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# Vortex Lattice Nucleation in Dipolar Bose-Einstein Condensates

S.B. Prasad, B.C. Mulkerin & A.M. Martin

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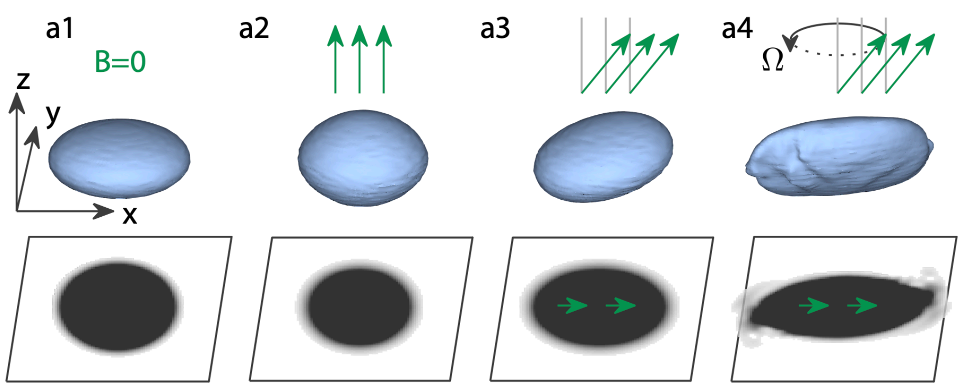
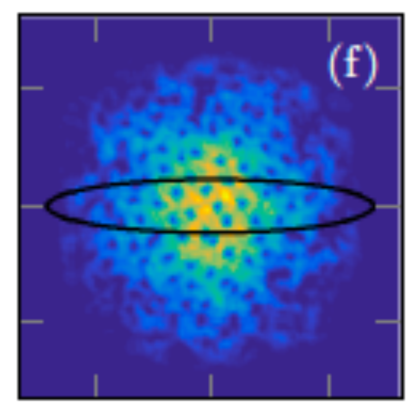
ANCORA IMPARO

Newcastle University



# Other Recent Research Topics

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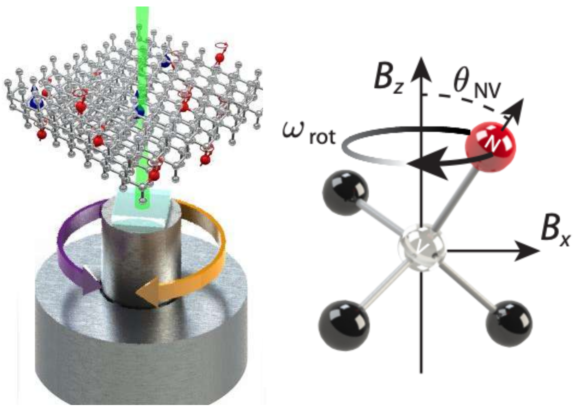
## Rotating NV




nature physics LETTERS
PUBLISHED ONLINE: 7 AUGUST 2017 | DOI: 10.1038/NPHYS4221

**Magnetic pseudo-fields in a rotating electron–nuclear spin system**

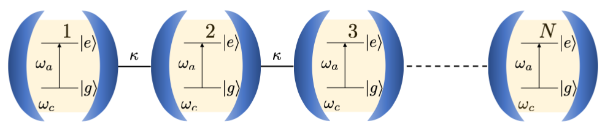
A. A. Wood[1], E. Lilette[1], Y. Y. Fein[1], V. S. Perunicic[1,2], L. C. L. Hollenberg[1], R. E. Scholten[1] and A. M. Martin[1]*

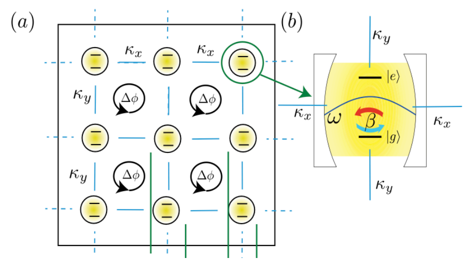
PHYSICAL REVIEW APPLIED **18**, 054019 (2022)

