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Exploring supersolidity and droplet formation in ultracold dipolar systems

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Due to the long-range and anisotropic character of dipolar interaction, ultracold dipolar systems have emerged as a unique platform for the exploration of the supersolid state of matter. In a supersolid two U(1) symmetries are simultaneously broken: the first one due to the presence of spatial long-range order and the second one to the emergence of a global phase giving rise to a super-fluid state. First, I will focus on the two dimensional (2D) case, where the superfluid transition follows the Berezinskii-Kosterlitz-Thouless (BKT) scenario. In a 2D dipolar system the anisotropy of the dipolar interaction is controlled by polarizing the dipoles with respect to the plane. The phase diagram in terms of density and tilting angle exhibits a transition from a gas to a stripe phase. By Performing Quantum Monte Carlo (QMC) calculations we show that both the gas and stripe phases follow the BKT scaling relations and thus, the stripe phase is a good candidate for a two-dimensional supersolid [1,2]. In the second part of the talk I will describe the phenomena of droplet formation and super-solidity in three dimensional arrays of dipolar droplets. These two phenomena emerge from a delicate balance between dipolar interactions, quantum fluctuations, and geometric confinement what makes their theoretical treatment challenging. QMC calculations can be used to determine accurately some experimental observables, such as the minimum number of atoms that is needed to form one of these droplets [3]. Furthermore the equation of state computed with QMC can be used to construct a density functional that outperforms in accuracy the widely used extended Gross Pitaievskii equation without increasing the computational cost.

[1] R. Bombin, J. Boronat, and F. Mazzanti, Dipolar bose supersolid stripes, Phys. Rev. Lett. 119, 250402(2017).
[2] R. Bomb´ın, F. Mazzanti, and J. Boronat, Berezinskii-kosterlitz-thouless transition in two-dimensional dipolar stripes, Phys. Rev. A 100, 063614 (2019).
[3] F. Böttcher, M. Wenzel, J.-N. Schmidt, M. Guo, T. Langen, I. Ferrier-Barbut, T. Pfau, R. Bombín, J. Sánchez-Baena, J. Boronat, and F. Mazzanti, Dilute dipolar quantum droplets beyond the extended Gross-Pitaevskii equation, Phys. Rev. Res. 1, 033088 (2019).

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