Many-body physics of cavity embedded quantum matter

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Why light-matter interaction in cavity QED?

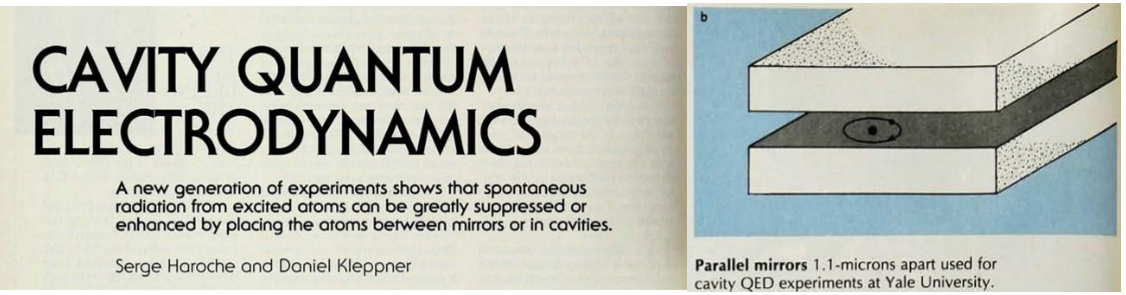
Fine structure constant

$$\alpha = \frac{e^2}{4\pi\,\epsilon_0\,\hbar c} \simeq \frac{1}{137}$$

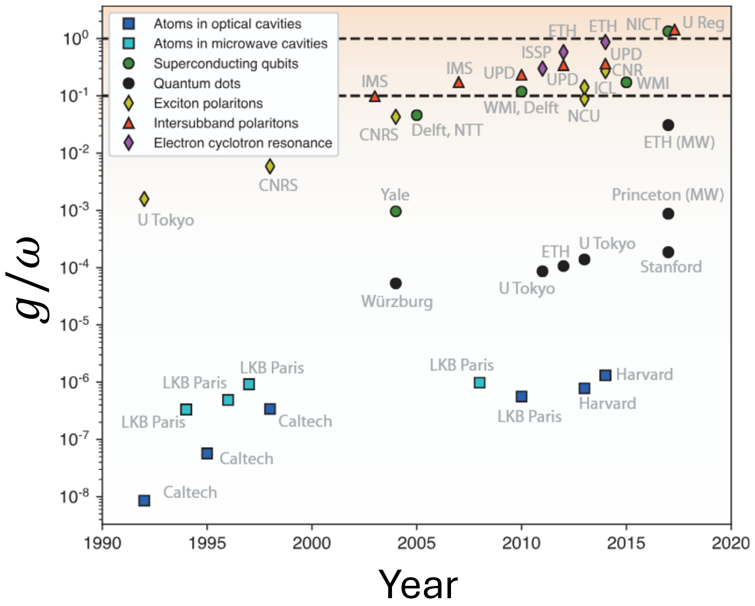
Need to enhance interactions

$$g \sim \vec{d} \cdot \vec{E}_{vac} \qquad E_{vac} \sim \frac{1}{\sqrt{V}}$$

Microwave resonators



Physics Today (1989)



Review strong coupling:

Forn Diaz et al. , Rev. Mod. Phys. (2019)

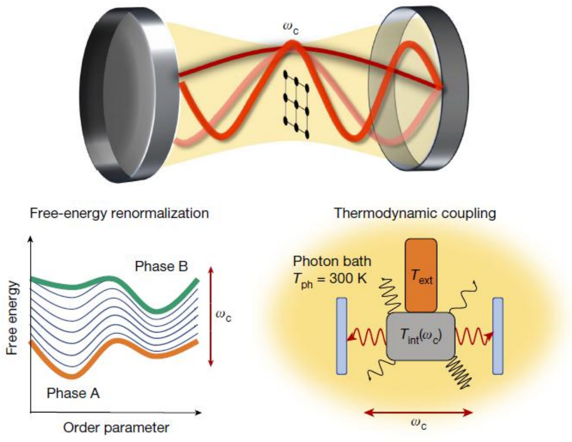
New avenues: controlling matter

Schlawin et al. , Appl. Phys. Rev. (2022)
Garcia-Vidal et al. , Science (2021)
Mivehvar et. al. , Adv. Phys. (2021)

Single emitters → Many-body

Control quantum matter by cavity embedding?

Quantum materials



Subwavelength cavities

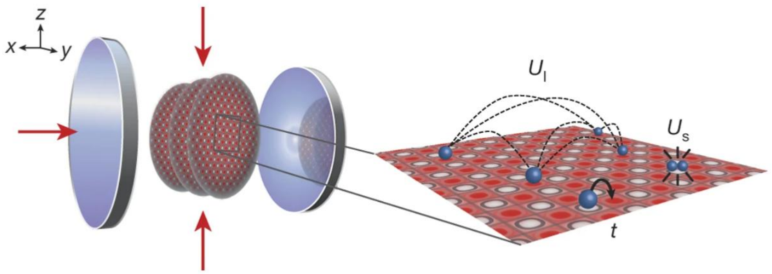
No external drive

Few control parameters

Fausti, Nature (2023)

Other exp: J. Faist (ETH Zurich),
S. Zhang (HKU), D. Basov (Columbia)

Cold atom systems



Fabri-perot cavities

Out-of-equilibrium

Highly controllable

Esslinger, Nature (2016)

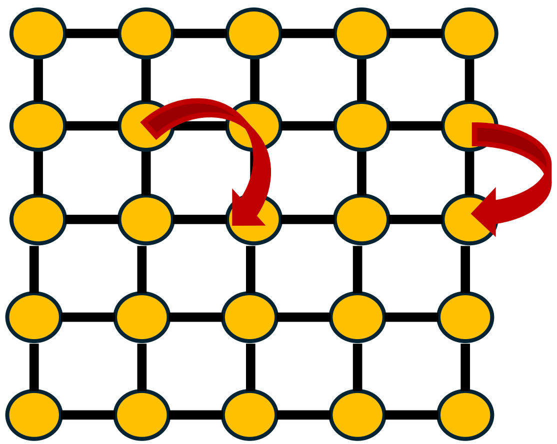
New hybdrid many-body scenario

«Standard»

$$\hat{H} = \sum_{<ij>} \hat{O}_i \, \hat{O}_j$$

Cavity embedded

$$\hat{H} = \sum_{<ij>} \hat{O}_i \, \hat{O}_j + \sum_{\alpha} \omega_\alpha \, \hat{a}_\alpha^\dagger \, \hat{a}_\alpha + \sum_{\alpha} g_\alpha \hat{O}_i (\hat{a}_\alpha^\dagger + \hat{a}_\alpha)$$

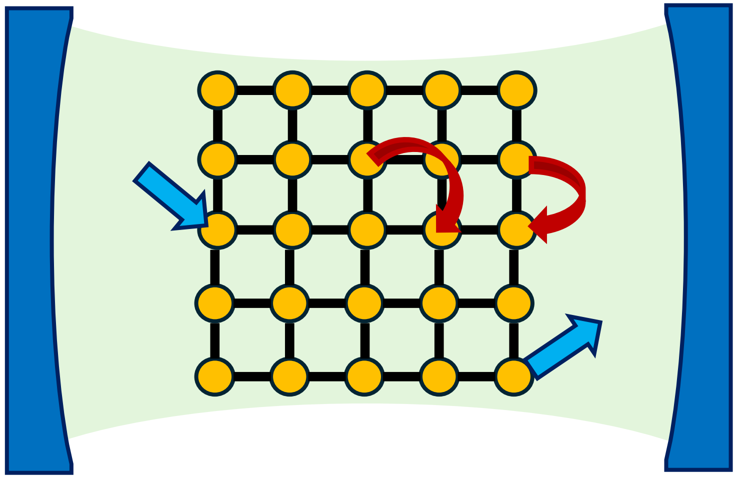


Electrons, atoms, spins ...

Locality

- Correlation structure
  Eisert et al. RMP, 82,277 (2008)
- Dynamical properties
  Chen et al. RPP, 86 ,116001 (2023)
- Topological protection
  X.-G. Wen, OUP (2007).

?



Non-local cavity modes

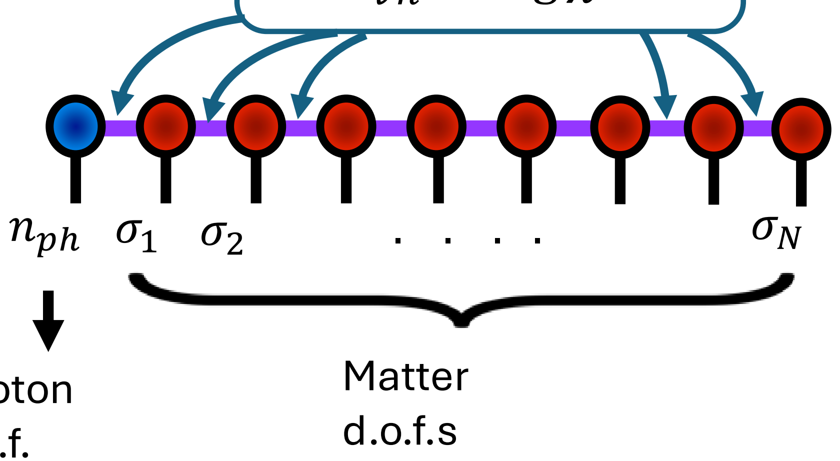
Methods: Matrix product states (MPS)

White PRL 69, 2863 (1992)
Schollowock, Ann. Phys. 321,1 (2011)
...

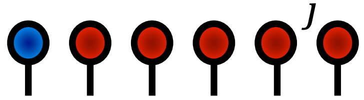
$$|\Psi\rangle = \sum_{n_{ph},\{\sigma_i\}} \Psi_{n_{ph},\sigma_1,\sigma_2,\ldots,\sigma_N} |n_{ph},\sigma_1,\sigma_2,\ldots\sigma_N\rangle$$

χ : bond dimension
$S_{vn} \propto \log\chi$

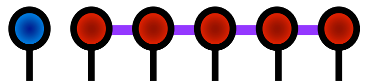
$$\Psi_{n_{ph},\sigma_1,\sigma_2,\ldots,\sigma_N} =$$



- Mean Field $|\Psi\rangle = |\psi_{ph}\rangle \prod_j |\phi_j\rangle$

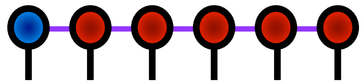


- Photon Mean Field $|\Psi\rangle = |\psi_{ph}\rangle|\psi_{mat}\rangle$



- Polaritons $|1_{ph},\{0\}\rangle + \sum_j \sigma_j^+ |0_{ph},\{0\}\rangle$

$\chi = 2$



Refs: C. Halati, A. Sheikhan, and C. Kollath PRR **2**, 043255 (2020)
G. Chiriacò, M. Dalmonte, and T. Chanda PRB **106**, 155113 (2022)
G. Passetti, C. J. Eckhardt, M. A. Sentef, and D. M. Kennes PRL **131**, 023601 (2023)
Z. Bacciconi, G. M. Andolina, T. Chanda, G. Chiriacò, M. Schirò, M. Dalmonte SciPost Phys. 15, 113 (2023)

Outline

I) Topology: FQH

Bacciconi et al.; PRX 15,021027 (2025)

- Introduction and motivation
- Stability of topology
- Emergent graviton-polaritons

II) Non-local dynamics: Rydberg atom array

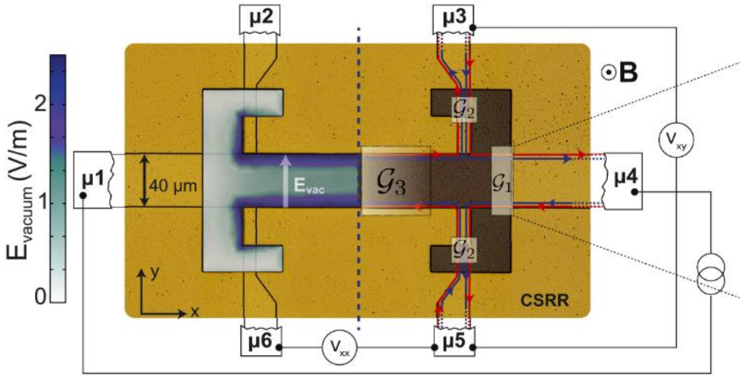
Bacciconi et al.; PRL 134,13604 (2025)

