Simulating quantum Hall physics in ultracold atomic gases

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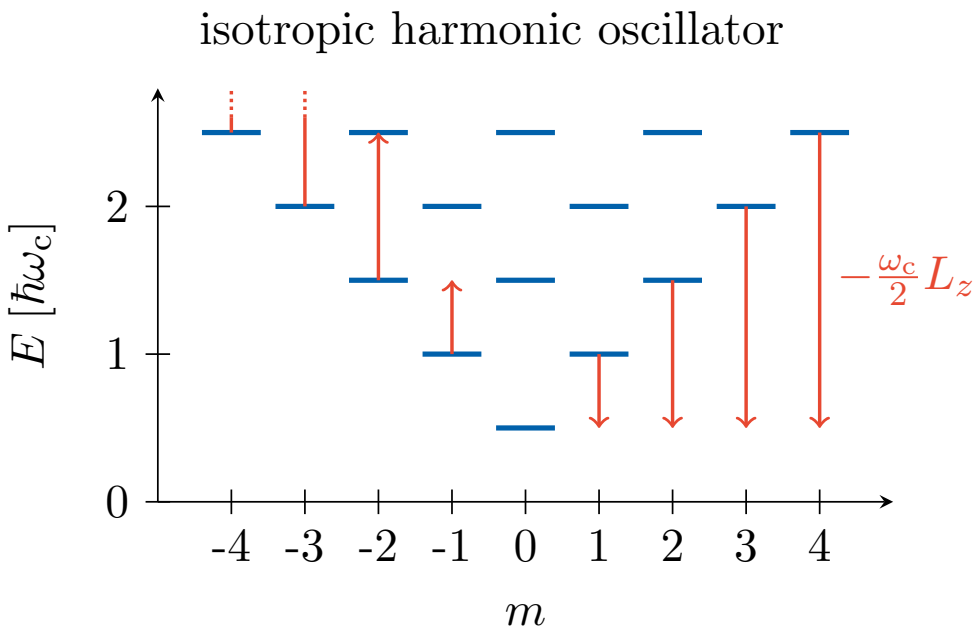
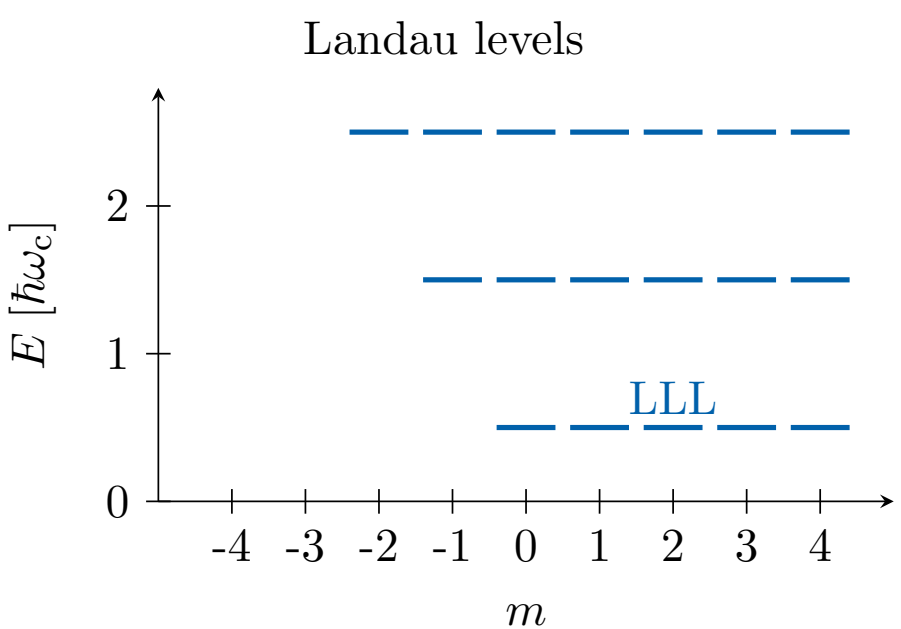
lecture notes at https://comptes-rendus.academie-sciences.fr/physique/articles/10.5802/crphys.243/

