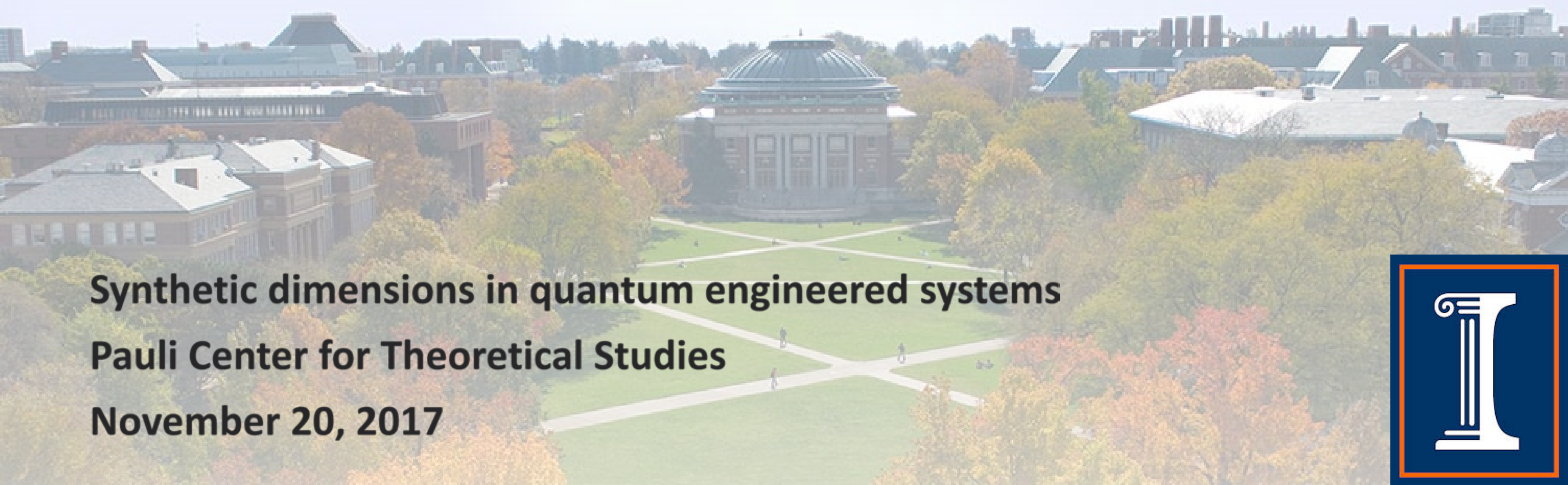
Synthetic momentum-space lattices:

exploring the interplay of topology, frustration, disorder, and interactions

Gadway group

University of Illinois at Urbana-Champaign

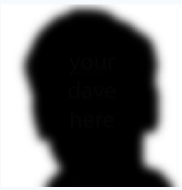


Synthetic dimensions in quantum engineered systems

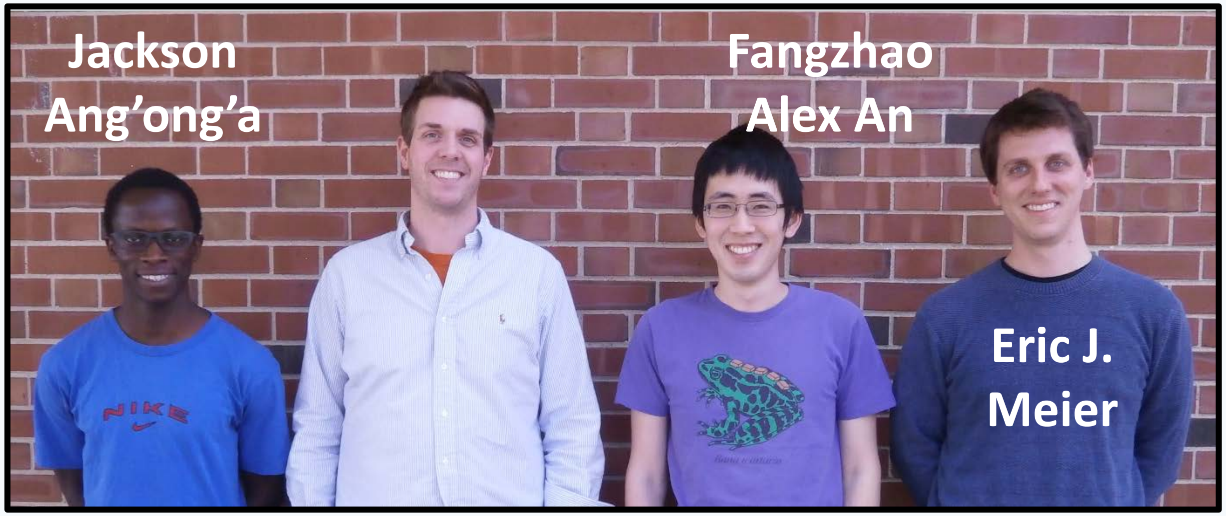
Pauli Center for Theoretical Studies

November 20, 2017

Acknowledgments


Muyan Du


Michael Highman



Current UG researchers / visitors: Hannah Manetsch, Samantha Lapp, Zejun Liu

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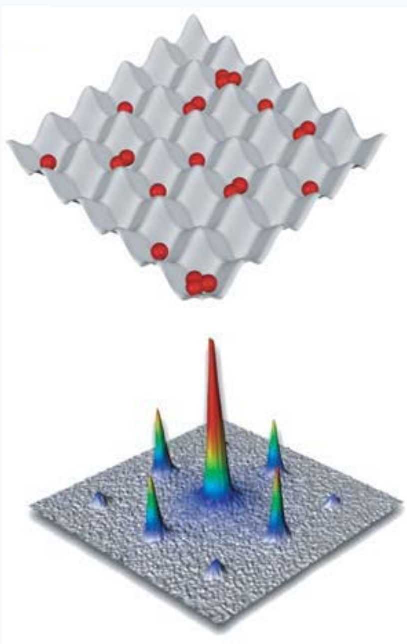
Theory friends & collaborators:
- Pietro Massignan, Maria Maffei, & Alexandre Dauphin (ICFO)
- Kaden Hazzard (Rice University)
- Taylor Hughes (UIUC)
- Smitha Vishveshwara (UIUC)

The promise of synthetic lattices
(as I see it, for cold atoms)

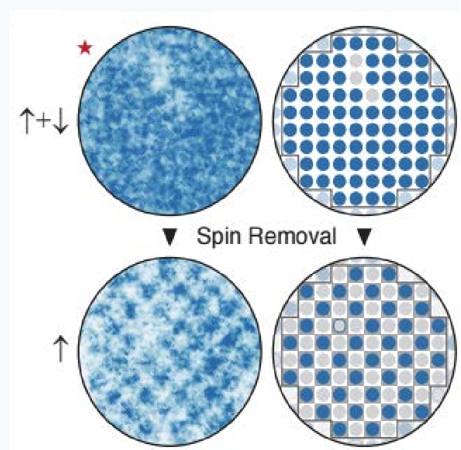
For some problems, it's best to just let atoms act naturally:

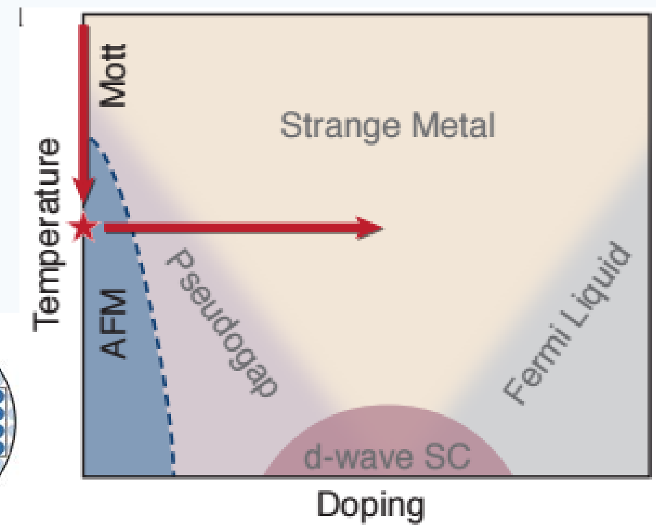
cold atoms in optical lattices ≈ ideal lattice Hubbard model

Jaksch, *et al*. PRL (1998)



Greiner, Bloch, Esslinger, Hänsch - Nature (2002)





Mazurenko, *et al.*, Nature (2017)

The promise of synthetic lattices
(as I see it, for cold atoms)

For other problems, one has to go to heroic efforts to engineer certain effects in real space lattices – often at a price

Examples:

- Mimicking the coupling of electrons to electromagnetic gauge fields
- Realizing periodic boundary conditions / hard-wall boundary conditions
- Realizing generic types of / forms of disorder
- Realizing higher-dimensional ($d \geq 4$) physics
- Random unitary lattices for boson sampling?

Some of these problems become much easier (even trivial) if one of the "dimensions" to a system is represented by discrete quantum states, such as internal states

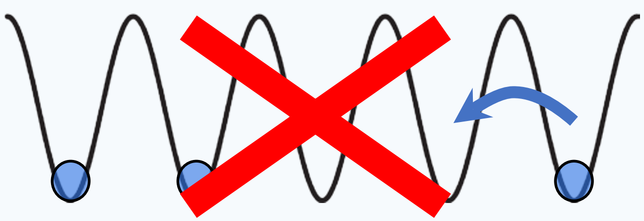
Boada, *et al*. PRL (2012)
Celi, *et al*. PRL (2013)

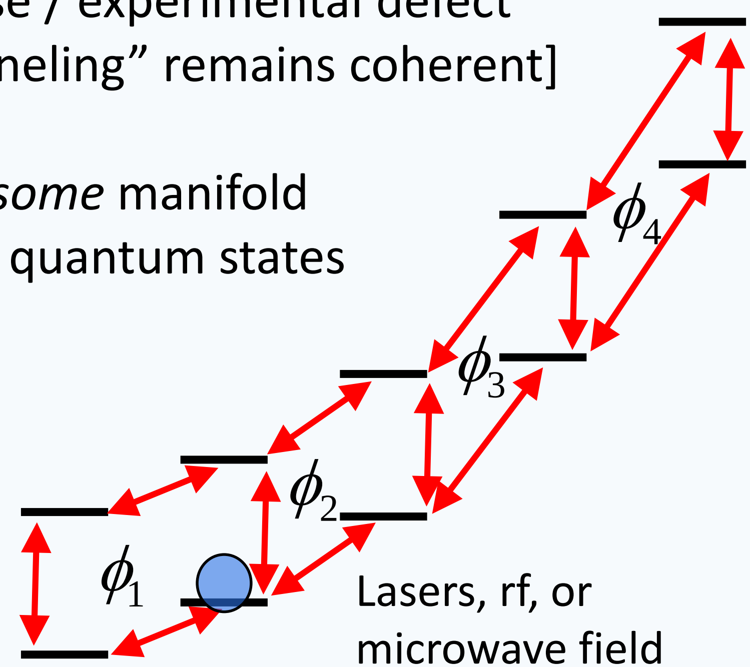
An ideal picture: a fully synthetic approach

Synthetic lattice wish list

- A large collection of discrete quantum states
- State-to-state energies are unique
  (i.e. we have full spectroscopic engineering of Hamiltonian)
- Transition frequencies are insensitive to noise / experimental defect
  [can make interactions dominant while "tunneling" remains coherent]

some manifold
of quantum states

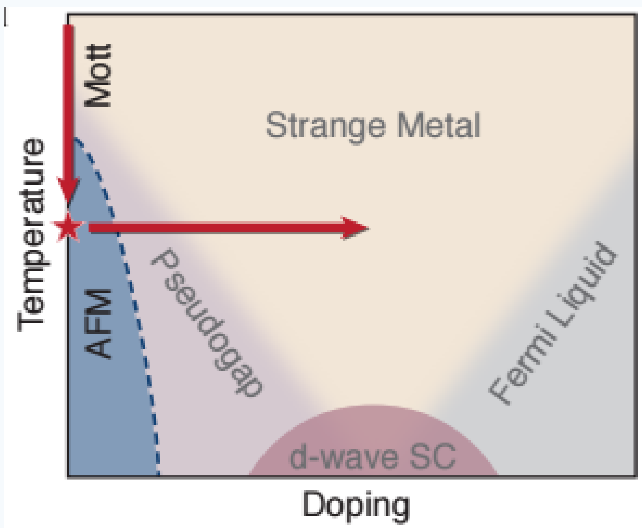




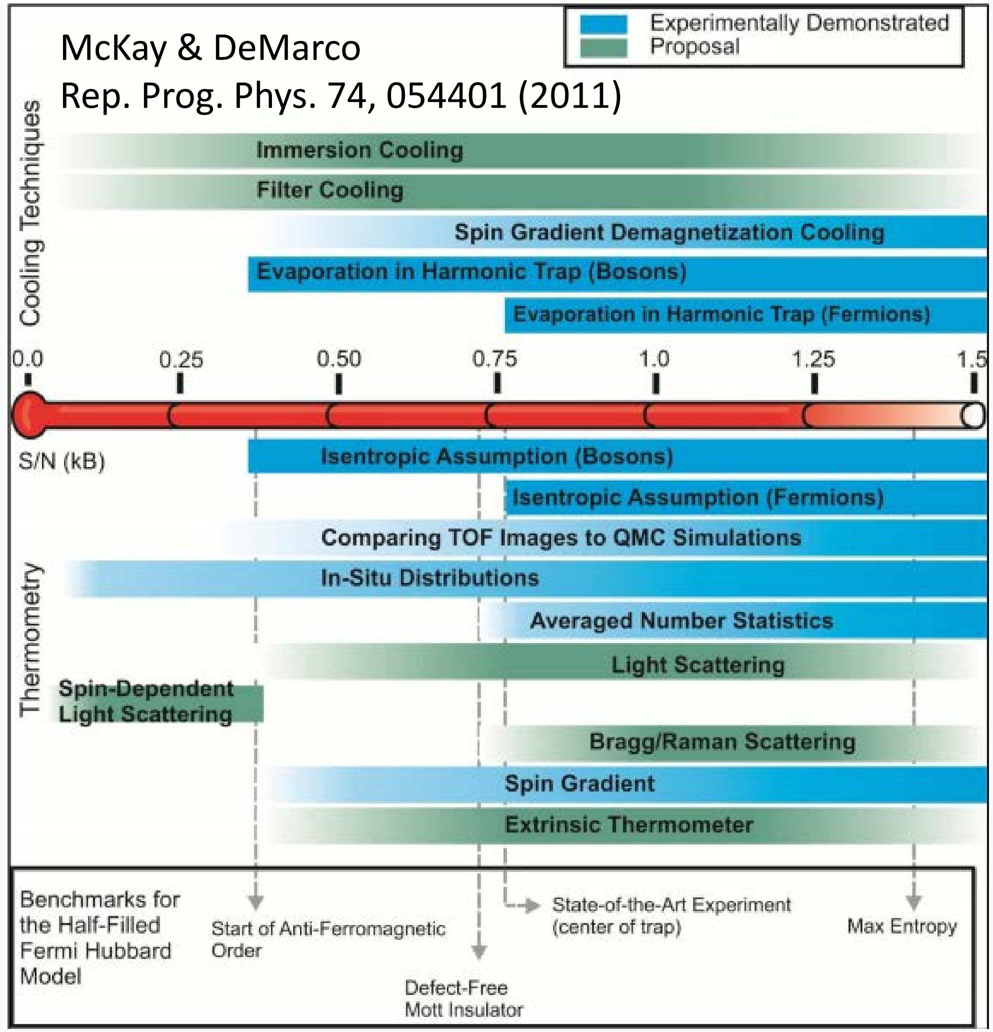
Lasers, rf, or
microwave field

Field-driven transitions between
states – form a "synthetic lattice"

One future promise of fully synthetic lattices



Mazurenko, *et al.*, Nature (2017)

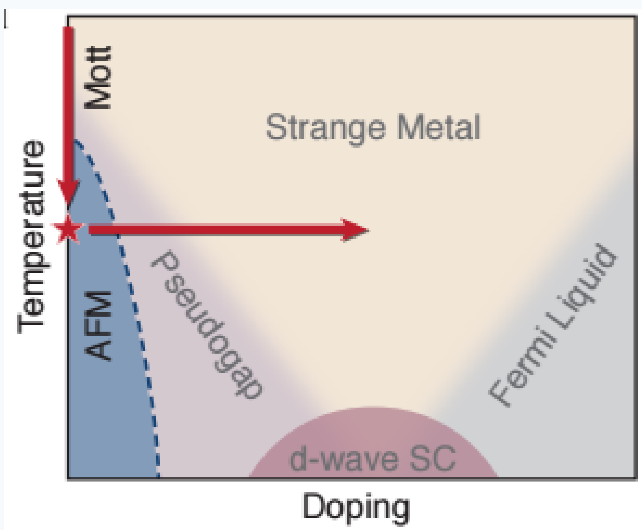


Measuring and lowering the temperature of atoms has been a big challenge for the past decade +

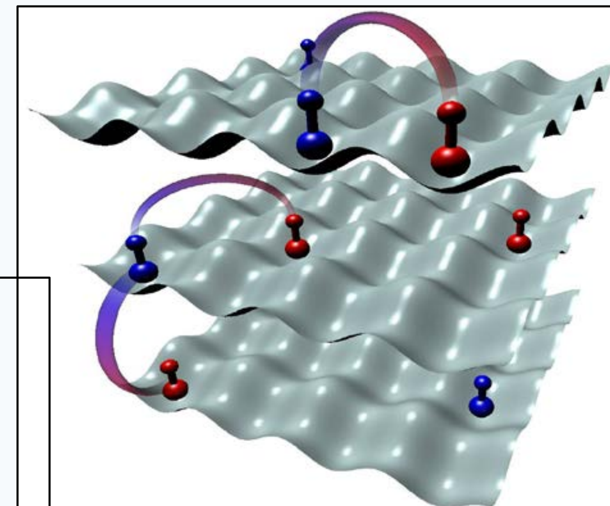
One future promise of fully synthetic lattices

If real-space motion is **fully** frozen out, then we are freed from coupling to residual motional entropy & heating effects

→ and we're really good at preparing / preserving low-entropy spin states and preserving coherence



Mazurenko, *et al.*, Nature (2017)



Yan, *et al*. Nature (2013)
Hazzard, *et al*. PRL (2014)

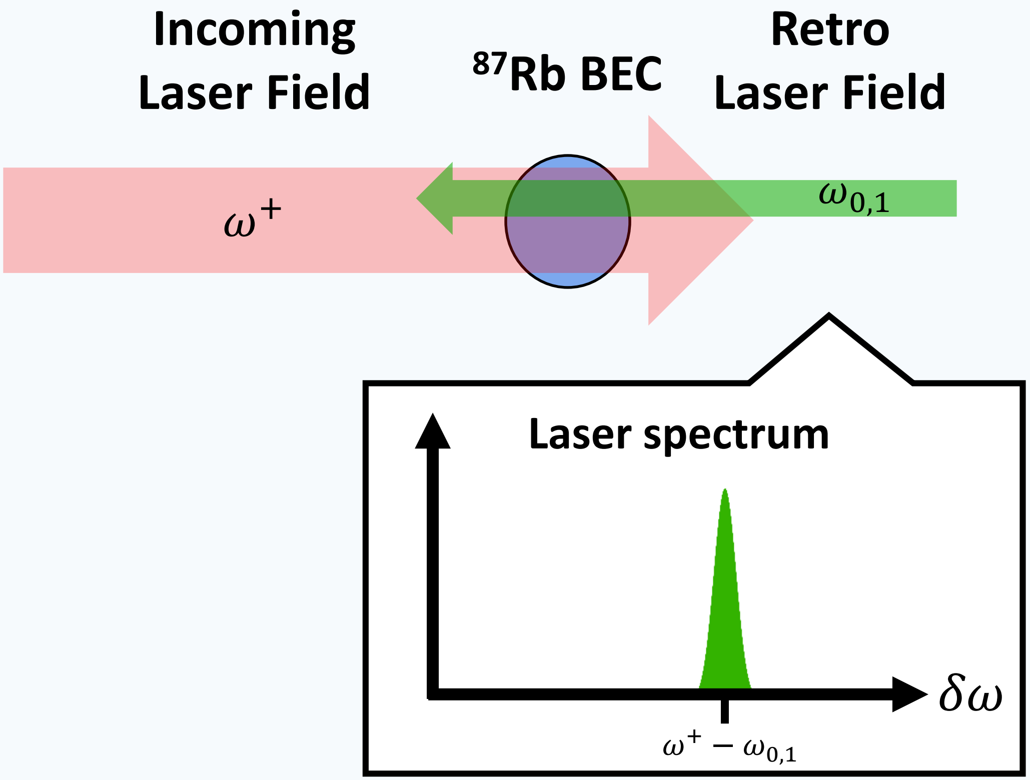
Such an approach would be limited, but well-suited to certain problems

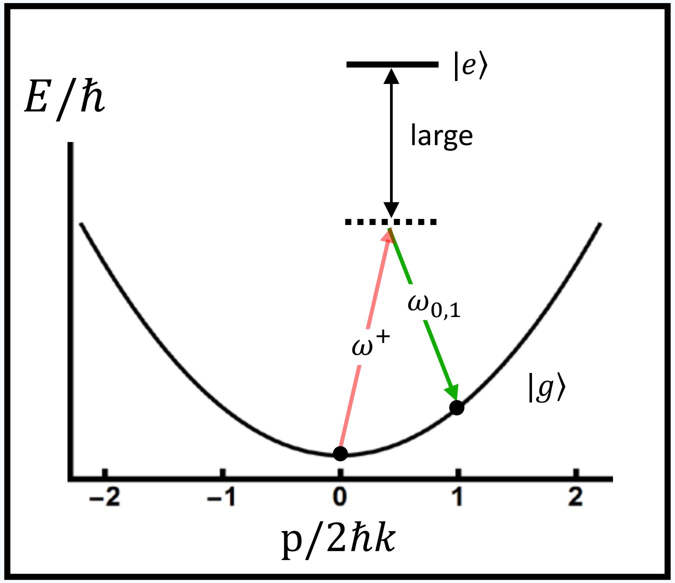
A testbed for fully synthetic lattices:

Synthetic momentum-space lattices

Note: there exists a great body of earlier work on the study of transport phenomena with atoms in momentum space, esp. kicked rotor studies

Coupling momentum states





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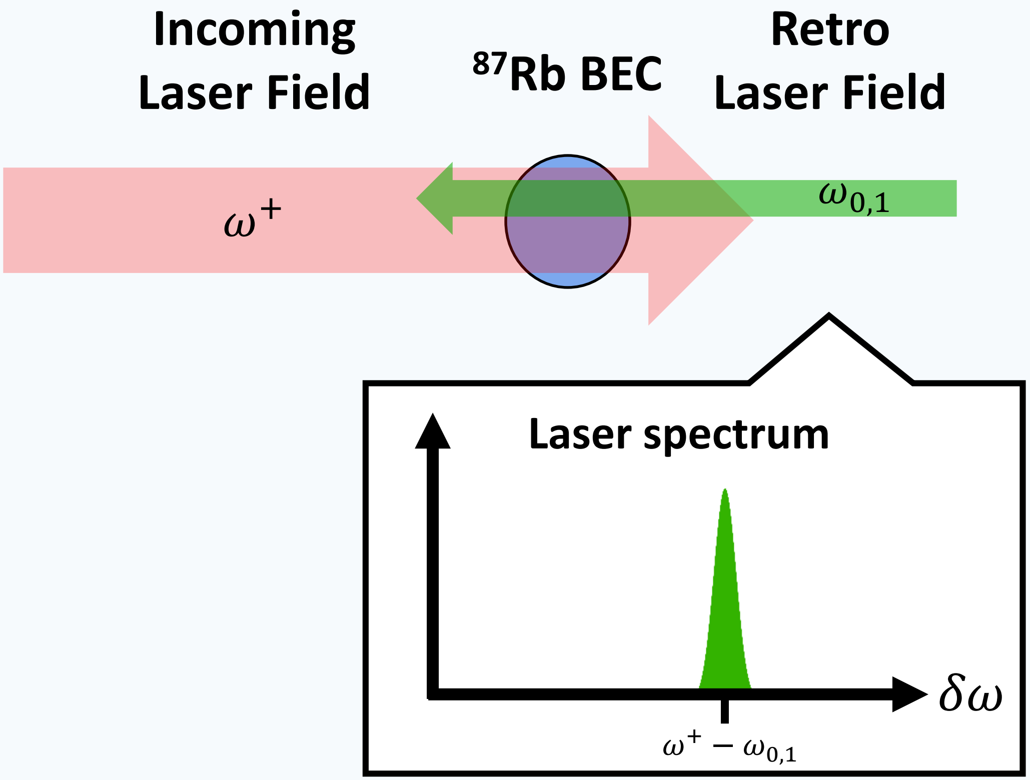
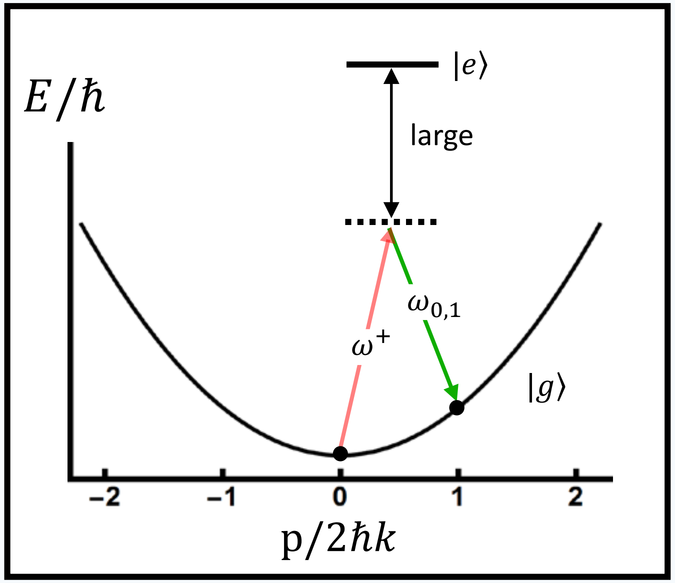
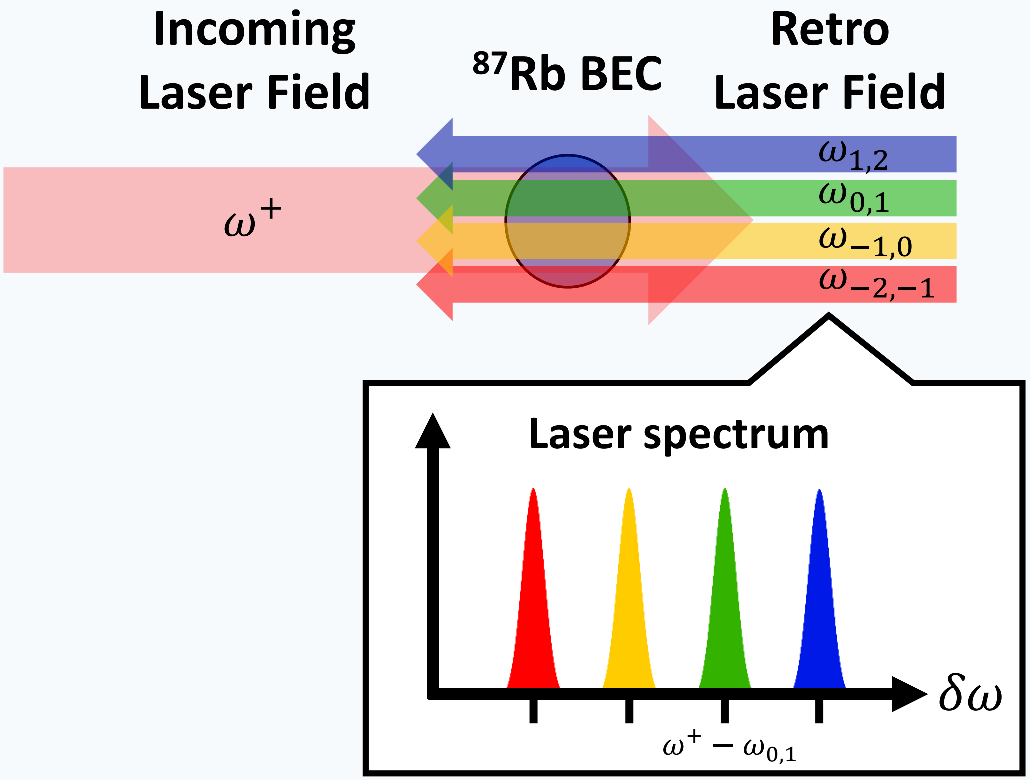
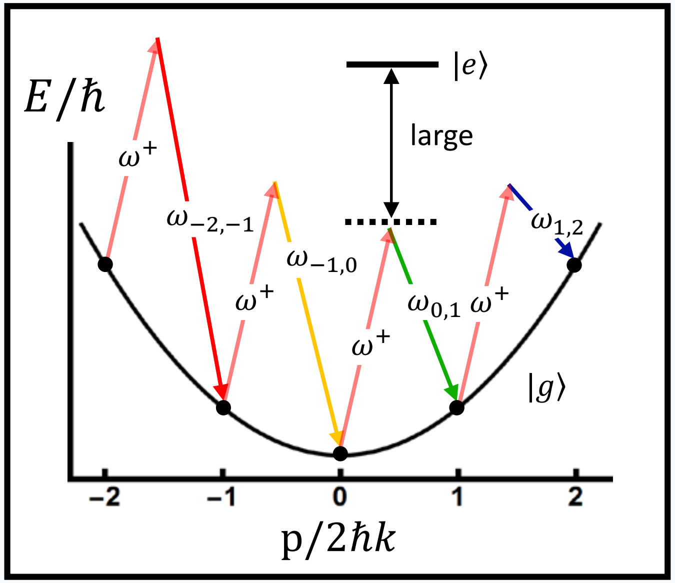




