Local stable supersolid of tilted dipoles

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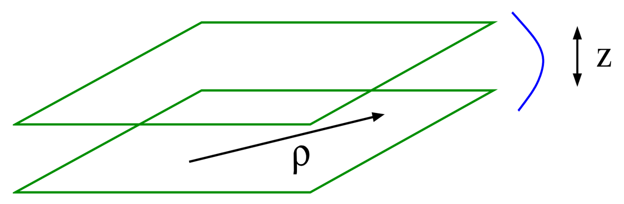
TOWARDS SUPERSOLID PHASE

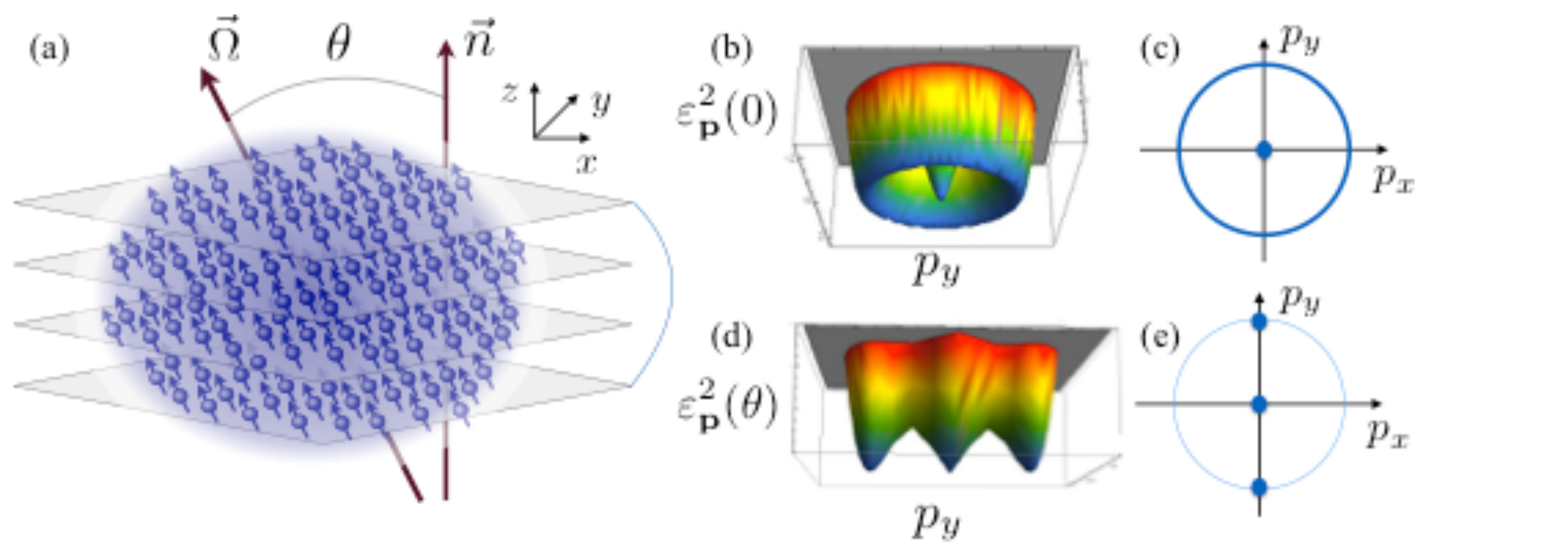
Pioneering work: L. Santos, G.V. Shlyapnikov, M. Lewenstein (2003).



- roton-maxon spectrum;
- rotonization;
- supersolid?

$V_d + g$ (short-range) $\quad g > 0$

A.K. Fedorov, I.L. Kurbakov, Y.E. Shchadilova, Yu.E. Lozovik (2014).



In contrast to rotational symmetry case tilted dipoles square of Bogoliubov spectrum touches the zero in two points.