- Introduction
- Mixed local and non-local excitations

Part I) Topology: Fractional Quantum Hall

1. *Theory of fractional quantum hall liquids coupled to quantum light and emergent graviton-polaritons,* Bacciconi, Xavier, Chanda, Carusotto, Dalmonte; PRX 15,021027 (2025)

Quantum Hall systems: experiments

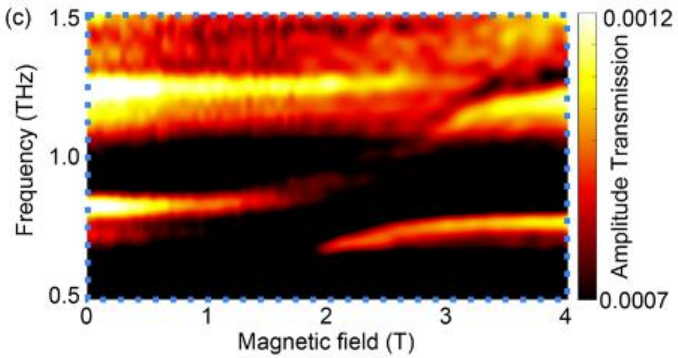


cavity ~ LC circuit

2DEG + split-ring resonator

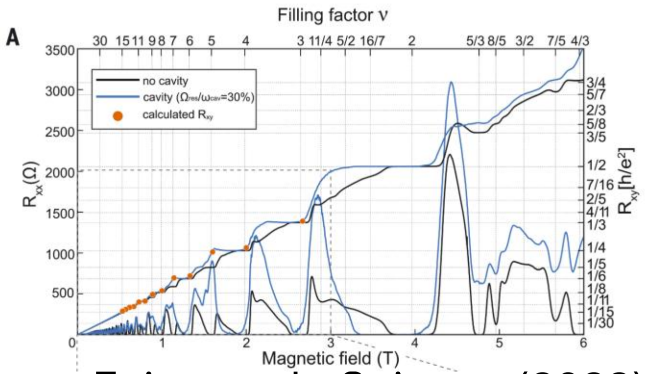
@ETH, J. Faist's group

Subwavelength cavity $\lambda \gg L$



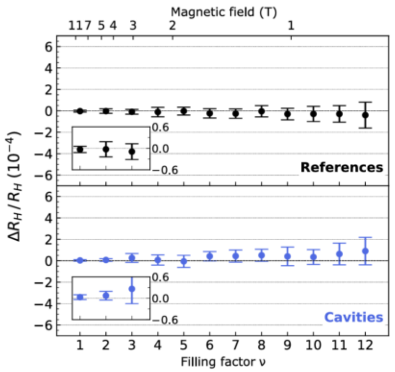
Integer Quantum Hall

«Breakdown of topological protection»



Appugliese, Faist, et al., Science (2022)

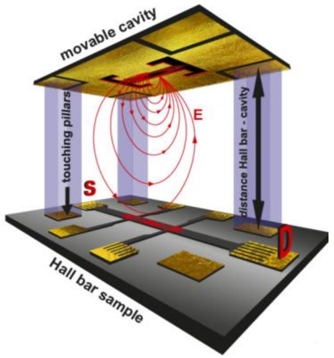
«Von Klitzing constant»

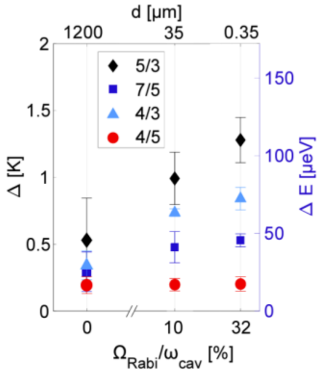


Enker, Faist, et al. , PRX (2024)

Fractional Quantum Hall

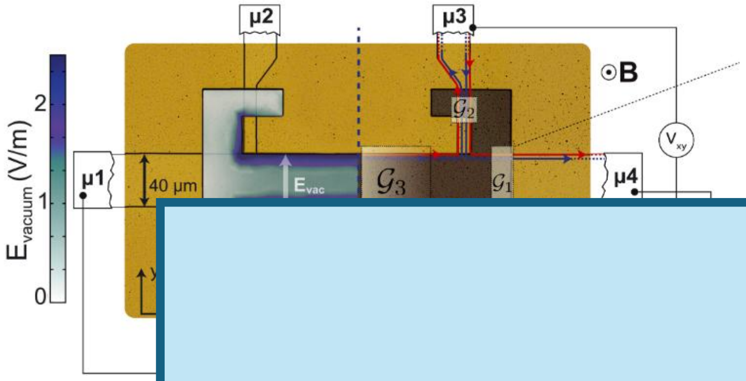
«Enhanced FQH gaps»



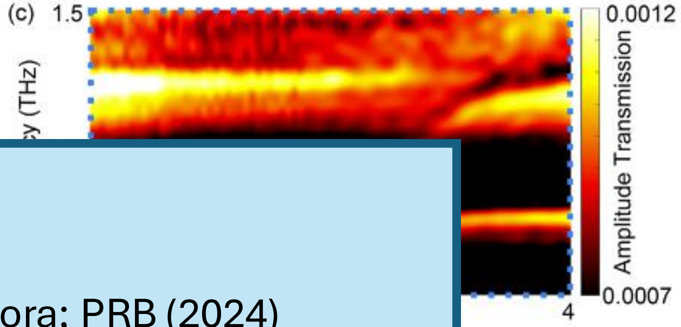


Enker, Faist et al. Nature (2025)

Quantum Hall systems: experiments



2DEG + split-ring resonator



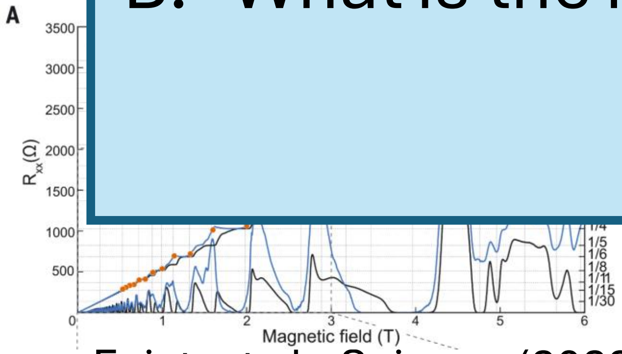
«Breakdov

ll

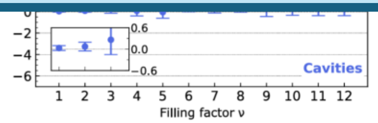
A. Non-locality and topology?

B. What is the key player in the FQH regime?

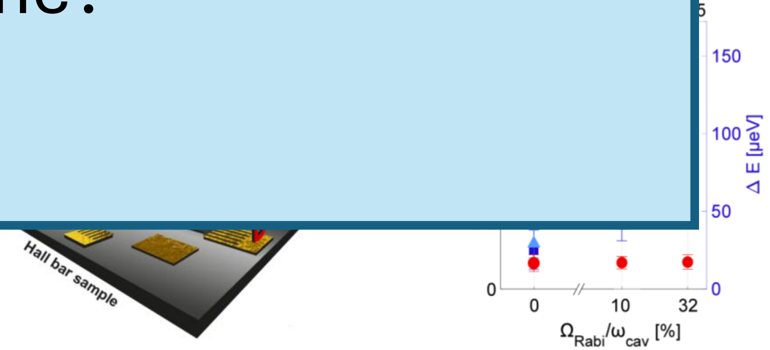
See also:
ZB, G.M. Andolina, C. Mora; PRB (2024)
G.M. Andolina, **ZB**, A. Nardin, M. Schirò, P. Rabl, D. De Bernardis, arxiv 2511.04744 (2025)



Appugliese, Faist, et al., Science (2022)

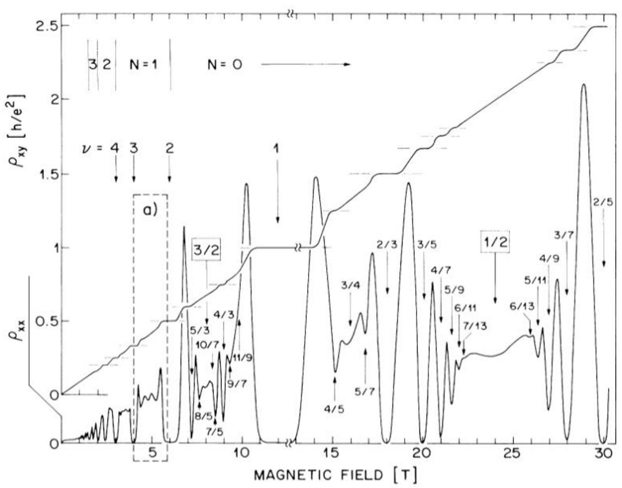


Enker, Faist, et al. , PRX (2024)

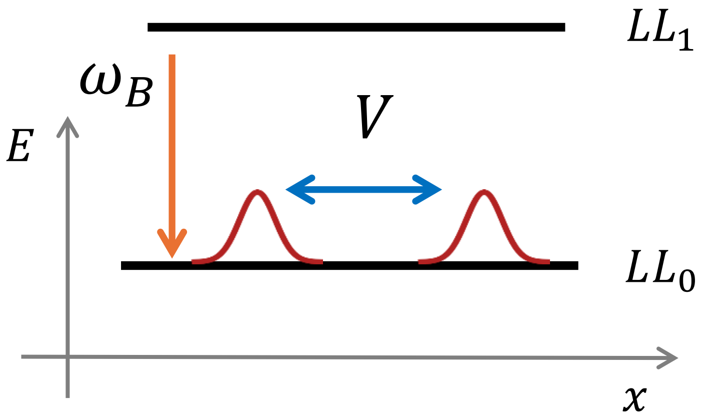


Enker, Faist et al. Nature (2025)

Intro: Fractional Quantum Hall effect

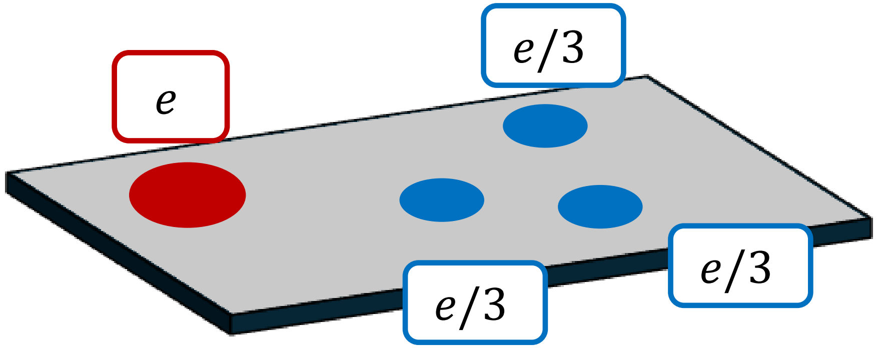


Laughlin, Stromer, Tsui
Nobel Prize 1998



Interactions
$\omega_B \gg V$
+
Landau Level filling
ν

Laughlin state $\nu = 1/3$



1) Quantized Hall reistivity

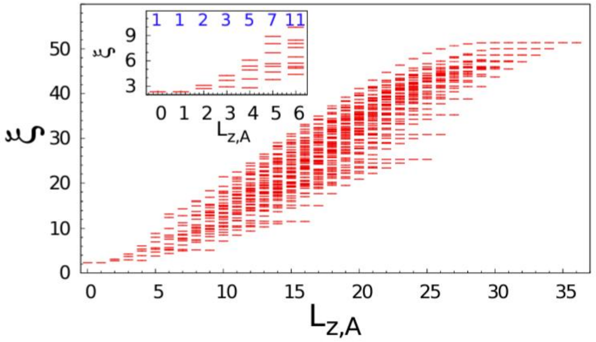
$$\rho_{xy} = \frac{e^2}{h}\frac{1}{\nu}$$

