Supersolid stripes enhanced by correlations in a Raman spin-orbit coupled system

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Main goal, Diffusion Monte Carlo and Spin Orbit Coupling

- **We want to compare the mean field and Diffusion Monte Carlo (DMC) phase diagrams of a many-body system under Raman SOC.**
- DMC is a numerical method that enables to study the ground state (g.s.) properties of a many-body quantum system.
- It relies on the application of the imaginary time evolution operator $\exp\left[-\tau \hat{H}\right]$ to a given trial wave function $\Psi_T(\vec{R})$.
- We deal with the non-locality of the novel SOC terms of the Hamiltonian via the T-moves approach [1, 2, 3].
- The coupling between a particle's momentum (linear or angular) and its spin is known as spin-orbit coupling (SOC).
- Our target systems are ultracold quantum gases, for which the realization of a synthetic type of SOC has been achieved.

Hamiltonian

The general form of the Hamiltonian we want to solve is:

$$\hat{H} = \sum_{k=1}^{N} \left[\frac{\hat{P}_k^2}{2M} + \hat{V}_k^{\text{1b}} + \hat{W}_k^{\text{SOC}} \right] + \sum_{k<l} \left[\sum_{s_k, s_l} V_{s_k, s_l}^{2\text{b}}(r_{kl}) |s_k, s_l\rangle\langle s_k, s_l| \right] ,$$

For our test cases:

$$\hat{W}_k^{\text{Rashba}} = \frac{\lambda_{\text{Rs}}\hbar}{2} \left[\hat{P}_k^y \hat{\sigma}_k^x - \hat{P}_k^x \hat{\sigma}_k^y \right]$$

$$\boldsymbol{\hat{W}_k^{\text{Raman}} = \frac{\lambda_{\text{Rm}}\hbar}{M} \hat{P}_k^x \hat{\sigma}_k^z + \frac{\lambda_{\text{Rm}}^2 \hbar^2}{2M} - \frac{\Omega}{2} \hat{\sigma}_k^x}$$

$$\hat{W}_k^{\text{Weyl}} = \frac{\lambda_{\text{We}}\hbar}{M} \left[\hat{P}_k^x \hat{\sigma}_k^x + \hat{P}_k^y \hat{\sigma}_k^y + \hat{P}_k^z \hat{\sigma}_k^z \right] + \frac{\lambda_{\text{We}}^2 \hbar^2}{2M} ,$$

DMC phase diagram of the system.

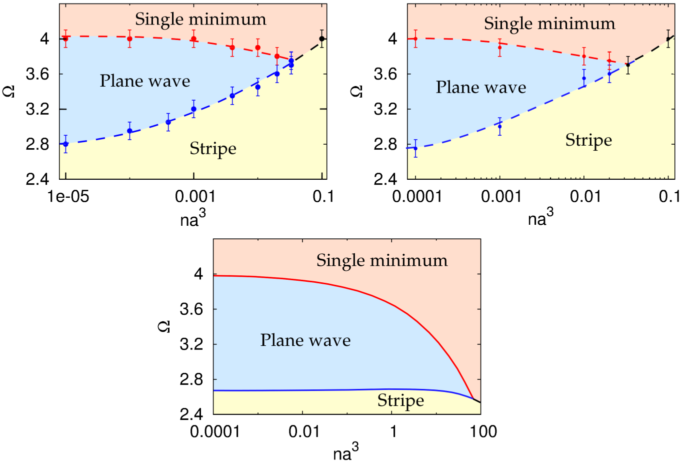

Figure: T-moves DMC diagrams of the Raman SOC system for a soft-spheres potential (upper left plot) and a Lennard-Jones potential (upper right plot). Other parameters are: $n = 3.7 \times 10^{-3}$, $\gamma = (a_{\uparrow,\uparrow} - a_{\uparrow,\downarrow})/(a_{\uparrow,\uparrow} + a_{\uparrow,\downarrow}) = 0.4$. The lower plot corresponds to the mean field diagram [4]. See Ref. [5] for details.

Static structure factor and superfluidity of the stripes

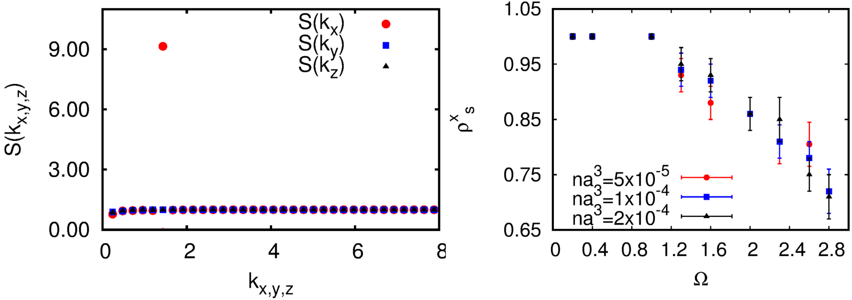

Figure: Static structure factor (left plot) and superfluid fraction along the x-axis (right plot) in the stripe phase. See Ref. [5] for details.

References I

- J. Sánchez-Baena, J. Boronat, and F. Mazzanti *Phys. Rev. A*, vol. 98, p. 053632, Nov 2018.
- C. A. Melton, M. C. Bennett, and L. Mitas *The Journal of Chemical Physics*, vol. 144, no. 24, p. 244113, 2016.
- M. Casula, S. Moroni, S. Sorella, and C. Filippi *The Journal of Chemical Physics*, vol. 132, no. 15, p. 154113, 2010.
- Y. Li, G. I. Martone, and S. Stringari, ch. CHAPTER 5, pp. 201–250.
- J. Sánchez-Baena, J. Boronat, and F. Mazzanti *Phys. Rev. A*, vol. 101, p. 043602, Apr 2020.