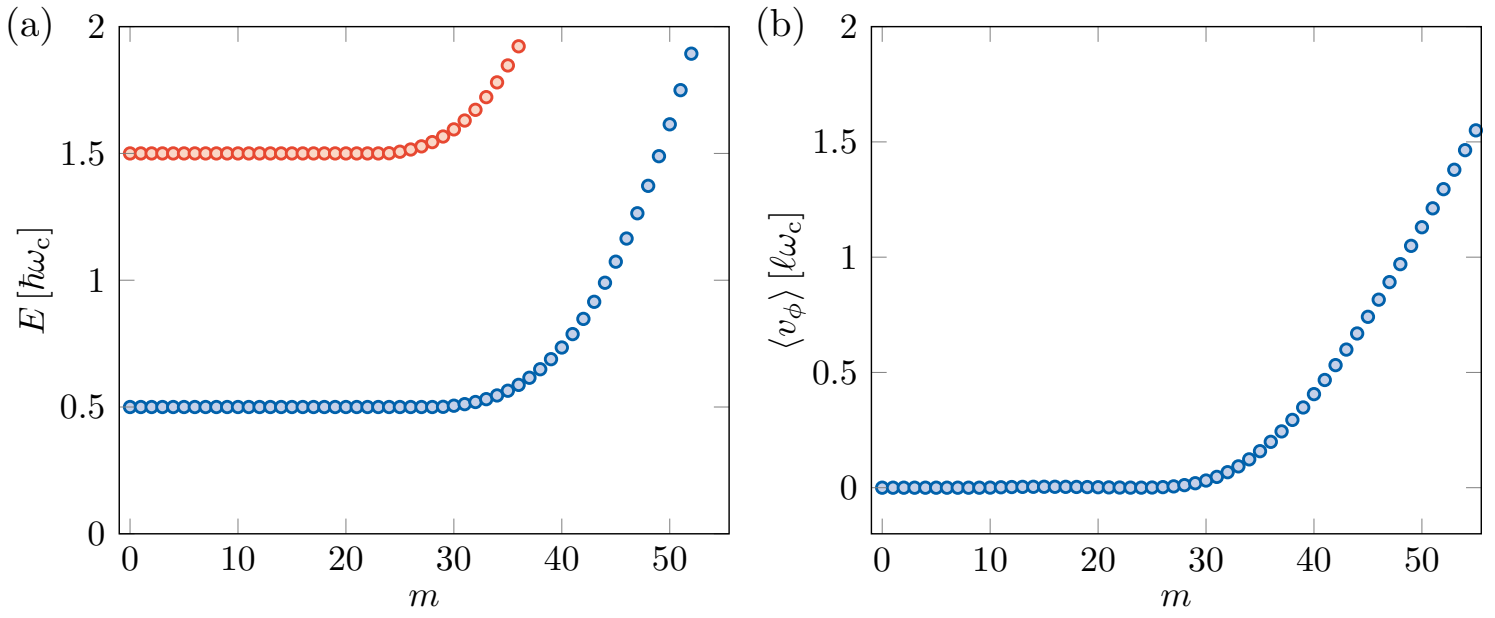
Outline

Landau levels



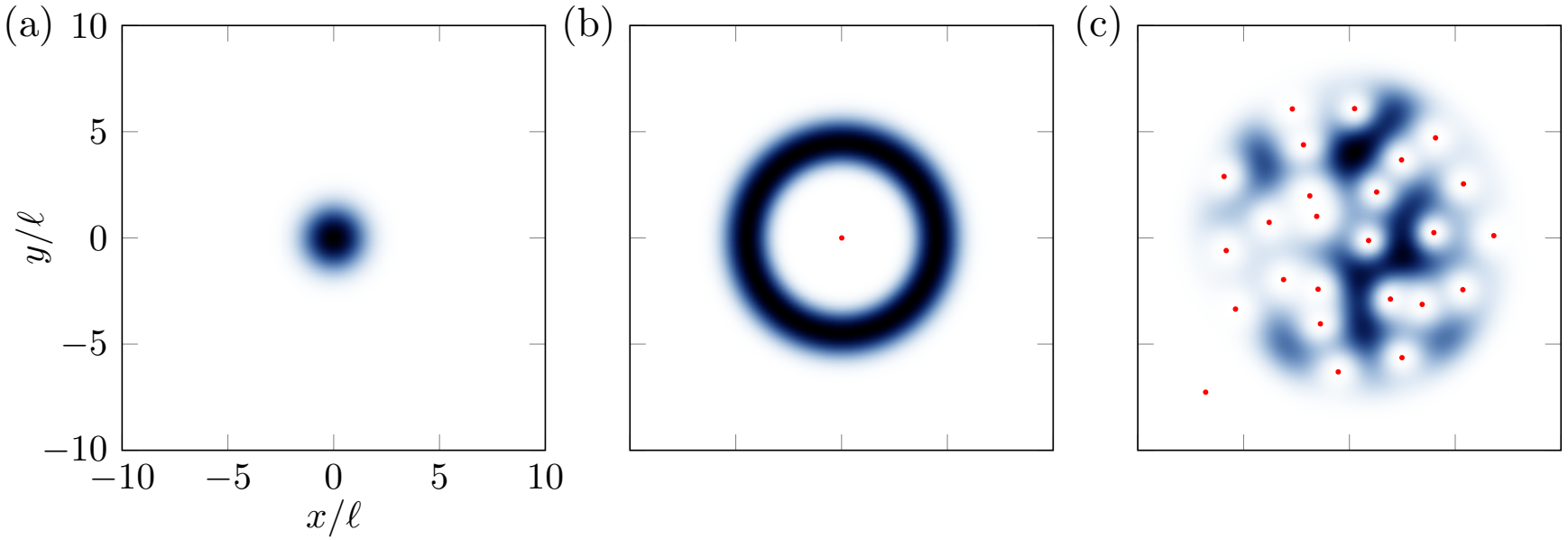


Edge states



Spectrum of a quantum Hall system restricted to a disk of radius $R = 10\,\ell$.