STABILITY PROBLEM

Effective 2D Hamiltonian for thin-layer motion has the form

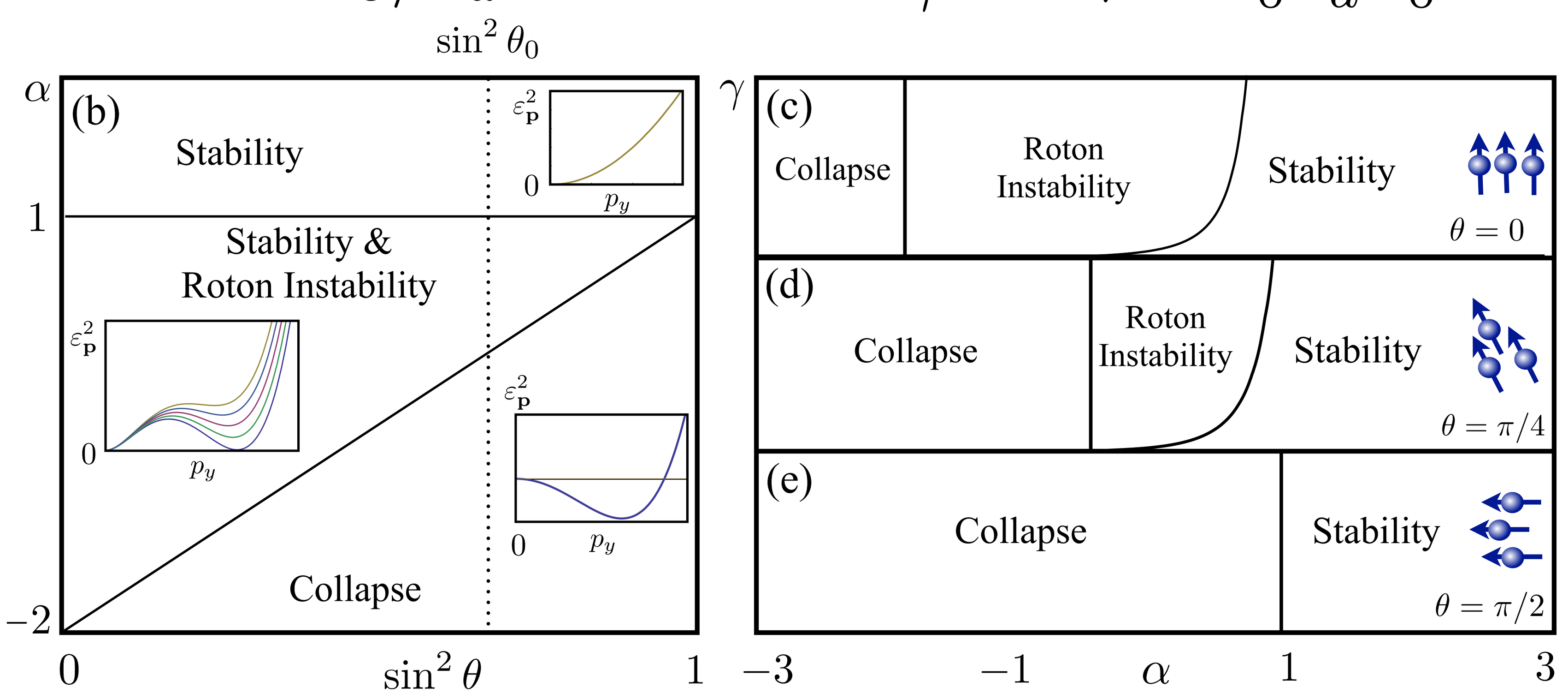
$$\hat{\mathcal{H}}_{2d} = \int d\mathbf{r}\, \hat{\Psi}^{+}(\mathbf{r}) \left(-\frac{\hbar^2}{2m}\Delta_2 - \mu + V(\mathbf{r}) \right) \hat{\Psi}(\mathbf{r}) + $$
$$+ \int d\mathbf{r}\, d\mathbf{r}'\, \mathcal{U}_{2d}(\mathbf{r}-\mathbf{r}')\hat{\Psi}^{+}(\mathbf{r})\hat{\Psi}^{+}(\mathbf{r}')\hat{\Psi}(\mathbf{r}')\hat{\Psi}(\mathbf{r})$$

Effective interaction potential of 2D dipoles in the Born approximation

$$\mathcal{U}_{2d}(\mathbf{p}, \theta) = g_s - \frac{g_d}{2} + U_h(\mathbf{p})\sin^2\theta + U_v(\mathbf{p})\cos^2\theta,$$