2) Fractionalized quasiparticles

$$e^* = \frac{e}{3} \qquad \theta_{br} = \frac{2\pi}{3}$$

3) Entanglement structure

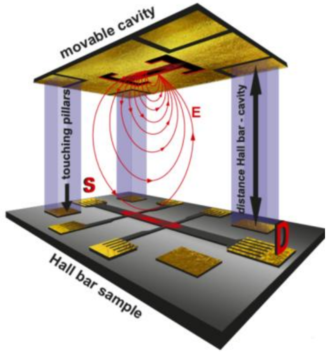
Li Haldane, PRL (2008)
N. Regnault, lecture notes (2015)

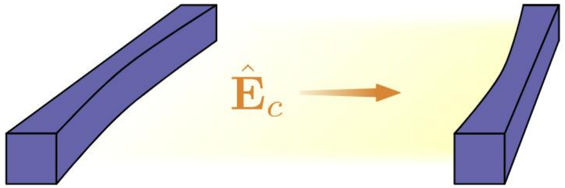


Quantum light-matter coupling

Split-Ring resonator $\simeq$ single cavity mode

Ciuti; PRB (2018)





1) Frequency $\quad \omega_c\, \hat{a}^\dagger \hat{a}$

2) Mode structure

$$\hat{\boldsymbol{E}}_c\ (\boldsymbol{r}) = (\hat{a}^\dagger + \hat{a})\, \boldsymbol{E}_c(\boldsymbol{r})$$

$$V_c(\boldsymbol{r}) = \int_{\boldsymbol{r_0}}^{\boldsymbol{r}} d\boldsymbol{r} \cdot \boldsymbol{E}_c(\boldsymbol{r})$$

Dipole gauge

$$\hat{\mathrm{H}}_{tot} = \hat{H}_{int} + \omega_c \hat{a}^\dagger \hat{a} + \omega_c (\hat{a}^\dagger + \hat{a})\, \hat{P} + \omega_c \hat{P}^2$$

$$\hat{P} = \int d^2\boldsymbol{r}\ \hat{\psi}^\dagger(\boldsymbol{r})\, \hat{\psi}(\boldsymbol{r})\, V_c(\boldsymbol{r})$$

Multipolar expansion

$$\hat{P} \simeq \mathbf{D} \cdot \boldsymbol{E}_c(\boldsymbol{r_0}) + \overleftrightarrow{\mathbf{Q}} \cdot \boldsymbol{\partial E_c}(\boldsymbol{r_0})$$

Only inter LL	Also intra LL!
ω_B	V

Dmytruck, Schirò; PRB (2021) Li, Eckstein et al; PRB (2021)

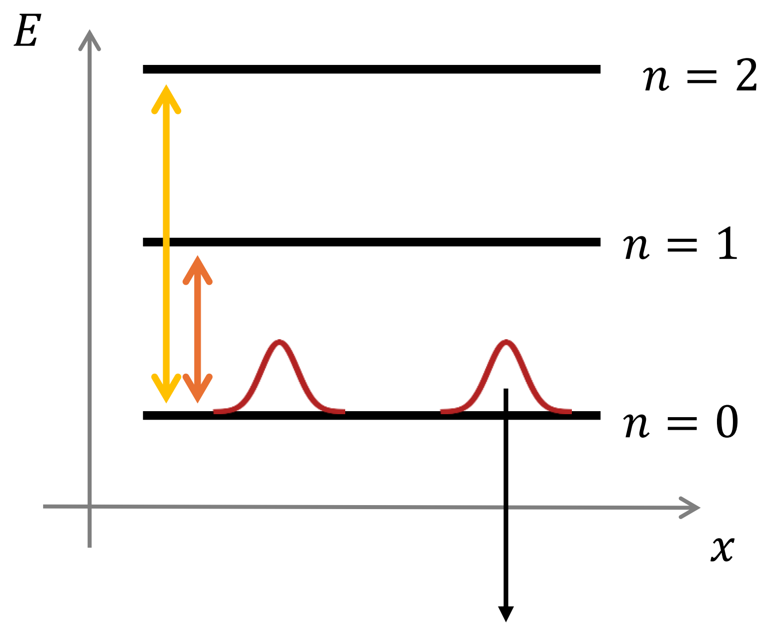
Quantum light-matter coupling: Landau Levels

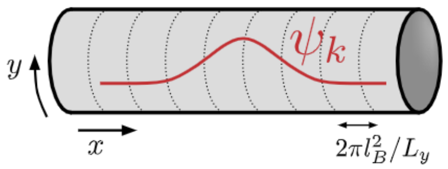
Polarization operator

$$\hat{P} = \sum_k \sum_{n,n'} \chi_k^{n,n'} \; \hat{c}^\dagger_{k,n} \hat{c}_{k,n'}$$

Simplifying assumption:

$$\boldsymbol{E_c}(\boldsymbol{r}) = E_c(x)\, \boldsymbol{u_x}$$





$$X_k = \frac{2\pi}{L_y} n_k$$

$$\omega_c\, \chi_k^{n,n'} = \; e\, l_B\, E_c(X_k) \left(\delta_{n\,,n+1} + \delta_{n\,,n-1}\right) +$$

$$+\, e\, l_B^2\, \partial_x E_c(X_k) \left(\delta_{n\,,n-2} + \delta_{n\,,n+2}\right) +$$

$$+\; \chi(X_k)\, \delta_{n,n'}$$

Inter-LL: Dipole, Quadrupole

Intra-LL: Quadrupole

No dipole intra-LL transitions!

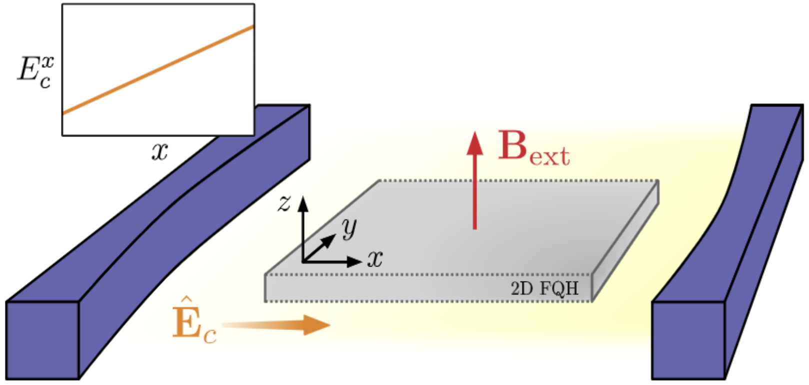
(without disorder or edges)

A toy model for $\nu = \frac{1}{3}$

1) Lowest Landau Level → No dipole transitions!

2) Uniform cavity gradient $g = e\, l_B^2 \frac{\partial_x E_c}{\omega_c}$ $Q_{xx} = \int x^2 \rho(x)$

3) Haldane pseudopotential $V(r) = V\, \nabla^2\, \delta(r)$



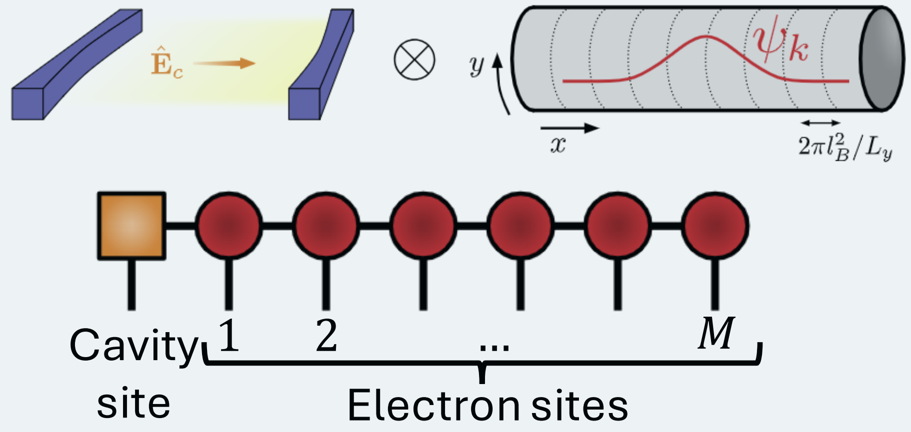
Laughlin $\nu = 1/3$ | Cavity

$$\hat{\mathrm{H}}_{tot} = \sum_{\boldsymbol{q}} V_{\boldsymbol{q}}\ \hat{\rho}_{-\boldsymbol{q}}\, \hat{\rho}_{\boldsymbol{q}} + \omega_c \hat{a}^\dagger \hat{a} +$$

$$+\, i\omega_c g\left(\hat{a}^\dagger - \hat{a}\right)\, \hat{Q}_{xx} + \omega_c\, g^2\, \hat{Q}_{xx}^2 \ + \text{ Stark shifts}$$

Light-matter interaction

MPS for cavity+matter



A toy model for $\nu = \frac{1}{3}$

1) Lowest Landau Level → No dipole transitions!

IMPORTANT REMARK:

Single particle coupling

$$g(a + \hat{a}^\dagger) \sum_{i=1}^{N} O_i$$

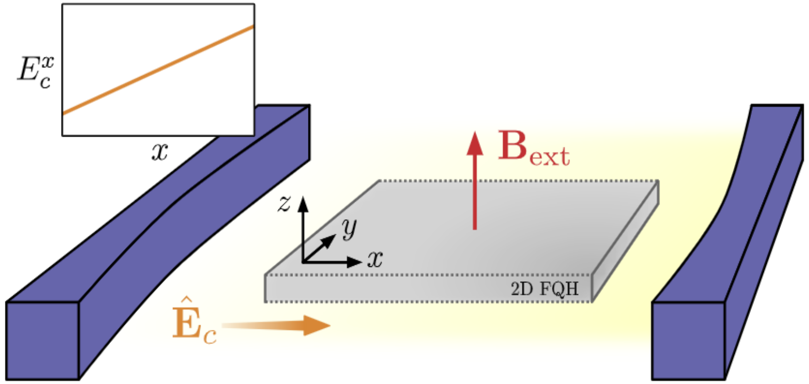
couples «everything»

Collective coupling $G = g\sqrt{N}$

$$\frac{G}{\sqrt{N}}(a + \hat{a}^\dagger) \sum_{i=1}^{N} O_i$$

q=0 collective modes!

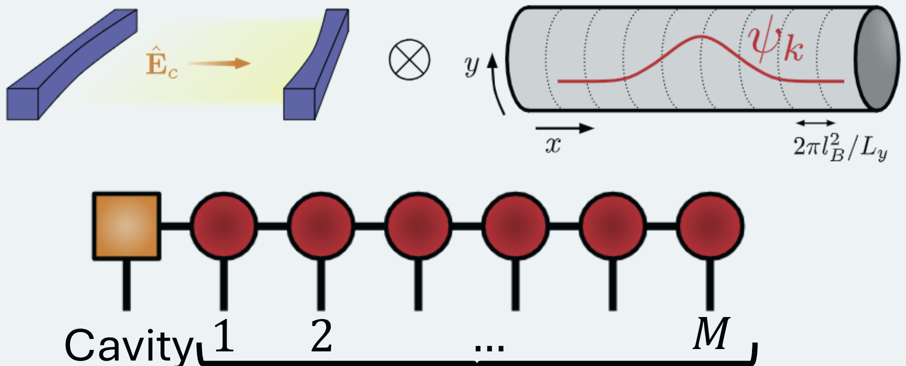
$\int x^2 \rho(x)$



$$+\, i\omega_c g(\hat{a}^\dagger - \hat{a})\, \hat{Q}_{xx} + \omega_c\, g^2\, \hat{Q}_{xx}^2 \;+\; \text{Stark shifts}$$