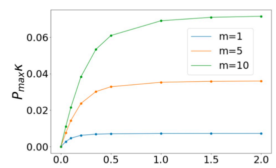
**dc Quantum Magnetometry below the Ramsey Limit**

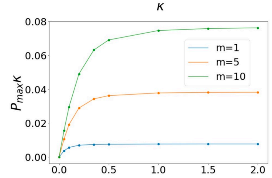
Alexander A. Wood,[1,*] Alastair Stacey,[2] and Andy M. Martin[1]

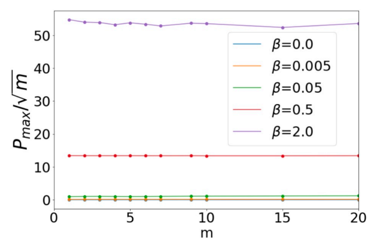
## Jaynes Cummings Hubbard Model




PRL **108,** 223602 (2012) PHYSICAL REVIEW LETTERS week ending 1 JUNE 2012

**Fractional Quantum Hall Physics in Jaynes-Cummings-Hubbard Lattices**

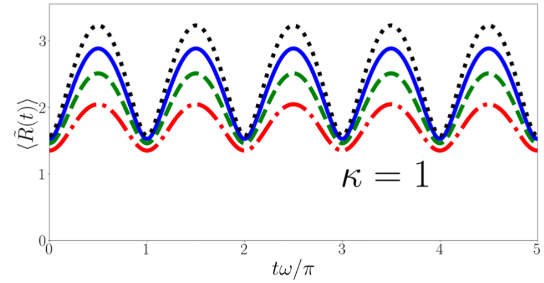
Andrew L. C. Hayward,[1] Andrew M. Martin,[1] and Andrew D. Greentree[1,2]

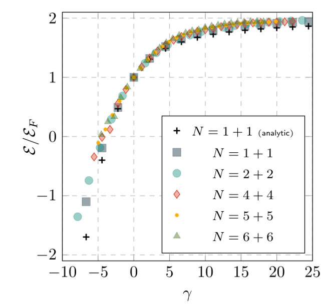
Quench dynamics in the Jaynes-Cummings-Hubbard and Dicke models

Andrew R. Hogan* and Andy M. Martin

arXiv:2210.01355

## Few-Body Systems




PHYSICAL REVIEW A **106**, 053310 (2022)

**Quench dynamics of mass-imbalanced three-body fermionic systems in a spherical trap**

A. D. Kerin and A. M. Martin

New J. Phys. 24 (2022) 053004 https://doi.org/10.1088/1367-2630/ac643d

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PAPER

Reduced density matrix approach to ultracold few-fermion systems in one dimension

Mitchell J Knight*, Harry M Quiney and Andy M Martin

# Rotating Dipolar BECs

nature physics

Article
https://doi.org/10.1038/s41567-022-01793-8

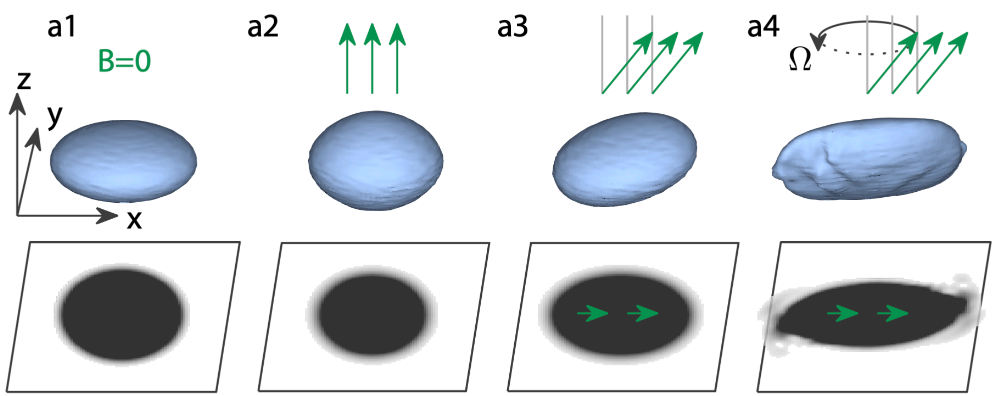
## Observation of vortices and vortex stripes in a dipolar condensate