Density of several LLL states

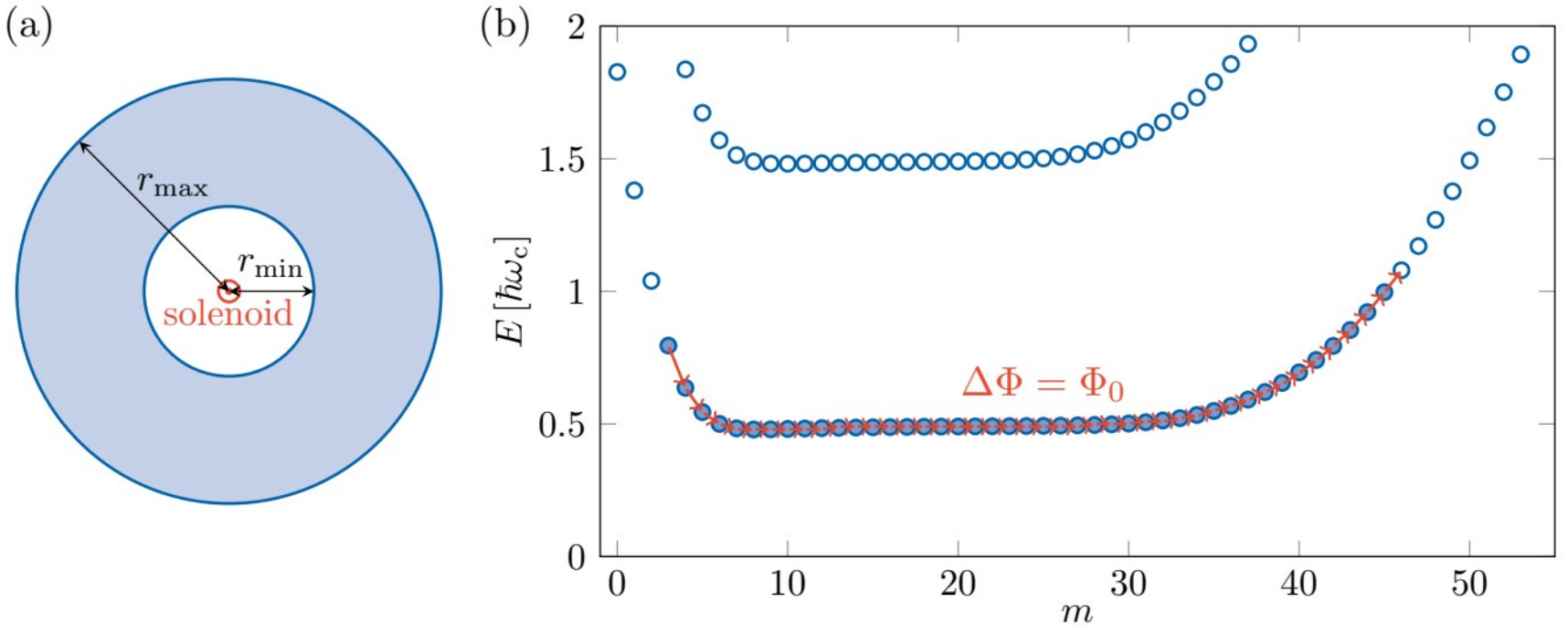


$\psi_{m=0}$

$\psi_{m=10}$

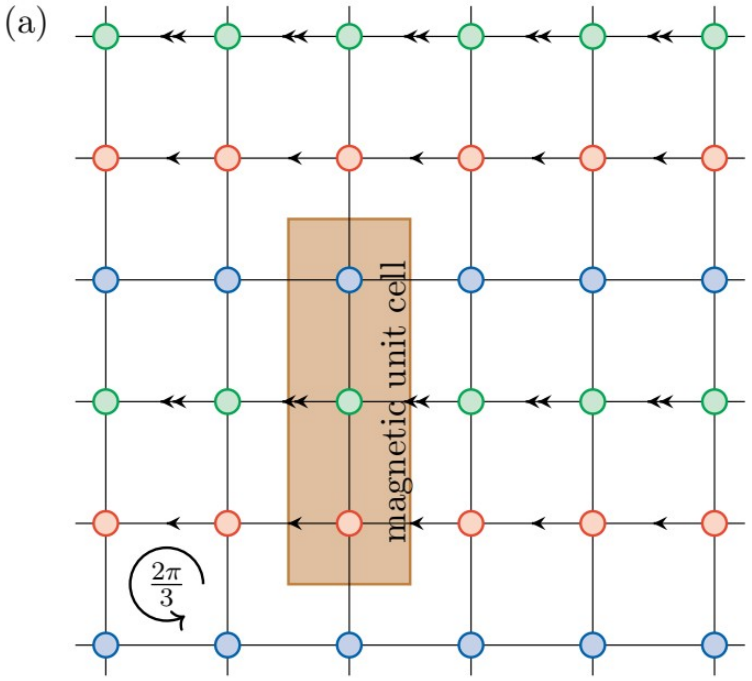
random complex polynomial of order 25

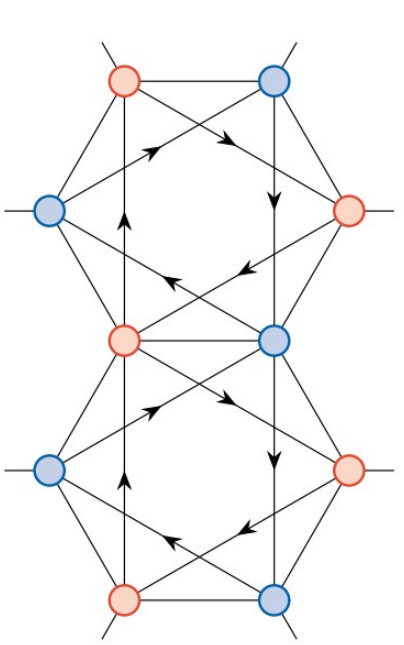
Quantized Laughlin pump (Corbino geometry)



$r_{\min} = 2\ell$ and $r_{\max} = 10\ell$.