Light-matter interaction

MPS for cavity+matter



Stability of Topology

Stability of Topology: Hall resistivity

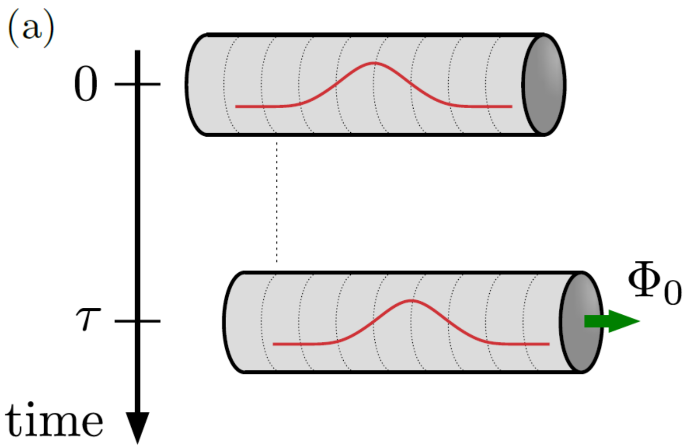
Flux insertion argument

D. J. Thouless, JMP (1994)

Zalatel et al., J. Stat. Mech (2015)

$$\Phi_{\text{ext}}(t) = \Phi_0 \frac{t}{\tau}$$

Rigid shift of Landau Level

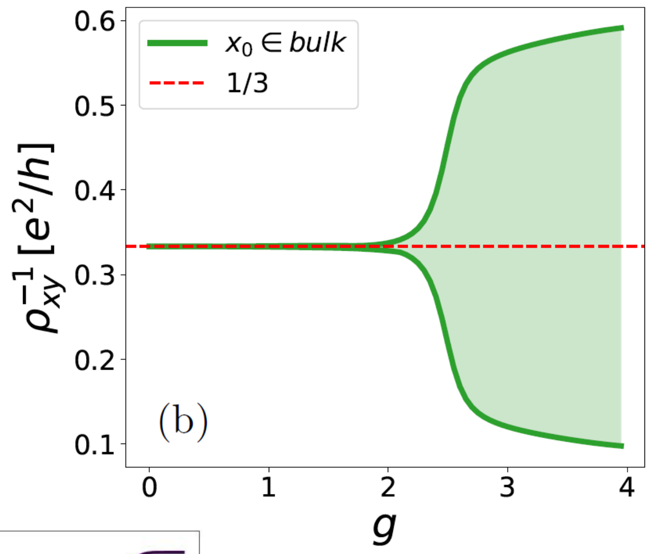


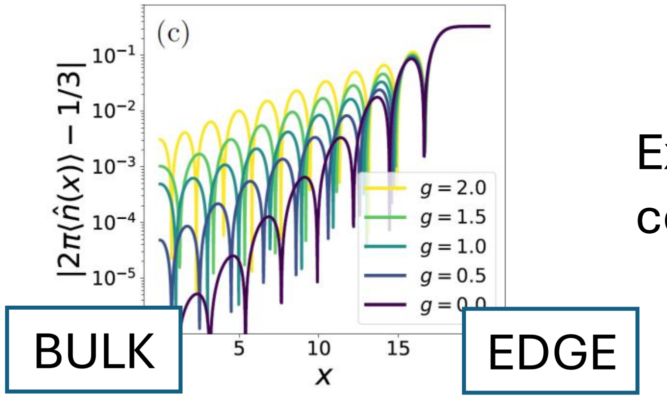
$$\rho_{xy}(x_0) = \frac{E^y_{ext}}{J^x(x_0)} = \frac{1}{2\pi}\frac{1}{\langle\, \hat{n}(x_0)\, \rangle}$$

Bulk density determines the Hall response!

Do numerical experiment....

Quantized!

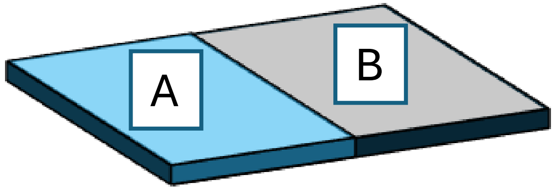




Exponential corrections

Stability of Topology: Entanglement spectrum

Bipartition of a system



$$\hat{\rho}_A = Tr_B\,[\,|\Psi\rangle\langle\Psi|\,]$$

$$\hat{\rho}_A = \exp(-\,\xi_j\,|\,j\,\rangle\langle\,j\,|\,)$$

If $|\Psi\rangle$ has topological order

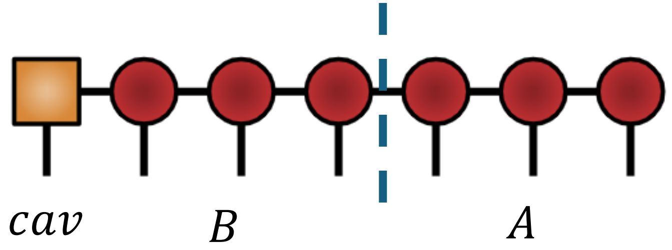
↓

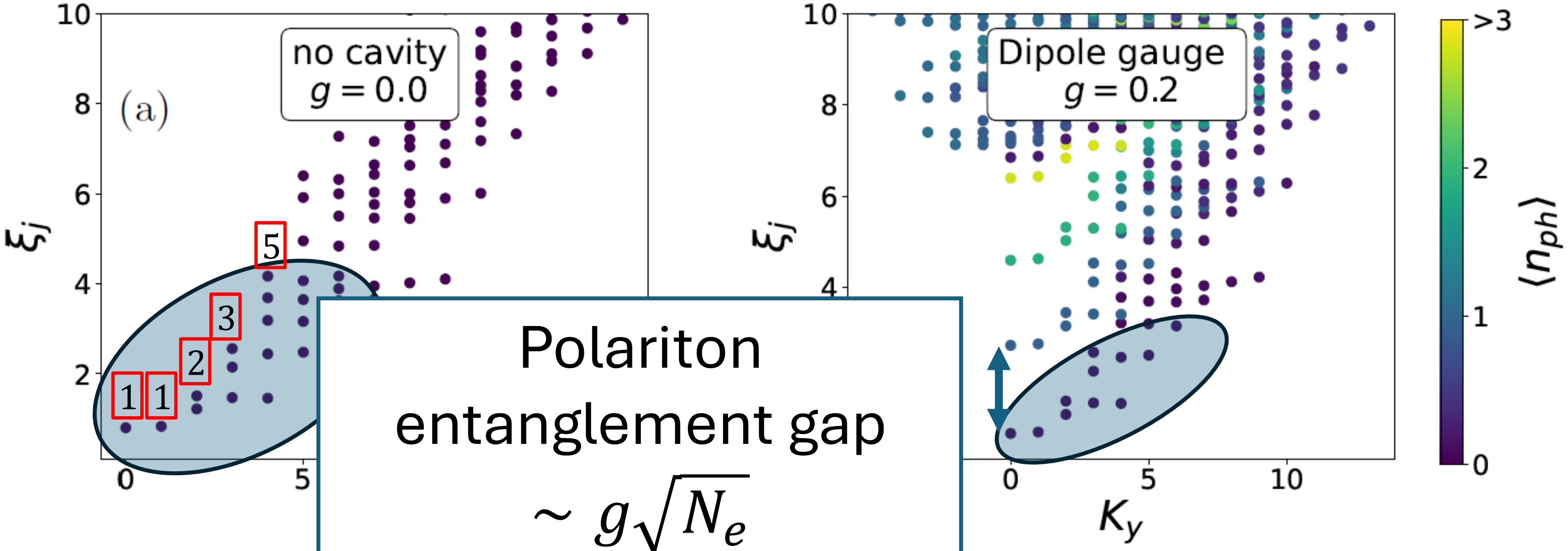
Low-energy of ξ_j is determined by edge structure

Li, Haldane, PRL (2008)

Bipartition of cavity+matter

$$\hat{\rho}_A = Tr_{B+cav}\,[\,|\Psi\rangle\langle\Psi|\,]$$





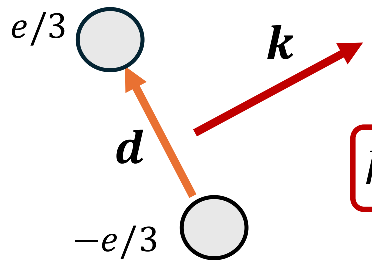
Polariton entanglement gap $\sim g\sqrt{N_e}$

What is the cavity coupling to?

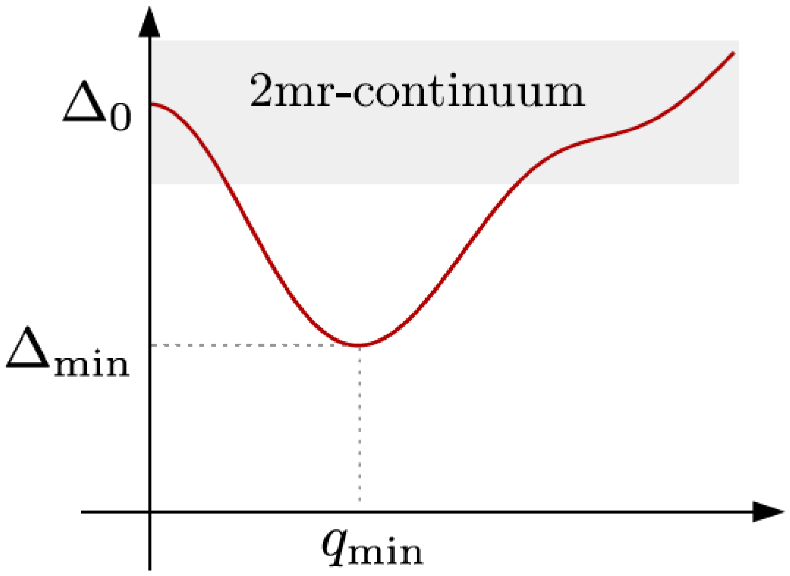
What is the cavity coupling to?

Magnetoroton mode

Girvin, MacDonald, Platzman, PRB (1985)



$$k^a \propto \epsilon_{a,b}\, d^b$$



Graviton-mode Δ_0

Haldane; PRL (2011)
Golkar, Nguyen, Son; JHEP (2013)
Liou, Haldane, Yang, Rezayi; PRL (2019)
Balram, Liu, Gromov, Papić; PRX (2022)

→ Fluctuations of emergent metric

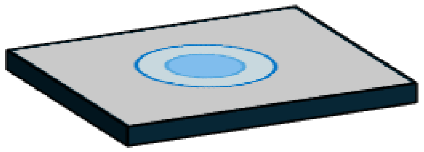
$$\psi_{1/3}(\{z_i\}) \sim (z_i - z_j)^3$$

$$z = \tilde{x} + \mathrm{i}\tilde{y} \qquad \tilde{R}^a = \Lambda^{a,b} R^a$$

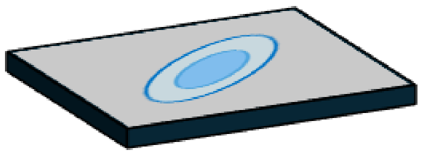
1) Long wavelength magnetorotos

2) No dipole, only quadrupole!

$$\Lambda^{a,b} = \begin{pmatrix} 1 & 0 \\ 0 & 1 \end{pmatrix}$$



$$\Lambda^{a,b} = \begin{pmatrix} 2 & 0 \\ 0 & 0.5 \end{pmatrix}$$

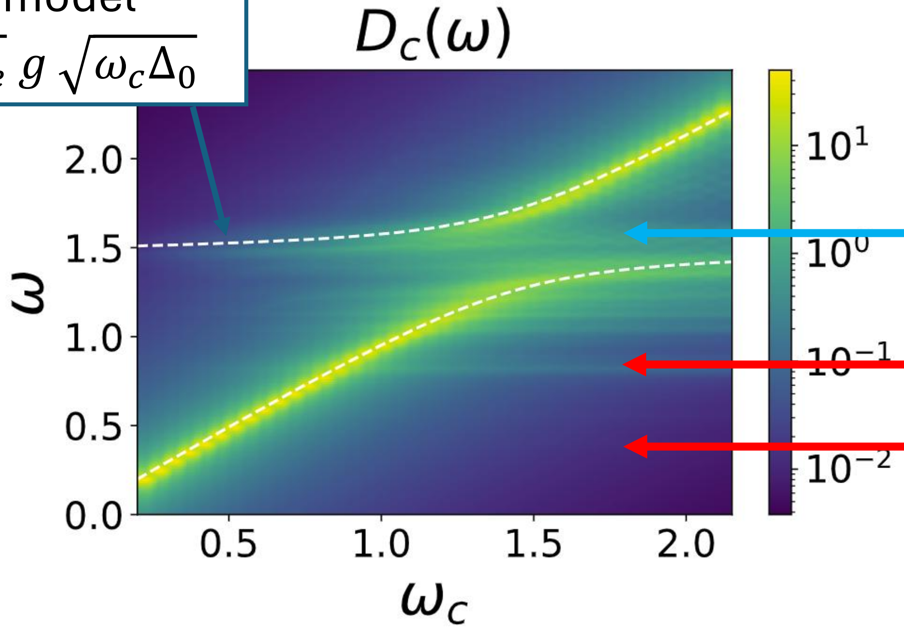


«shape of liquid correlations»