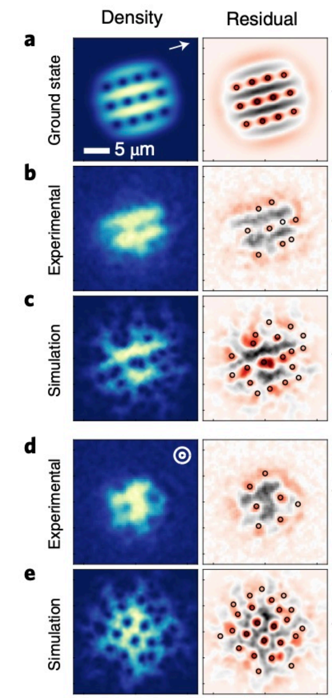
Received: 15 June 2022

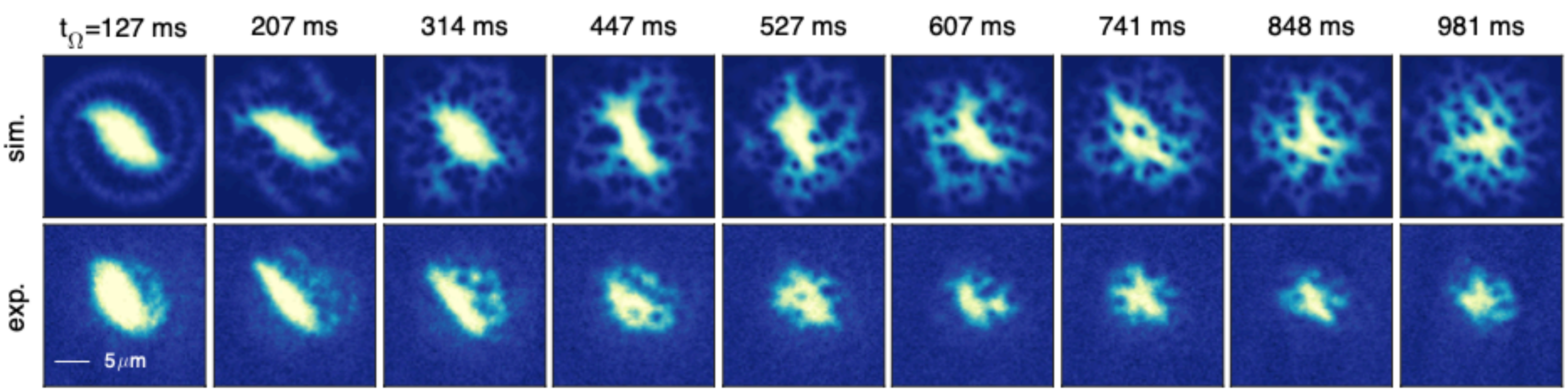
Accepted: 8 September 2022

Published online: 31 October 2022

Lauritz Klaus[1,2,4], Thomas Bland[1,2,4], Elena Poli[2], Claudia Politi[1,2], Giacomo Lamporesi[3], Eva Casotti[1,2], Russell N. Bisset[2], Manfred J. Mark[1,2] and Francesca Ferlaino[1,2]



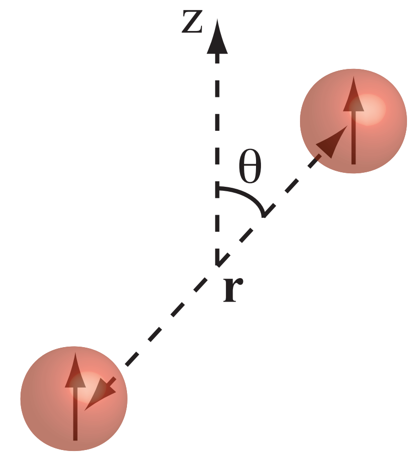
# Dipolar BECs



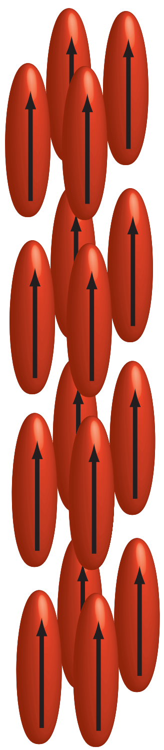
$$U_{dd}(\mathbf{r}) = \frac{C_{dd}}{4\pi}\left[\frac{1 - 3\cos^2\theta}{r^3}\right]$$