Hofstadter and Haldane lattice models



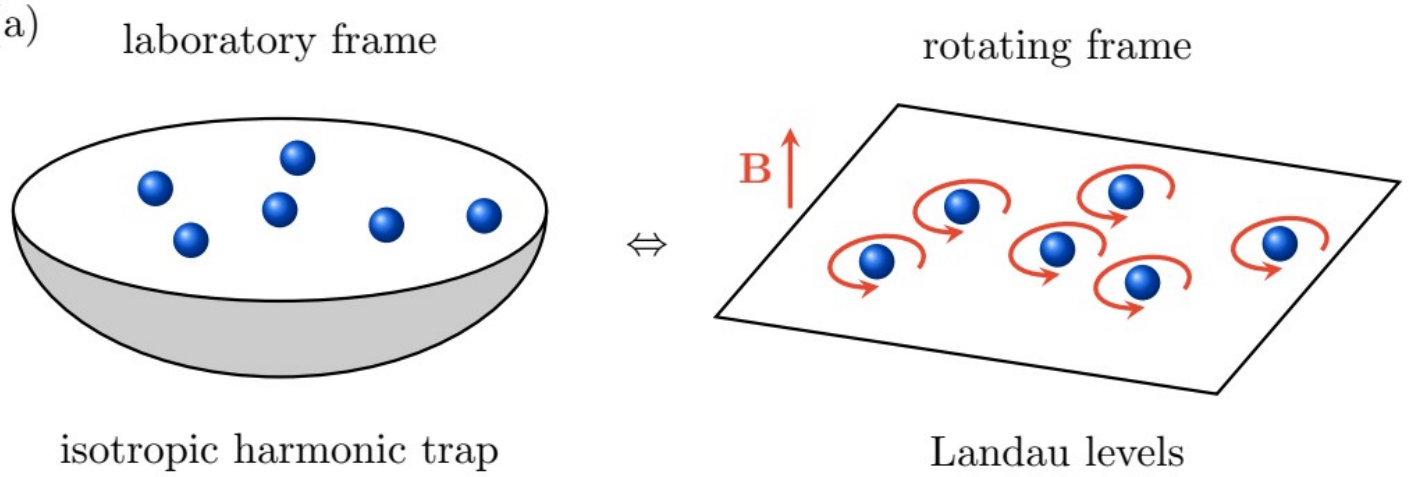


link	——	←—	←←—
Peierls phase	0	$-2\pi/3$	$-4\pi/3$

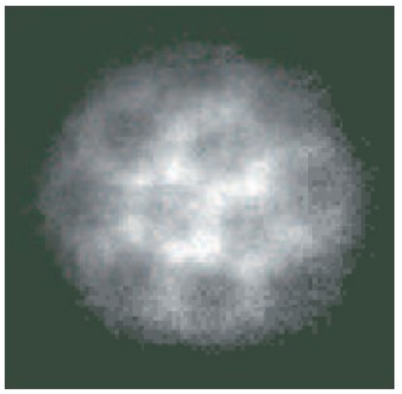
link	——	—→
Peierls phase	0	$\neq 0$

Quantum Hall effect in rotating gases

(a)

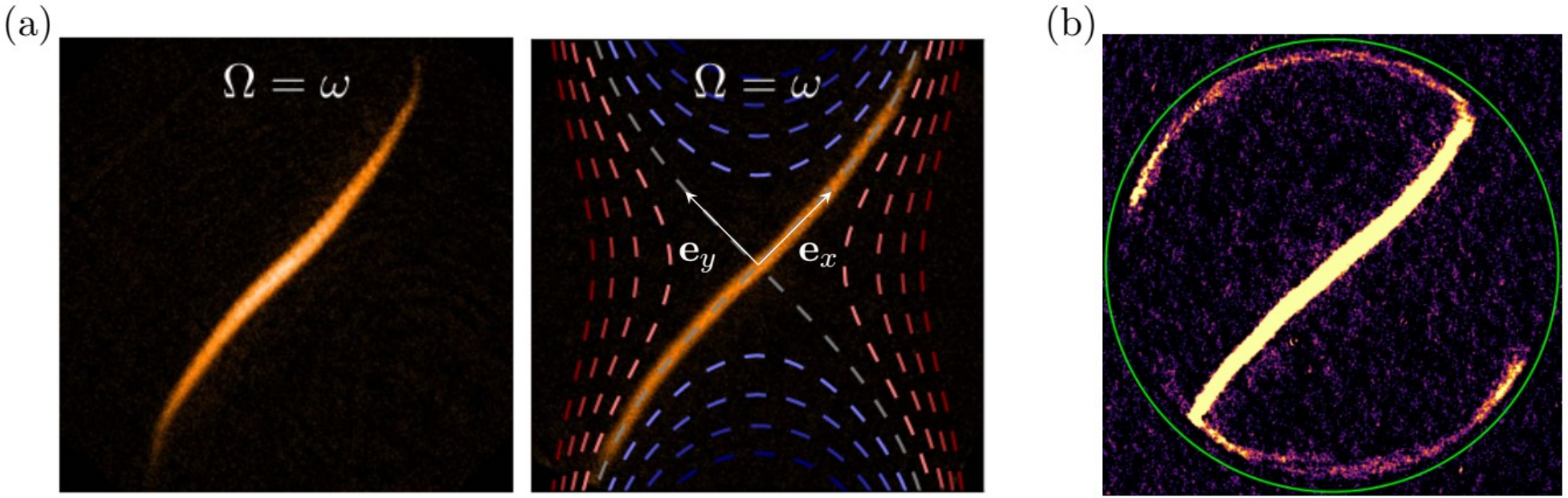


(b)



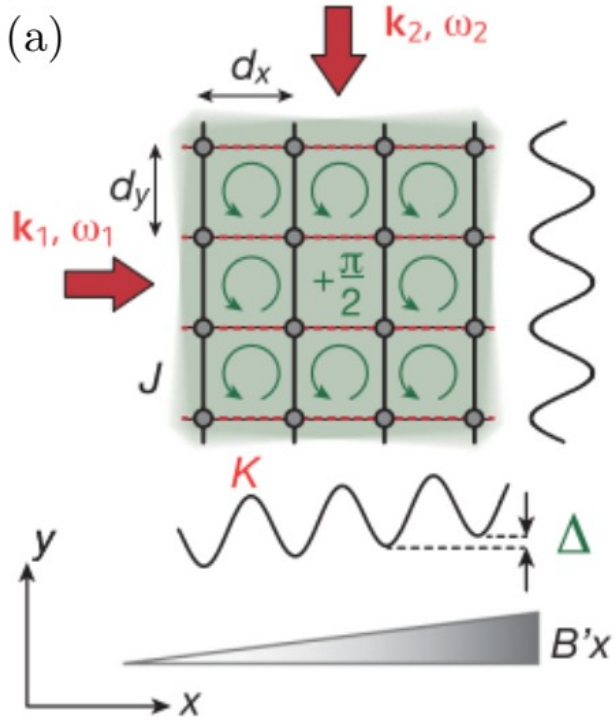
J. Dalibard group (2000),
see also E. Cornell
and W. Ketterle groups