Emergent graviton-polaritons

Cavity density of states $$D_c(\omega) = \sum_n \left|\langle\, n |\, \hat{a}^{\dagger} | 0\, \rangle\right|^2 \delta(\omega - E_n + E_0)$$

Effective model
$\Omega = s_4^{xx} \sqrt{N_e}\, g \sqrt{\omega_c \Delta_0}$



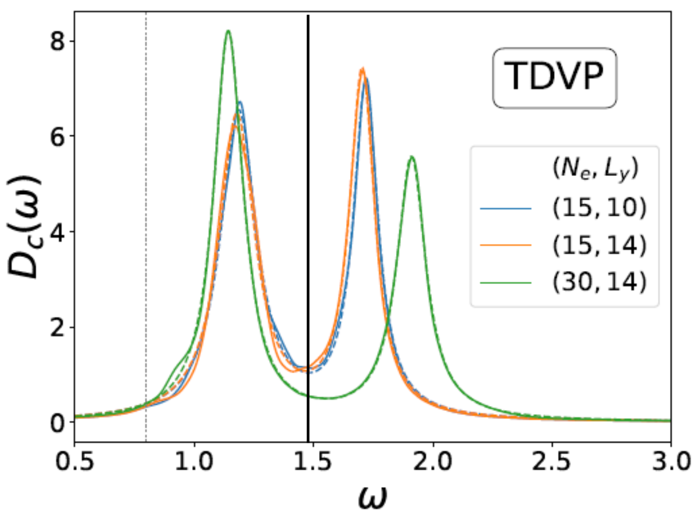
$\Delta_0 \simeq 1.5$

$2\Delta_{min} \simeq 0.8$

$\Delta_{min} \simeq 0.4$

Anticrossing at the Graviton-mode energy
+
2-MR continuum

$\omega_c = 1.5$



$(N_e\,, L_y)$	$(15\,,10)$	$(15\,,14)$	$(30\,,14)$	**Effective model**
$\Omega_{fit}\,/\Omega$	0.91	0.91	0.94	1

Ultra-strong coupling regime

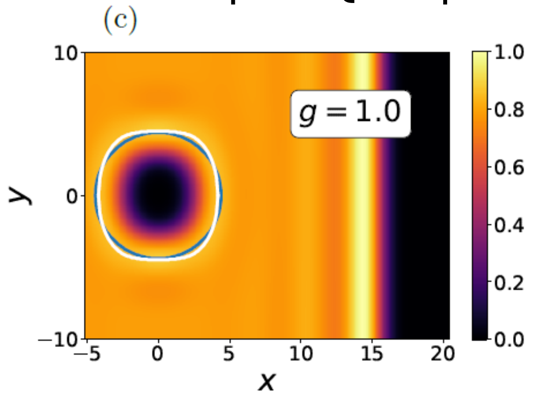
Aka where to look for ground state changes

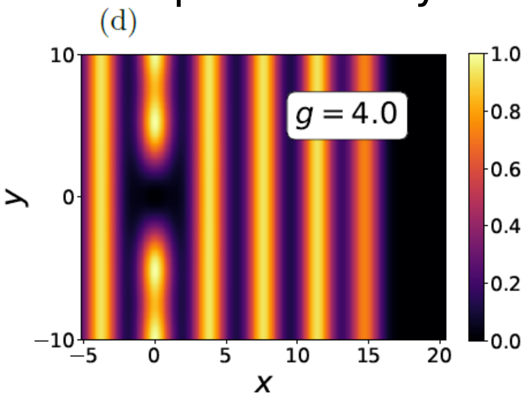
FQH geometry vs Cavity-induced Stark shift

Vacuum fluctuations penalize quadrupole!

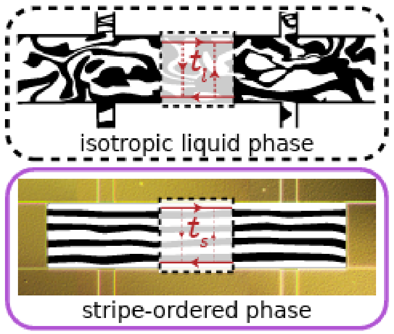
$$H_{pMF} = H_{int} + g^2\omega_c(Q_{xx} - \langle Q_{xx}\rangle)^2$$

Anisotropic FQH liquid → Stripe instability





~ Cavity-oriented stripes



Graziotto, Faist et al., arxiv2502.15490

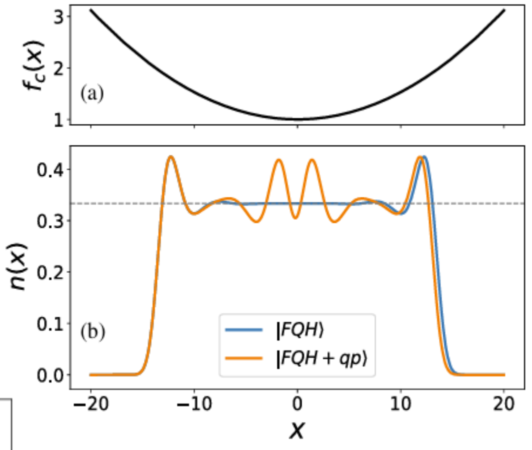
Reintroduce

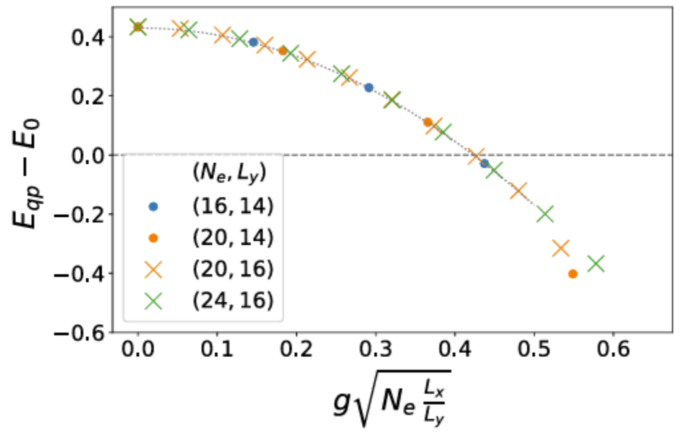
Light-matter interaction

$$\text{Stark shifts} \sim \int dx\, \rho_{LLL}(x) \frac{E_c^2(x)}{2\omega_c}$$

Static potential

$$V_{eff} = l_B^2 \frac{E_c^2(x)}{2\omega_c}$$





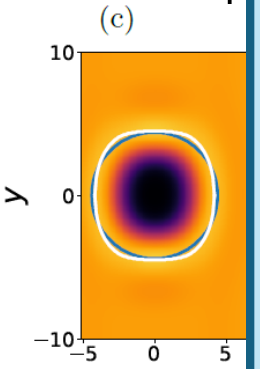
Quasi-particle creation!

FQH geometry vs Cavity-induced Stark shift

Vacuu[illegible]

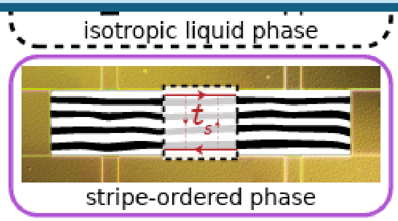
H_{pM} [illegible]

Anisotrop[illegible]



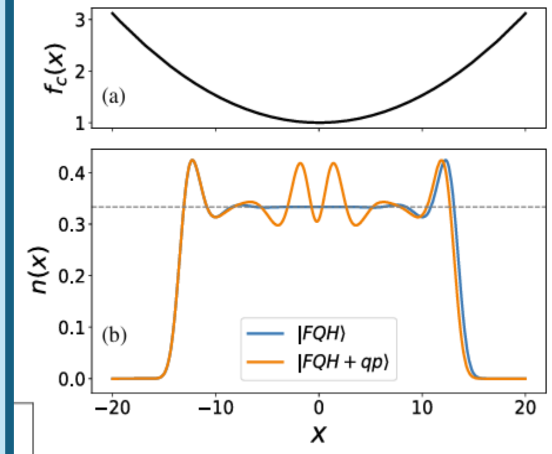
~ Cavity-oriented stripes

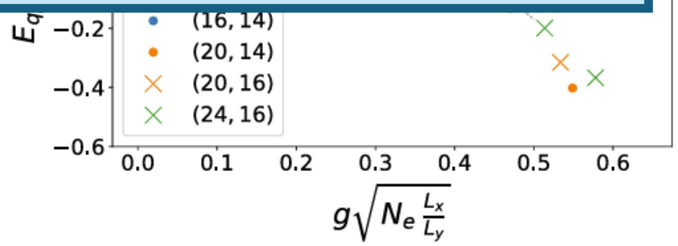
Graziotto, Faist et al., arxiv2502.15490



Light-matter interaction

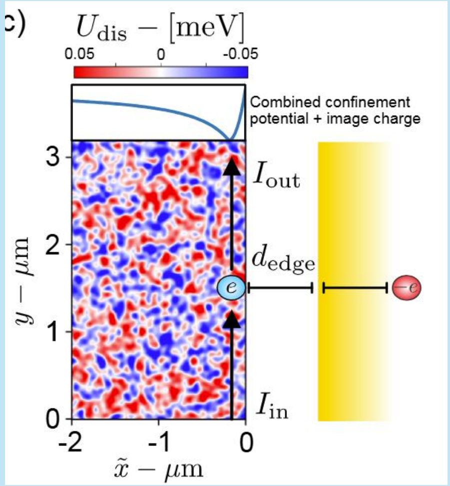
[illegible]s $\sim \int dx\, \rho_{LLL}(x) \frac{E_c^2(x)}{2\omega_c}$

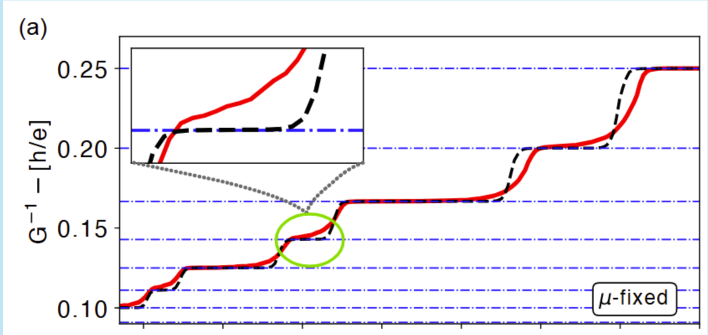




Quasi-particle creation!

At ultra-strong coupling, other off-resonant and electrostatics contributions can be relevant!





