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Stop Press II

Collective Behaviour

Nobel Laureate Professor Ilya Prigogine in the context of his nonlinear thermodynamics had studied what may be called Collective Behaviour. His basic point was that far away from equilibrium in the usual statistical sense, other exotic phenomena begin to manifest themselves [(Cf.ref. Nicolis, G. and Prigogine, I. Exploring Complexity, W.H. Freeman, New York, 1989 , p.10]. Perhaps what he called the chemical clock is one such spectacular example where BZK mechanism kicks in. Patterns begin to get formed and the colour of the chemicals changes in a very predictable and periodic way. All this is for macroscopic systems.

However very recently such a what may be called Collective phenomena was observed for just a few particles. A this can be explained in a simple way by saying that at low dimensions and at low temperatures it is as if the particles are squeezed by the lack of degrees of freedom. Interestingly such Collective phenomena are also shown by flying birds, which go in formations. Such researches in Germany indicate that this happened because of a magnetic sense in the brains of these birds.

A team led by researchers at the University of Heidelberg, Germany, using a quantum simulator investigated how collective behaviour emerges in a microscopic structure. They found that an ensemble of just six atoms displays all the signatures of a phase transition expected for a many-particle system. This new work advances our understanding of many-body physics, which describes phenomena that cannot be understood simply by studying the behaviour of individual particles.

A team led by Selim Jochim of the University of Heidelberg's Institute of Physics tackled this problem by trapping up to 12 ultracold lithium-6 (^{6}Li) atoms, assembled in two internal hyperfine states, at the focus of a laser beam. The trap's geometry is such that the atoms can move in just two spatial directions, meaning that the system is effectively two-dimensional. The researchers applied a special cooling technique that brought the system very close to its motional ground state, at a temperature just above absolute zero. This set-up also allowed the researchers to continuously tune the strength of the interactions between the atoms via an applied magnetic field, using so-called Feshbach resonances.

Jochim and colleagues in their experiments, configured their applied magnetic field so that the atoms attracted one another. They found that if the attraction was strong, the atom formed pairs that could subsequently undergo a phase transition to a superfluid (a state in which the particles flow without friction). The researchers also observed how the atoms formed pairs as a function of their interaction strength and their number by measuring the binding energy of the atom pairs. To their surprise, they found that their atoms behaved like a many-body system even with only six atoms present.

Luca Bayha and Marvin Holten noted that the type of pairing they studied is the precursor of a quantum phase transition to a superfluid phase with an associated "Higgs mode".

Members of the team which also include collaborators at the universities of Lund, Sweden, and Aarhus, Denmark, say that they are now planning to study superfluidity in such mesoscopic systems in much more detail. The present work is detailed in *Nature*.