Long-Range

Anisotropic

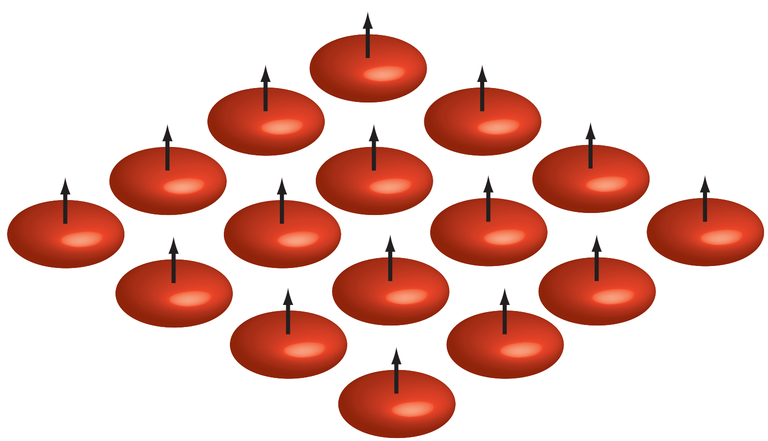



$$\varepsilon_{dd} \equiv \frac{C_{dd}}{3g}$$



Prolate:

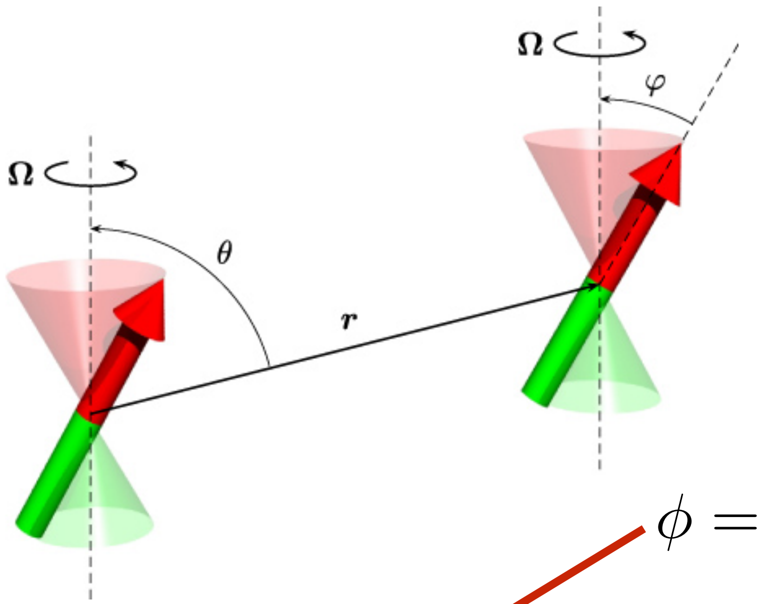
net top-to-tail attractive interaction



Oblate:

net side-by-side repulsive interaction

# Rotate the Dipoles




$\phi = \pi/2$

$$\langle\langle U_{dd}(\mathbf{r})\rangle\rangle = \frac{C_{dd}}{4\pi}\left(\frac{3\cos^2\varphi - 1}{2}\right)\left(\frac{1 - 3(\hat{z}\cdot\mathbf{r})^2}{|\mathbf{r}|^3}\right).$$

First discussed by Giovanazzi et al. in Phys. Rev. Lett. **89**, 130401 (2002) - but without GPE simulations or extended Thomas-Fermi calculations

# Rotate the Dipoles: Stationary

PHYSICAL REVIEW LETTERS 122, 050401 (2019)