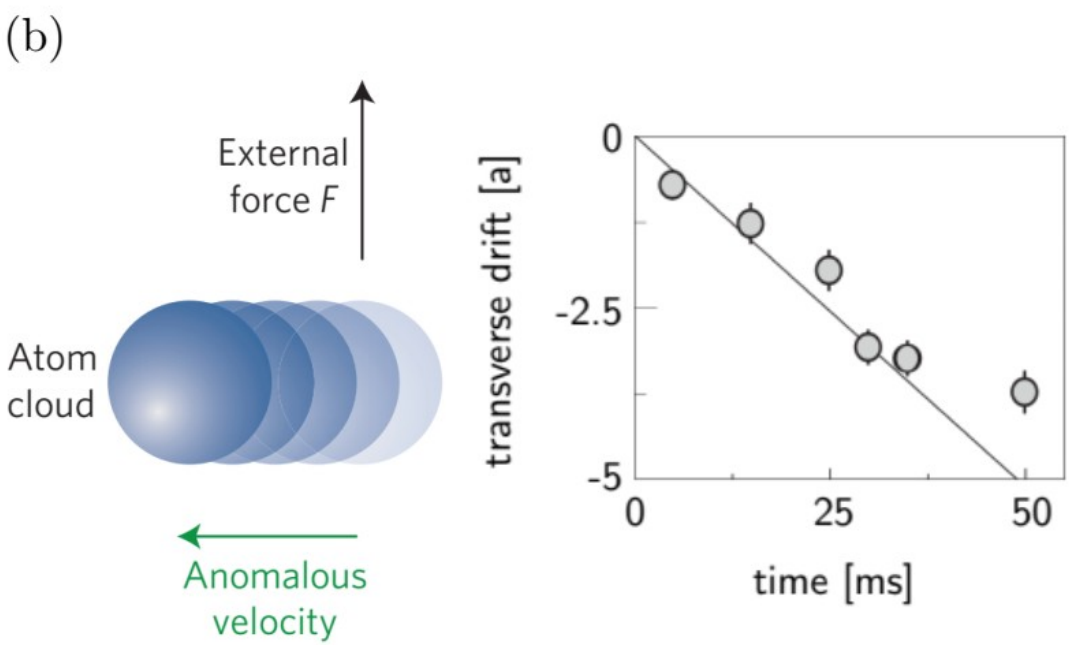
LLL states in a box



Zwierlein group (2021 & 2023)

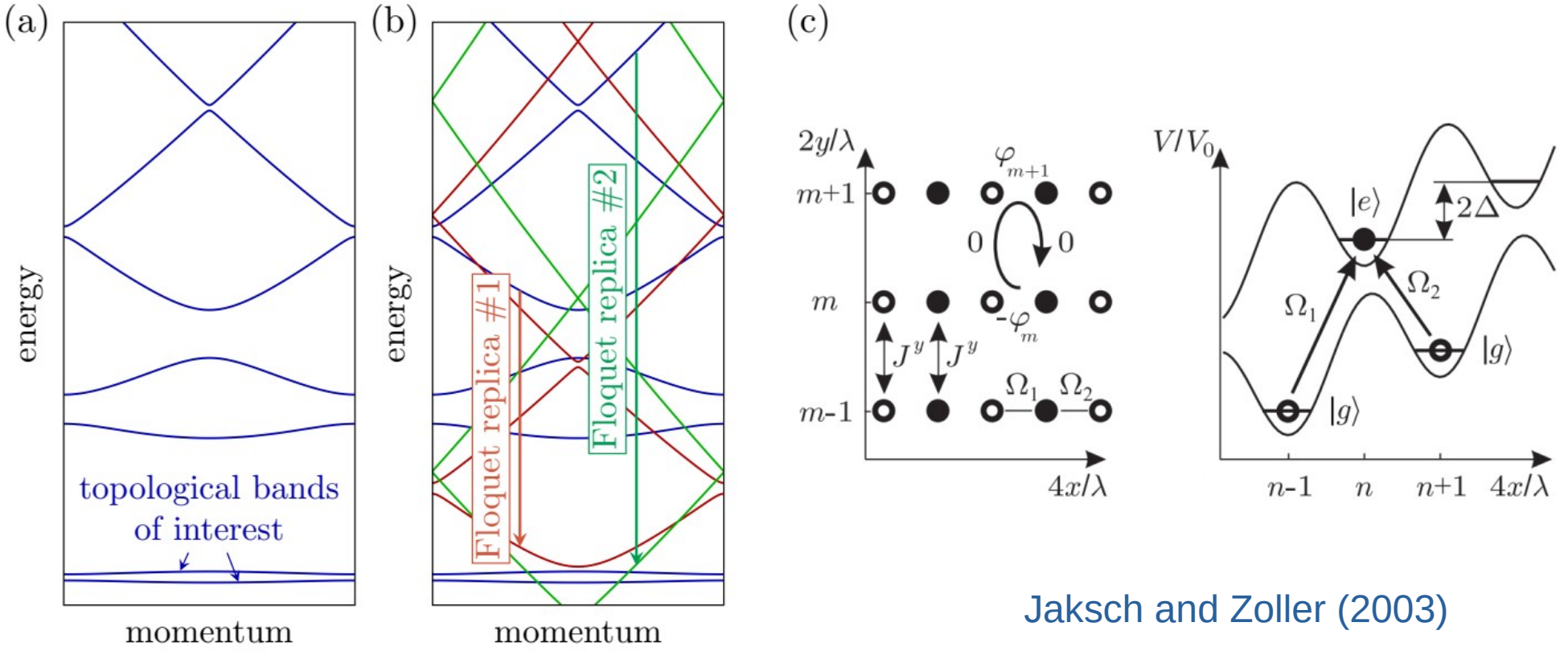
Modulated optical lattice simulating the Hofstadter model