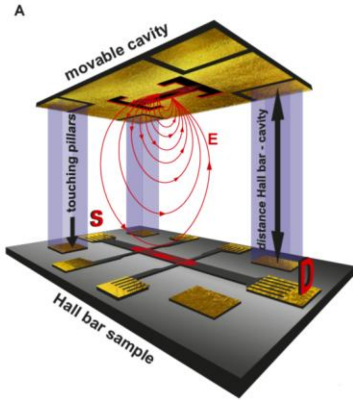
Andolina, Bacciconi, ..., De Bernardis, arxiv 2511.04744

Experimental remarks

Cavity set-up

Split-ring resonator

Appugliese, Faist, et al. , Science (2022)
Enker, Faist, et al. , PRX (2024)
Enker, Faist et al. Nature (2025)
Xue, Zhang et al. arxiv (2025)



Resonance

$$\omega_c \simeq 2\pi\ 100\ GHz \simeq 0.4\ meV$$

Strong coupling

$$g = e\ l_B^2 \frac{\partial_x E_c}{\omega_c} \simeq 10^{-5} - 10^{-8}$$

$$\partial_x E_c^x \simeq 10^5 - 10^8\ V/m^2$$

$$l_B \simeq 10\ nm$$

$$\frac{\Omega}{\omega_c} \simeq g\sqrt{N_e} \simeq 10^{-2} - 10^{-5}$$

What we did not consider

- Spin degree of freedom
- Off-resonant inter-LL mixing
  $e l_B E_c$ vs $e l_B^2 \partial_x E_c$
- Finite temperatures
- Electrostatic effects

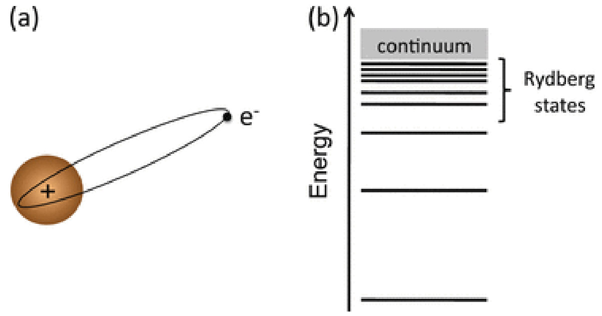
Part II) Non-local dynamics: Rydberg arrays

2. *Local vs Non-local dynamics in cavity coupled Rydberg atom arrays*, **Bacciconi**, Xavier, Marinelli, Bhakuni, Dalmonte; PRL 134,13604 (2025)

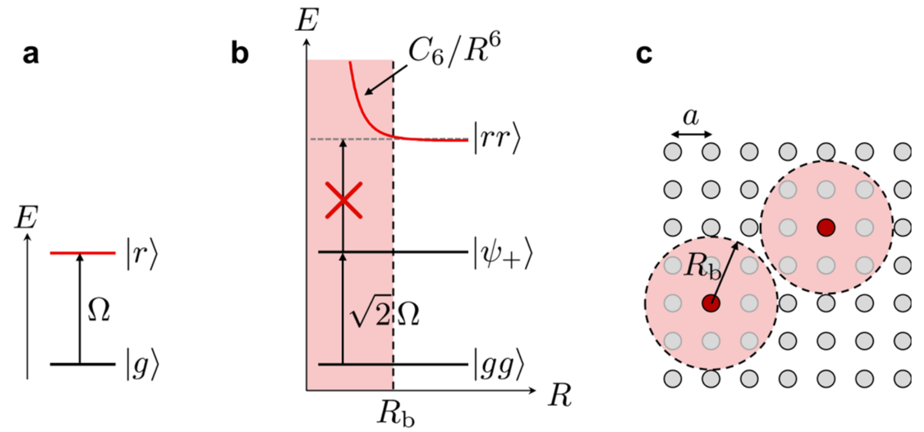
Rydberg atom arrays: what and why

What

Atoms with high principal quantum number



strong Van der Waals interactions



$a \simeq \mu m$

$V \simeq \; MHz$

$\gamma_r \simeq \; kHz$

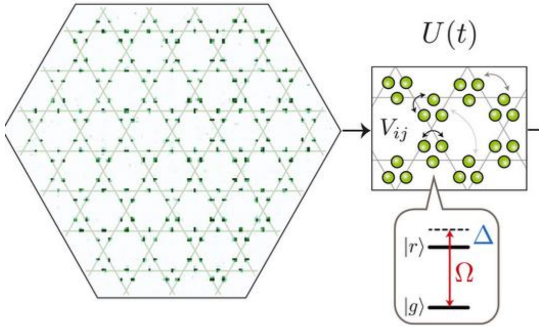
Broweys and Lahaye, Nat. Phys. (2020)

Why

Quantum Simulation!

$$H \simeq V \sum_{<ij>} \hat{\sigma}_i^z \, \hat{\sigma}_j^z + \Omega \sum_j \hat{\sigma}^x$$

Quantum spin liquid



Semeghini, Lukin et al; Science (2021)

- ✓ High interaction tunability
- ✓ Long coherence times
- ✓ Space and time resolution

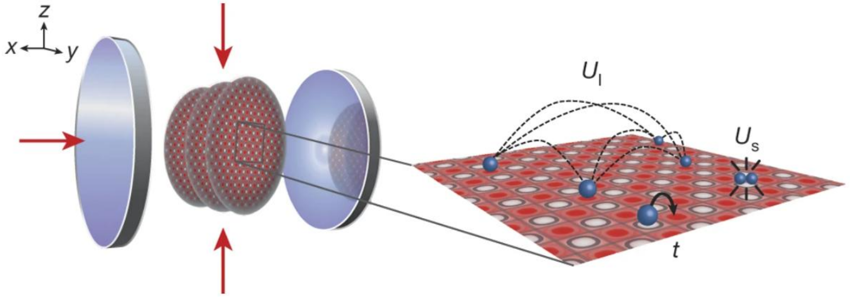
Boston, Lukin
Los Angeles, Endres
Paris, Broweys
Munich, Zeiher
Wuhan, Li
...

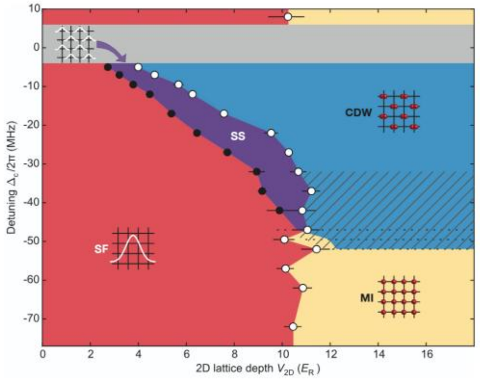
of interest for quantum computing!

Cavity QED with atoms

Ultracold atomic gases in high finesse Fabri-Perot

Review: Mivehvar et. al., Adv. Phys. (2021)

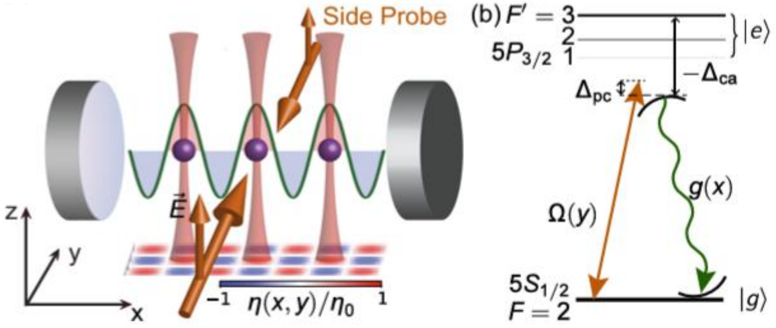




Esslinger, Nature (2016)

Atom in tweezers inside an **optical** cavity

Lukin (Harvard), Vuletic (MIT), Brantut (EPFL), Schleier-Smith (Stanford), Stamper-Kurn (Berkeley), Simon (Stanford) Leonard (Vienna), Welte (Stuttgart), Covey (Illinois), Schine (Maryland), Zeiher (MPQ), **Marinelli** (UniTs)



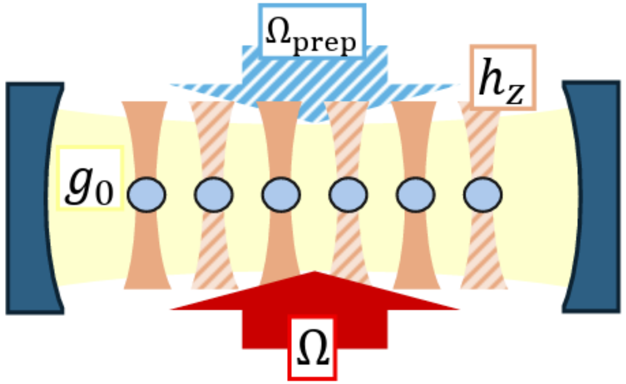
Stamper-Kurn et al. , PRL (2023)

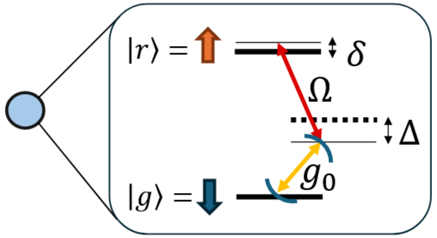
Cavity QED with rydberg atoms

See other works

Zhang et al., PRL (2013)
Gelhausen et al., SciPost (2016)
Puel, Macrì, PRL (2024)
Hosseinabadi, Marino et al. arXiv (2025)
Mann, Chang, et al. (2025)

Our proposal: Tavis-Cumming-Ising model





Rydberg — Local potential

$$\hat{H}_{eff} = V \sum_i \hat{\sigma}_i^z \hat{\sigma}_{i+1}^z + \sum_i h_i \, \hat{\sigma}_i^z$$

$$+ \delta \, \hat{a}^\dagger \, \hat{a} + g \sum_i \left(\hat{a}^\dagger \hat{\sigma}_i^- + \hat{a} \, \hat{\sigma}_j^+ \right)$$

Detuning — 2 photon transition

$$g = g_0 \Omega / \Delta \sim 0.1 \, MHz$$

$$V \sim 1 \, MHz$$

$$\kappa \sim 0.05 \, MHz$$

Low energy excitations $(g \ll V)$

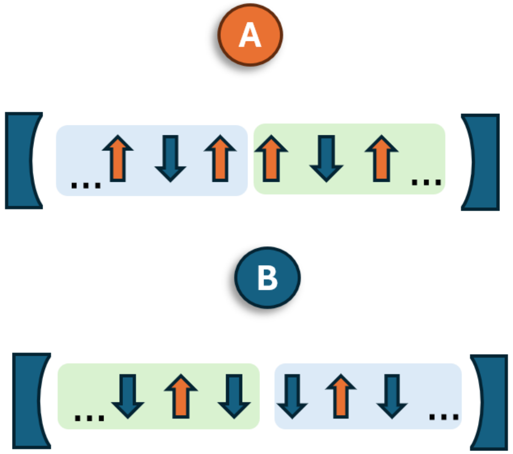
$$\hat{H} = V \sum_i \hat{\sigma}_i^z \hat{\sigma}_{i+1}^z + h_s \sum_i (-1)^i \, \hat{\sigma}_i^z + \delta \, \hat{a}^\dagger \, \hat{a} \, + \\ + g \sum_i (\hat{a}^\dagger \hat{\sigma}_i^- + \hat{a} \, \hat{\sigma}_j^+)$$

$$|GS\rangle \sim \begin{array}{c} |\uparrow\downarrow\uparrow\downarrow\uparrow\downarrow\rangle|0_{ph}\rangle \\ or \\ |\downarrow\uparrow\downarrow\uparrow\downarrow\uparrow\rangle|0_{ph}\rangle \end{array} \quad \Delta E = h_s \, N$$

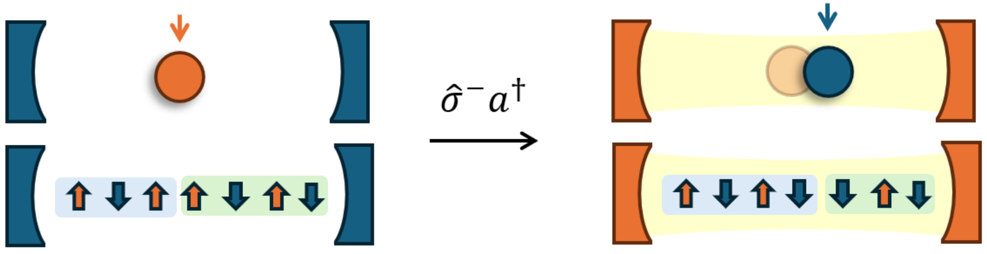
Minimal excitation: Domain wall

$U(1)$ conservation

$$\hat{Q} = \hat{a}^\dagger \, \hat{a} + \sum_i \hat{n}_i$$



Dynamics induced by the cavity!