Two-photon Bragg transition

Synthetic momentum-space lattices





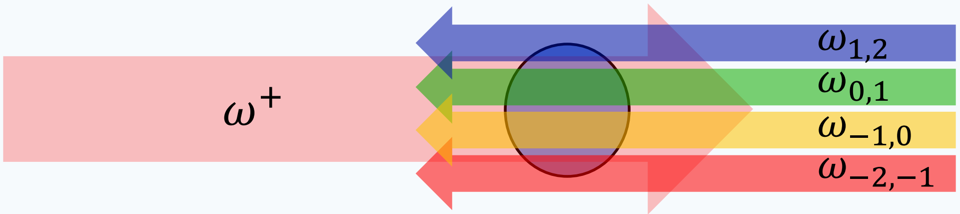
Two-photon Bragg transition

Many resonantly-coupled states, with individual addressing of all transitions

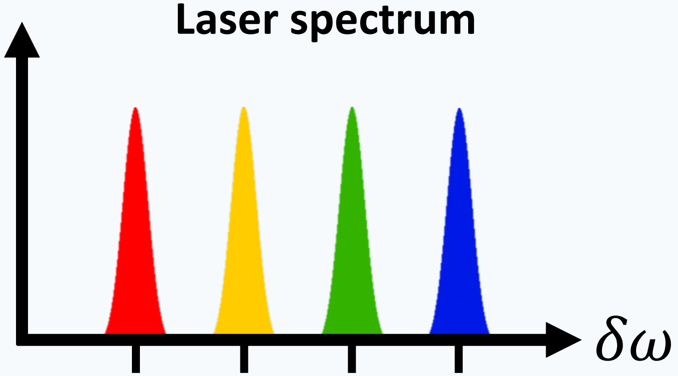
BG PRA (2015) – proposal ; E. J. Meier, F. A. An, and BG. PRA(R) (2016) – experimental demonstration

Spectroscopic Hamiltonian engineering

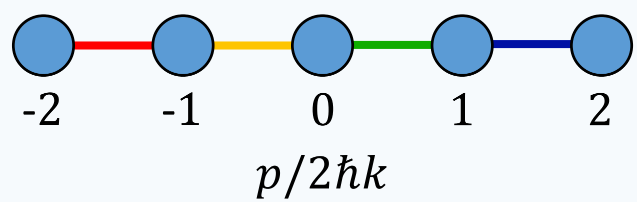
Incoming Laser Field **^{87}Rb BEC** **Retro Laser Field**



Laser spectrum



Momentum-space lattice



potential landscape *tunneling amplitudes and phases*

$$H_{s.p.} = \sum_n \varepsilon_n c_n^\dagger c_n - \sum_n t_n \left(e^{i\varphi_n} c_n^\dagger c_{n+1} + \mathrm{h.c.} \right)$$

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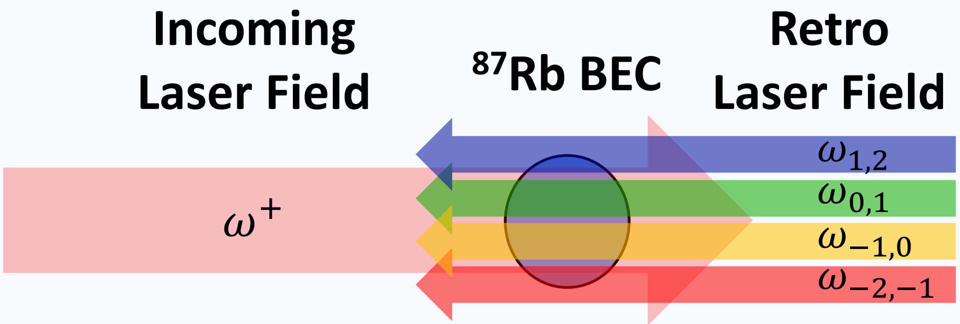
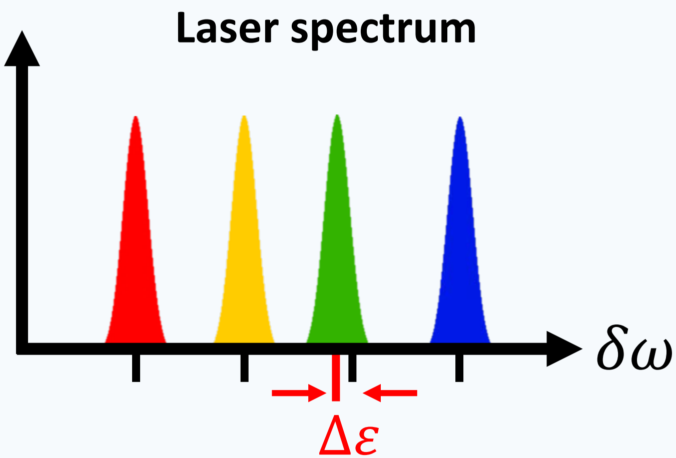
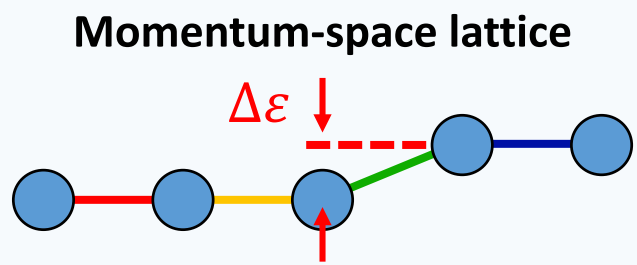
Spectroscopic Hamiltonian engineering







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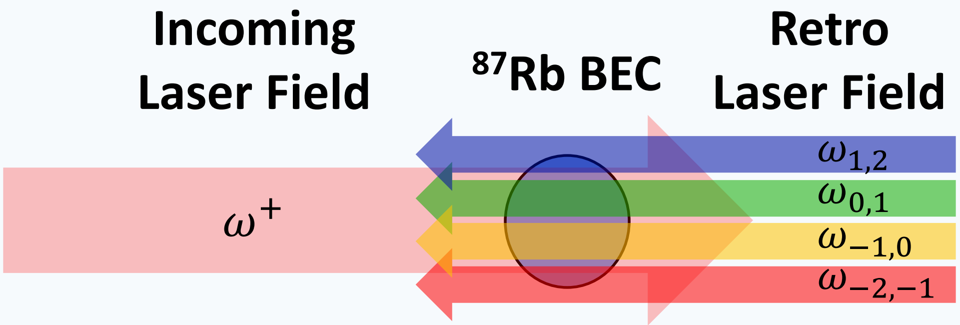

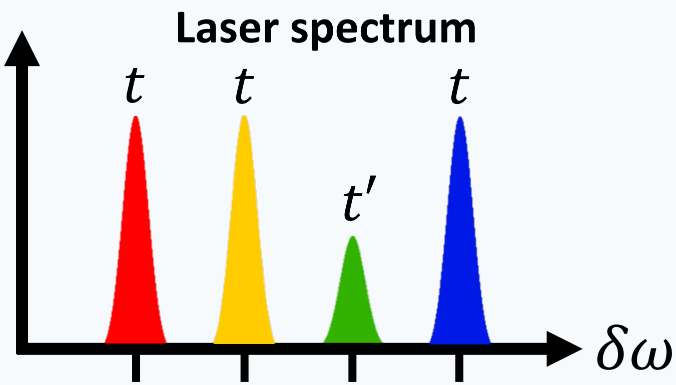

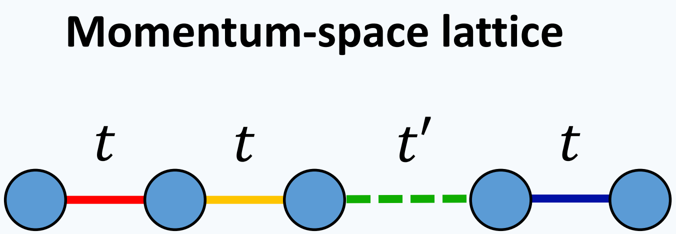

tunneling amplitudes

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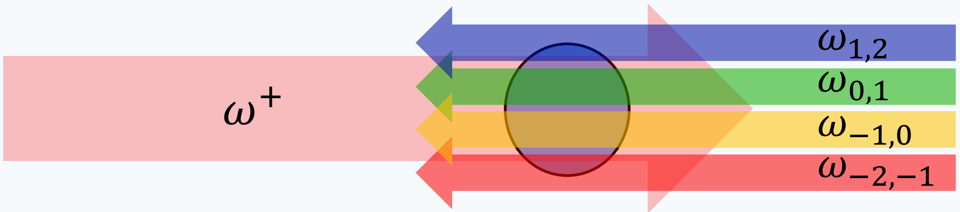

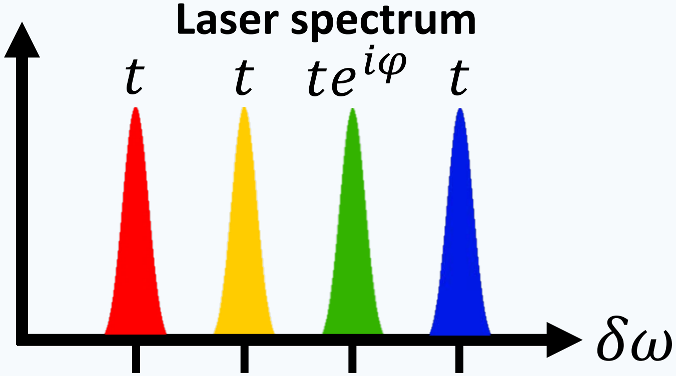

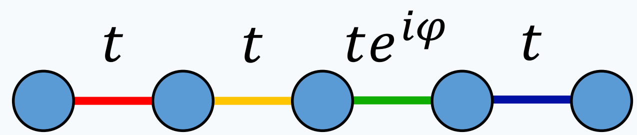

tunneling phases

$$H_{s.p.} = \sum_n \varepsilon_n c_n^\dagger c_n - \sum_n t_n \left(e^{i\varphi_n} c_n^\dagger c_{n+1} + \text{h.c.} \right)$$

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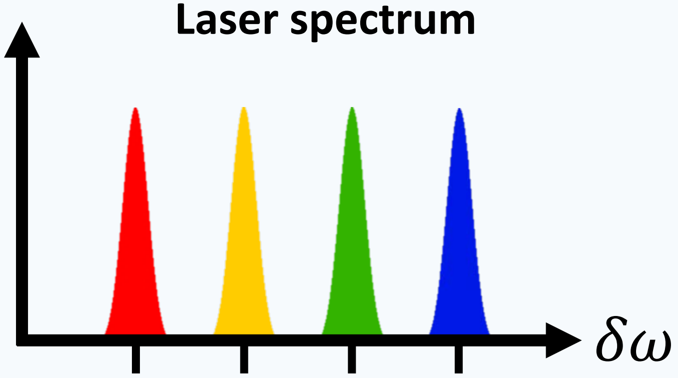
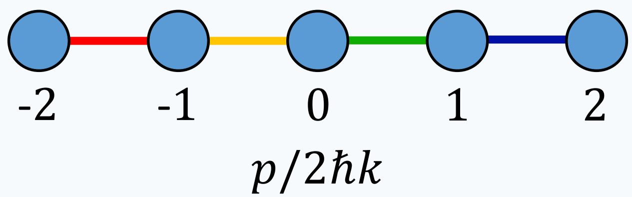
Spectroscopic Hamiltonian engineering

disorder, topology, hard-wall boundaries, …

- local, time-dependent control *[interesting for Floquet physics]*
- higher-dimensions, long-range tunneling *[interesting for synthetic gauge fields]*
- multiple internal states *[interesting for local loss, classical U(2) gauge fields, etc.]*
- ***interactions*** are naturally present and can be dominant over t's & ε's





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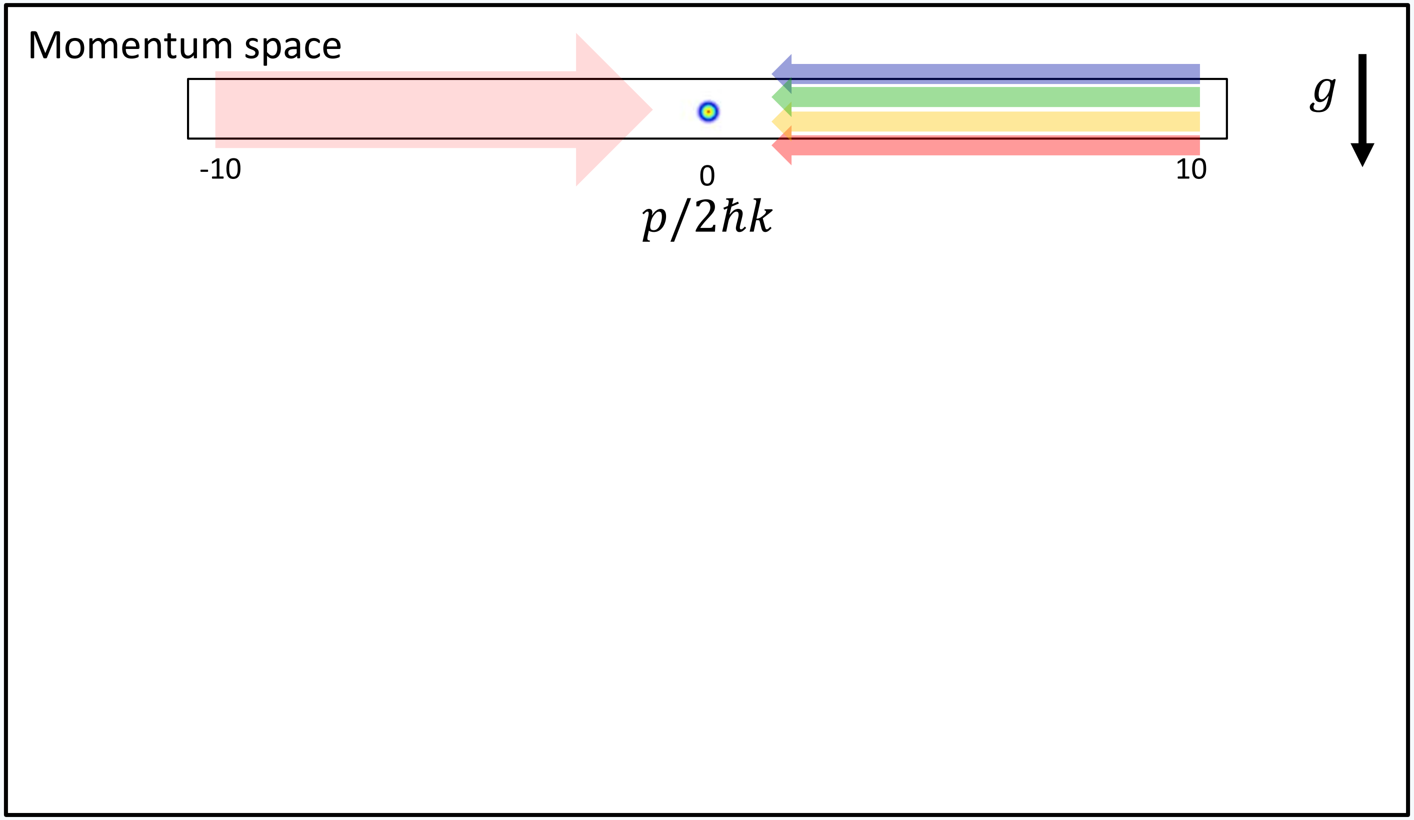
How we measure the atomic distributions



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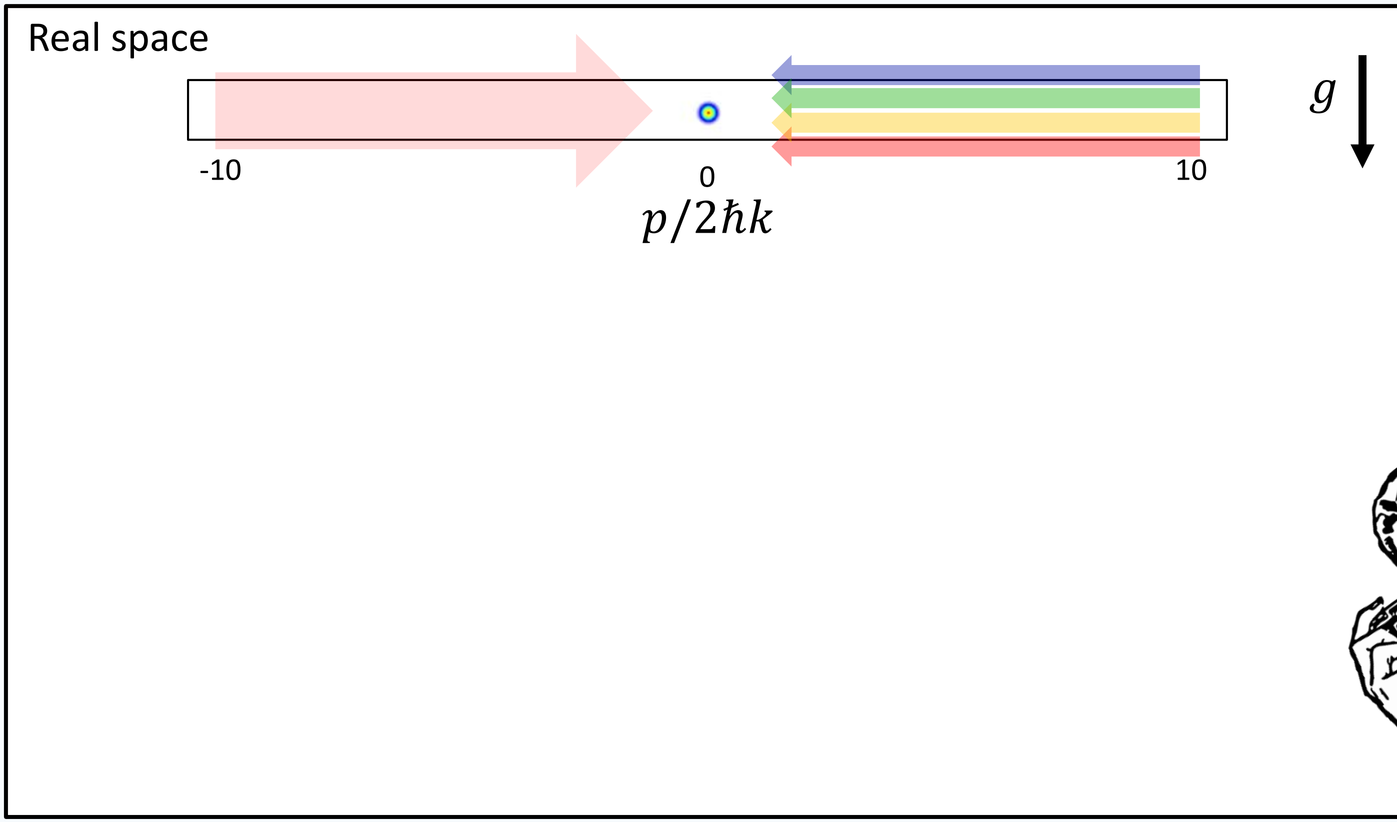
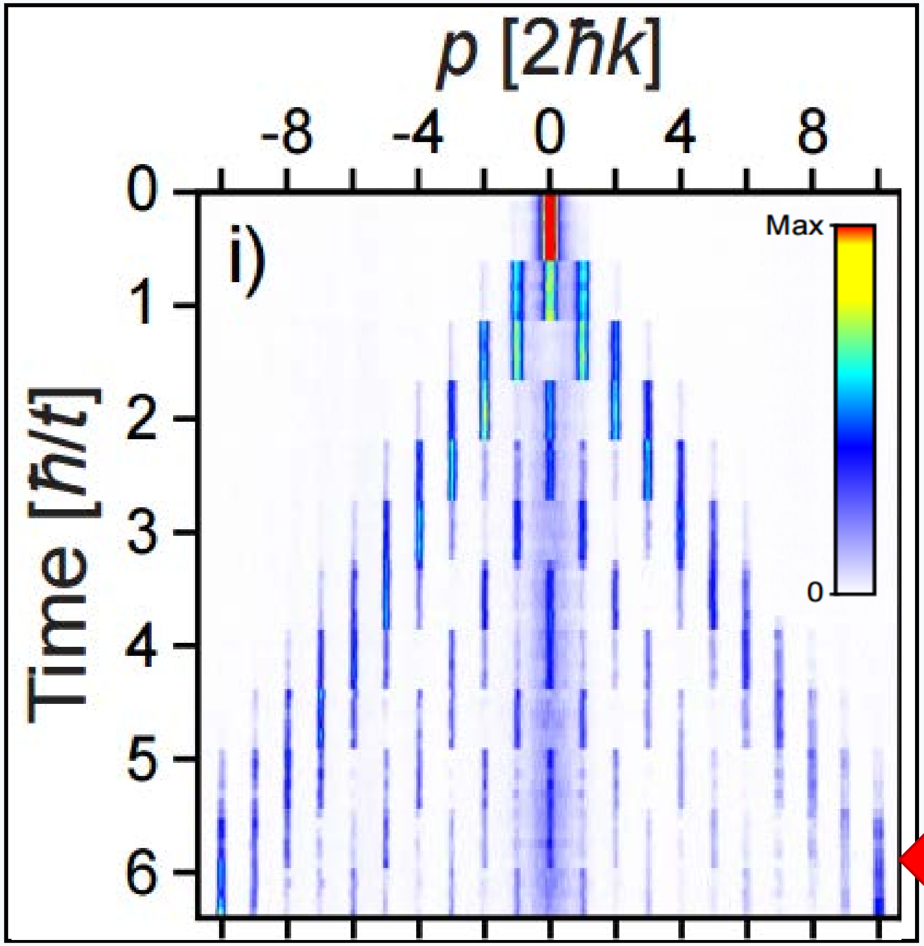


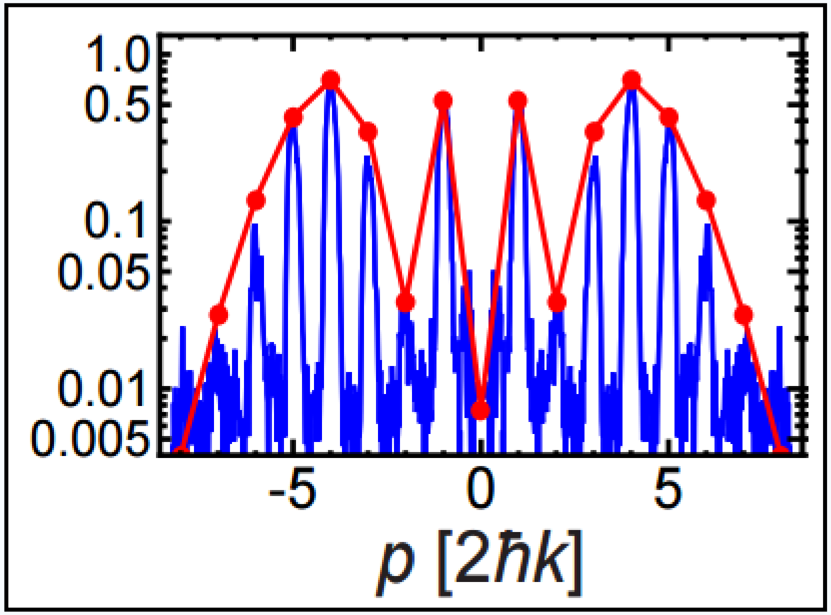
site-resolved measurement comes for free

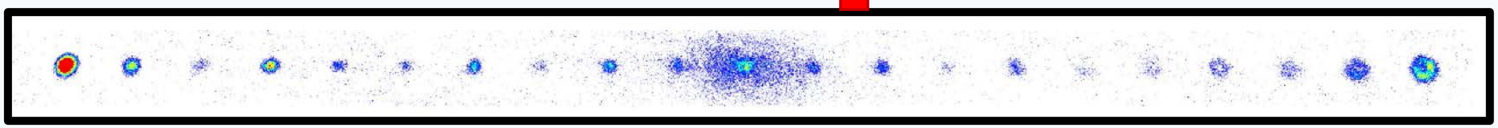
BG PRA (2015) – proposal ; E. J. Meier, F. A. An, and BG. PRA(R) (2016) – experimental demonstration