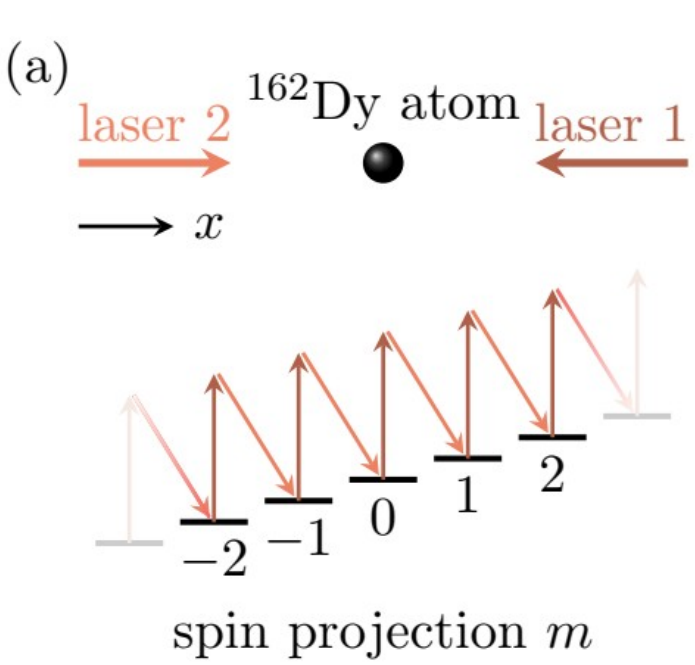
Bloch group (2013 & 2015), see also W. Ketterle, T. Esslinger groups

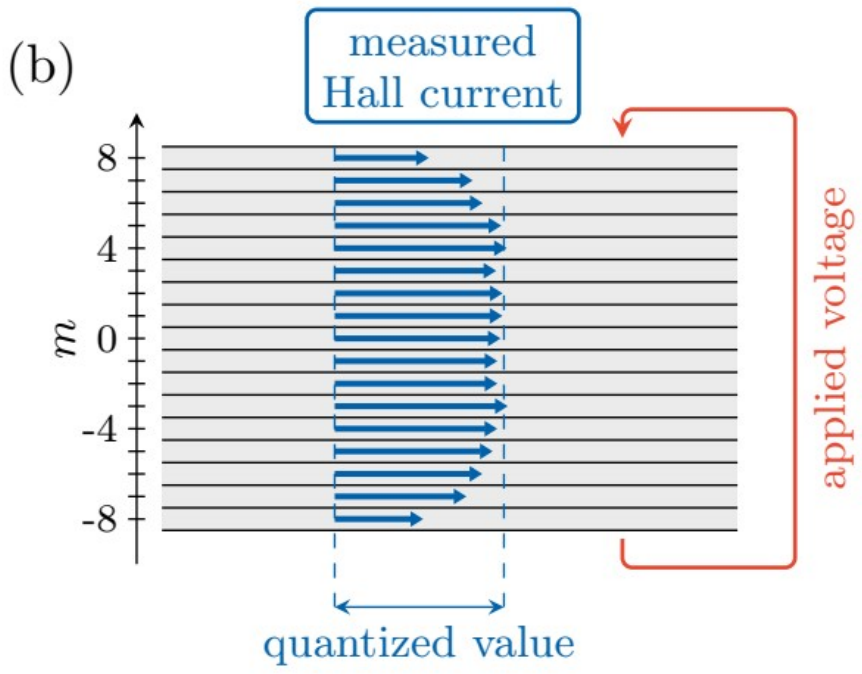
The issue of Floquet heating (and possible solution)



Jaksch and Zoller (2003)

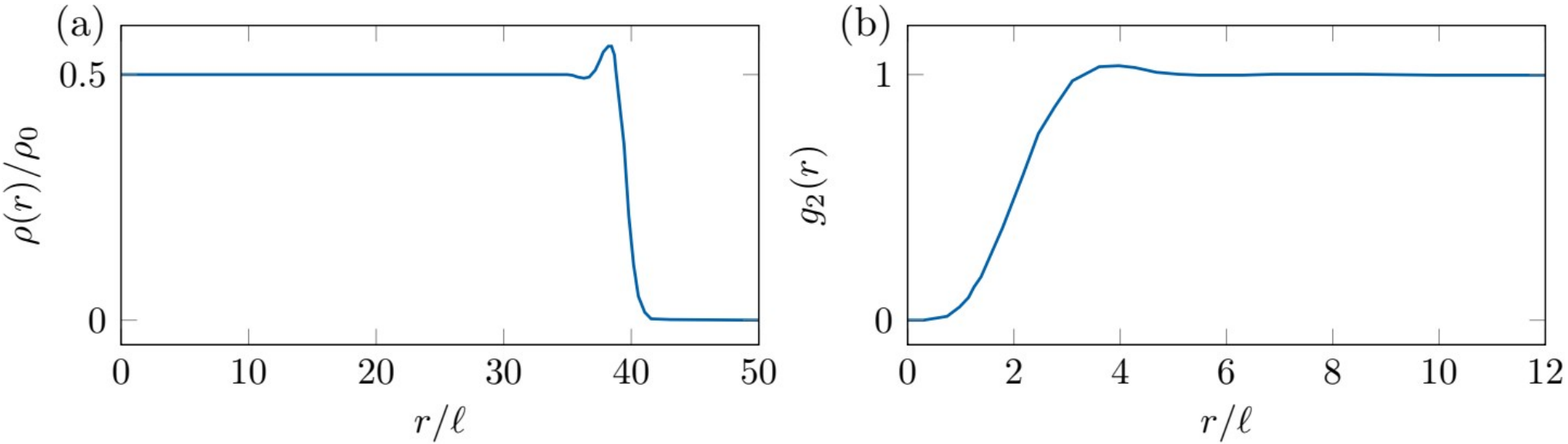
Quantum Hall system using a synthetic dimension