Low energy excitations $(g \ll V)$

$$\hat{H} = V \sum_i \hat{\sigma}_i^z \hat{\sigma}_{i+1}^z + h_s \sum_i (-1)^i \hat{\sigma}_i^z + \delta \hat{a}^\dagger \hat{a} + $$
$$+ g \sum_i (\hat{a}^\dagger \hat{\sigma}_i^- + \hat{a}\, \hat{\sigma}_j^+)$$

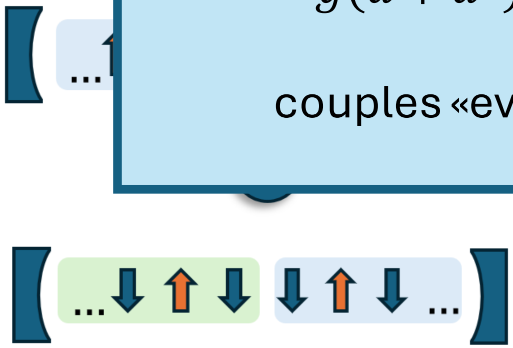
$|GS\rangle \sim$ $|\Uparrow \Downarrow \Uparrow \Downarrow \Uparrow \Downarrow\rangle |0_{ph}\rangle$ *or* $\rangle$

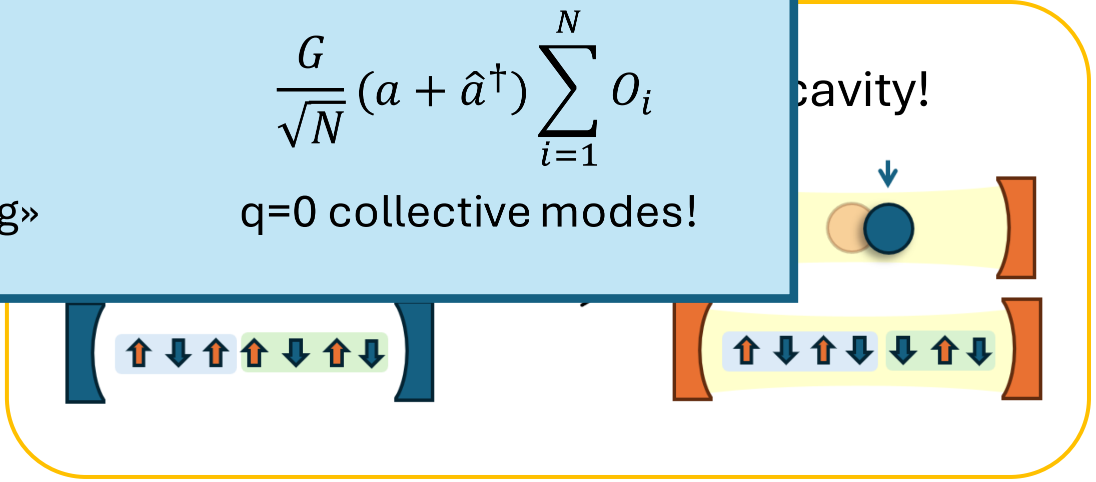
$\Delta E = h_s N$

Minimal excitation: Domain wall

$U(1)$ conservation

$$\hat{Q} = \hat{a}^\dagger \hat{a} + \sum_i \hat{n}_i$$



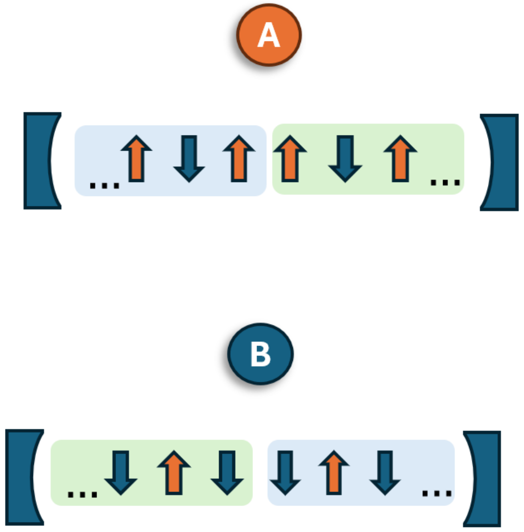


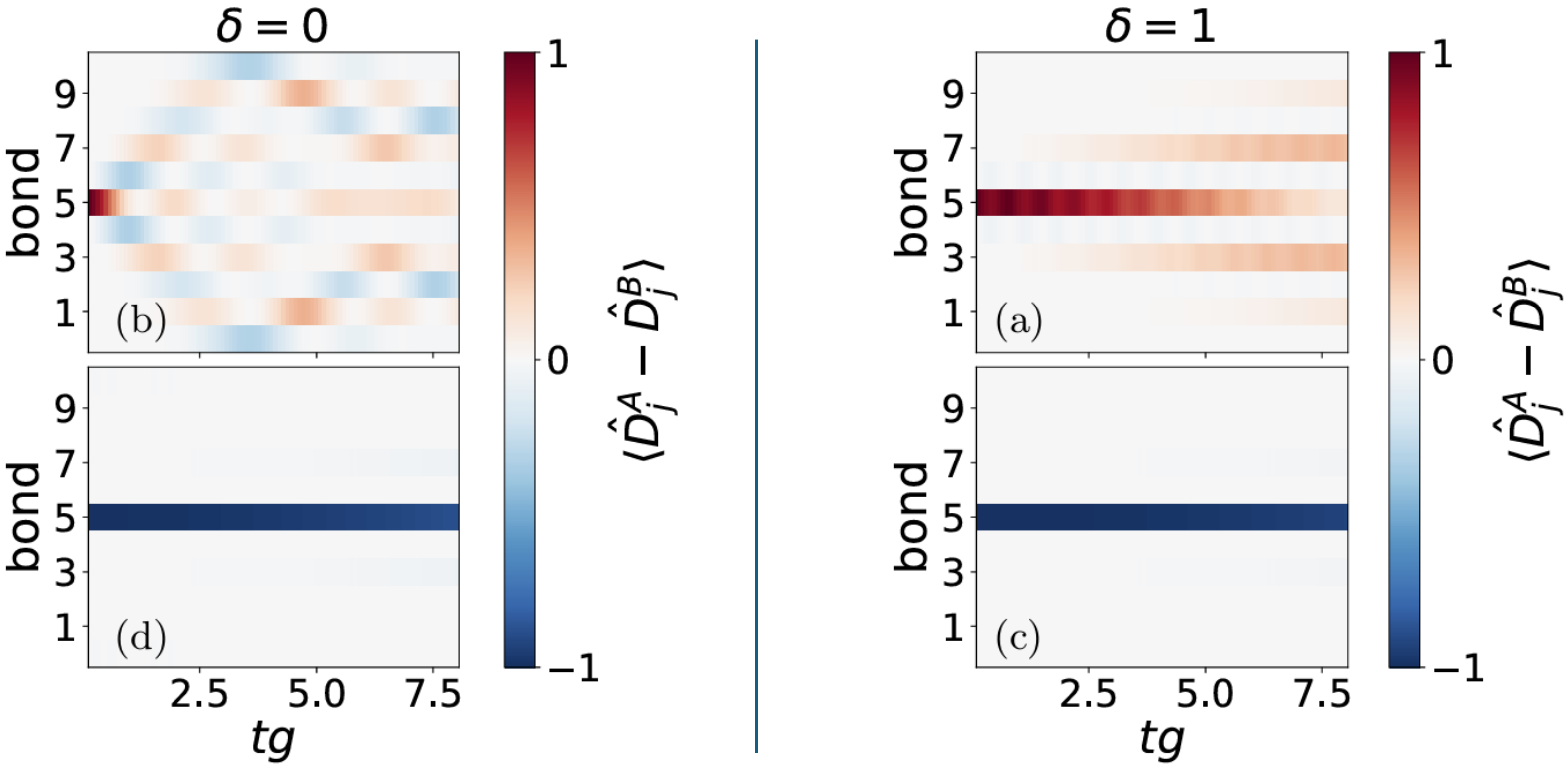
IMPORTANT REMARK (hopefully clearer now):

Single particle coupling	Collective coupling $G = g\sqrt{N}$
$g(a + \hat{a}^\dagger) \sum_{i=1}^N O_i$	$\frac{G}{\sqrt{N}} (a + \hat{a}^\dagger) \sum_{i=1}^N O_i$
couples «everything»	q=0 collective modes!

Domain wall dynamics: $h_s = 0 \quad g = 0.1$

Domain wall density $\hat{D}_j^A = |\uparrow\uparrow\rangle\langle\uparrow\uparrow| \quad \hat{D}_j^B = |\downarrow\downarrow\rangle\langle\downarrow\downarrow|$