**Instability of Rotationally Tuned Dipolar Bose-Einstein Condensates**

S. B. Prasad,[1] T. Bland,[2] B. C. Mulkerin,[3] N. G. Parker,[1,2] and A. M. Martin[1]

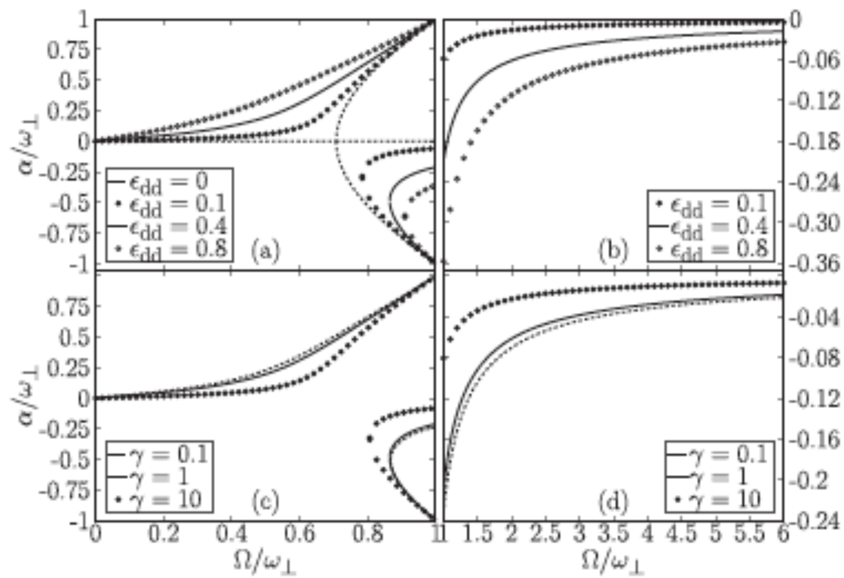
$$i\hbar \frac{\partial \psi}{\partial t} = \left[ -\frac{\hbar^2 \nabla^2}{2m} + V_{\mathrm{T}} + V_{\mathrm{int}} + i\hbar\Omega \left( x\frac{\partial}{\partial y} - y\frac{\partial}{\partial x} \right) \right] \psi .$$

Thomas-Fermi Approximation

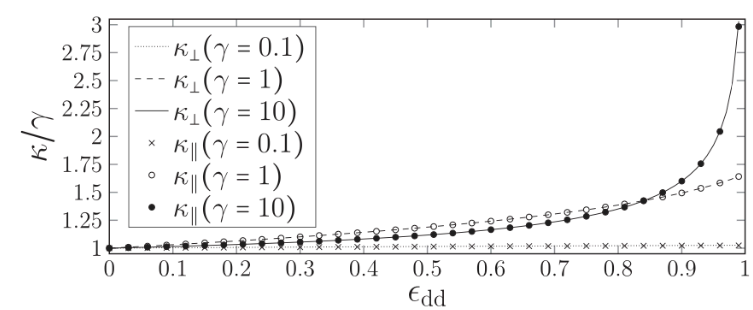
$$n_{\mathrm{TF}}(\mathbf{r}) = n_0 \left( 1 - \frac{x^2}{\kappa_x^2 R_z^2} - \frac{y^2}{\kappa_y^2 R_z^2} - \frac{z^2}{R_z^2} \right).$$

$$S_{\mathrm{TF}}(\mathbf{r}, t) = \alpha xy - \mu t/\hbar,$$

Some maths




Comparison




$$\langle\langle U_{\mathrm{dd}}(\mathbf{r}) \rangle\rangle = \frac{C_{\mathrm{dd}}}{4\pi} \left( \frac{3\cos^2\varphi - 1}{2} \right) \left( \frac{1 - 3(\hat{z}\cdot\mathbf{r})^2}{|\mathbf{r}|^3} \right).$$

# Rotate the Dipoles: Stability

PHYSICAL REVIEW LETTERS 122, 050401 (2019)