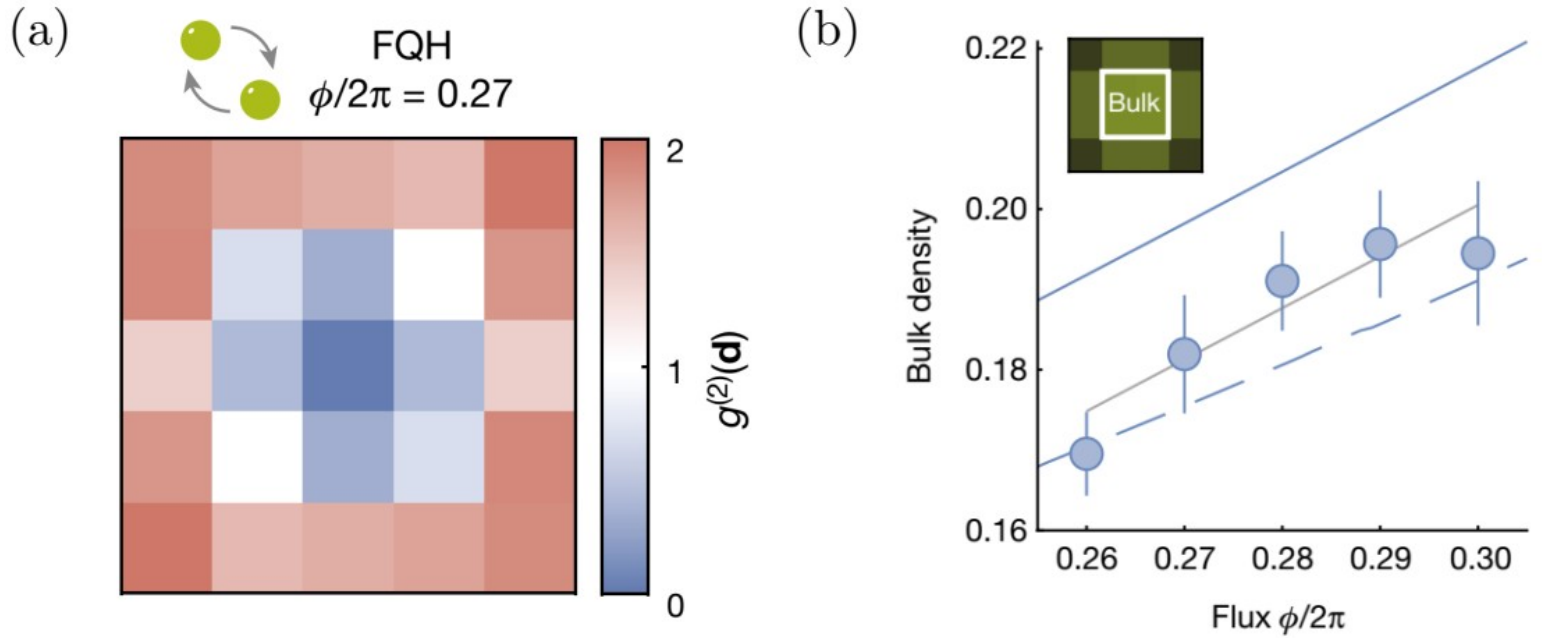
SN group (2020), see also I. Spielman and L. Fallani groups

Density profile and g_2 function of a Laughlin state



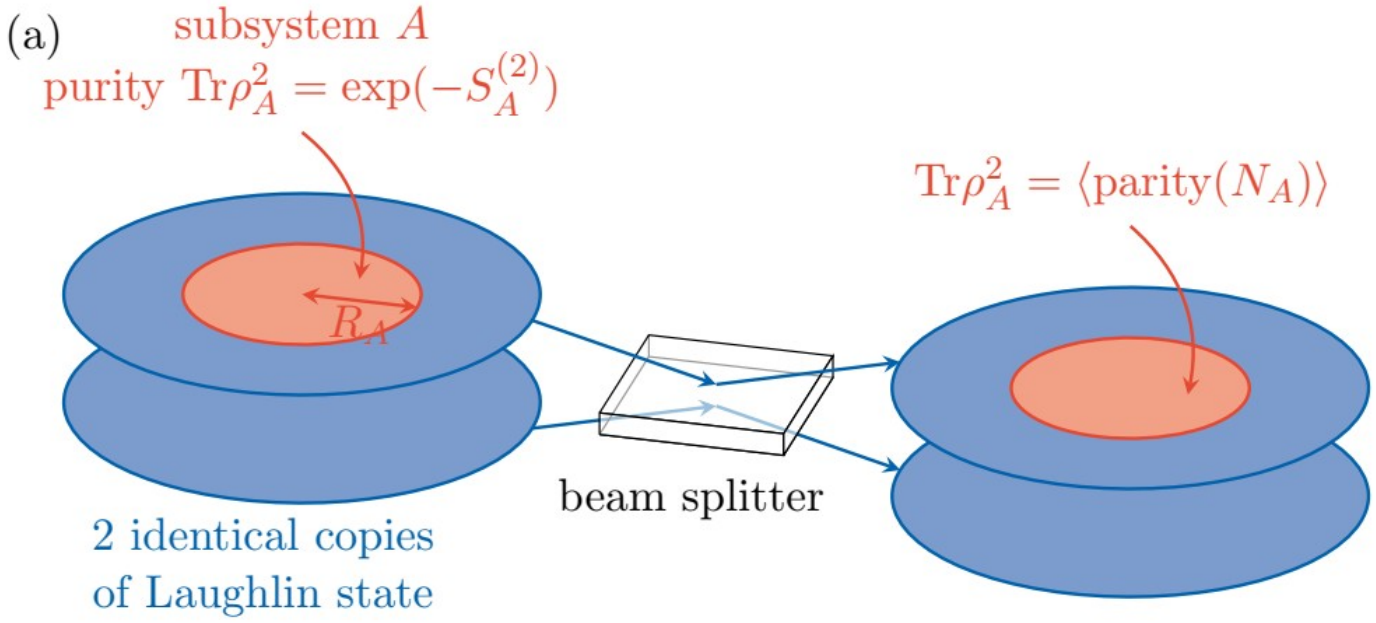
Laughlin state with 400 particles (Monte-Carlo simulation from O. Ciftja, 2006)