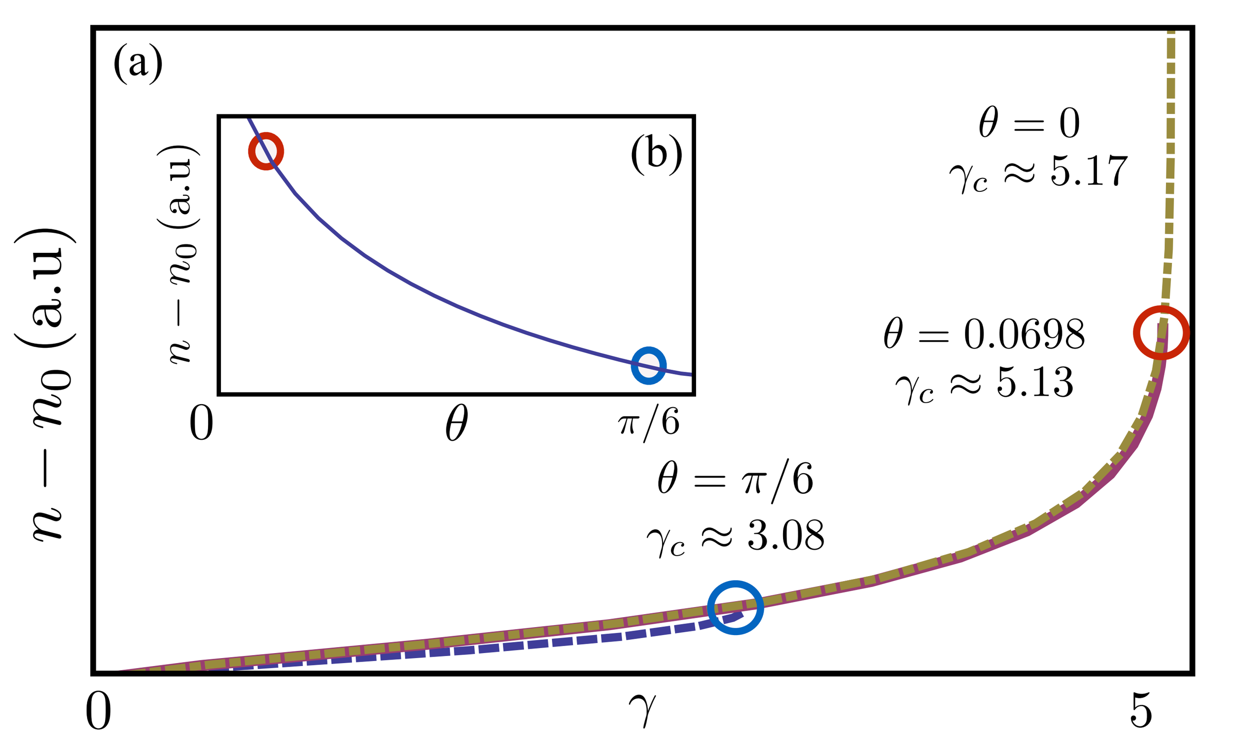
STABILITY DIARGAMS

$$\alpha = a_s/a_d \qquad \gamma = 2\sqrt{2\pi} z_0 a_d n_0$$



CONVEGENCE OF THE DEPLITION

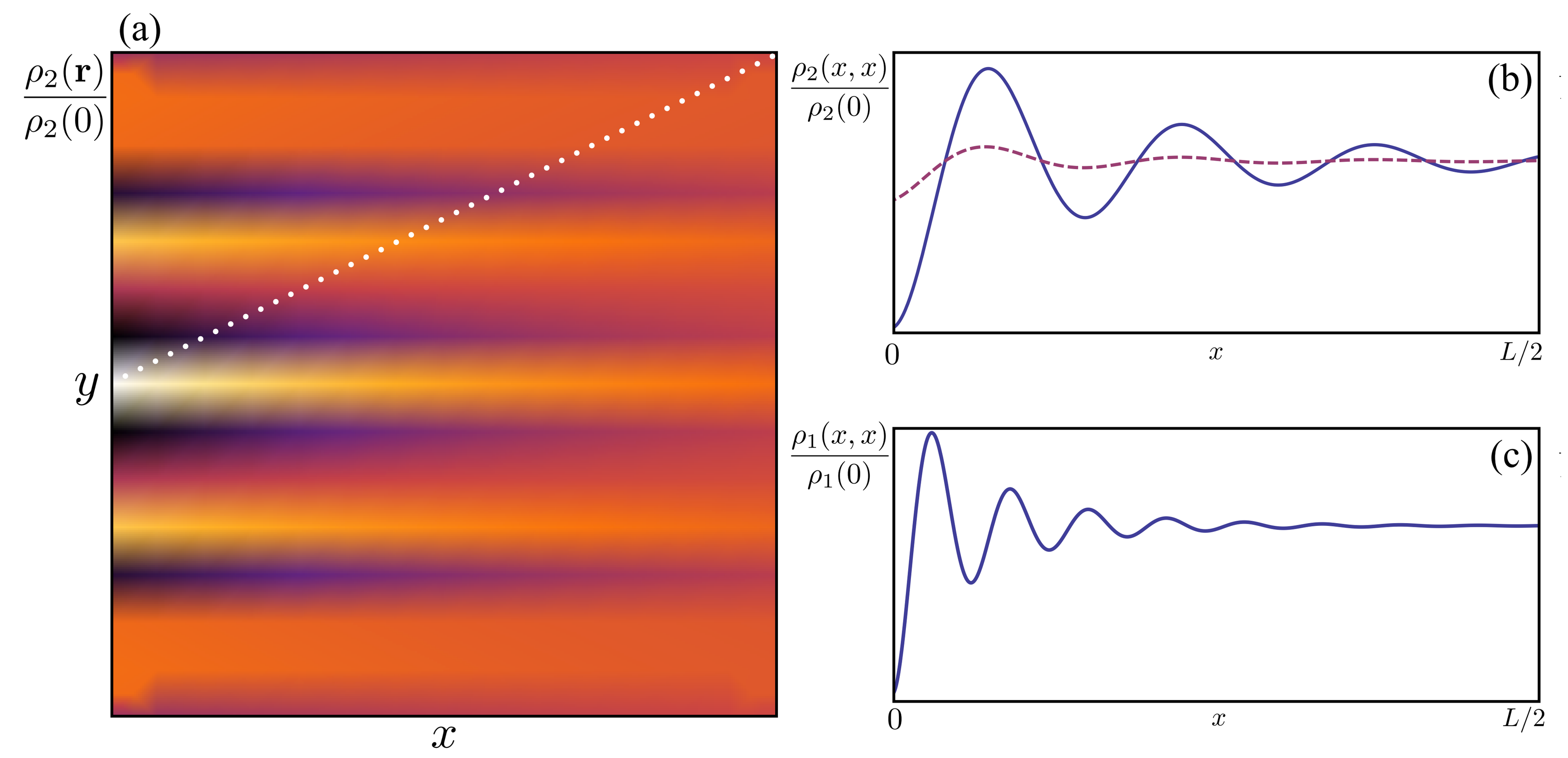
The condensate depletion in the system diverges at the threshold of the roton instability for normal to the layer dipoles [U.R. Fisher, 2006].