**Instability of Rotationally Tuned Dipolar Bose-Einstein Condensates**

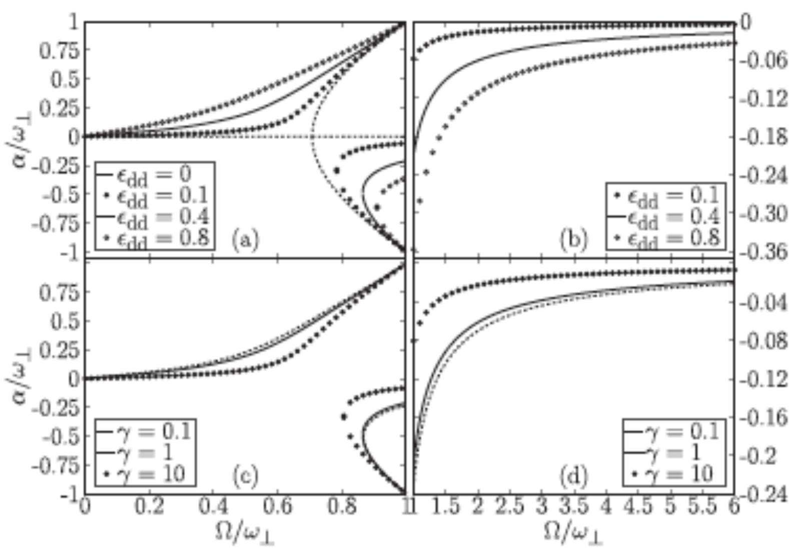
S. B. Prasad,[1] T. Bland,[2] B. C. Mulkerin,[3] N. G. Parker,[1,2] and A. M. Martin[1]

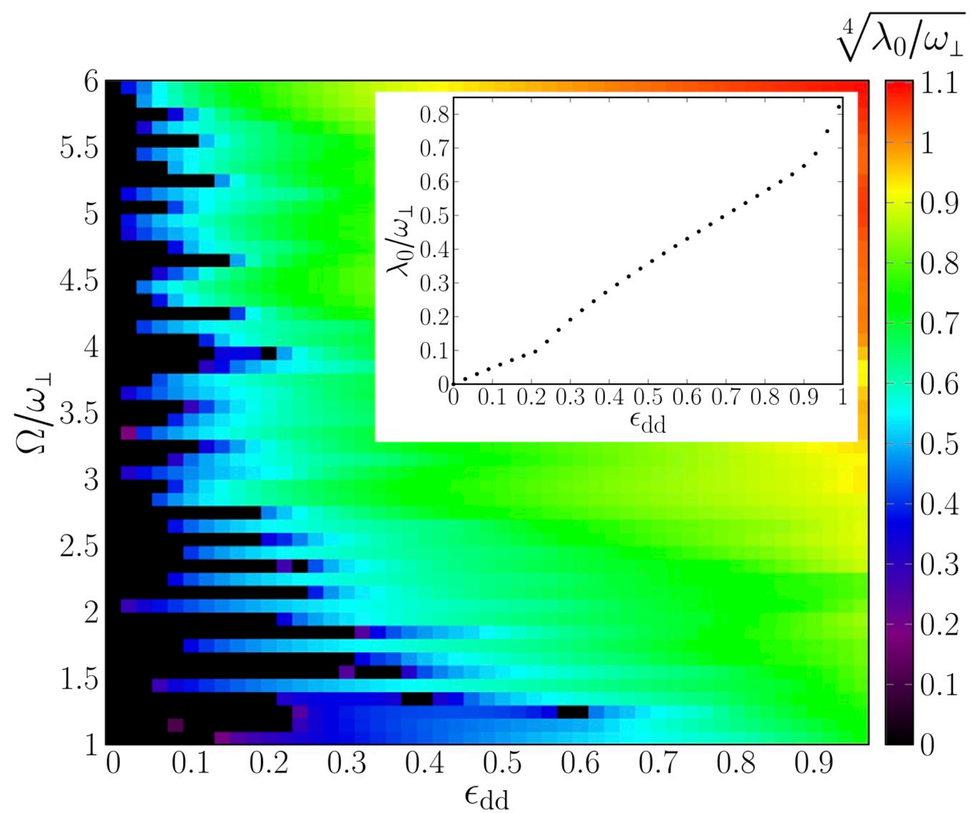
$$n(\mathbf{r},t) = n_{\mathrm{TF}}(\mathbf{r}) + \delta n(\mathbf{r},t);$$