Simplest type of measurement: quench dynamics



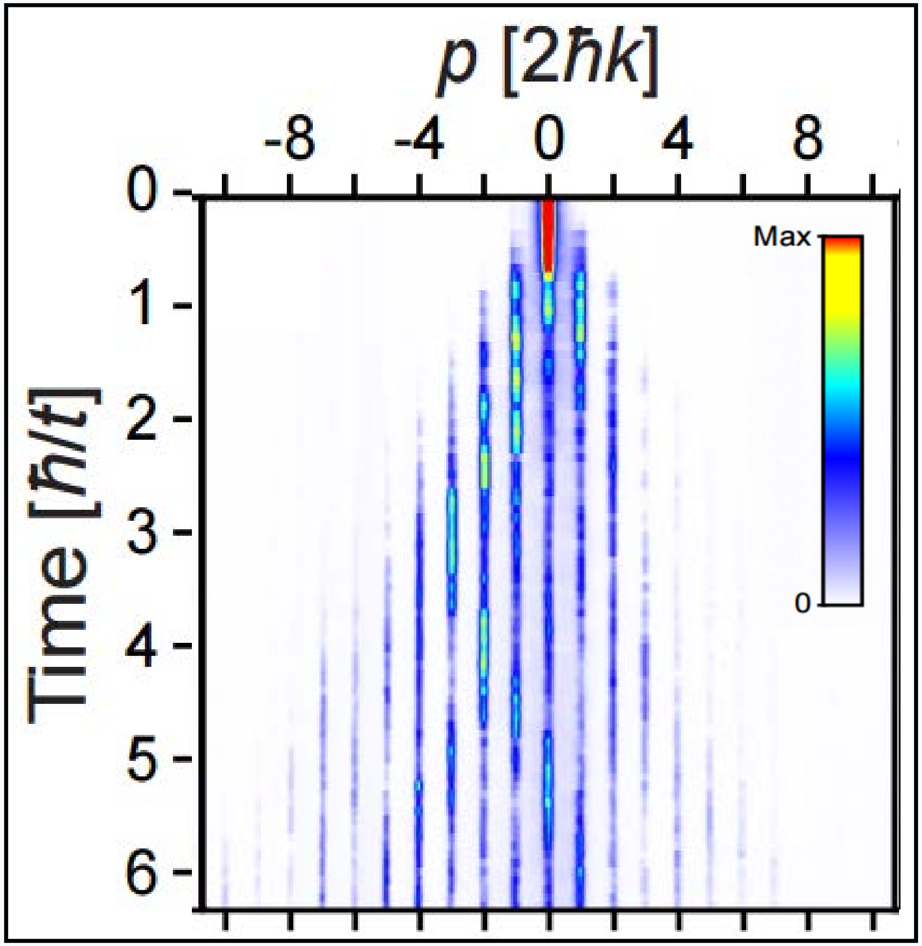
Ballistic quantum walk



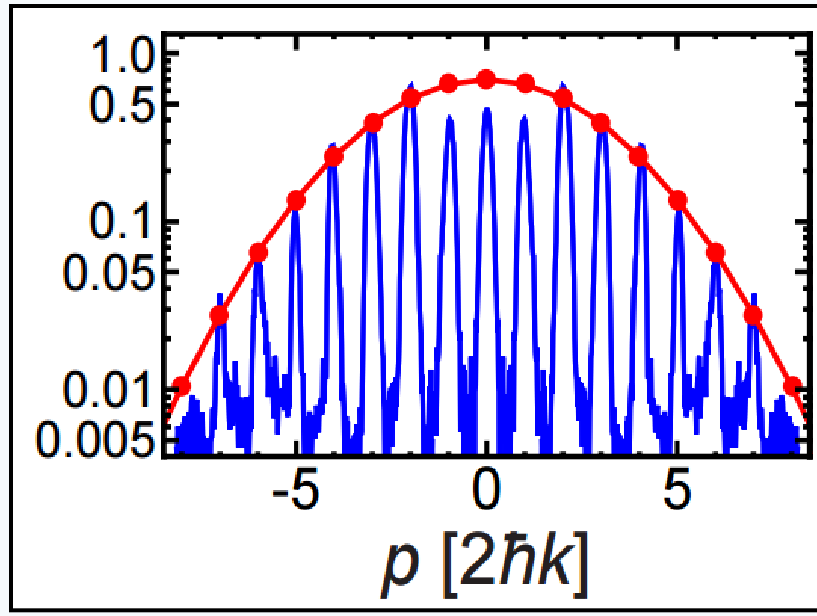


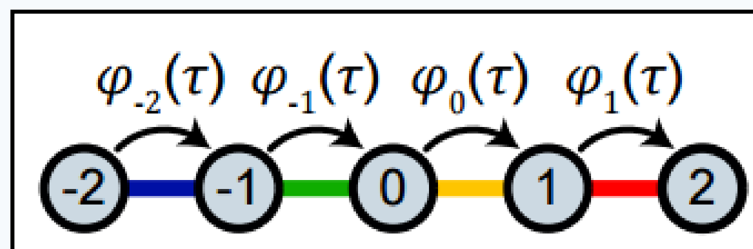
F. A. An, E. J. Meier, BG, Nature Communications (2017)

Quench dynamics in dynamical disorder



Dynamical phase disorder
→ "classical" random walk





Random, dynamical disorder in the tunneling phases

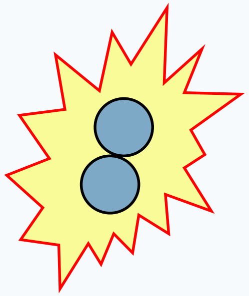
F. A. An, E. J. Meier, BG, Nature Communications (2017)

Interactions in momentum-space lattices

Momentum-space interactions

real space

$$V_{ij} \approx g \sum_{i,j} \delta\left(\vec{r}_i - \vec{r}_j\right)$$



only short-range
s-wave collisions
$T \ll 100\ \mu\mathrm{K}$

real-space interactions are nearly zero range (contact) at low energy

Should relate to infinite-ranged interactions in momentum space **...right?**

momentum space

all-to-all: $V_{ij} = V_{kl} \ \forall \ i, j, k, l$

NO!

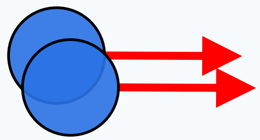
(although this simple argument holds for distinguishable particles)

Direct + exchange interactions

Consider two identical bosons at rest in their center of mass frame, i.e. with the same momentum

+V

repulsive interaction



For repulsive interactions, let's assume two atoms experience a positive energy shift V

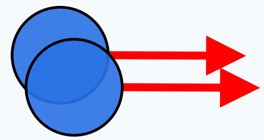
Now consider two identical bosons colliding with some relative momentum (let's assume mode-preserving interactions in 1D)

+2V

repulsive interaction

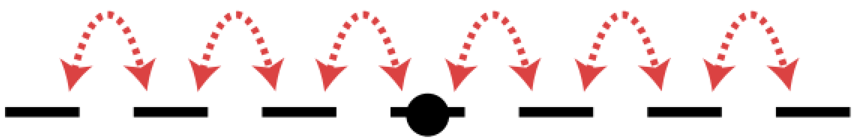
Total pair wave function needs to be symmetric
→ factor of 2 enhancement of collisional energy shift
(added "exchange energy")

Effective momentum-space attraction

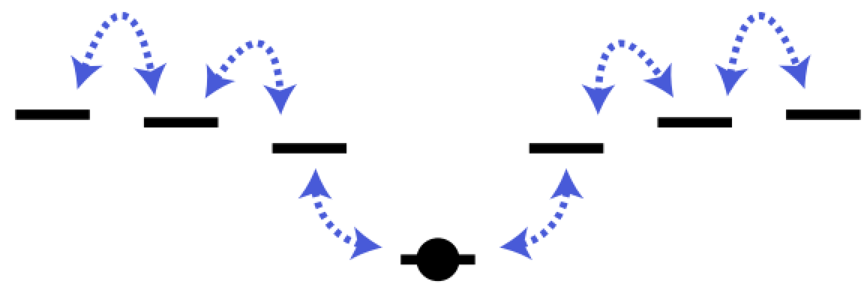


weaker repulsive interaction

Looks like an effective local attraction for particles in same momentum state (site)!



$g = 0$

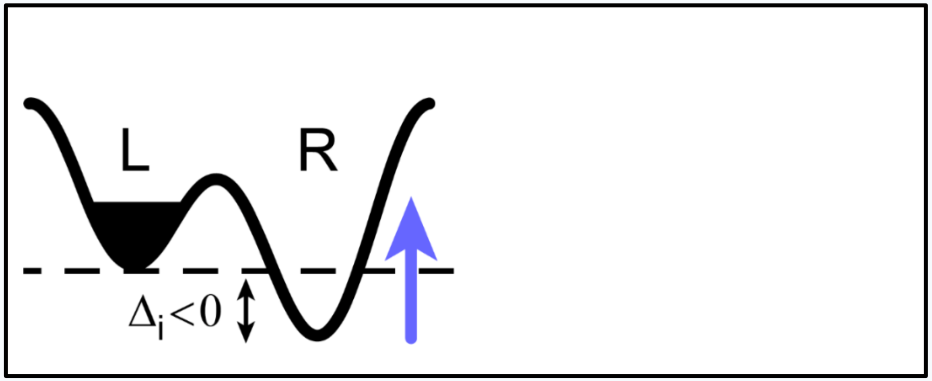


$g > 0$

The "attractive" interaction is mostly local (on-site)
[some off-site component due to screening effects, which vanish for $k\xi \gg 1$]

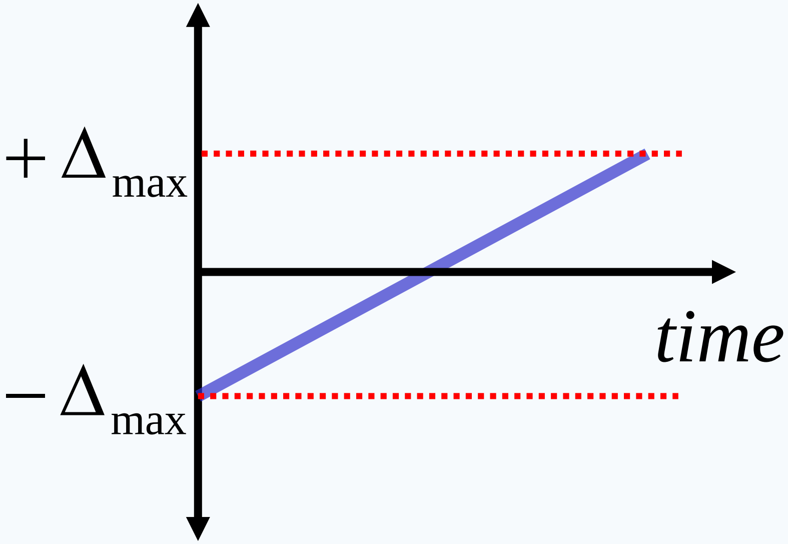
F. A. An*, E. J. Meier*, J. Ang'ong'a, and BG, arXiv:1708.01237 (2017).

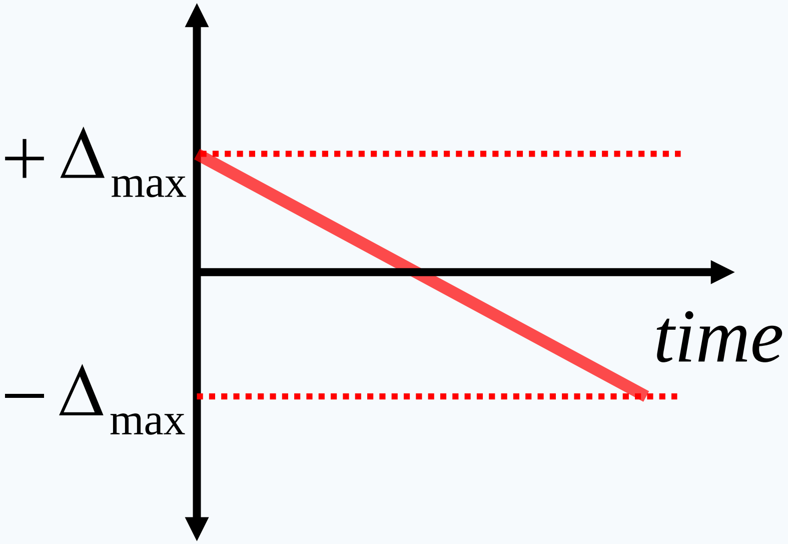
Interactions in a double-well system



***U* = 0 prediction**

Details of population transfer should be ***independent*** of the sweep direction





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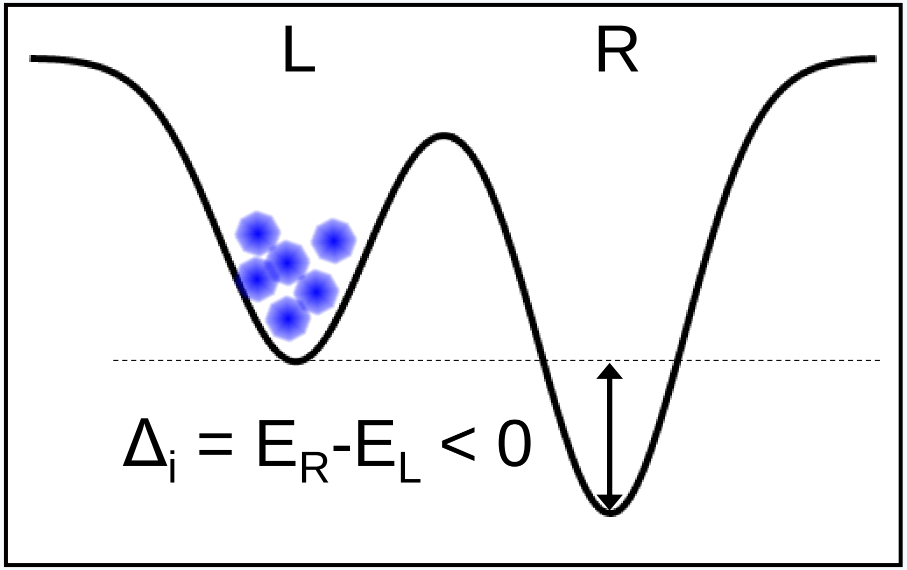

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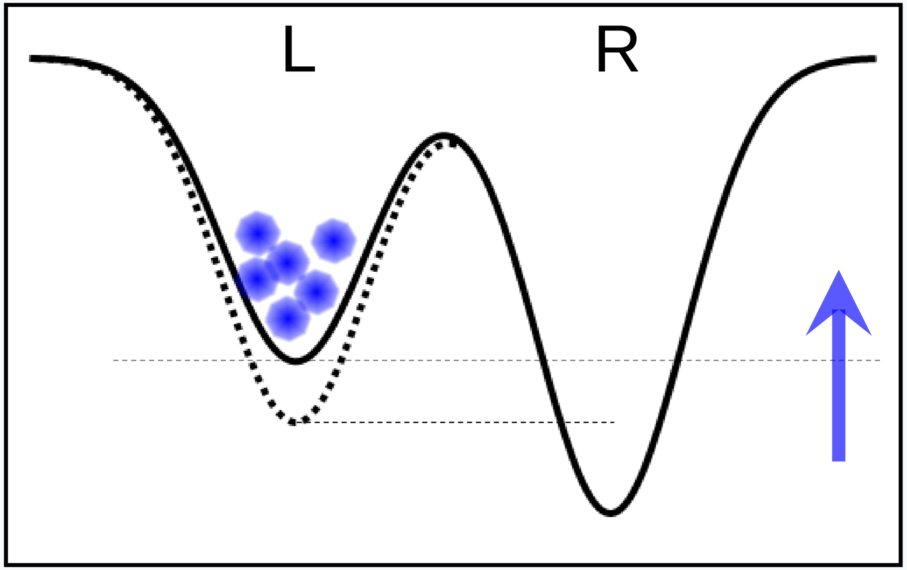

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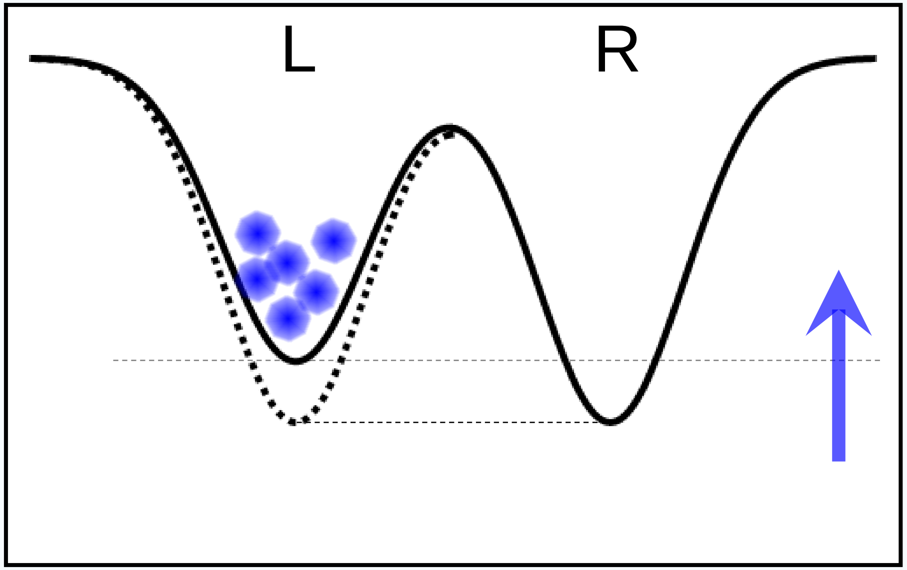

- appears to transfer "early"

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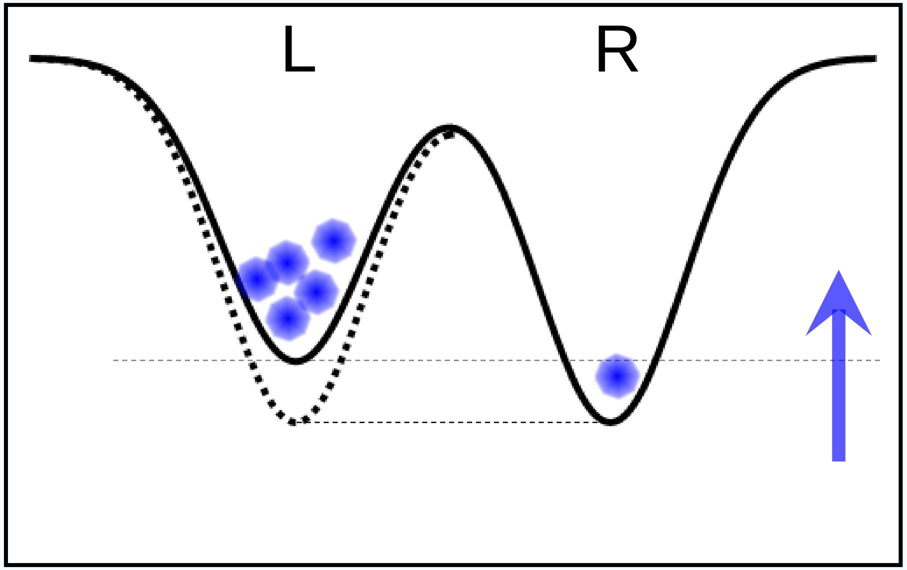

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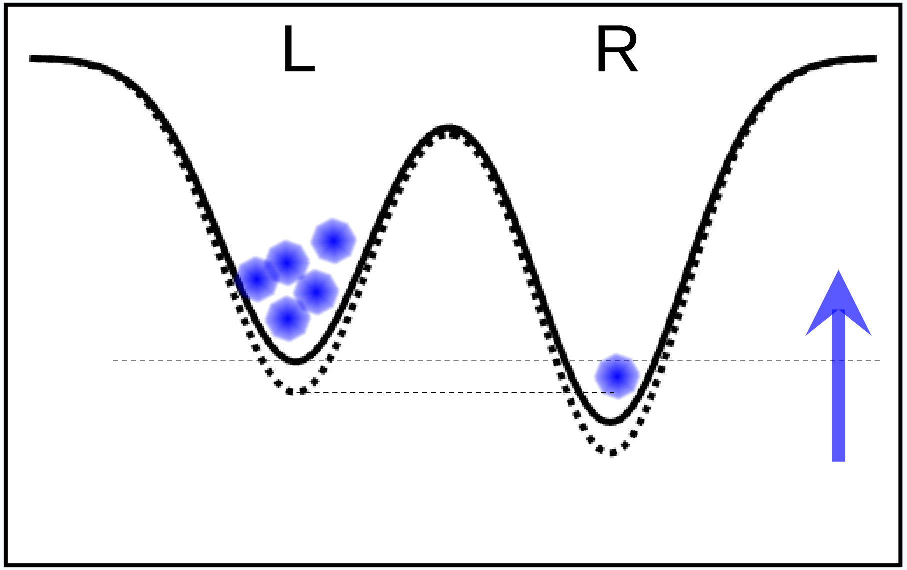
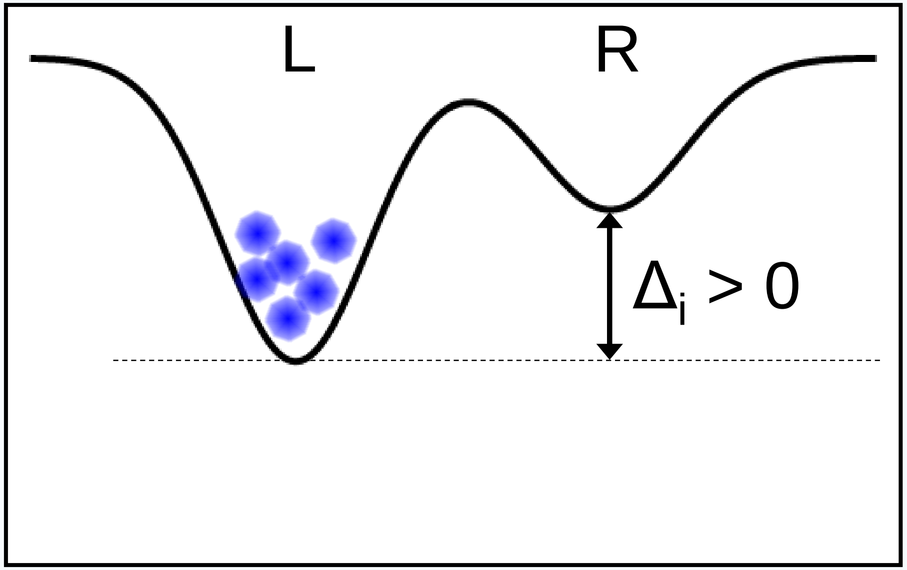


- appears to transfer “early”
- ramp direction allows for continued transfer

F. A. An*, E. J. Meier*, J. Ang’ong’a, and BG, arXiv:1708.01237 (2017).

Interactions in a double-well system



F. A. An*, E. J. Meier*, J. Ang'ong'a, and BG, arXiv:1708.01237 (2017).

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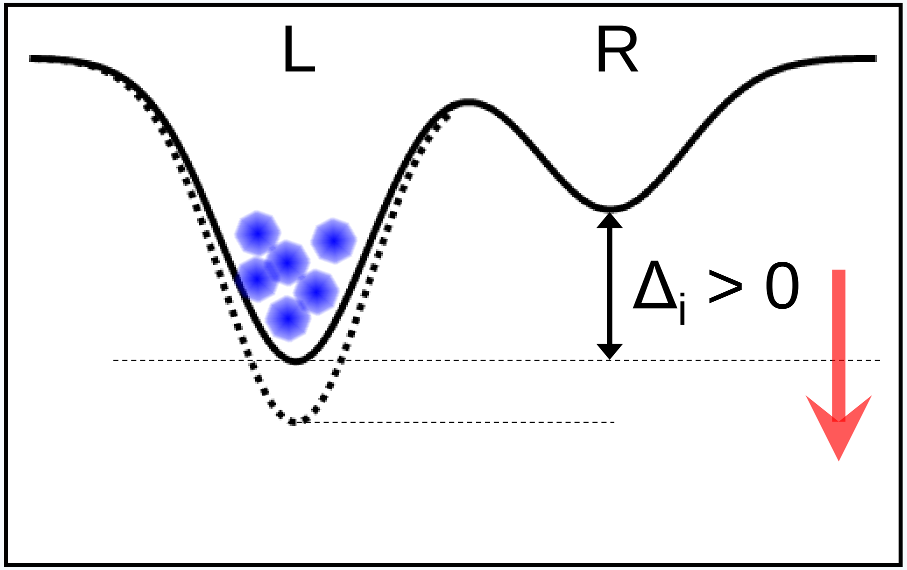

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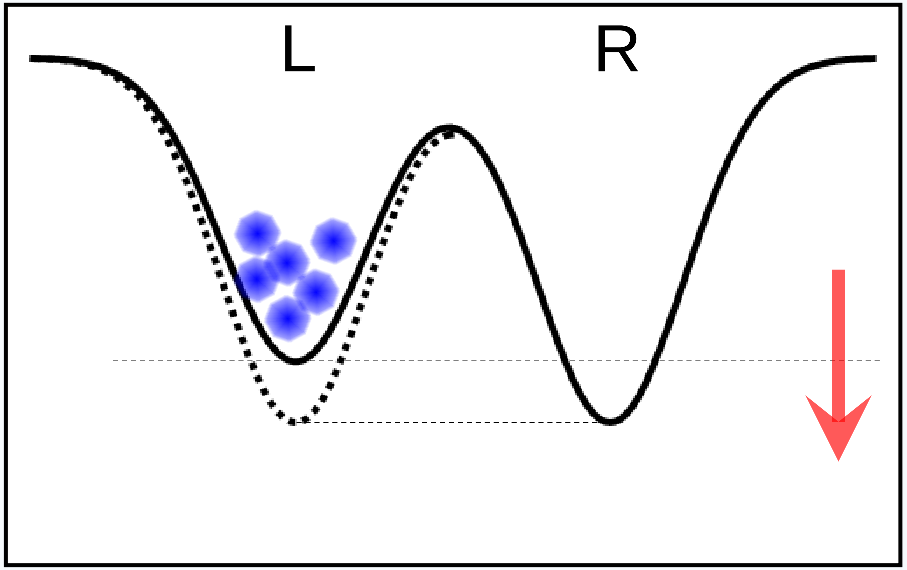
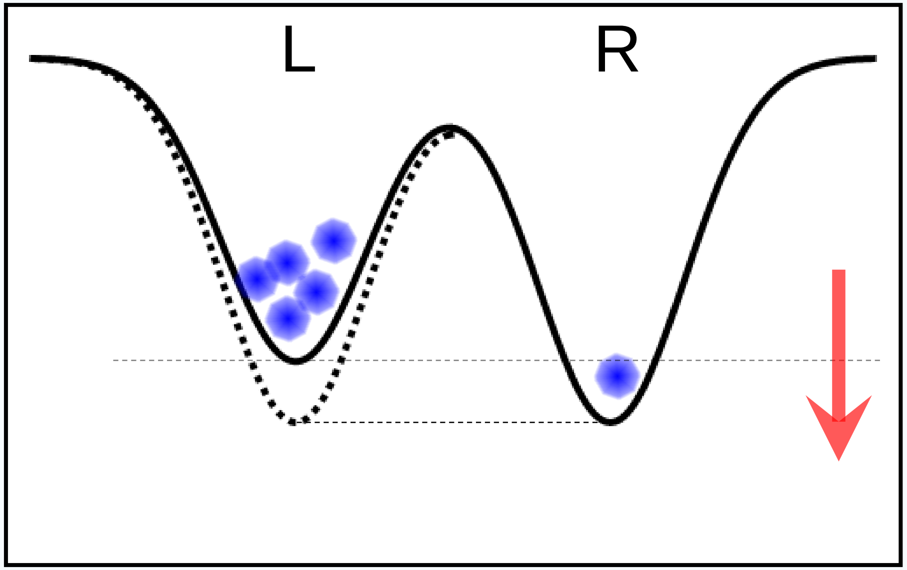


