From Ultracold Atoms to Ultracold Molecules. Prospects for Novel Physics

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Abstract

Last years are marked by advanced achievements in the physics of ultracold atomic Fermi gases. Experiments have reached the regime of quantum degeneracy and widely employed Feshbach resonances for tuning the interaction strengtgh from negative (atttraction) to infinitely large and then to positive. This has led to exciting developments, such as the direct observation of superfluid behavior in the strongly interacting regime through the vortex formation, and the observation of a crossover from the Cooper pairing on the negative side of the resonance to the regime of BEC of weakly bound dimers on the positive side of the resaonance. Being successful with the studies of the s-wave resonances in two-component Fermi gases, experiments did not succeed with p-wave resonances, mostly because of the collisional instability in the strongly interacting regime and on the molecular side of the resonance. The recent success in creating degenerate ultracold clouds of fermionic polar molecules draws fascinating prospects in this direction. I will make a link between atomic and molecular studies and show that microwave-dressed polar molecules in the 2D geometry can form a topological superfluid px+ipy phase, which is a promising candidate for topologically protected quantum information processing. Due to the dipole-dipole tail of the interaction potential, this phase is characterized by a sufficiently large transition temperature far from resonance and can be made collisionally stable. I then show that bilayered systems of fermionic polar molecules can exhibit a peculiar BCS-BEC crossover where Cooper pairs on one side of the resonance and bound two-particle states on the other side are formed by fermions of different layers. The talk will be completed by the discussion of possibilities to obtain a ferromagnetic state of fermionic polar molecules.