$$S(\mathbf{r},t) = S_{\mathrm{TF}}(\mathbf{r},t) + \delta S(\mathbf{r},t).$$

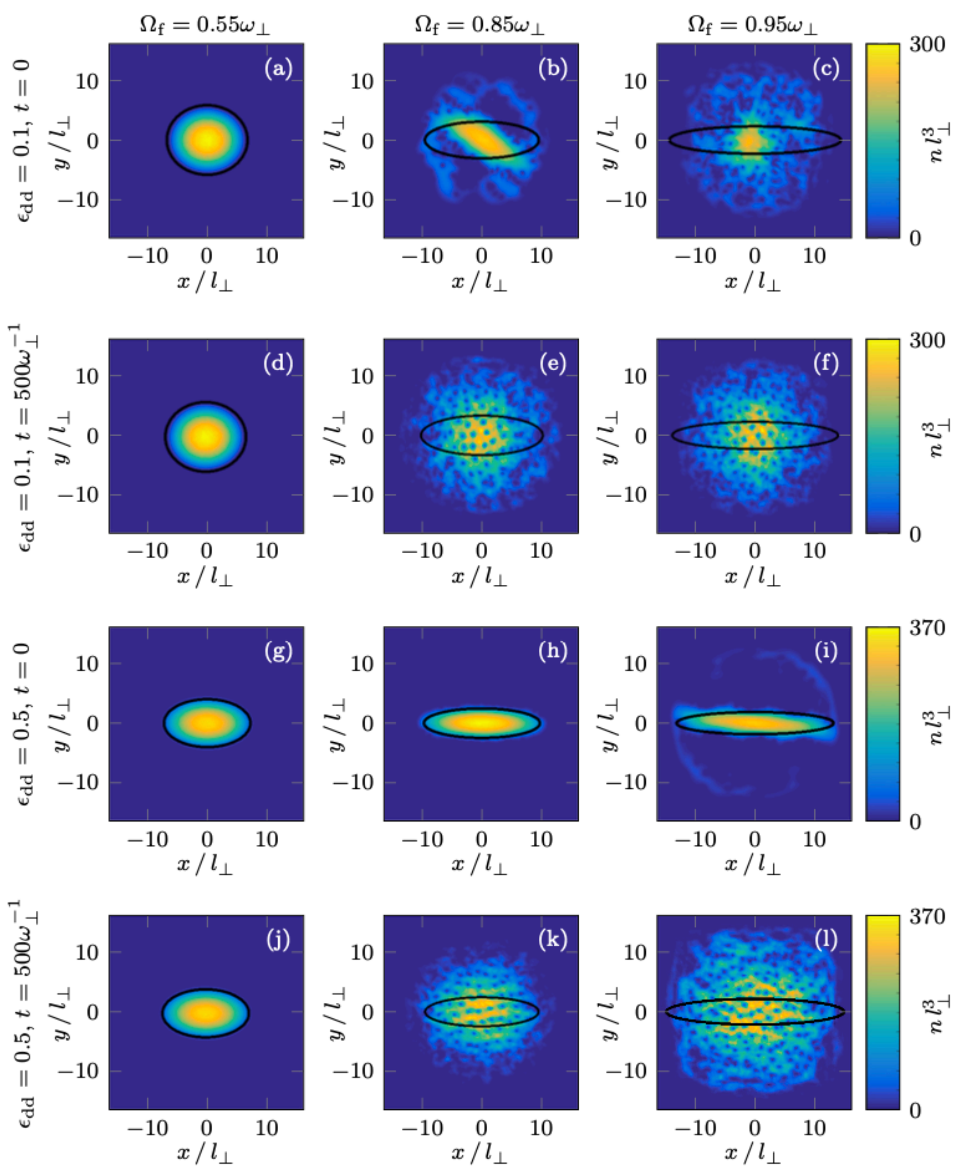
Linearize

$$\frac{\partial}{\partial t}\begin{pmatrix}\delta S\\ \delta n\end{pmatrix} = \mathcal{L}\begin{pmatrix}\delta S\\ \delta n\end{pmatrix},$$