- appears to transfer "late"

F. A. An*, E. J. Meier*, J. Ang'ong'a, and BG, arXiv:1708.01237 (2017).

Interactions in a double-well system



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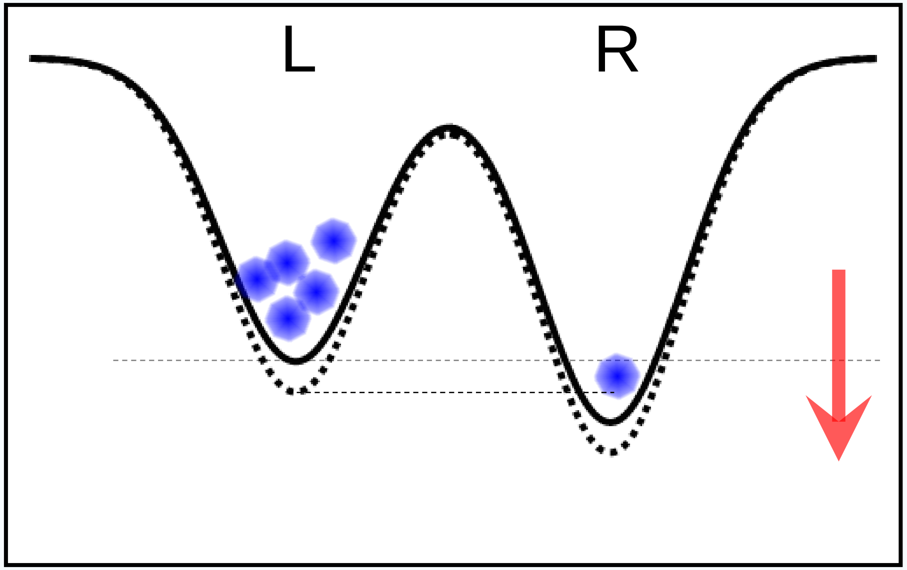
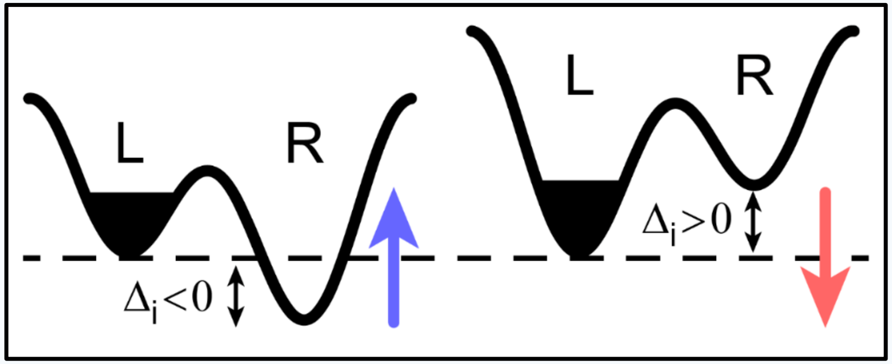
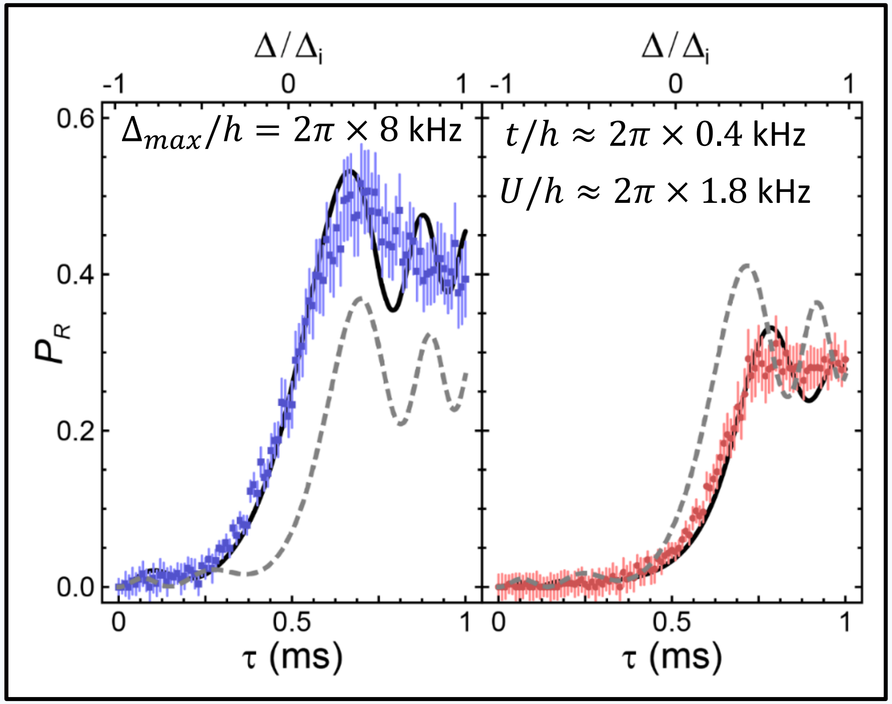


- appears to transfer “late”
- ramp direction runs past resonance condition

F. A. An*, E. J. Meier*, J. Ang’ong’a, and BG, arXiv:1708.01237 (2017).

Interactions in a double-well system





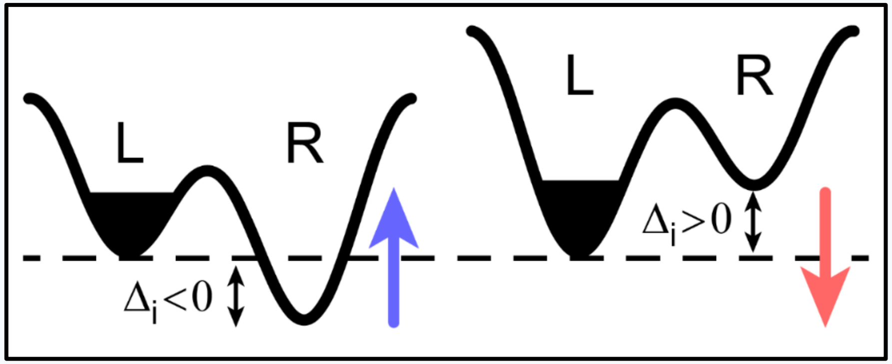
What do we observe?

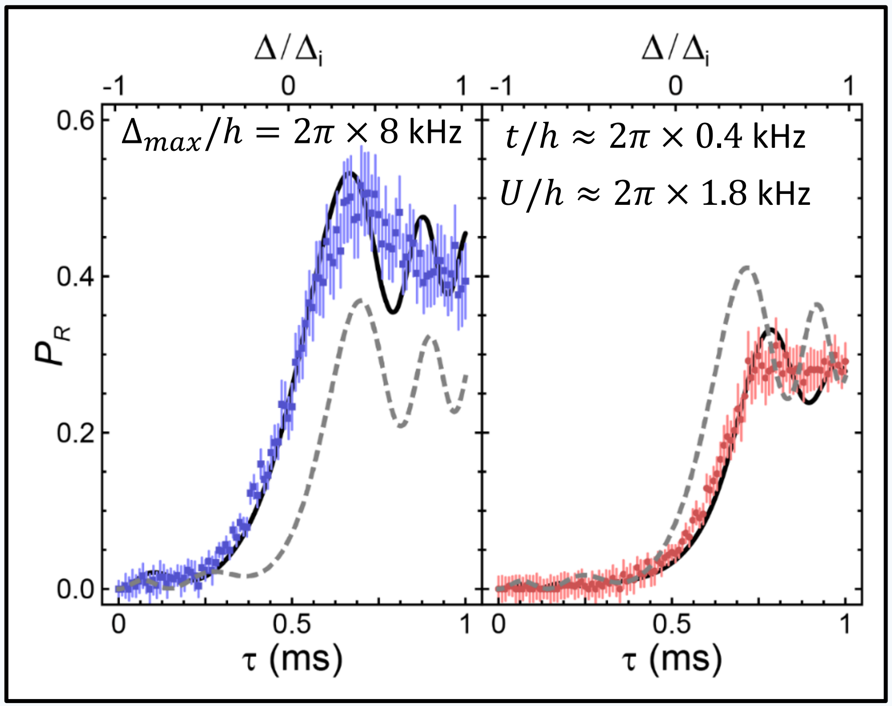
onset of nonlinear self-trapping due to interactions

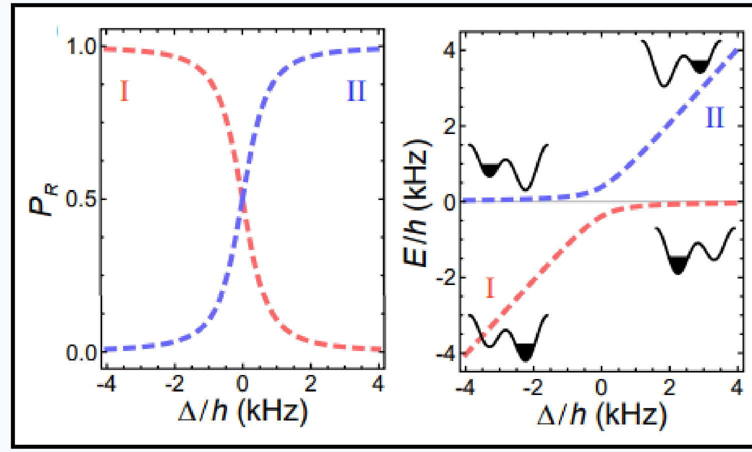
- positive ramp transfers early
- negative ramp transfers late
- enhanced/suppressed transfer depending on sweep direction

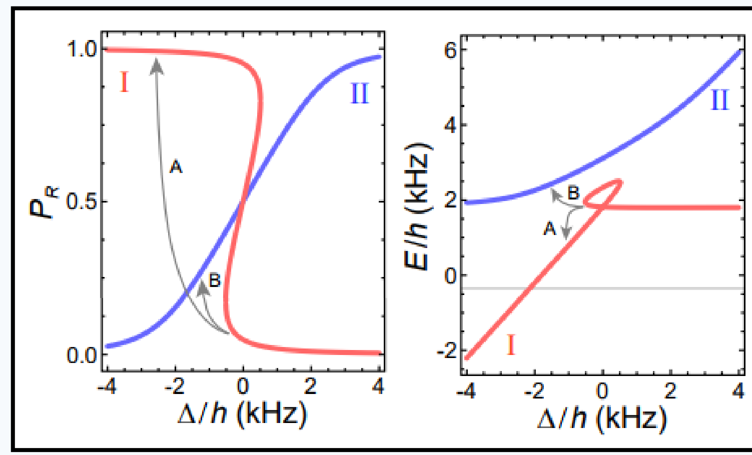
F. A. An*, E. J. Meier*, J. Ang'ong'a, and BG, arXiv:1708.01237 (2017).

Interactions in a double-well system









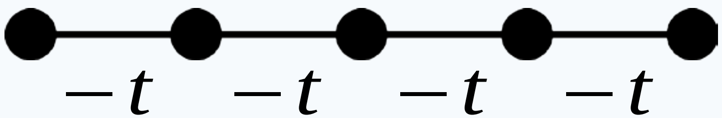
- same physics underlying bosonic Josephson effects, hysteresis in interacting spin systems
- can give rise to k-space "squeezing"

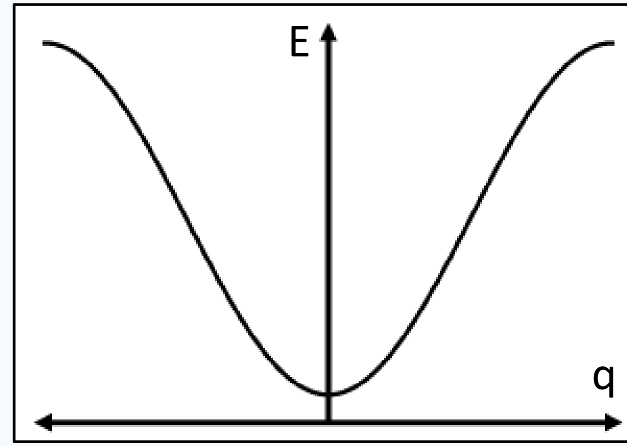
F. A. An*, E. J. Meier*, J. Ang'ong'a, and BG, arXiv:1708.01237 (2017).

Exploring the
interplay of topology & disorder

1D topological wires: Realizing the Su-Schrieffer-Heeger model

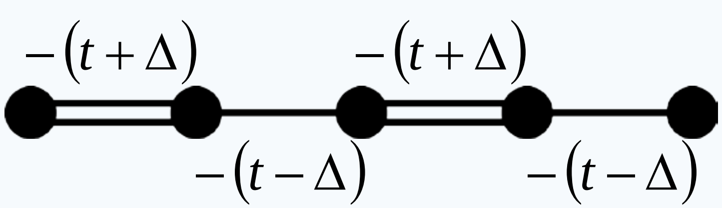
Simple cosine-like band structure

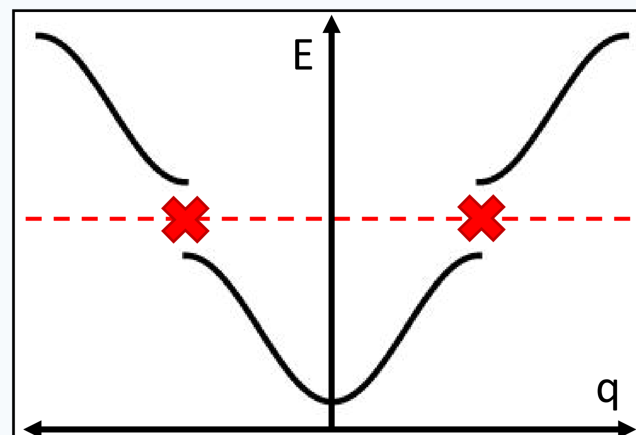




1D topological wires (Su-Schrieffer-Heeger model)

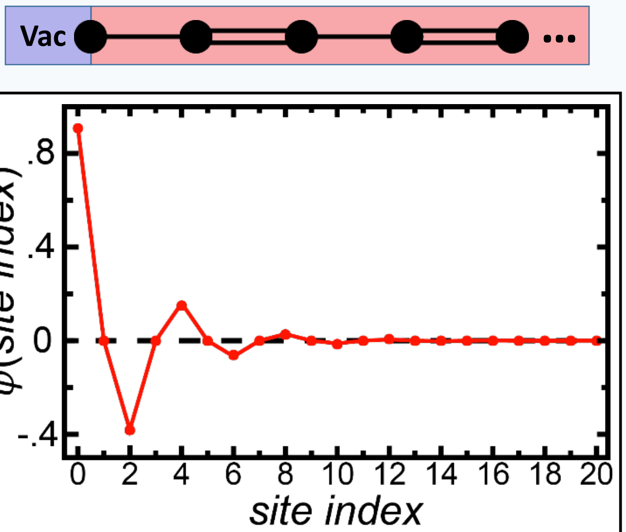
“textbook” topological free-fermion model



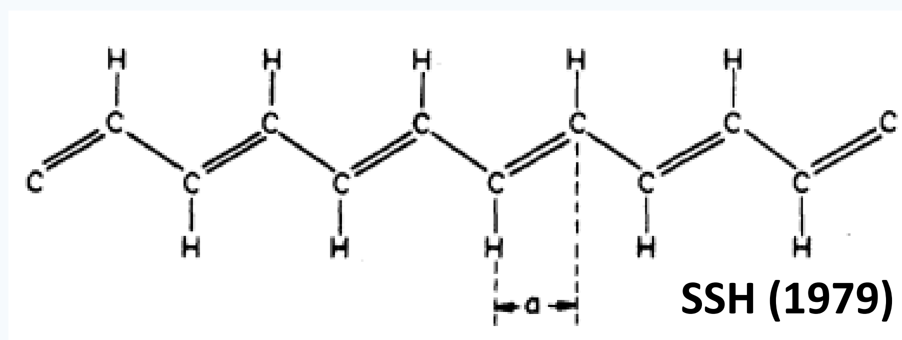


E. J. Meier, F. A. An, and BG. Nat. Comm. 7, 13986 (2016)
cf also work with superlattices (Bloch group, Takahashi group, etc.)

Probing the boundary modes



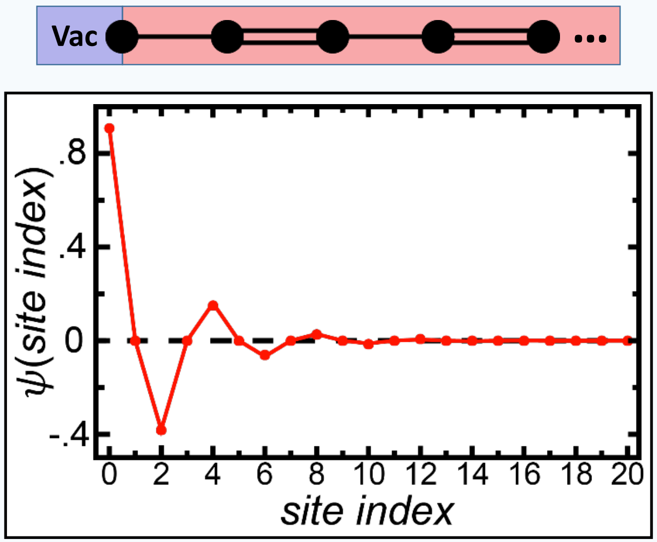
Bound state at defects / interface



10^9 x increase in conductivity of doped polyacetylene

E. J. Meier, F. A. An, and BG. Nat. Comm. 7, 13986 (2016)

Probing the boundary modes



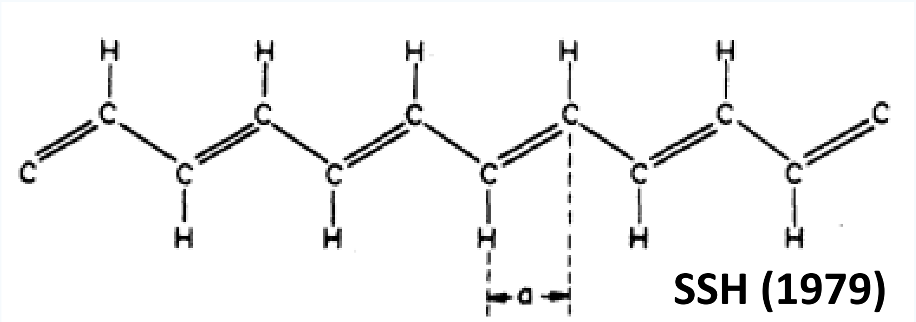
Bound state at defects / interface

Three methods to probe our midgap state:

1. **Nonadiabatic projection**
   Inject population directly at system boundary.

2. **Phase-sensitive projection**
   Initialize atoms in a state that matches amplitude and phase of midgap state.

3. **Adiabatic preparation**
   Begin in ground state of $H_{initial}$, slowly evolve towards H_{final}



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Probing the boundary modes

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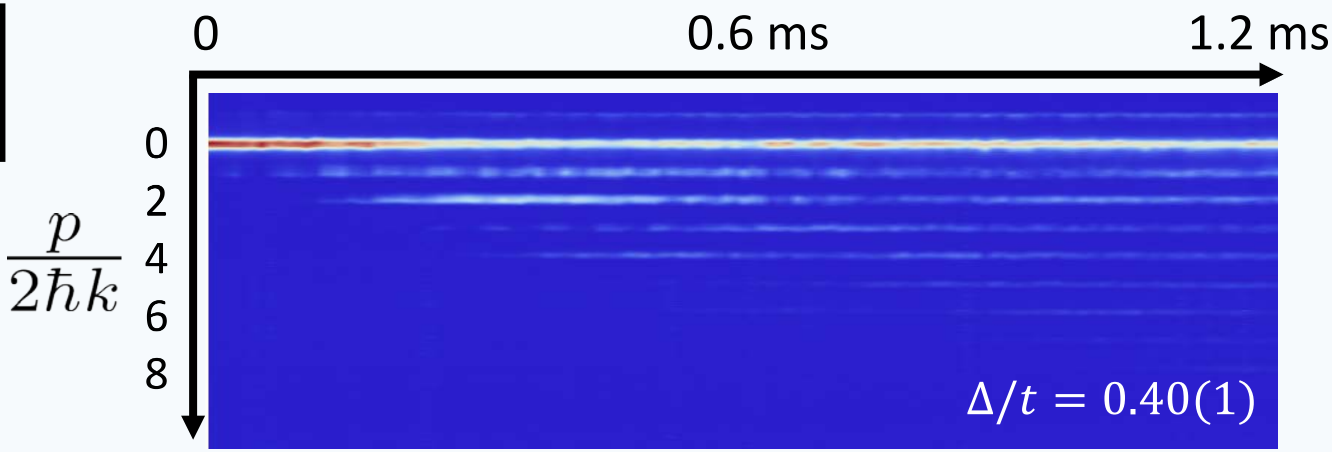
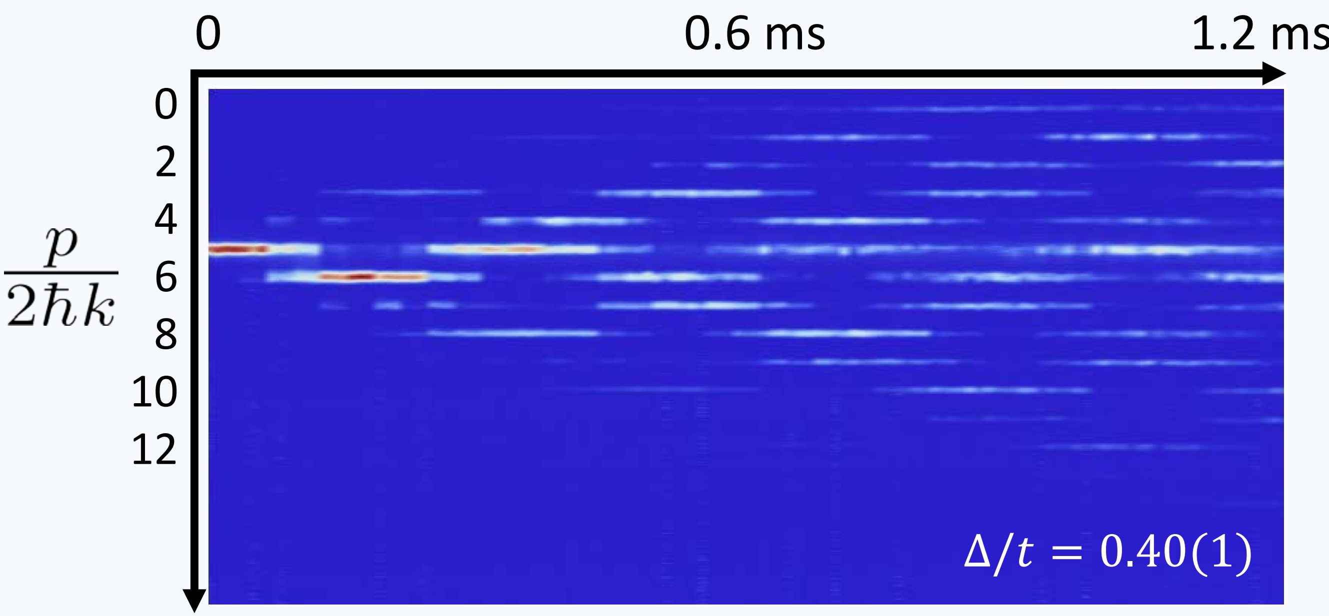
   Initialize atoms in a state that matches amplitude and phase of midgap state.
3. **Adiabatic preparation**
   Begin in ground state of fully dimerized lattice; adiabatically ramp up weak links.





E. J. Meier, F. A. An, and BG. Nat. Comm. 7, 13986 (2016)

Probing the boundary modes

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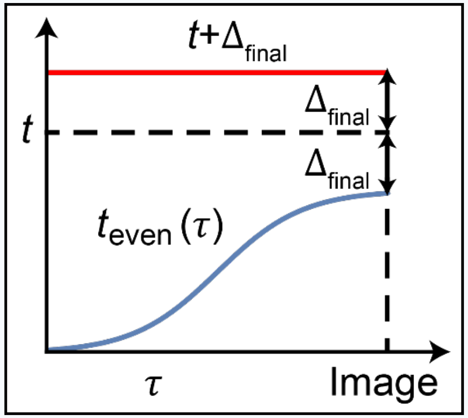
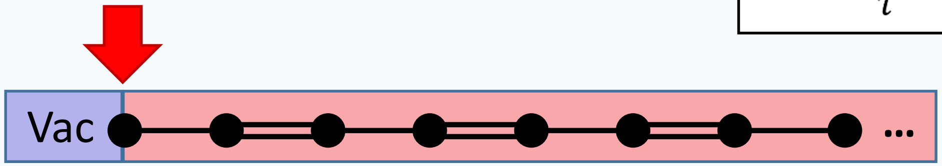
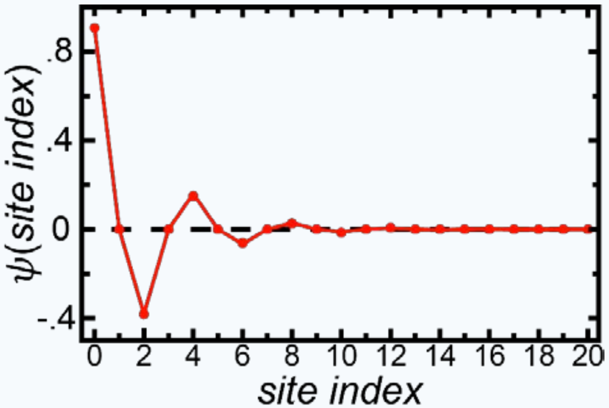
   Begin in ground state of fully dimerized lattice; adiabatically ramp up weak links.

Adiabatically prepare ground state of interest

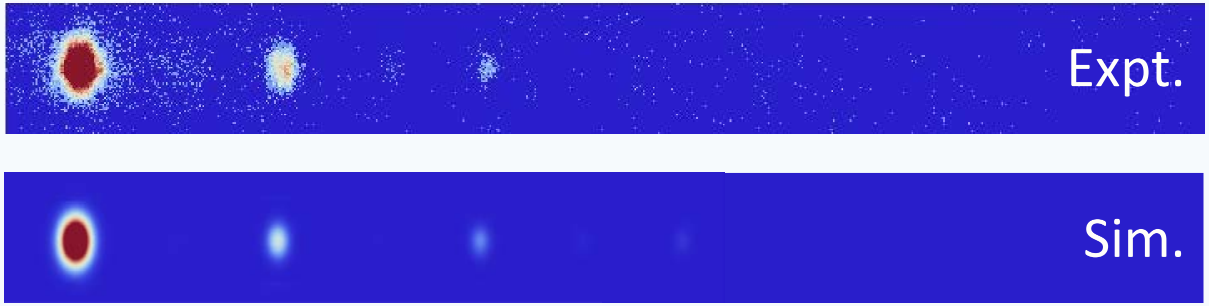
- Start with strong links at $t+\Delta_{final}$ and weak links at zero.
- Ramp up weak links to a final value of $t-\Delta_{final}$ while holding strong links constant.





