induced antiferromagnetic phases of atomic excitations and trying to understand the mechanisms behind this effect.
We show that by tuning the laser frequency and engineering interaction between Rydberg atoms, one can theoretically predict self-induced antiferromagnetic phases of atomic excitations exhibiting long-range order that can emerge in two-dimensional lattices. From a more general perspective we show that optically driven Rydberg gases provide an experimentally accessible, non-trivial setting to study the physics of non-equilibrium phase transitions in driven, open systems - a subject that has recently attracted considerable interest.

Ref.: M. Hoening *et al*., Phys. Re. A 90, 021603(R) (2014)