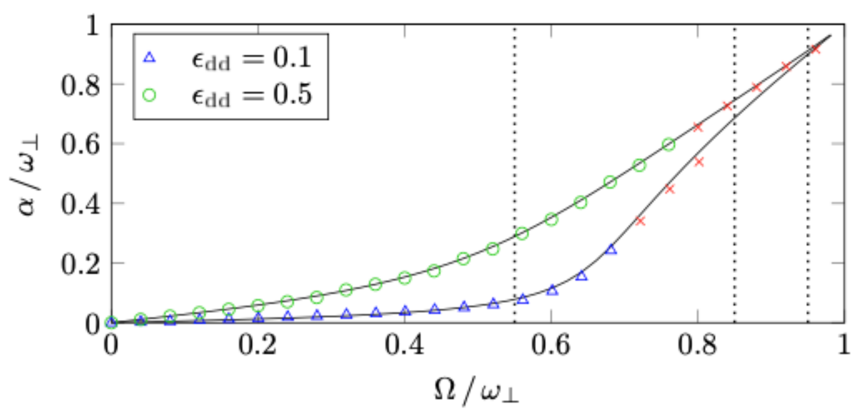
# Rotate the Dipoles: Vortices

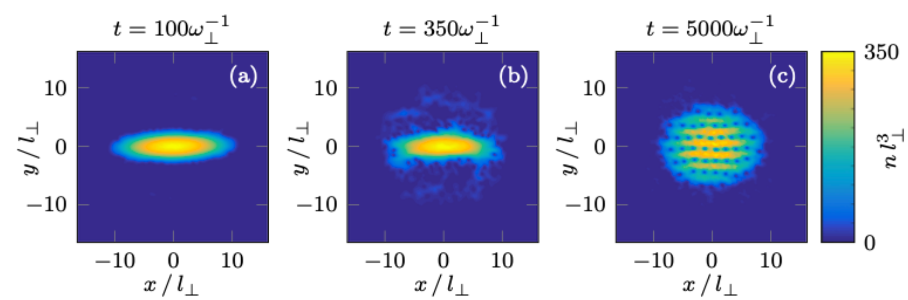



PHYSICAL REVIEW A **100**, 023625 (2019)

**Vortex lattice formation in dipolar Bose-Einstein condensates via rotation of the polarization**

Srivatsa B. Prasad,[1,*] Thomas Bland,[2] Brendan C. Mulkerin,[3] Nick G. Parker,[1,2] and Andrew M. Martin[1]
[1]*School of Physics, University of Melbourne, Melbourne, 3010, Australia*
[2]*Joint Quantum Centre Durham-Newcastle, School of Mathematics, Statistics and Physics, Newcastle University, Newcastle upon Tyne, NE1 7RU, United Kingdom*
[3]*Centre for Quantum and Optical Science, Swinburne University of Technology, Melbourne, 3122, Australia*



# People, Posters and Talks

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## Talks

DC Magnetometry Below the Ramsey Limit with Rapidly Rotating Diamonds
Alex Wood: R5: 2:30-3:00 (Wednesday)

Reduced Density Matrix Approach to Ultracold Fermionic Systems in 1D
Mitchell Knight: R2: 2:45-3:00 (Wednesday)

Dynamics of Quasi-One-Dimensional Dipolar Condensate Droplets
Junfan Wang: R4: 5:15-5:30 (Wednesday)

Tunable Gyromagnetic Augmentation of Nuclear Spins in Diamond
Russell Goldblatt: R6: 2:30-2:45 (Thursday)

## Posters

Quench Dynamics of Trapped Many-Body Systems
Alex Kerin: 5:30-7:00 (Tuesday)

Quench Dynamics of the Extended Su-Schrieffer-Heeger Model
Anirban Ghosh: 5:30-7:00 (Tuesday)

Quench Dynamics in the Jaynes-Cummings-Hubbard and Dicke Models
Andrew Hogan: 5:30-7:00 (Thursday)