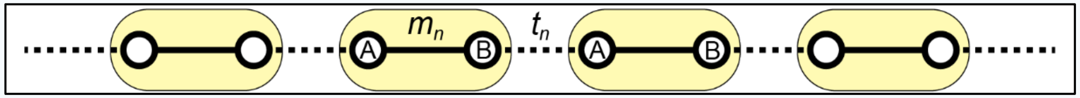


$\Delta/t = 0.38(1)$



E. J. Meier, F. A. An, and BG. Nat. Comm. 7, 13986 (2016)

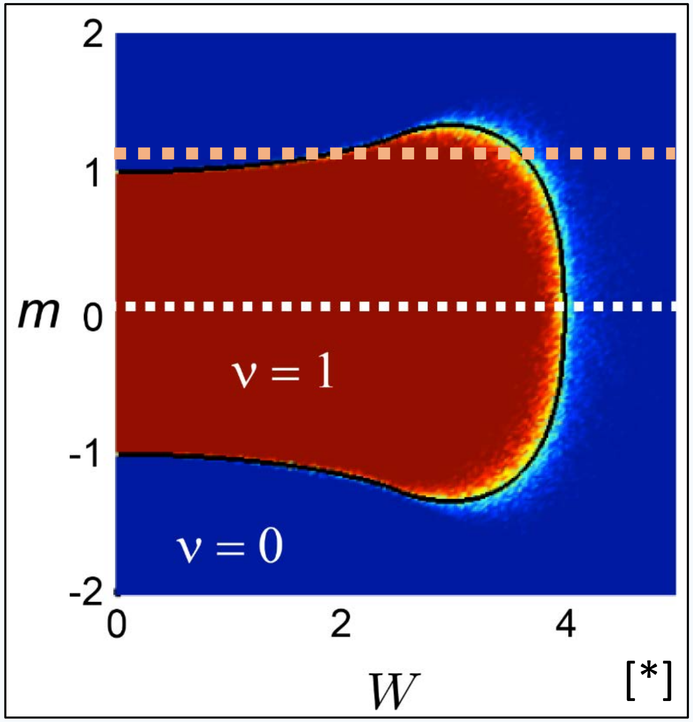
Probing the influence of disorder



$$\mathcal{C} = 2\langle n \otimes \sigma_z \rangle$$

$$t_n = t(1 + \frac{W}{2}\omega_n)$$

$$m_n = t(m + W\omega'_n)$$



* I. Mondragon-Shem, T. L. Hughes, J. Song, and E. Prodan, Phys. Rev. Lett. 113, 046802 (2014).
F. Cardano, et al. Nat. Comms. 8, 15516 (2017)
M. Maffei, A. Dauphin, F. Cardano, M. Lewenstein, and P. Massignan, arXiv:1708.02778

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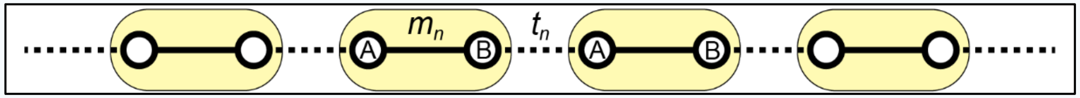

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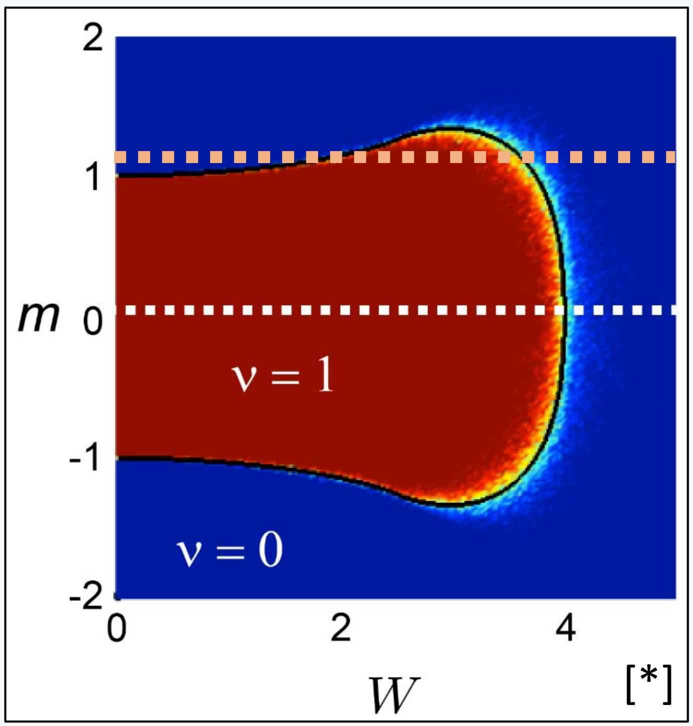

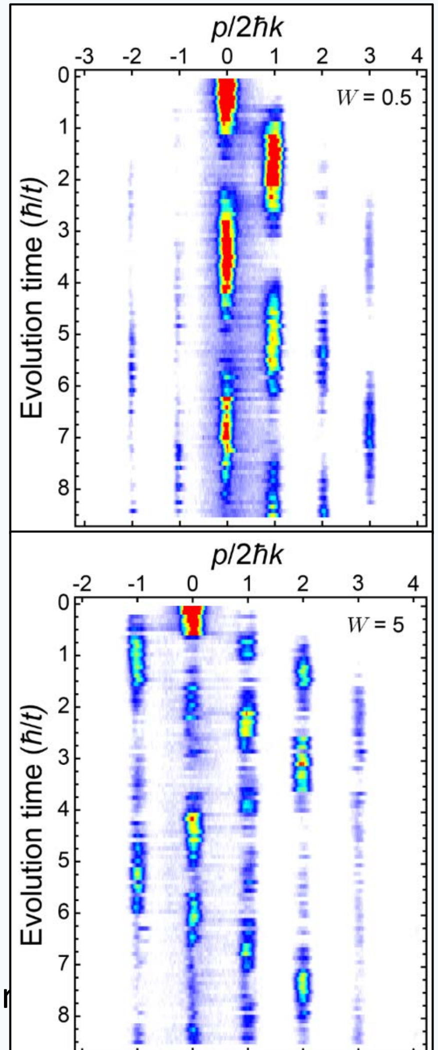

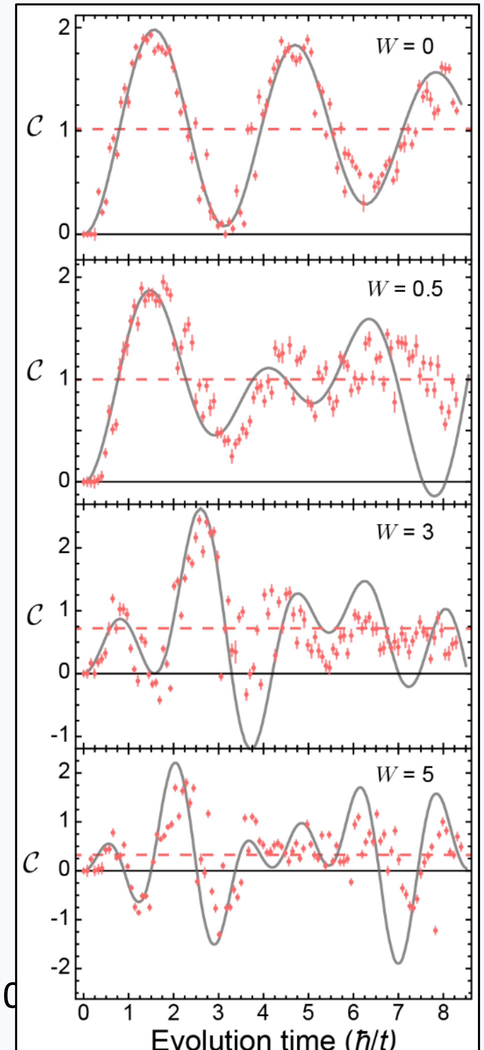

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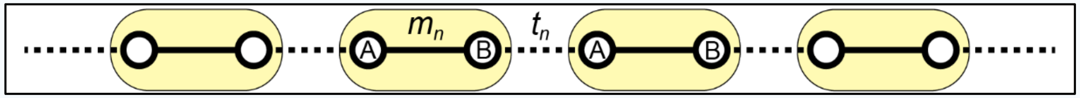

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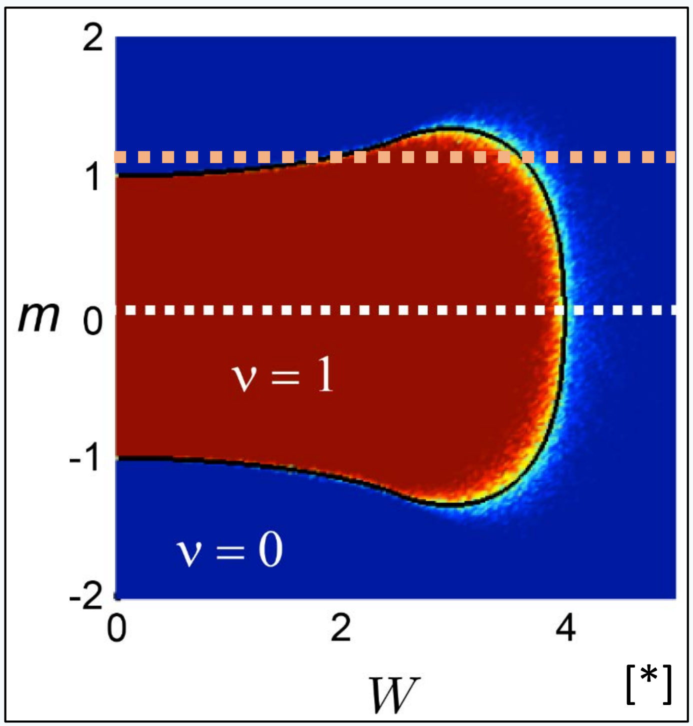
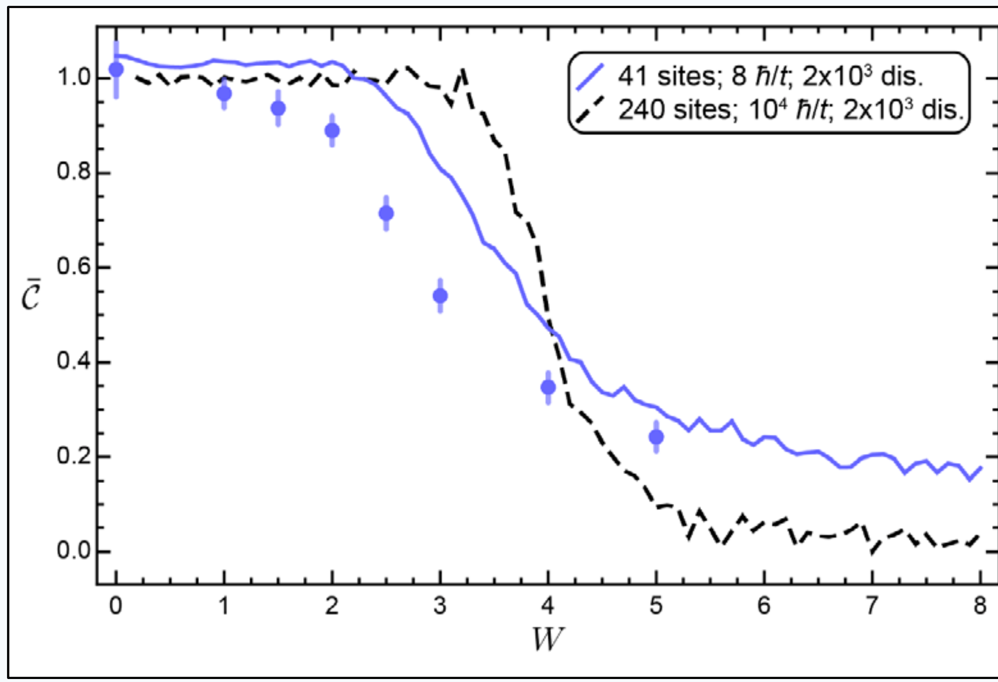
evidence for a topological-to-trivial crossover driven by disorder

now investigating predicted “topological Anderson insulator”





E.J. Meier, *et al.* (in prep)

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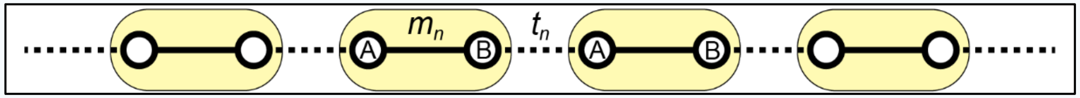

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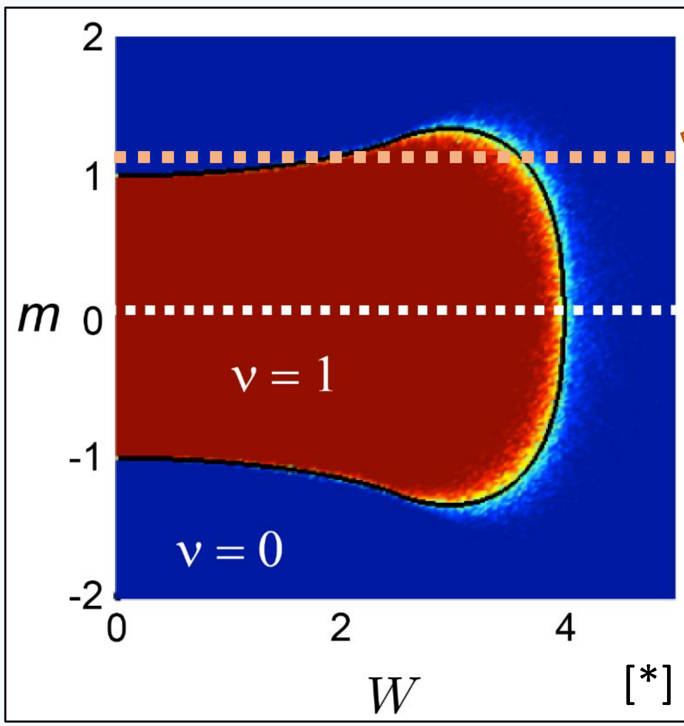
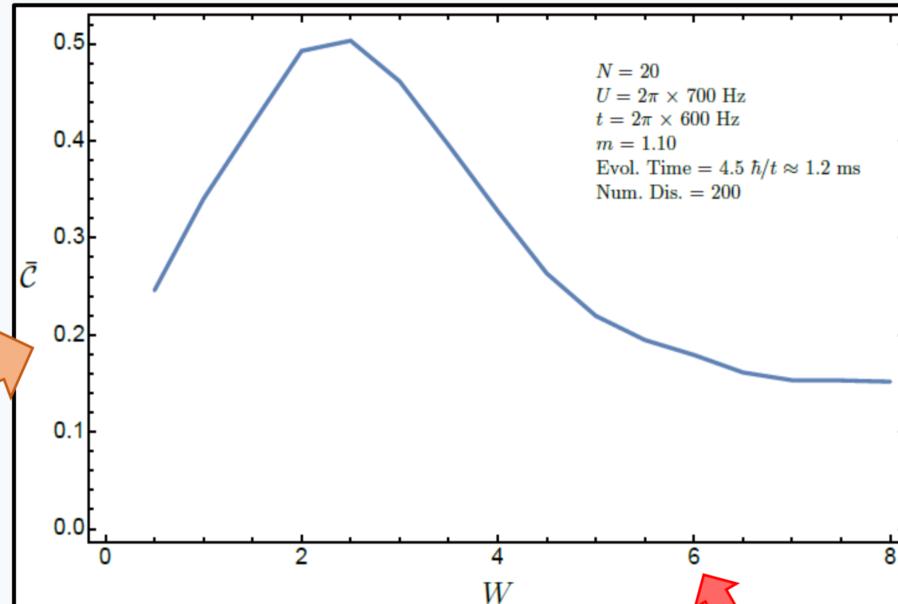
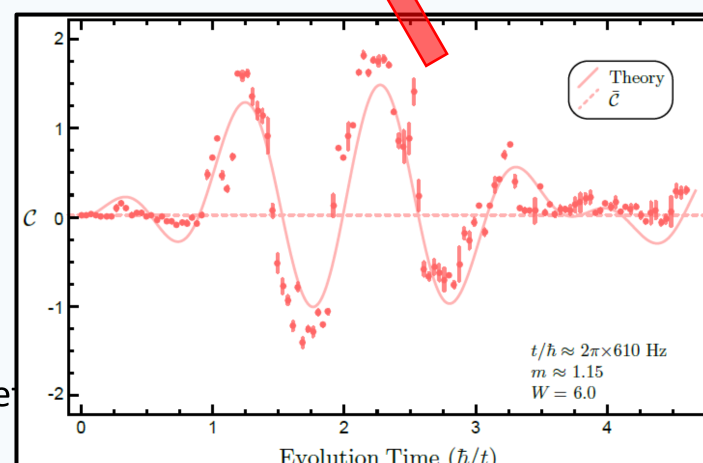




Looks promising so far, even for large *W*



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F. Cardano, et al. Nat. Comms. 8, 15516 (2017)
M. Maffei, A. Dauphin, F. Cardano, M. Lewenstein, and P. Massignan, arXiv:1708.02778

Exploring ***single-particle*** & ***many-body*** mobility edges in (pseudo)disordered 1D lattices

(interplay of frustration, disorder & interactions)

Previous work on single-particle mobility edges:

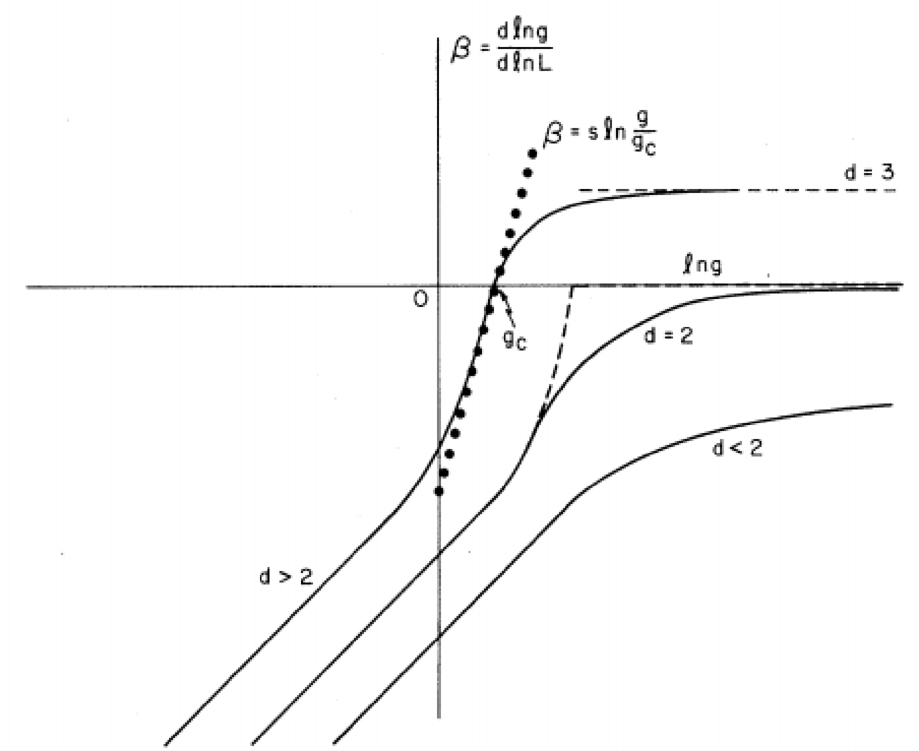
in 3D ($\sim$random disorder):
- Fattori/Inguscio/Modugno group, LENS [Semeghini, *et al.* Nat. Phys. (2012)]
- DeMarco group, UIUC [Kondov, *et al*., Science (2011)]

recently, in 1D (correlated disorder):
- Bloch group, Munich/Garching [Lüschen, *et al*. arXiv:1709.03478]

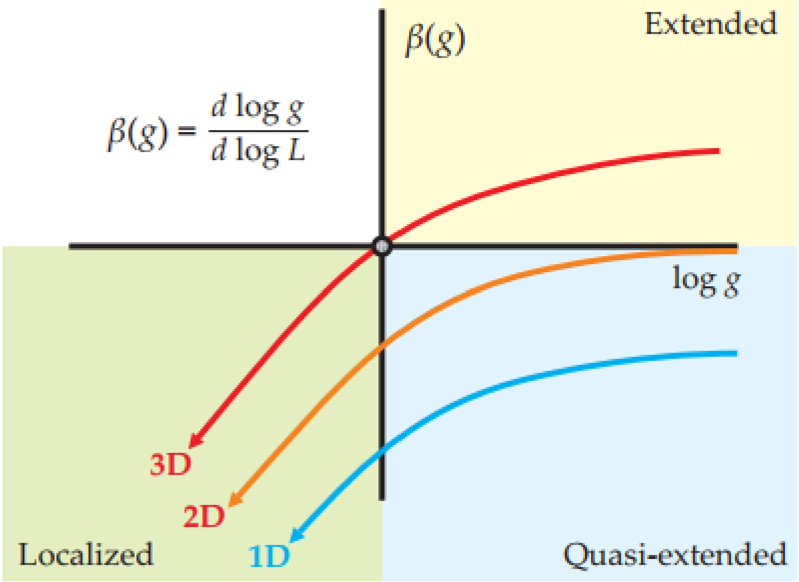
Mobility edges in disordered systems

<u>**For free electrons + random site-energy disorder: localization in 1D and 2D**</u>

Scaling Theory of Localization: Absence of Quantum Diffusion in Two Dimensions



Abrahams, Anderson, Licciardello, and Ramakrishnan (PRL, 1979)



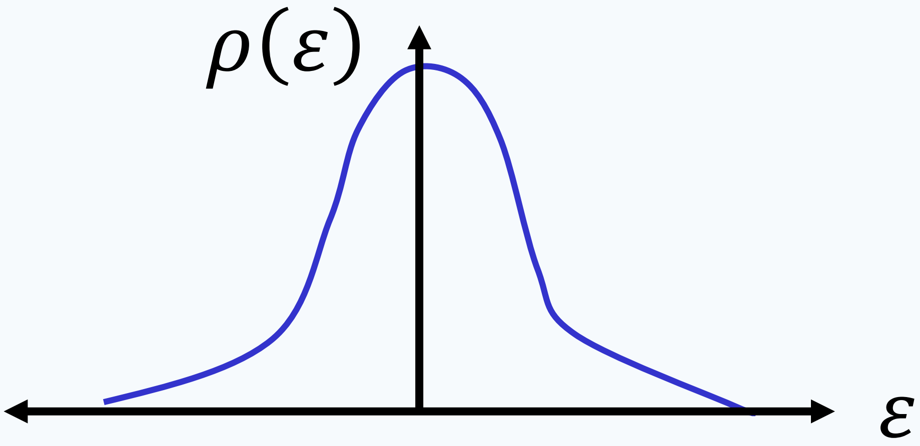
Lagendijk, van Tiggelen, and Wiersma (Physics Today, 2009)

Mobility edges in disordered systems

<u>For free electrons + random site-energy disorder: localization in 1D and 2D</u>

<u>In 3D systems with random disorder – mobility edge</u>

→ ***Localization depends on the energy of a state, or more specifically the density of states at a particular energy***



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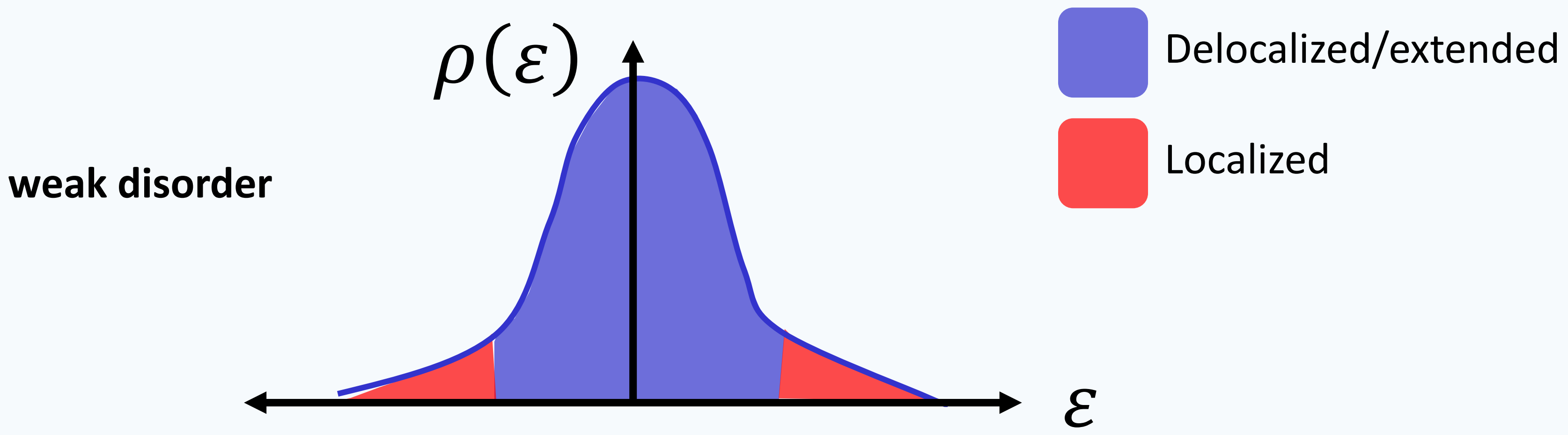