The condensate depletion for a 2D dilute gas of tilted dipoles converges close to the threshold of the roton instability.

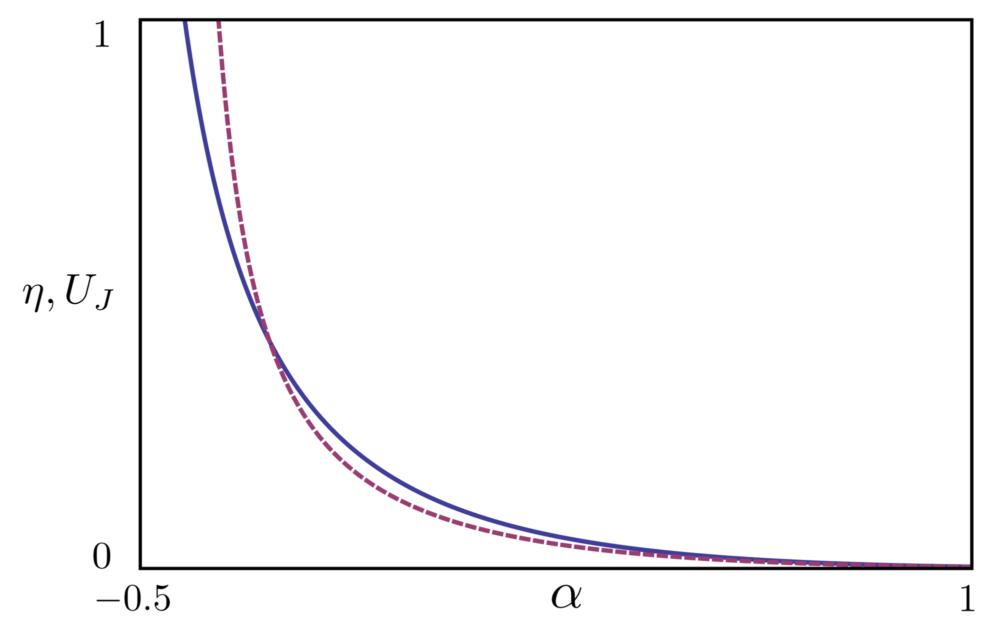
CAPTURING SUPERSOLIDITY: LOCAL DENSITY WAVES

The local supersolid phase is manifested by (i) density waves at mesoscopic scales, which coexist with (ii) Bose-Einstein condensation and (iii) superfluidity.