Laughlin state with 2 atoms on a lattice

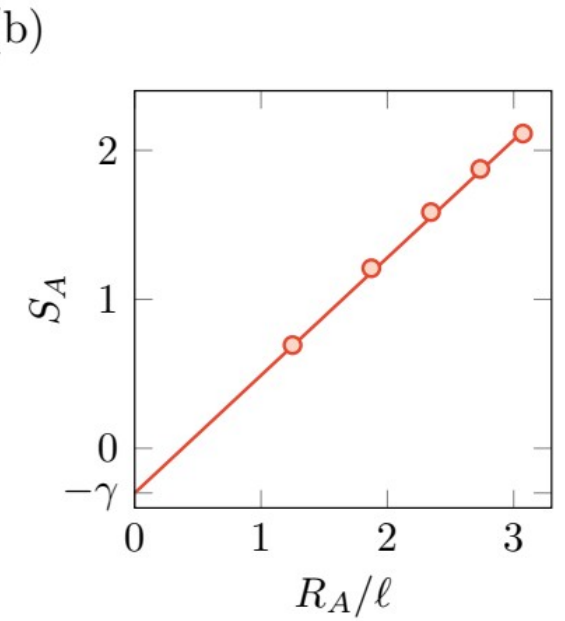


M. Greiner group (2023), see also S. Jochim group

Measuring the entanglement entropy



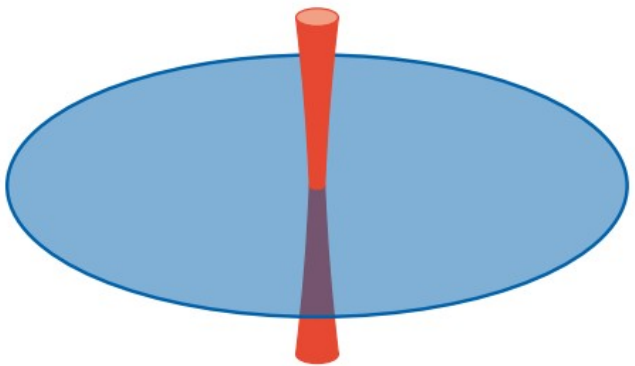
M. Greiner group (2015)



A. G. Morris,
D. L. Feder (2009)

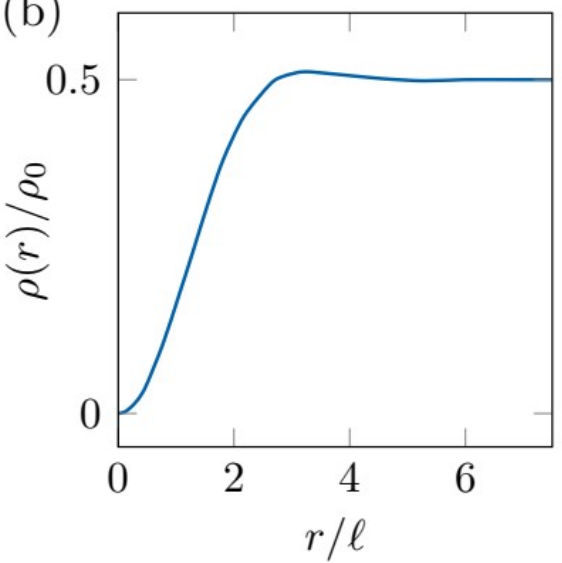
Quasi-hole excitation, fractional charge and statistics

(a)



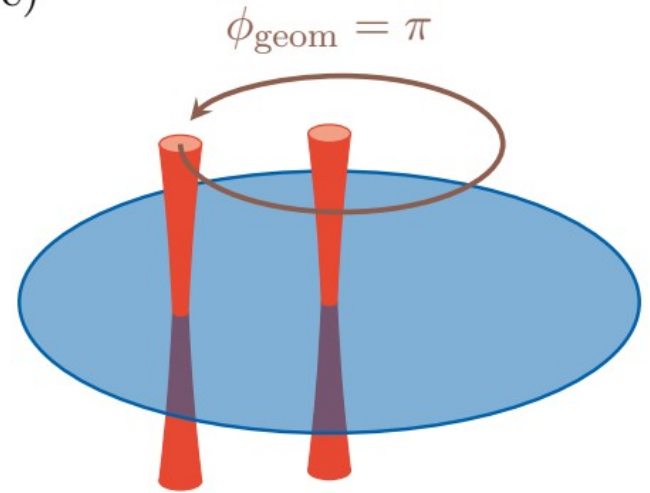
repulsive potential
nucleating a quasi-hole

(b)



quasi-hole density dip
→ charge 1/2, spin 1/4

(c)



braiding operation
→ fractional statistics