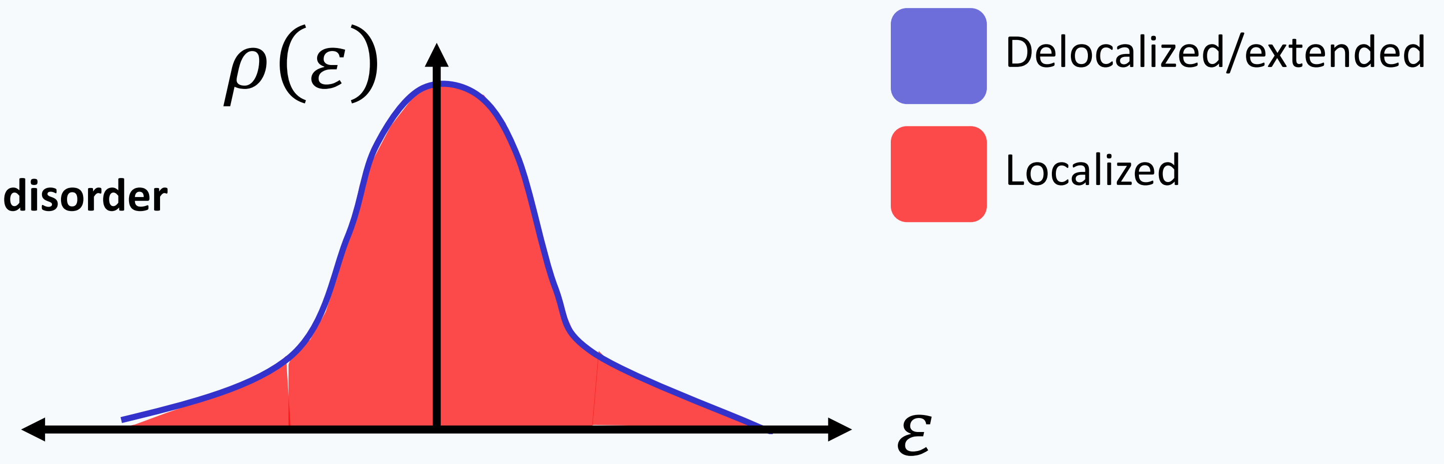
Mobility edges in disordered systems

For free electrons + random site-energy disorder: localization in 1D and 2D

In 3D systems with random disorder – mobility edge

→ ***Localization depends on the energy of a state, or more specifically the density of states at a particular energy***

very strong disorder



The Aubry-André model

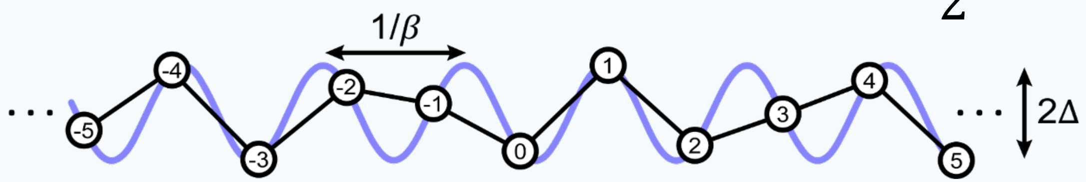
<u>1D pseudodisordered model with a localization-delocalization transition</u>

$$H = \sum_n \varepsilon_n \hat{c}_n^\dagger \hat{c}_n - t \sum_n \left(\hat{c}_{n+1}^\dagger \hat{c}_n + \hat{c}_n^\dagger \hat{c}_{n+1} \right)$$

$$\beta = \frac{\sqrt{5}-1}{2}$$

$$\varepsilon_n = \Delta \cos(2\pi\beta n + \varphi)$$

β irrational

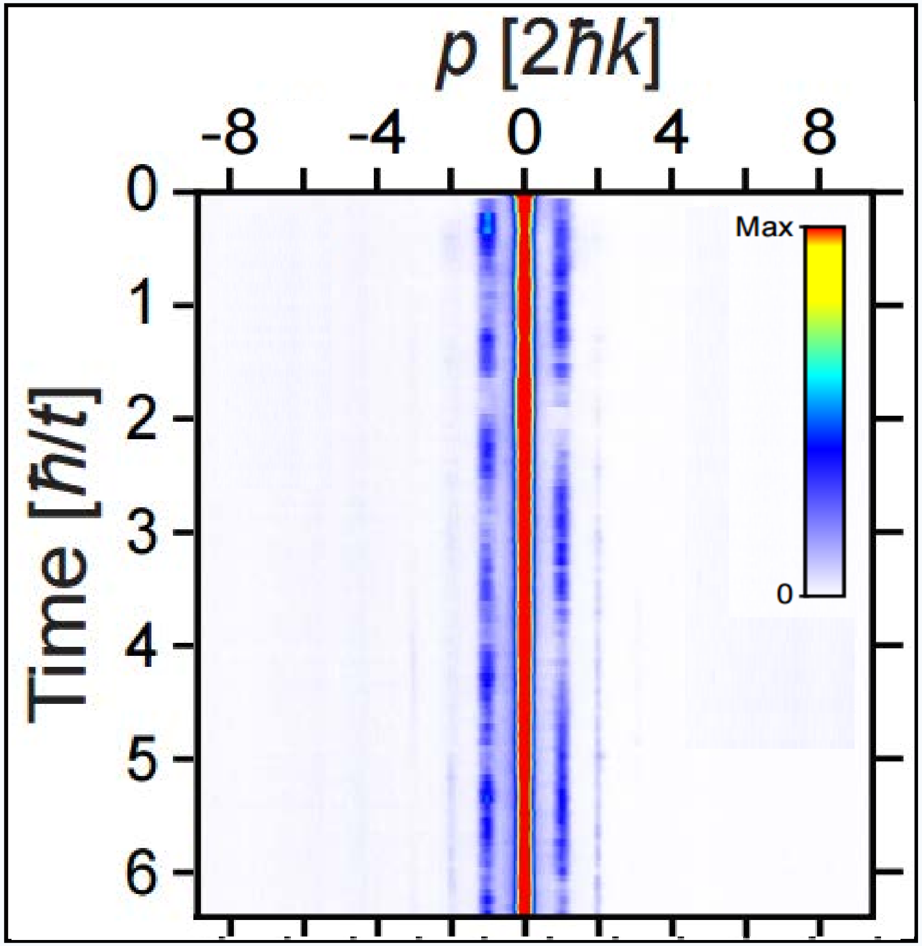


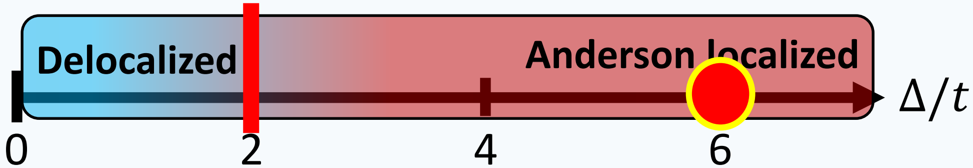
<u>Some funny properties</u>:

- **kinetic energy and site energy terms have matching cosine distributions**
- **duality between tunneling terms / potential terms**
- **consequence: *no single-particle mobility edge* -- ALL eigenstates undergo insulator-to-metal transition at same point, $\Delta = 2t$!**

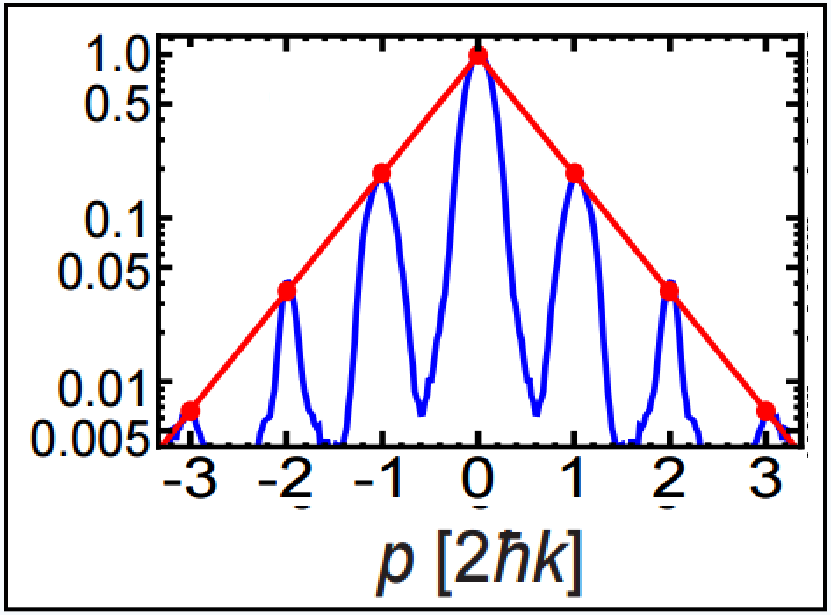
S. Aubry and G. André, Ann. Israel Phys. Soc. 3, 133 (1980)
D. R. Hofstadter, Phys. Rev. 14, 2239 (1976)
D. J. Thouless, Phys. Rev. B 28, 4272 (1983)

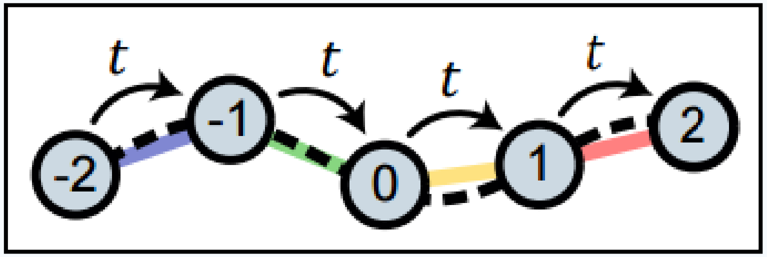
Quench in the Aubry-André





Disordered quantum walk
→ exponential localization

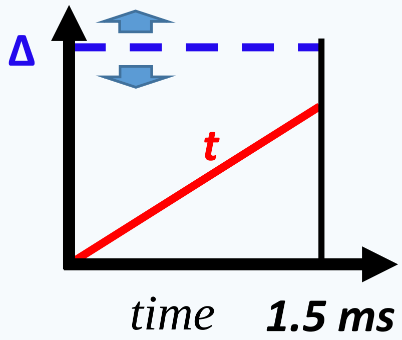


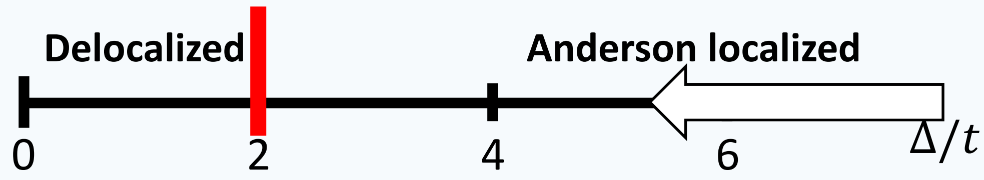


F. A. An, E. J. Meier, BG, Nature Communications (2017)

Adiabatic probing for localization

Aubry-André model



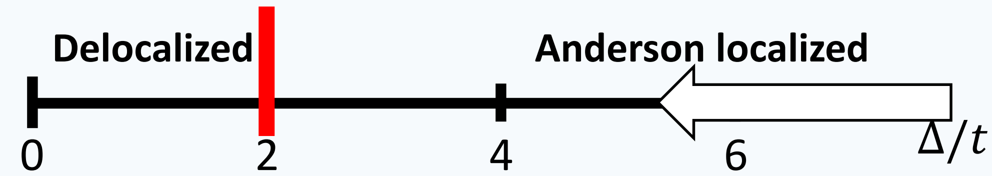


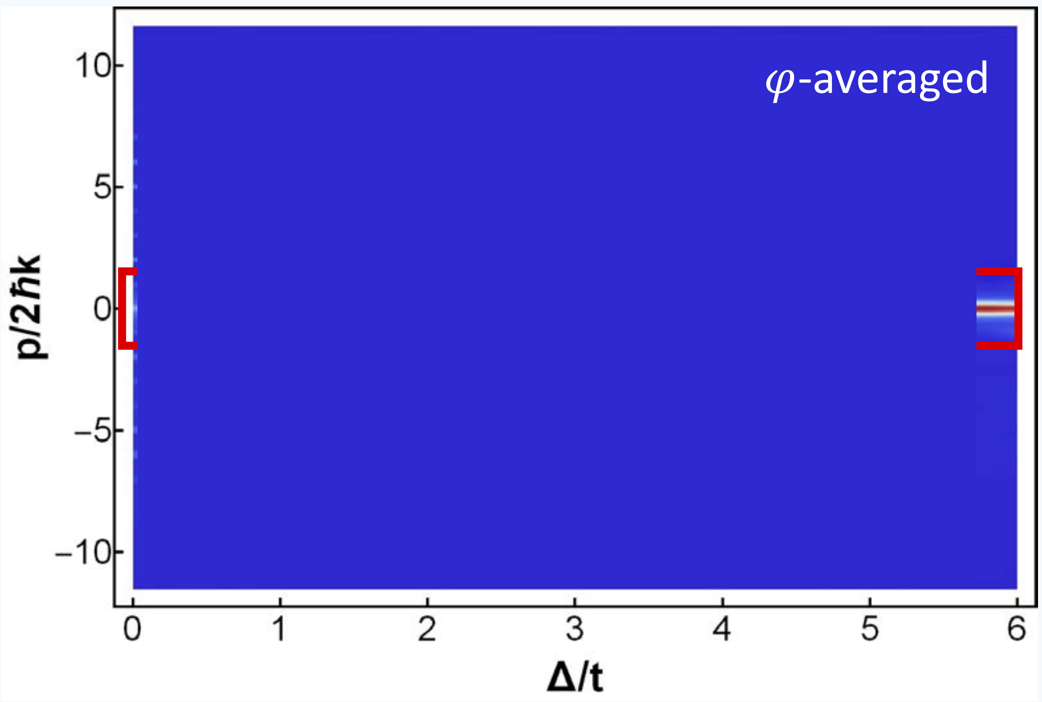
All eigenstates (i.e. at all energies) undergo localization transition at same Δ/t ratio

F. A. An, E. J. Meier, and BG, arXiv:1705.09268 (2017)

Adiabatic probing for localization

Aubry-André model





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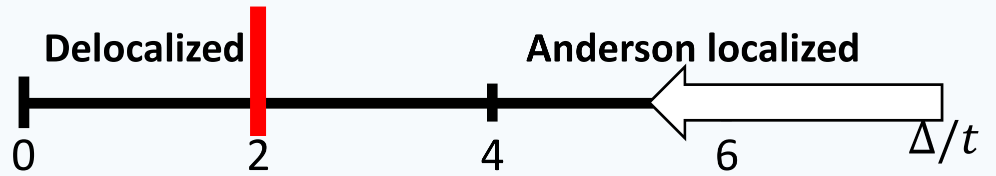
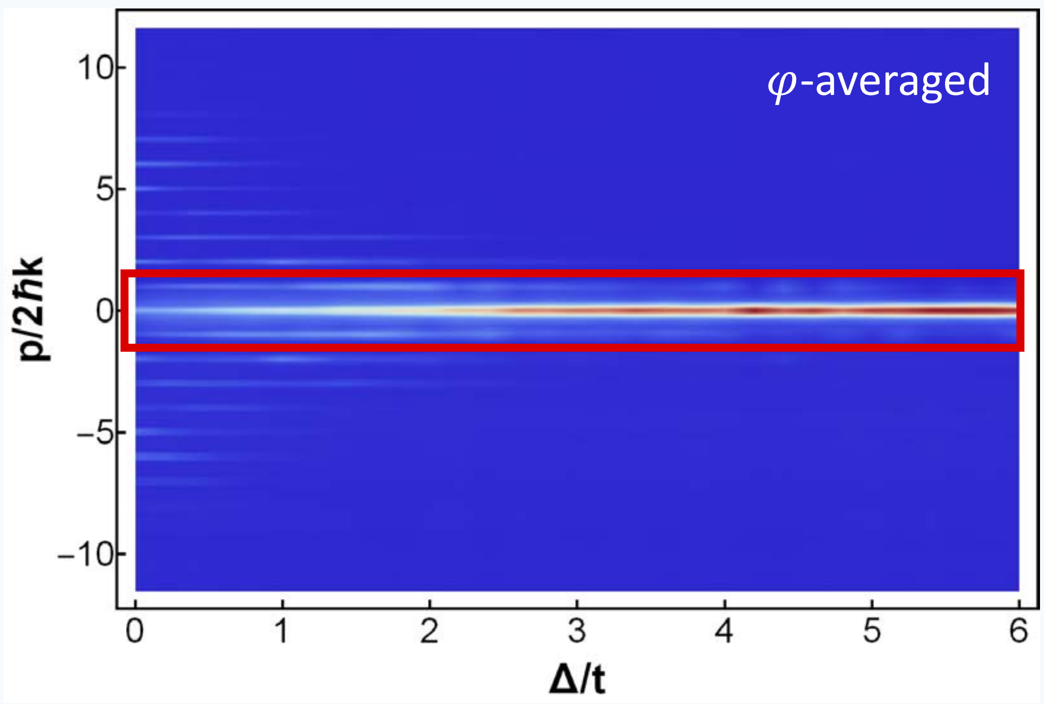
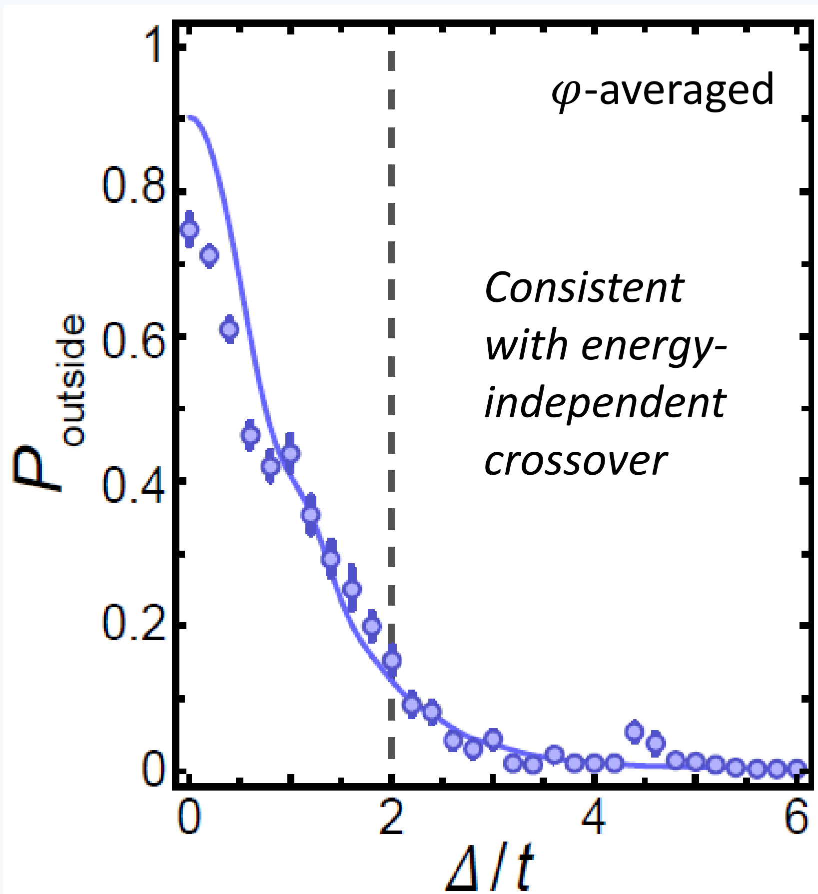
Adiabatic probing for localization

Aubry-André model

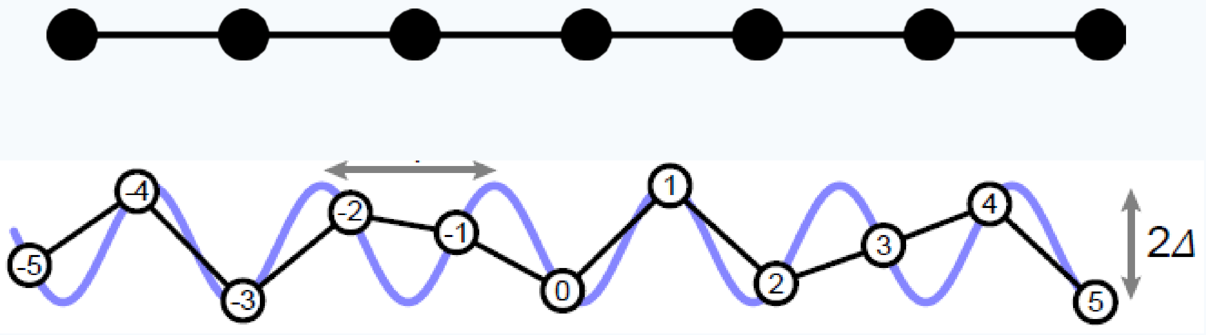






F. A. An, E. J. Meier, and BG, arXiv:1705.09268 (2017)

Engineering a single-particle mobility edge

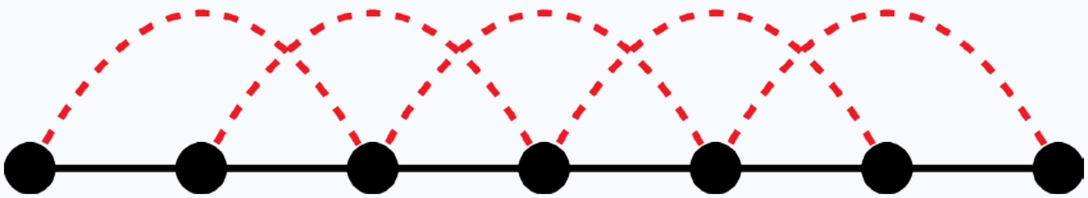


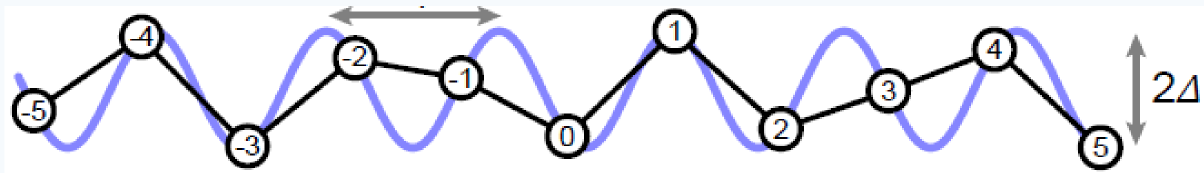
The Aubry-André model is, in some sense, fine-tuned.

- modifying either the dispersion or the disorder potential should introduce a single-particle mobility edge (SPME)

F. A. An, E. J. Meier, and BG, arXiv:1705.09268 (2017)

Engineering a single-particle mobility edge





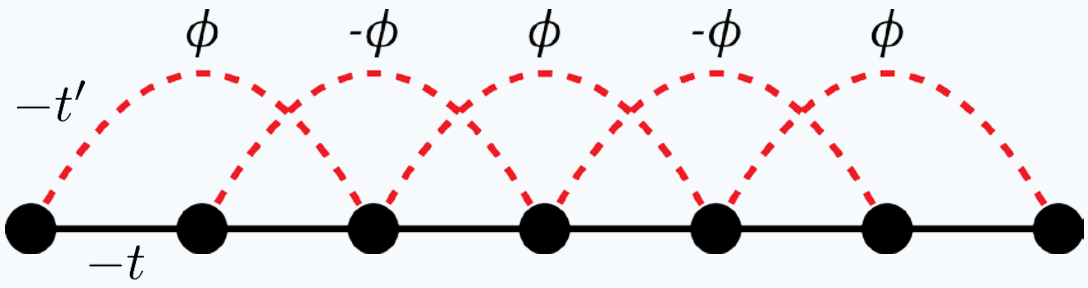
The Aubry-André model is, in some sense, fine-tuned.

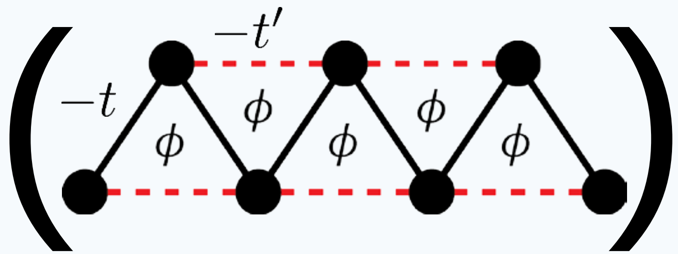
- modifying either the ***dispersion*** or the disorder potential should introduce a single-particle mobility edge (SPME)

add NNN tunneling

F. A. An, E. J. Meier, and BG, arXiv:1705.09268 (2017)

Creating zig-zag ladders

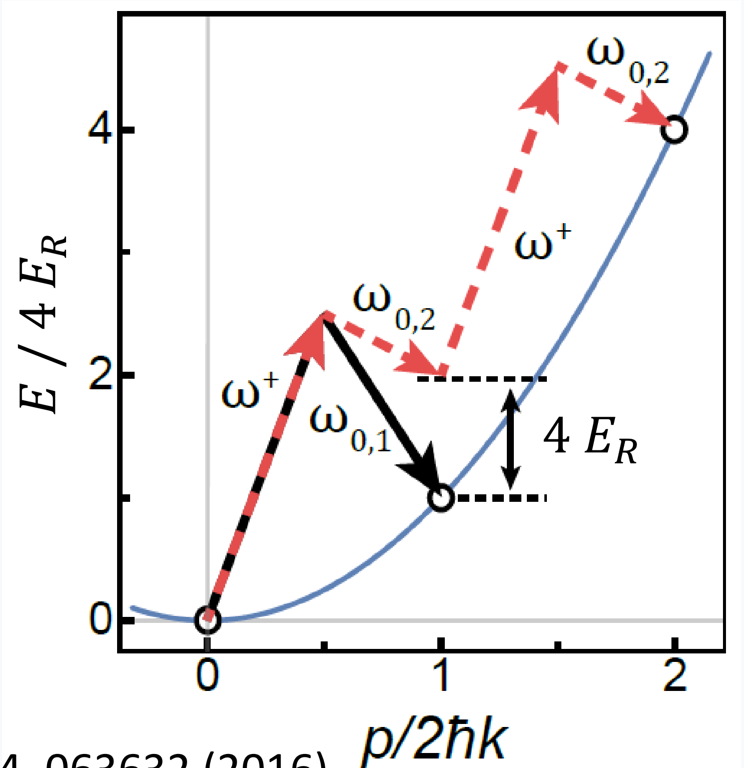




Nearest and next-nearest neighbor tunneling

Zig-zag flux ladder

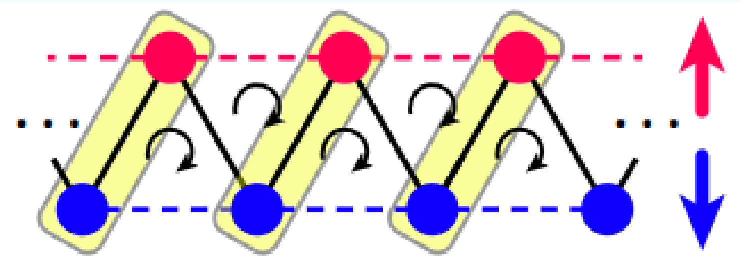
Nontrivial flux loops!