The manifestation of local DWs at mesoscopic scales in the system at the finite temperature and the finite tilting angle in the vicinity of the threshold of the roton instability close to the boundary of the collapsed phase. In (a) the two-body density matrix is shown as the function of (x,y) with the diagonal short-range order (dotted line corresponds to x=y). In (b) the two-body density matrix along the line x = y for zero temperature (dashed, amplitude is enhanced on the factor 10) and non-zero temperature (solid) cases. In (c) the one-body density matrix along the line x=y for non-zero temperature case.

CAPTURING SUPERSOLIDITY: UNIVERSAL JUMP AND CONDENSATE



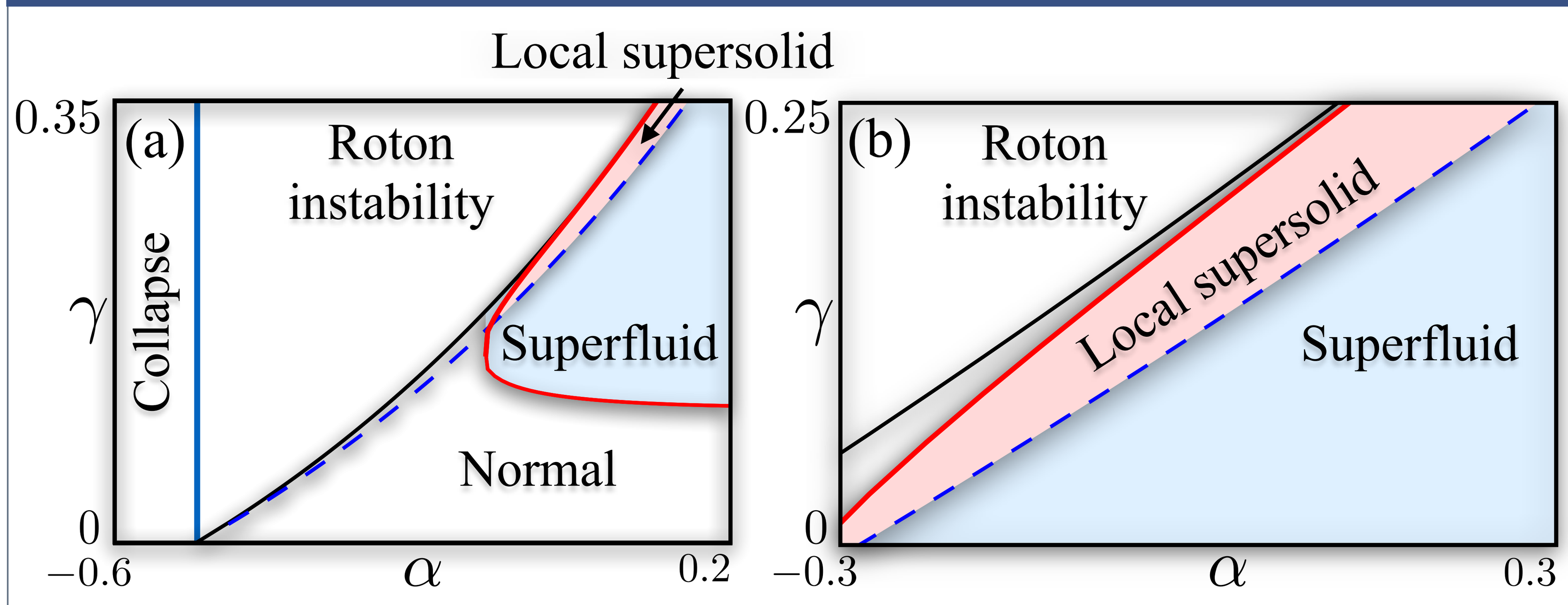
Condensate parameter

$$\eta = \frac{C_T}{4}\ln\frac{1}{\mathcal{R}_s} + \frac{T}{T_0}\ln\frac{L}{r_s}, \qquad r_s \sim \hbar/p_r,$$

Universal jump

$$U_J \equiv \frac{2mT}{\pi\hbar^2 n_s} = \left(\frac{T_0}{4T} - \frac{p_r^2}{2\kappa m^2 B^2}\ln\frac{1}{\mathcal{R}_s} \right)^{-1}$$

PHASE DIAGARAM



EXPERIMENTAL REALIZATIONS:

(i) atoms with a large magnetic moment (chromium and dysprosium), for which Bose-Einstein condensation has been recently demonstrated;
(ii) Rydberg atoms in electric field;
(iii) diatomic polar molecules with electrically induced dipole moment;
(iv) and spatially separated excitons in a semiconductor layer.

ACKNOWLEDGEMENTS

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