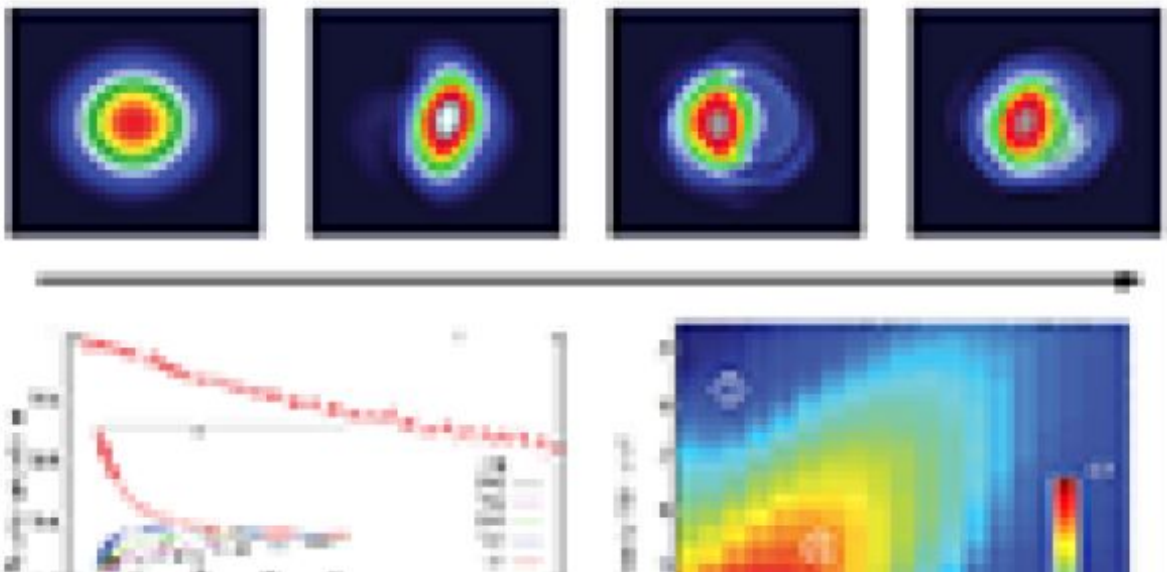


ULRICH EBLING
Adjuncting Ulrich Ebling
Award Board



PhD Thesis Defense **ULRICH EBLING** 'Dynamics of Spinor Fermions'

ULRICH EBLING

November 03, 2014

Monday, November 3, 11:00. ICFO Auditorium

ULRICH EBLING

Quantum Optics Theory

ICFO-The Institute of Photonic Sciences, SPAIN

Ultracold atomic gases have established themselves as quantum systems, which are clean and offer a high degree of control over crucial parameters. They are well isolated from their environment and thus offer the possibility to study coherent many-body dynamics. In this thesis, we address the dynamics of ultracold Fermions with large spin. Fermionic spinor gases differ from the typical situation in condensed matter physics, due to both the presence of the trap and the possibility of having fermions with large ($>1/2$) spin. Compared to the spin-1/2 case, large spin fermions must have one of two possible new properties. Either they

obey an enhanced $SU(N)$ symmetry, or they feature spin-changing collisions and a quadratic Zeeman shift. Here, we address the latter case.

In the weakly interacting scenario, there are three different regimes. For very weak interactions, the system is in a collisionless regime and interactions can be taken into account on a mean-field level. For stronger interactions, collisions ensure local equilibrium and the system is described by hydrodynamic equations. For an intermediate regime however, there is no easy description. Moreover, the scattering cross-section for spin-changing and spin-conserving collisions can be different for large-spin fermions and we find a situation where the system is hydrodynamic with respect to one process but not the other. In this thesis, a semi-classical Boltzmann equation with full spin coherence is developed, which allows interpolating between the collisionless and hydrodynamic regime in the presence of the trap and for large spins. This approach goes beyond mean-field theory and treats the single-particle dynamics as an open system coupled to an environment given by all other particles. We find good agreement with experiments performed in the group of Klaus Sengstock at Hamburg University, using ultracold Potassium-40.

We begin by investigating the effect of the harmonic trap for a collisionless system. We find a dynamical mechanism for spin-segregation, the mean-field driven creation of two domains of opposite magnetization in phase-space. The effect finds a transparent explanation when introducing the concept of dynamically induced long-range interactions, occurring when the fast phase-space rotation induced by a strong parabolic trap effectively smears out the contact interactions.

Further results in this thesis have been achieved in collaboration with an experimental group in Hamburg. In the first project, we study the collective excitations of a trapped four-component Fermi gas. Long wavelength spin waves are excited by using a magnetic field gradient to wind up a spin spiral. During the subsequent dynamics, the spin components oscillate in the trap, while the total density remains constant. The dynamics can be understood quantitatively by disentangling it into dipolar, nematic and octupolar configurations.

In a subsequent experiment with spin-9/2 fermions, we were able to find that spin-changing interactions can lead to collective and coherent oscillations of the spin state of the whole Fermi sea with long lifetimes. It is theoretically known that these giant oscillations are protected from spatial dephasing by dynamically induced long-range interactions. We identify the suppression of such oscillations in the high-density regime as the consequence of incoherent non-forward scattering.

In the last project, we have carried out an in-depth study of collision processes in ultracold Potassium . We find that they can be arranged in 3 categories: Spin-changing vs. spin-conserving collisions, processes depending on density vs. processes depending on density gradients and forward vs. lateral scattering. With this categorization, as well as the exact dependence of each process on scattering lengths and momenta, we can explain and simulate not only the coherent mean-field driven oscillations, but also relaxation effects that appear to be incoherent on the single-particle level.

Monday, November 3, 11:00. ICFO Auditorium

Thesis Advisor: Prof. Maciej Lewenstein

Thesis Co-advisor: Dr. Andre Eckardt