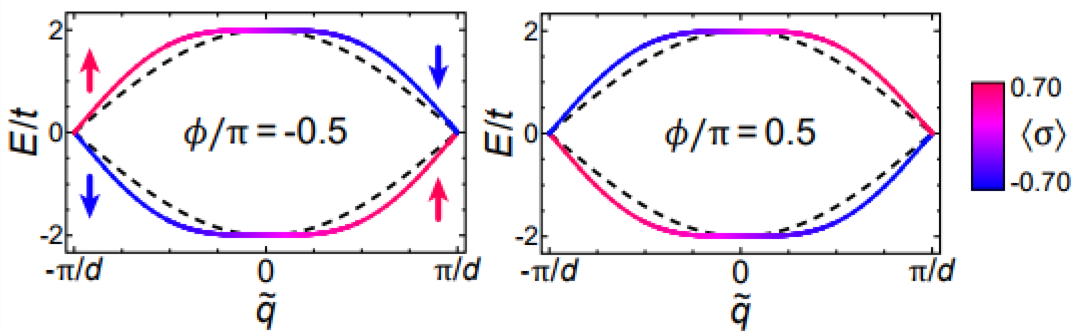


add NNN tunneling
→ second-order Bragg transitions

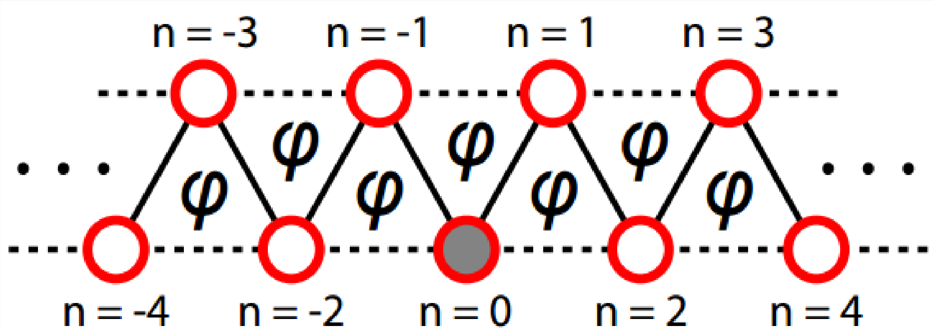
recent proposal:
Anisimovas, et al. [Gediminas Juzeliunas] PRA 94, 063632 (2016)

Aside: chiral quantum walks & spin-momentum locking





$|t'/t| \approx 0.5$



$\phi / \pi = 0.5$

related works:

Fallani group & Ye group with synthetic dimensions (Yb/Sr optical transitions)

Bloch group, superlattices + Raman-assisted tunneling (RAT) ; Greiner group, RAT

Fallani group & Spielman group, synthetic dimensions Raman

F. A. An, E. J. Meier, and BG, arXiv:1705.09268 (2017)

[also: **F. A. An, E. J. Meier, and BG. Science Advances 3, e1602685 (2017)**]

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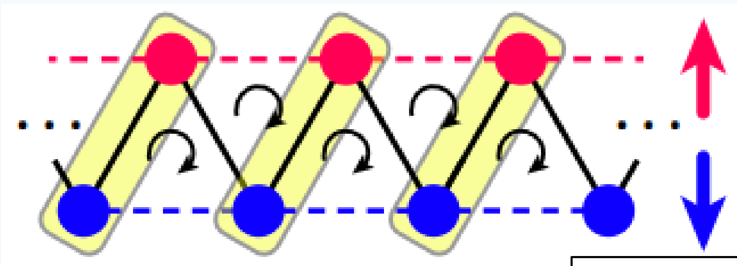

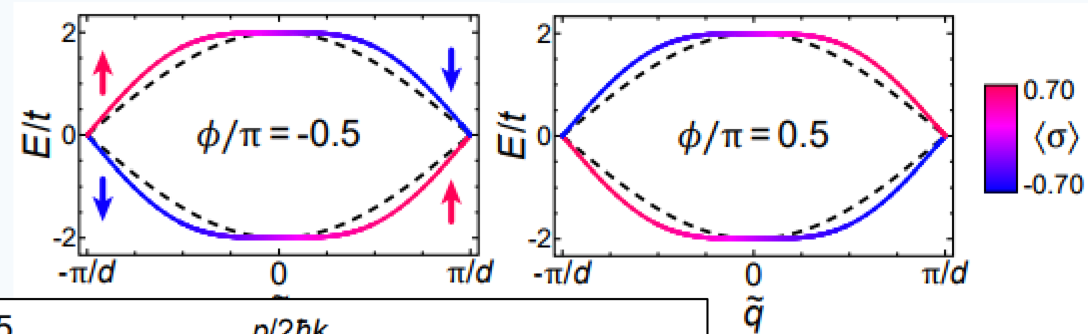

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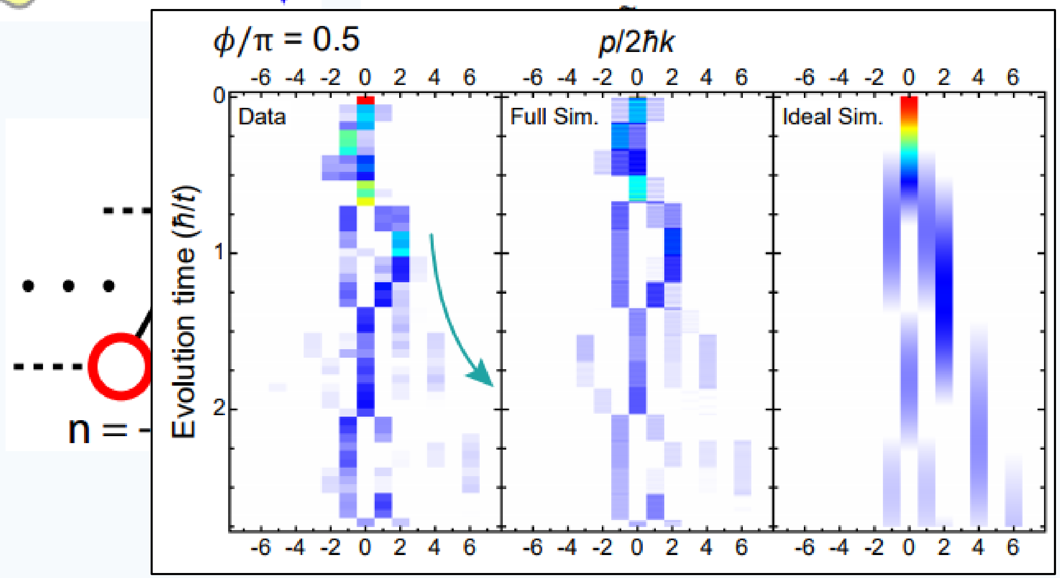

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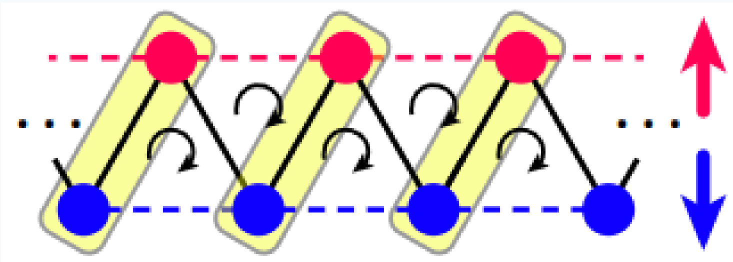

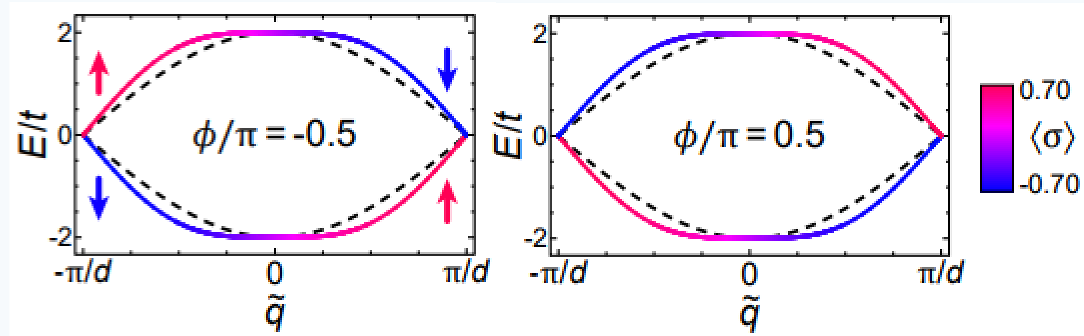

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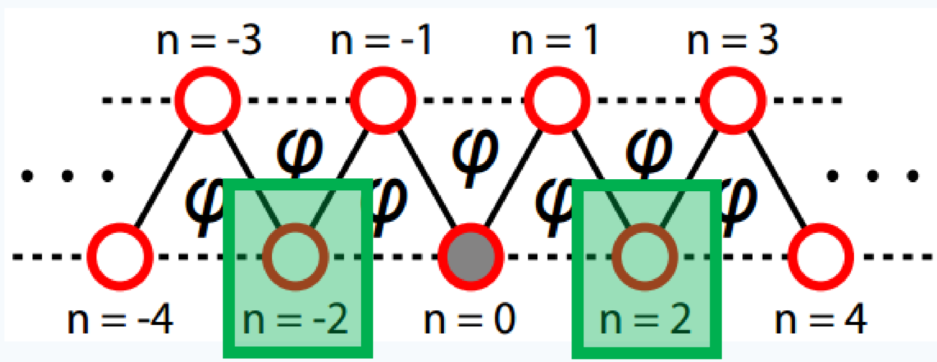

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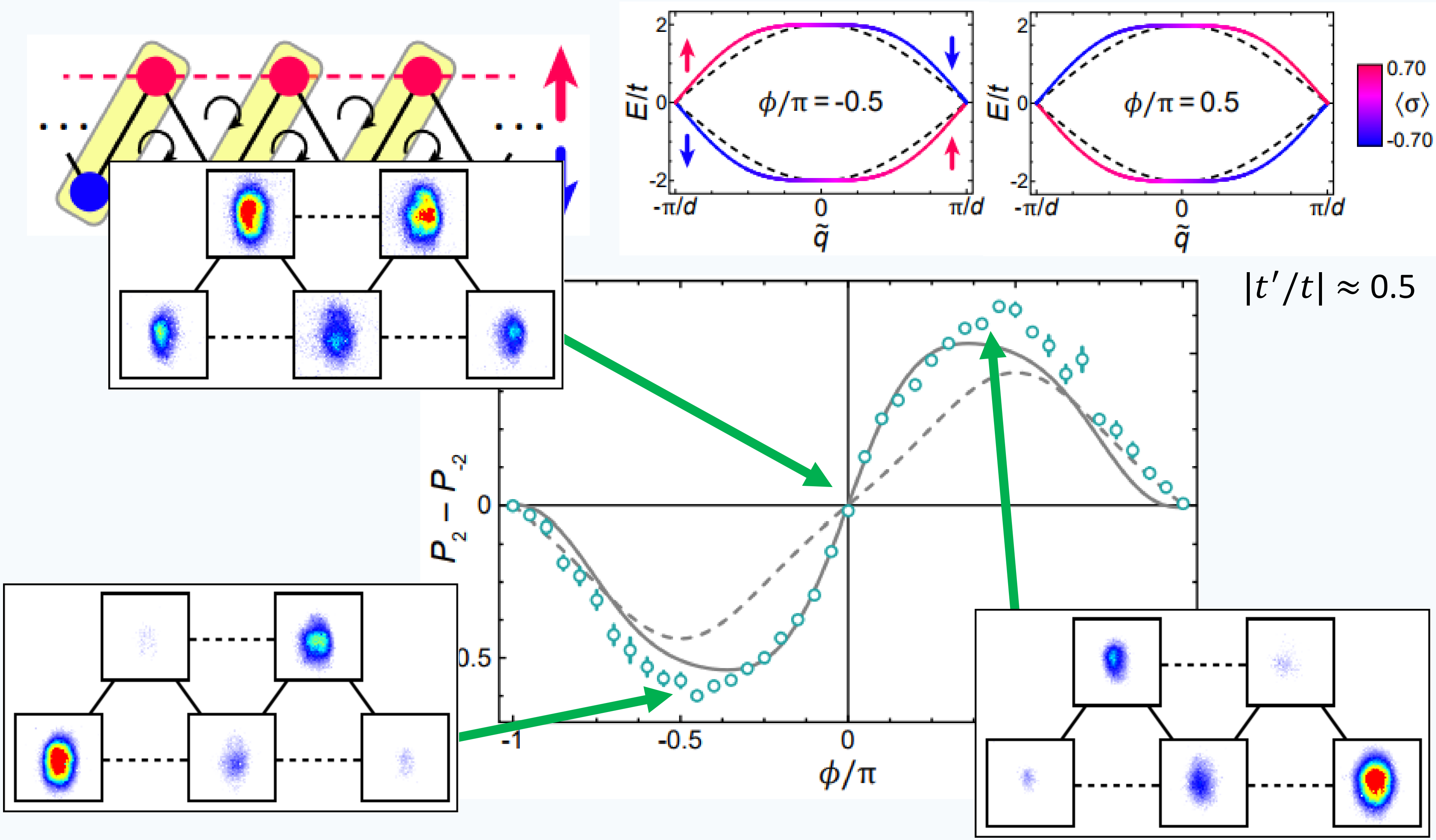
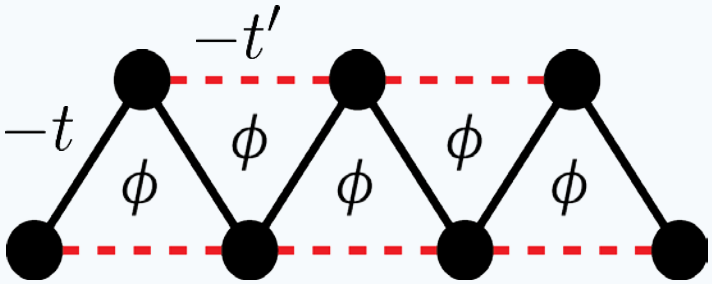
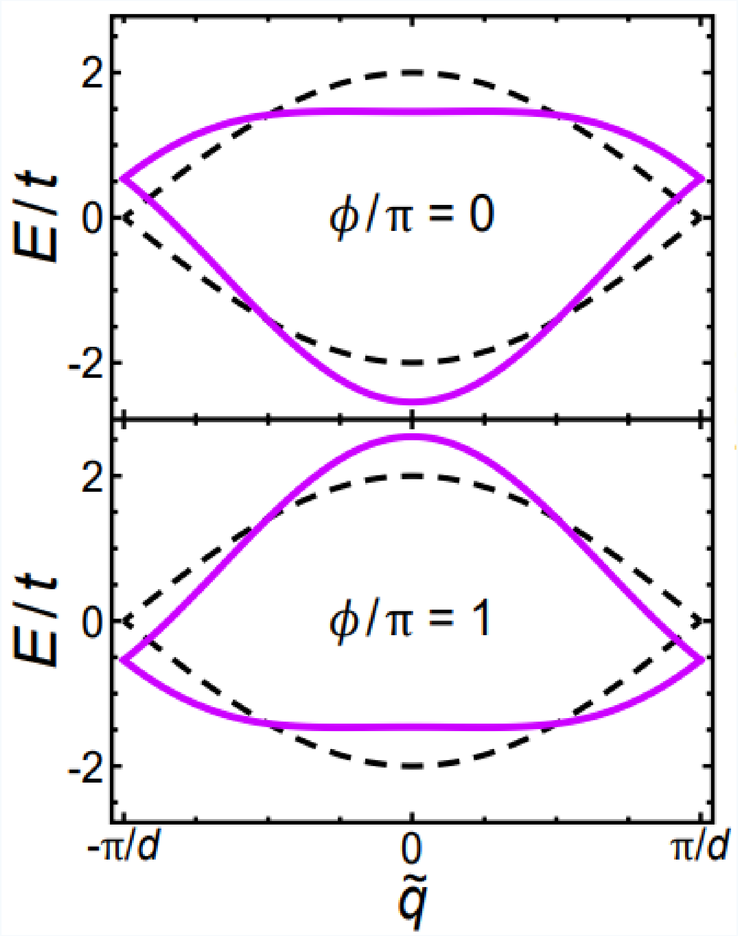


Dispersion engineering



$|t'/t| \approx 0.25$

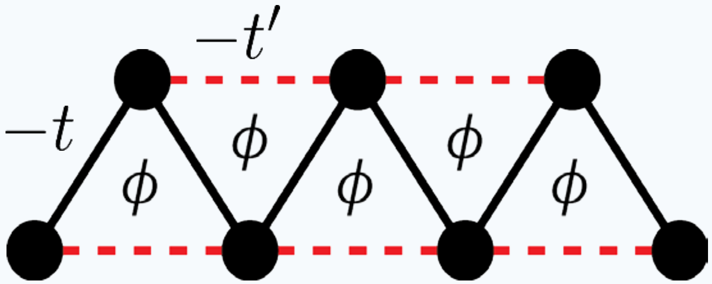
for t' / t = 0 , normal lattice band structure (dashed line)



Kinetic frustration gives quartic, nearly flat dispersions

F. A. An, E. J. Meier, and BG, arXiv:1705.09268 (2017)

Dispersion engineering



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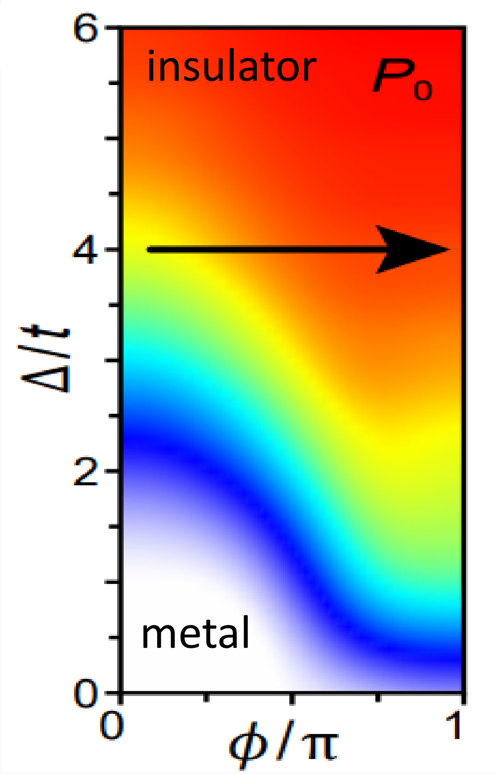
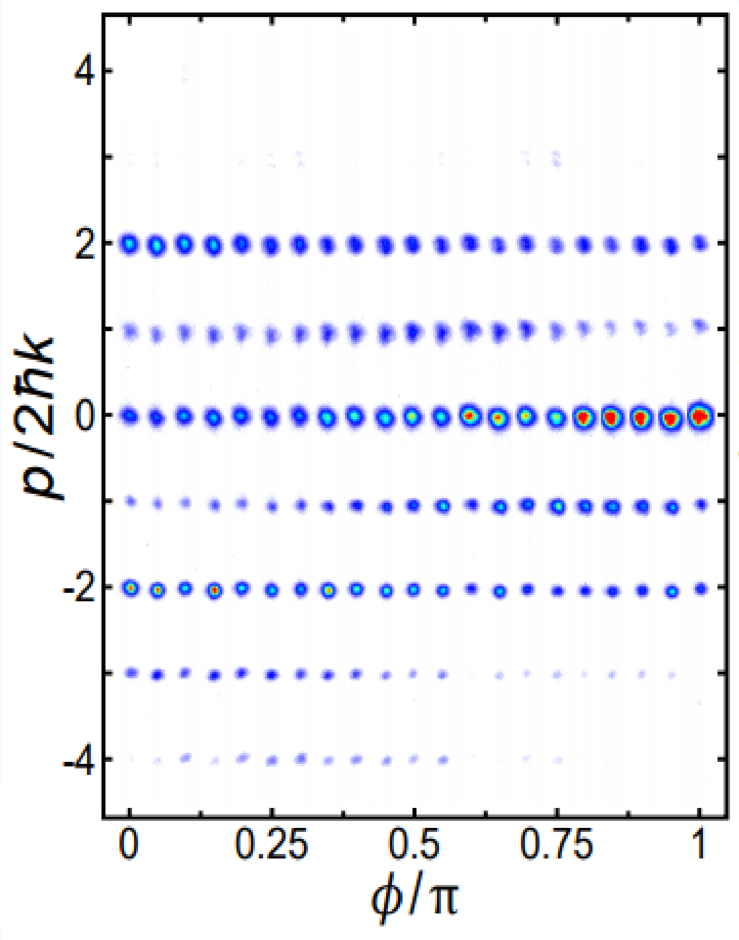
Localization properties of <u>ground state</u>

flux-dependent localization

ground state localization properties are suggestive of a flux-dependent mobility edge





F. A. An, E. J. Meier, and BG, arXiv:1705.09268 (2017)

Dispersion engineering

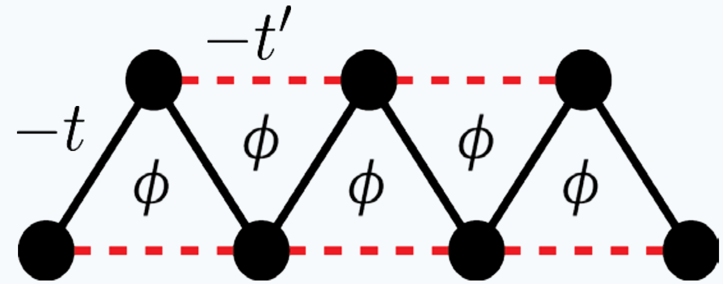
Can we push this dispersion engineering further?

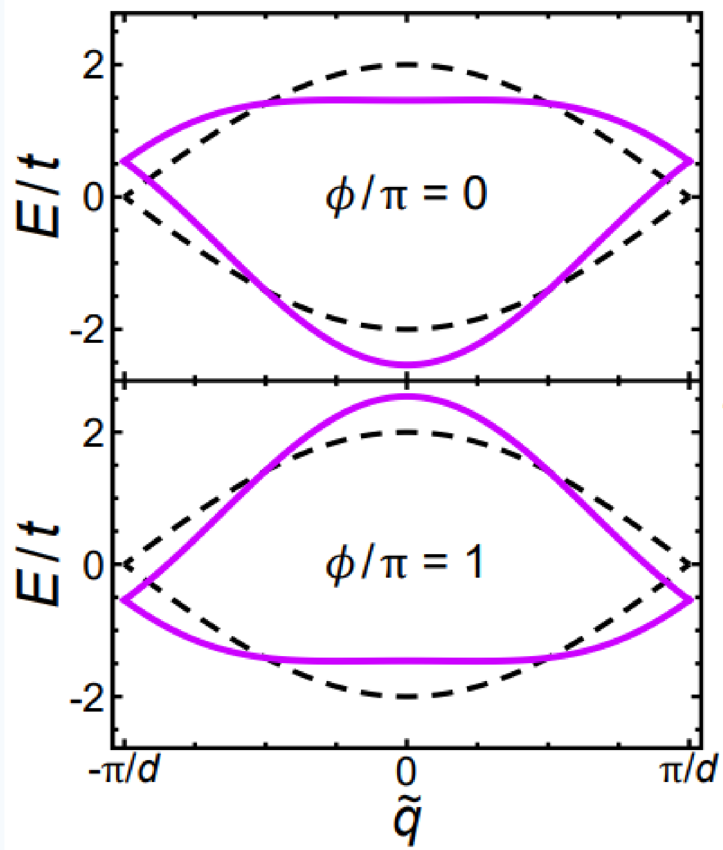
By adding longer- and longer-ranged tunneling terms, we should be able to engineer a **completely** flat band

~ “Fourier synthesis of bands”

this would be technically challenging…

duality of the AA model is forgiving! Adding higher-order tunneling terms is ***dual*** to adding higher harmonics of the $\Delta\cos(2\pi\beta n + \varphi)$ potential





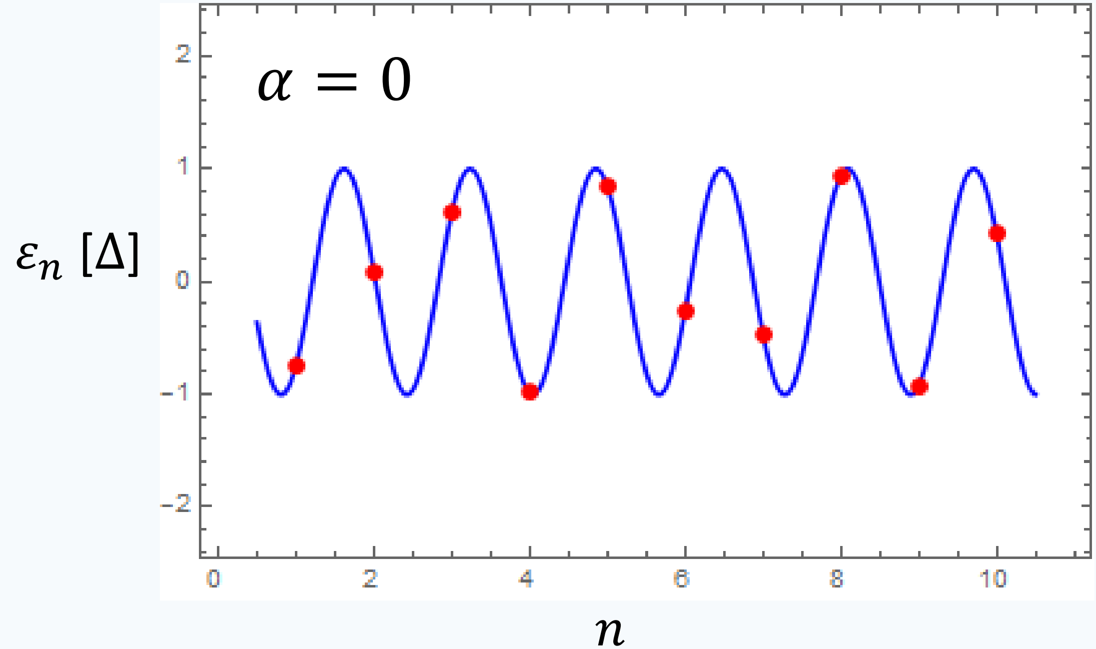
Modified AA model with SPME

Ganeshan, Pixley, and Das Sarma, PRL (2015)

$$H = \sum_n \varepsilon_n \hat{c}_n^\dagger \hat{c}_n - t \sum_n \left(\hat{c}_{n+1}^\dagger \hat{c}_n + \hat{c}_n^\dagger \hat{c}_{n+1}\right)$$

$$\varepsilon_n = \frac{\Delta \cos(2\pi b n + \varphi)}{1 - \alpha \cos(2\pi b n + \varphi)} = \Delta \sum_{j=1}^{\infty} \alpha^{j-1} [\cos(2\pi b n + \varphi)]^j$$

$$b = \frac{\sqrt{5} - 1}{2}$$



F. A. An, E. J. Meier, *et al.* (in prep)

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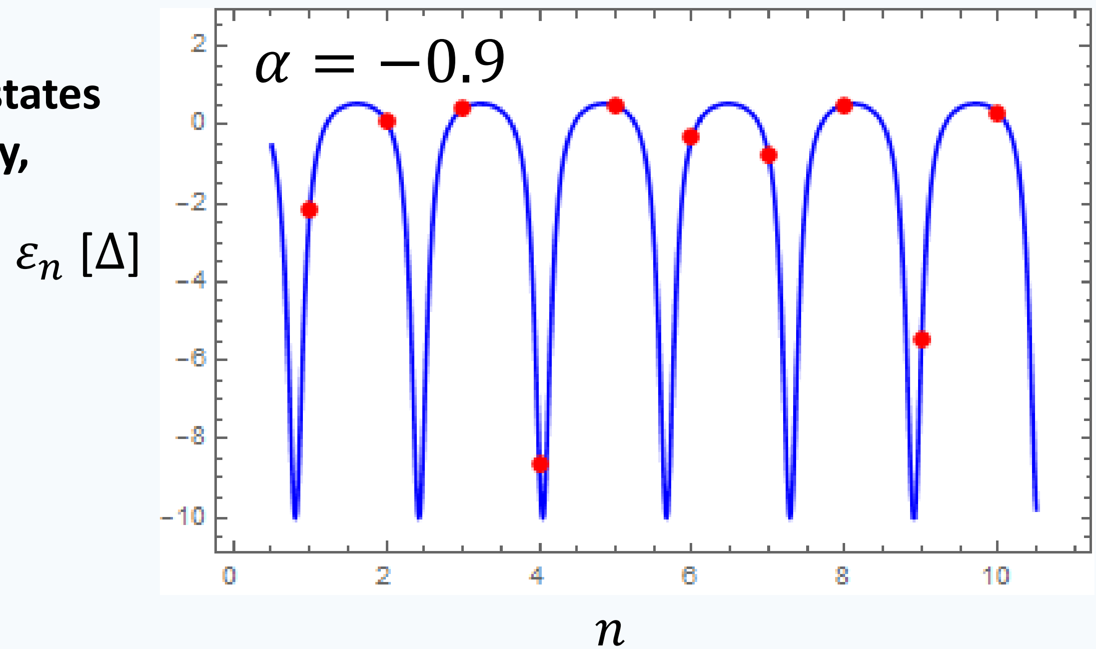
$$b = \frac{\sqrt{5} - 1}{2}$$