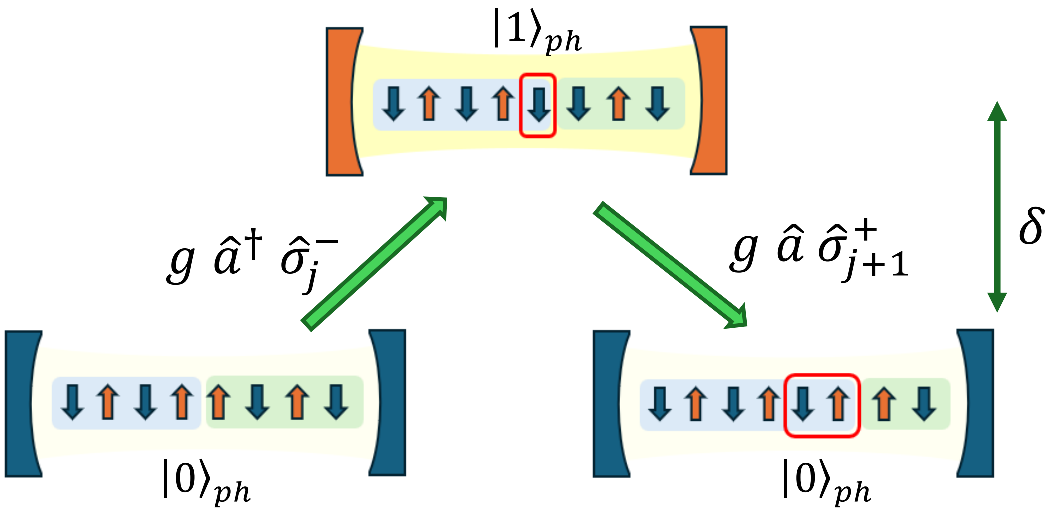




Domain wall dynamics: perturbation theory

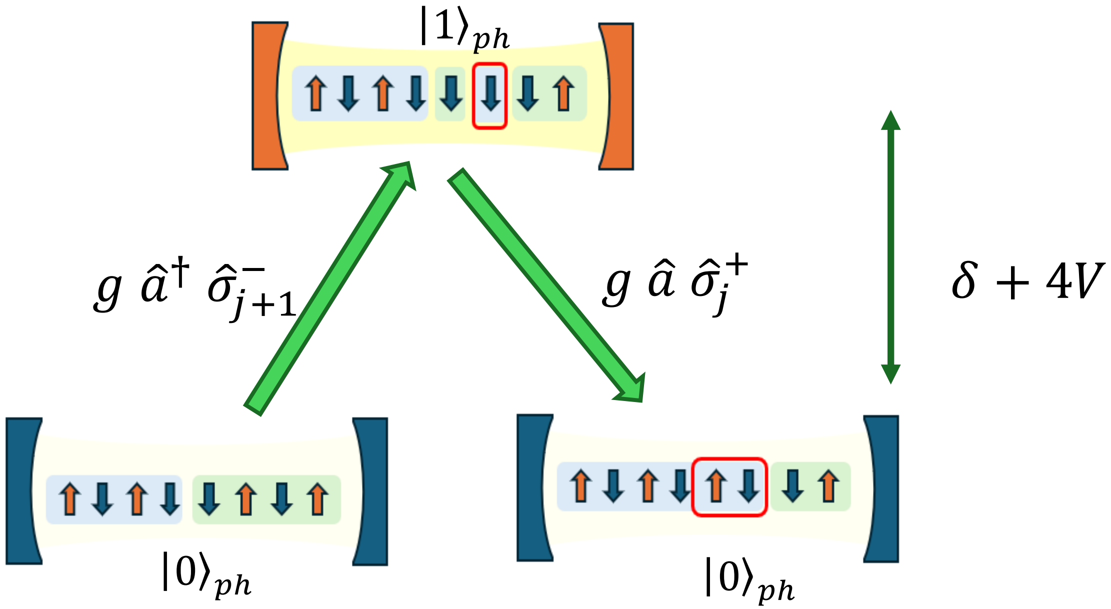
Type A domain wall

$$J_A = \frac{g^2}{\delta}$$



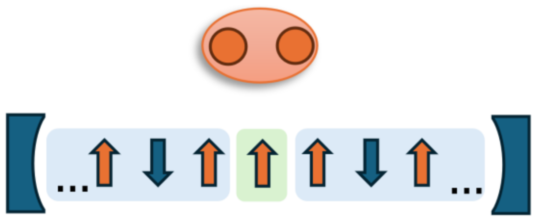
Type B domain wall

$$J_B = \frac{g^2}{\delta + 4V}$$



Composite excitations: mesons

Meson $E_\pi = 4V + 2h_s$

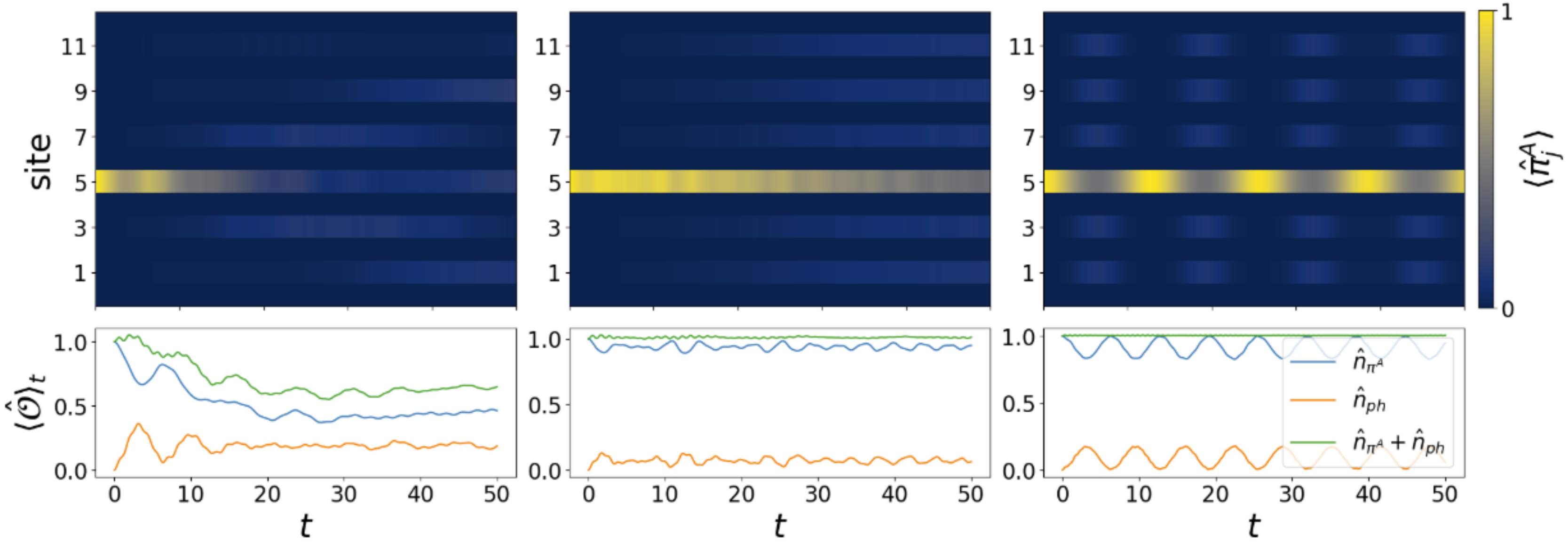


$$\hat{\pi}_j^A = |\uparrow\uparrow\uparrow\rangle\langle\uparrow\uparrow\uparrow|$$

Meson-polaritons ($G = g\sqrt{N}$)

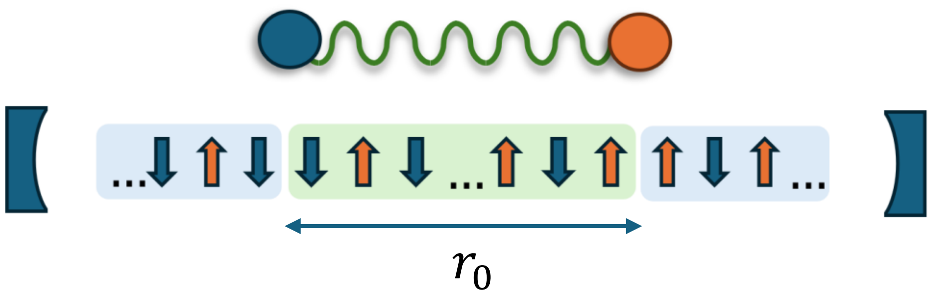
$$\hat{\sigma}_j^+ \, \hat{a} \quad |AFM\rangle|1_{ph}\rangle \leftrightarrow \frac{1}{\sqrt{N/2}}\sum_j |\pi_j^A\rangle|0_{ph}\rangle$$

Not confined	Confined Off resonance	Confined On resonance
$h_s = 0 \quad \delta = 1.$	$h_s = 0.4 \quad \delta = 1.$	$h_s = 0.4 \quad \delta = 4.8$



Composite excitations: strings

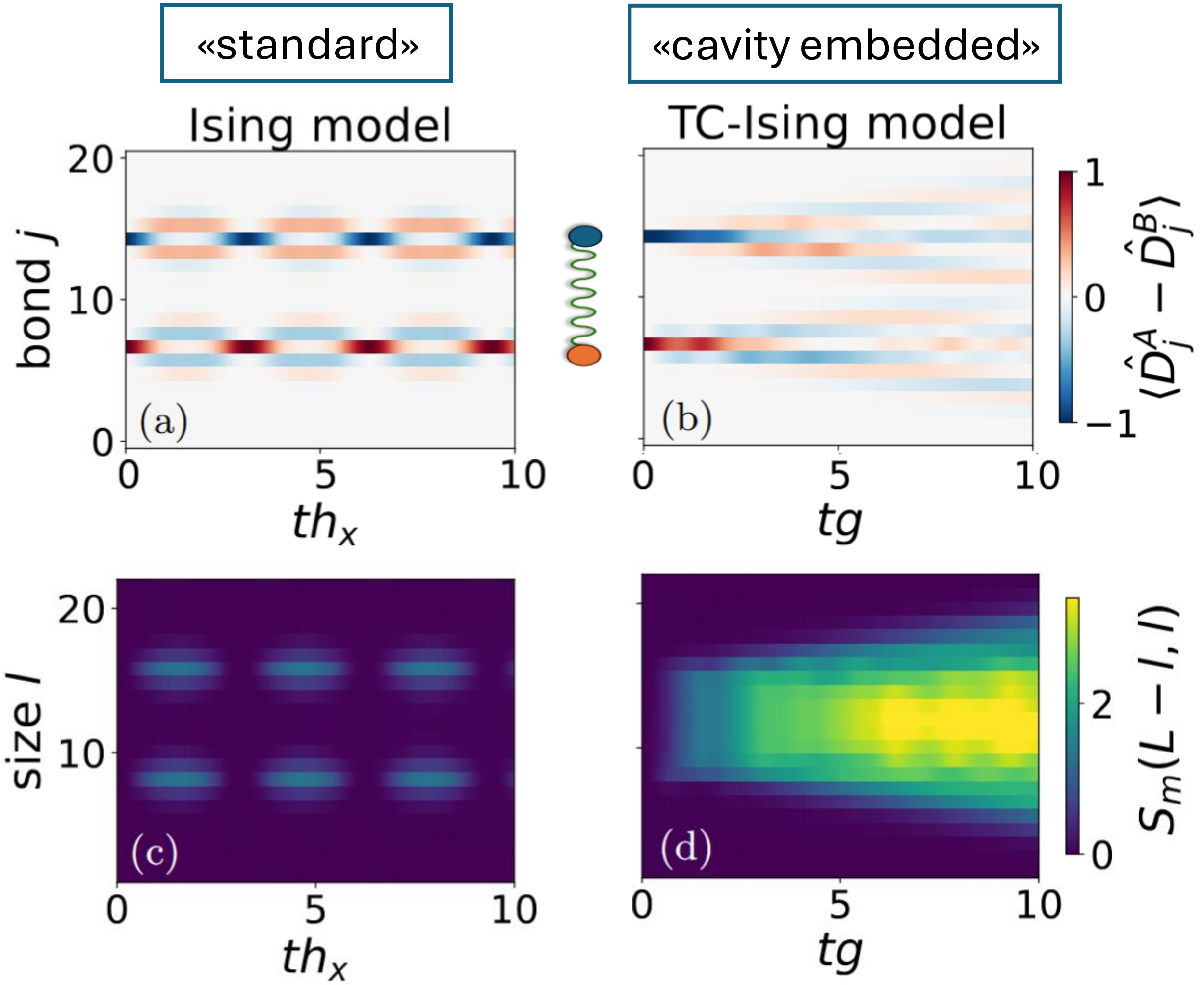
String $E_s = 4V + 2\, r_0\, h_s$



Long range interaction between domain walls!

Mutual information
$$S_{vn}(A) + S_{vn}(B) - S_{vn}(AB)$$

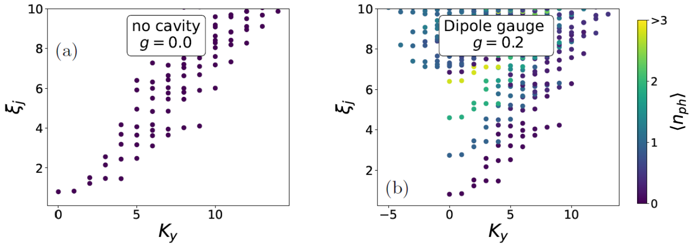
$$J_s^{loc} \propto e^{-r_0} \qquad J_s^{cav} \propto \frac{g^2}{h_s + \delta}$$



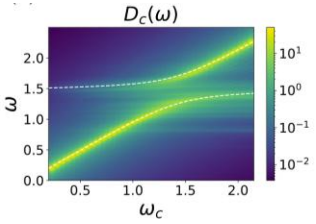
Summary

I) Topological matter: FQH

- Topology is stable under *some* **non-local** perturbations

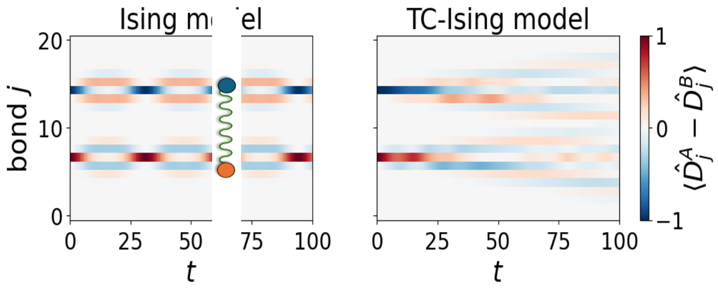


- Spectroscopy of graviton-polaritons excitations

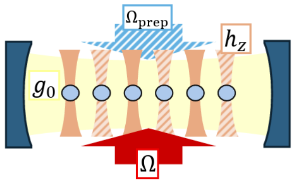


II) Non local dynamics in Rydberg atom arrays

- Cavity modes generate **non-local** dynamics



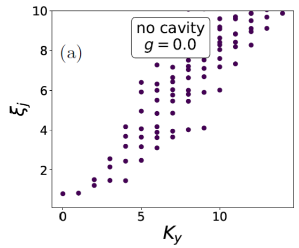
- *Simple* experimental scheme



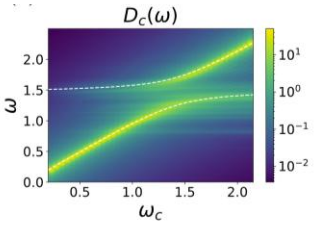
Summary

I) Topological matter: FQH

- Topology is stable under *some* **non-local** perturbations



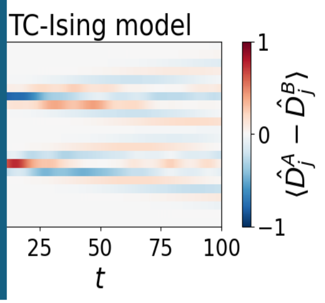
- Spectroscopy of gr
excitations



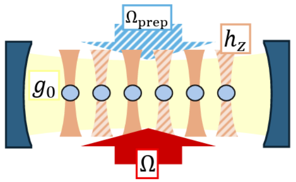
New phenomena from cohexistence of local and non-local modes!

II) Non local dynamics in Rydberg atom arrays

- Cavity modes generate **non-local**



- *Simple* experimental scheme

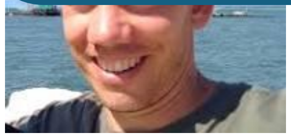


Acknowledgements



Thank you for the attention!

Trento



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