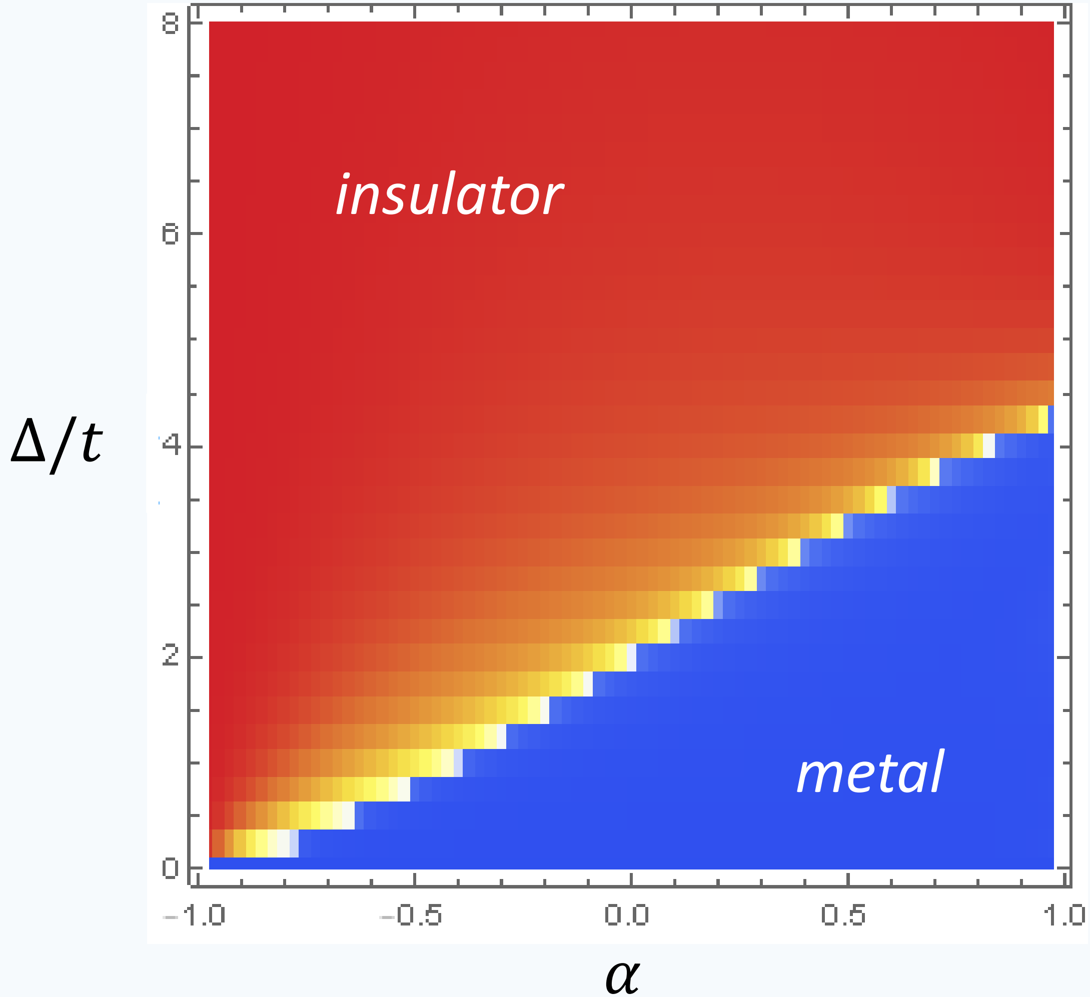
Modifies the density of states (now lower at low energy, higher at high energy)



F. A. An, E. J. Meier, *et al*. (in prep)

Mobility edge vs. α

Ground state localization properties ($\varphi = 0$)



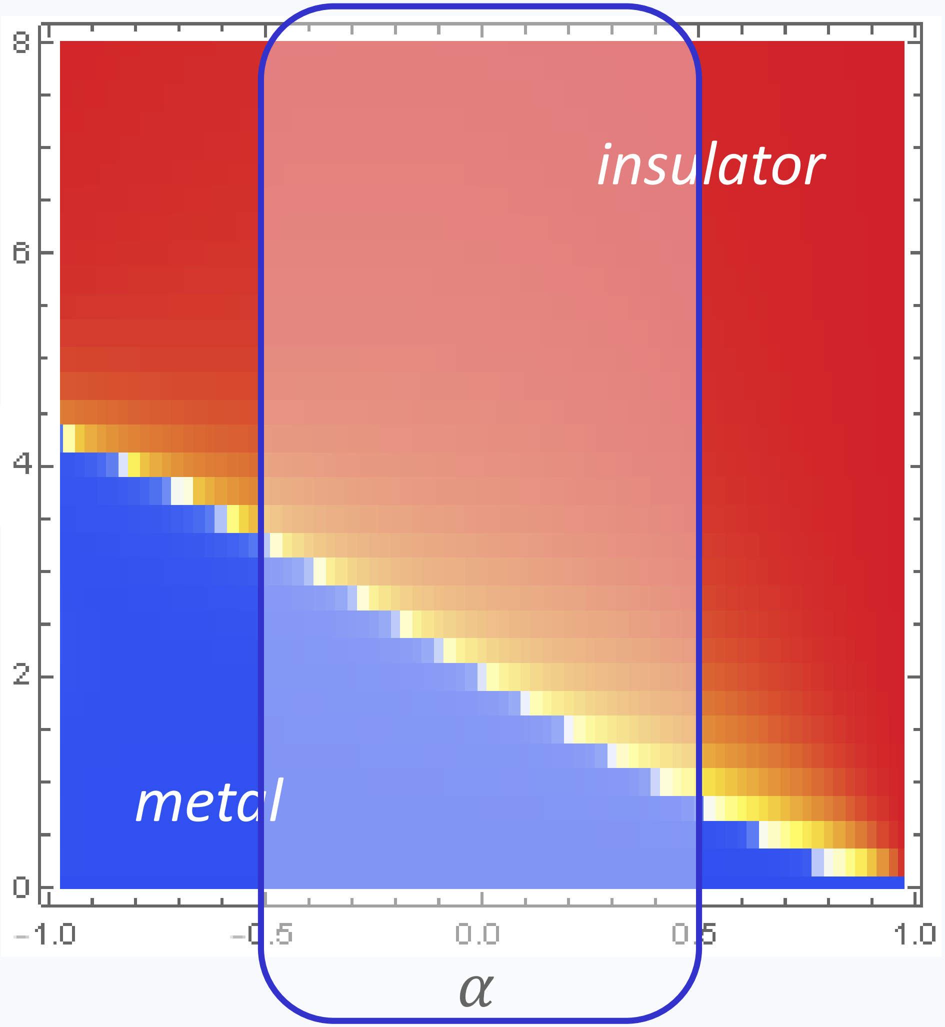
$$\varepsilon_n = \frac{\Delta\cos(2\pi bn + \varphi)}{1 - \alpha\cos(2\pi bn + \varphi)}$$

F. A. An, E. J. Meier, *et al*. (in prep)

Mobility edge vs. α

"max" excited state localization properties ($\varphi = \pi$)

Δ/t



$$\varepsilon_n = \frac{\Delta \cos(2\pi b n + \varphi)}{1 - \alpha \cos(2\pi b n + \varphi)}$$

excited state $\rightarrow$ ground state

$$\varphi \rightarrow \varphi + \pi$$

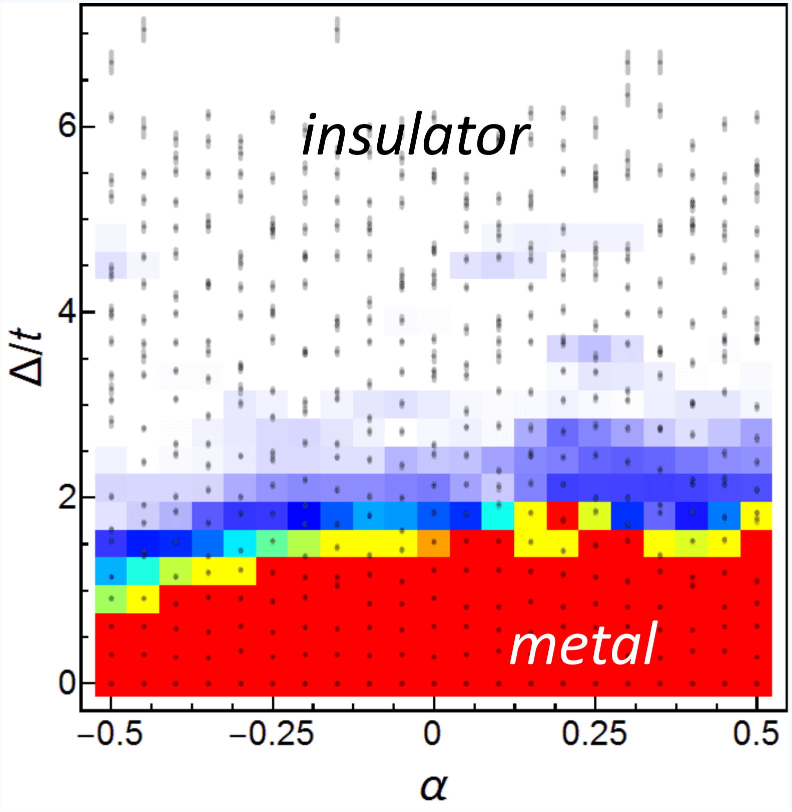
$$\alpha \rightarrow -\alpha$$

Note: values of α near ± 1 lead to infinite potential

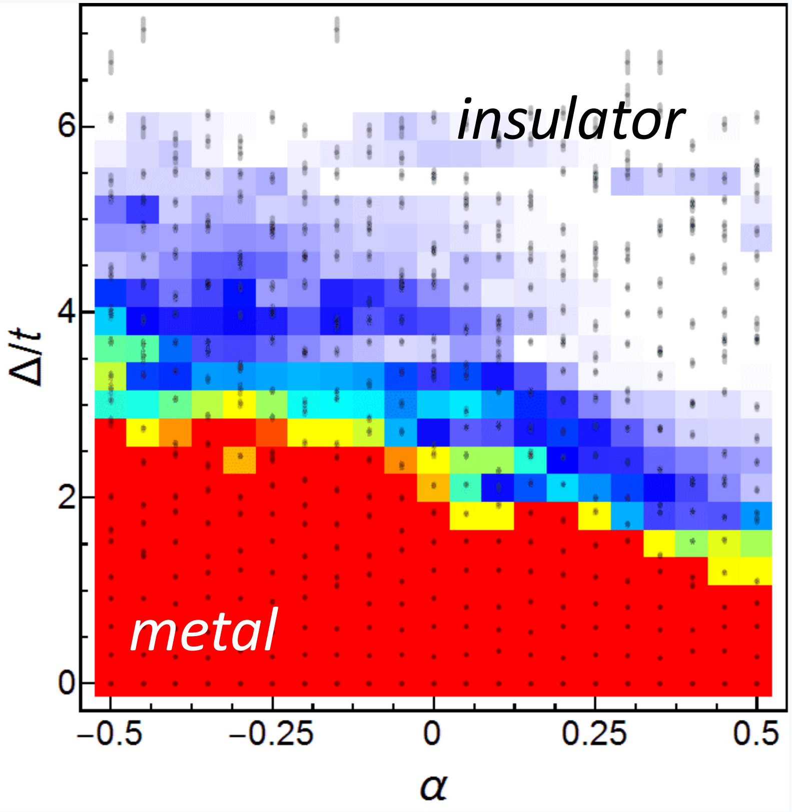
F. A. An, E. J. Meier, *et al*. (in prep)

So what do we see in experiment?

Ground state s.d. ($\varphi = 0$)



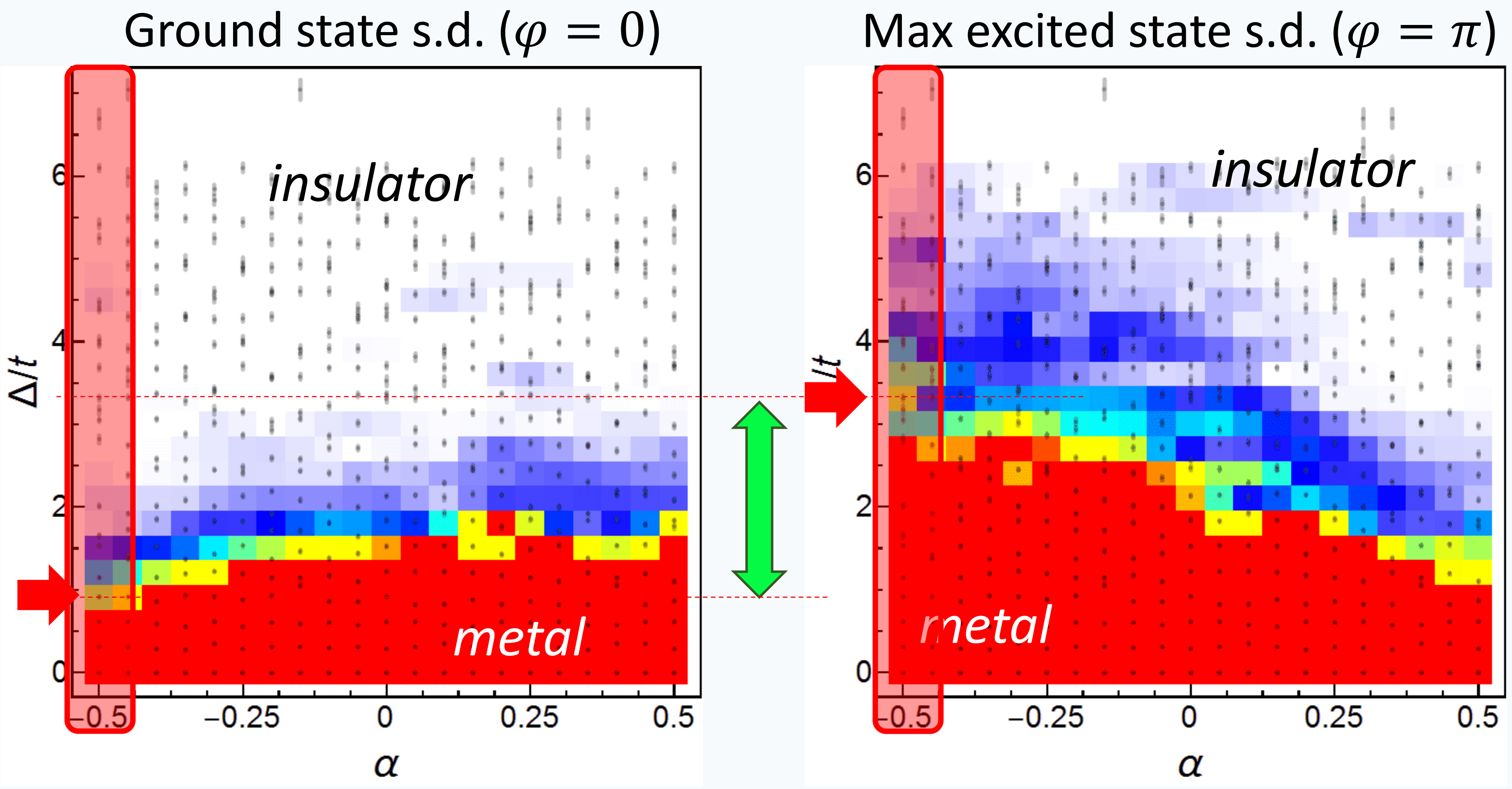
Max excited state s.d. ($\varphi = \pi$)



F. A. An, E. J. Meier, *et al*. (in prep)

So what do we see in experiment?

Some definite evidence for a mobility edge

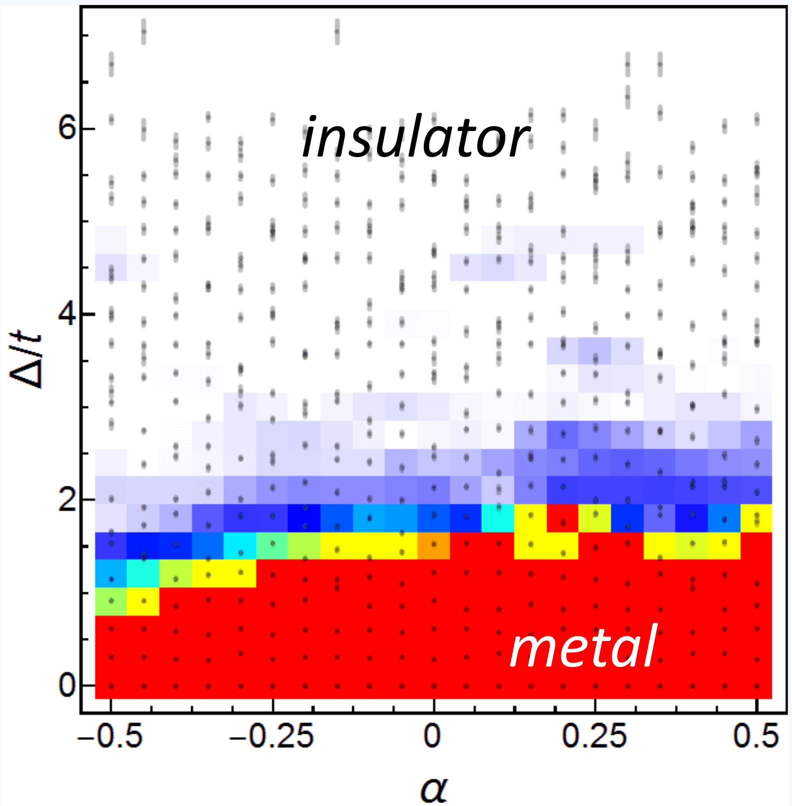


F. A. An, E. J. Meier, *et al*. (in prep)

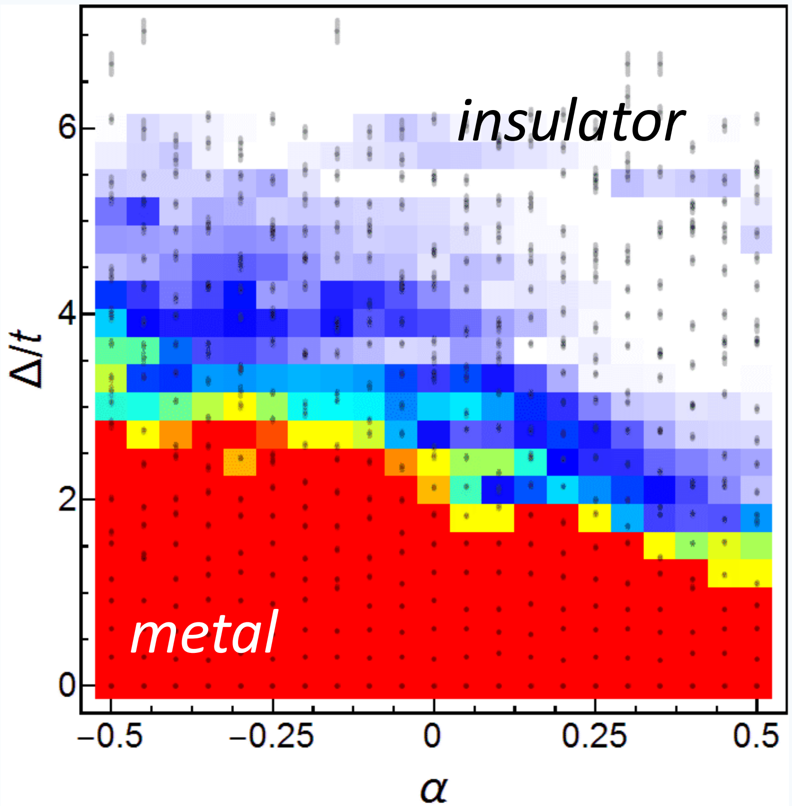
So what do we see in experiment?

but these don't look like mirror images…

Ground state s.d. ($\varphi = 0$)



Max excited state s.d. ($\varphi = \pi$)

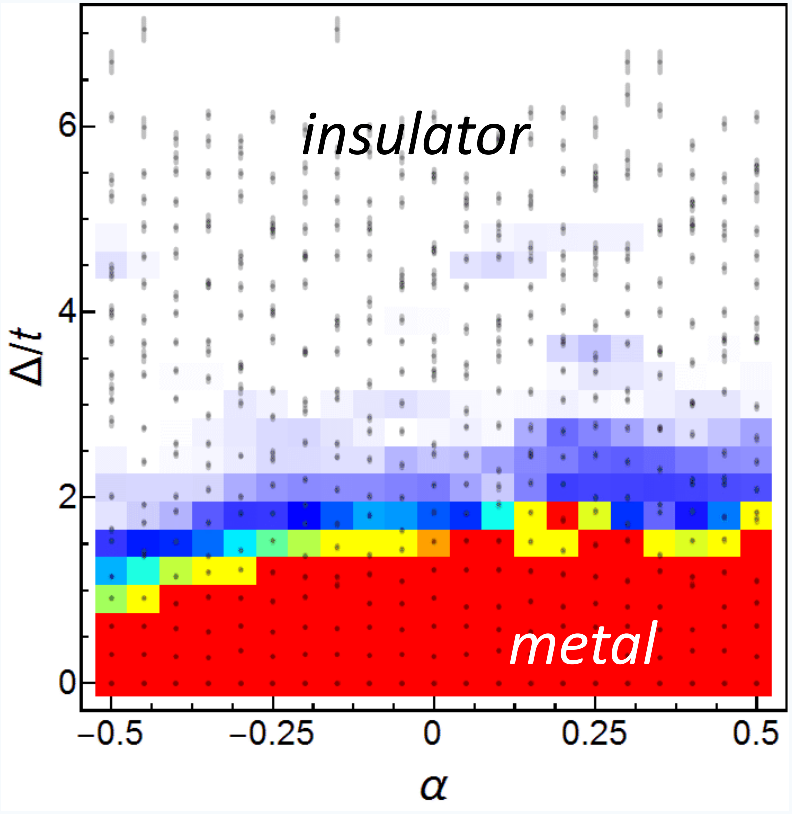


F. A. An, E. J. Meier, *et al.* (in prep)

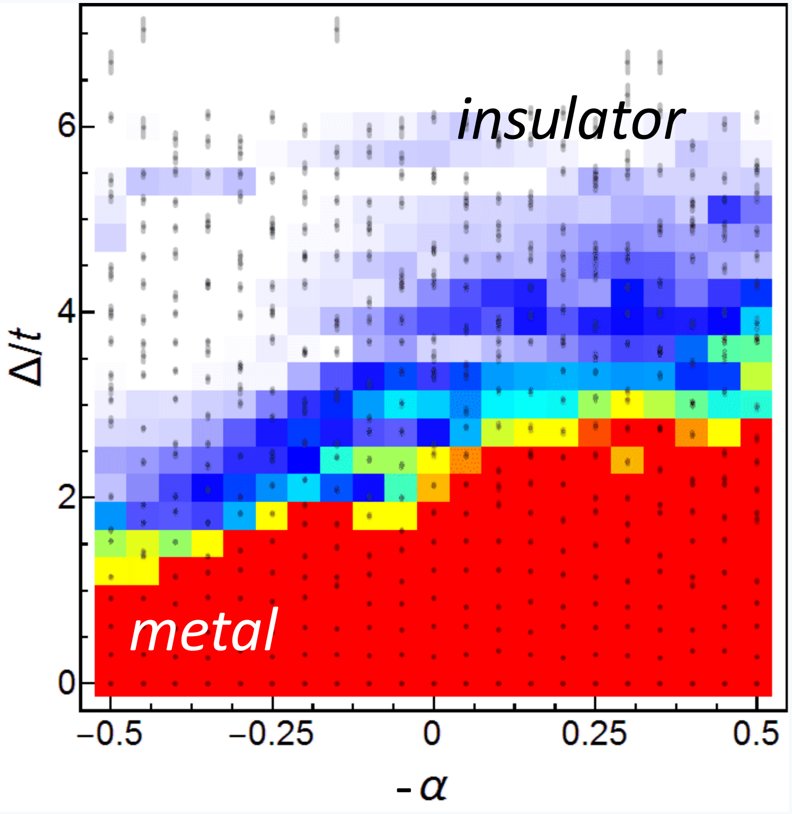
So what do we see in experiment?

OK, definitely not mirror images…what gives?

Ground state s.d. ($\varphi = 0$)



Max excited state s.d. ($\varphi = \pi$)



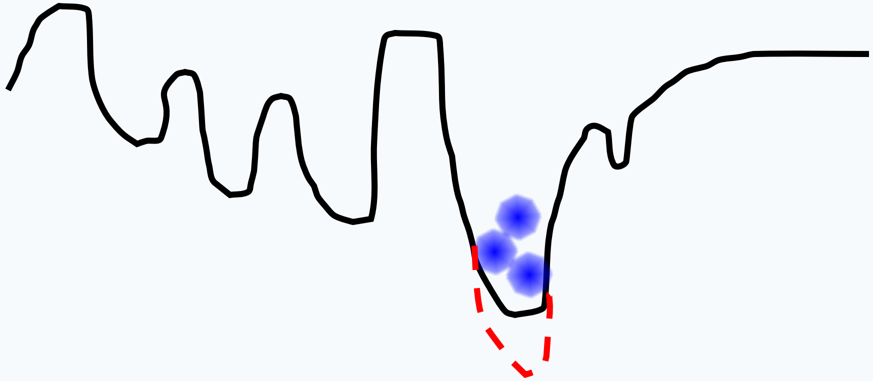
<u>it's the interactions!</u>

F. A. An, E. J. Meier, *et al*. (in prep)

Influence of interactions

Influence of effectively *attractive* interactions

ground state ($\varphi = 0$):
starts at potential minimum – interactions bring it further away in energy from other wells



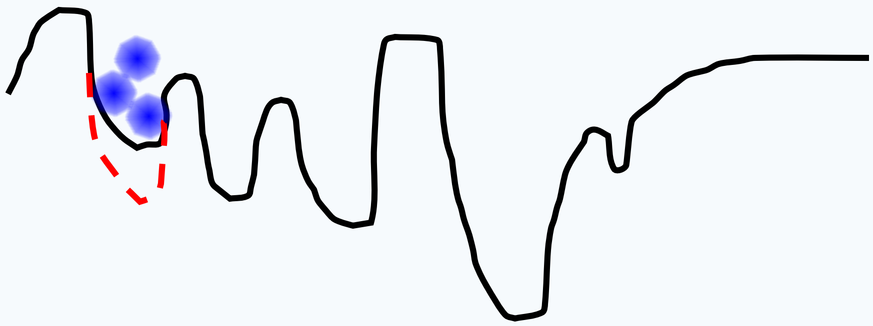
more likely to localize!

F. A. An, E. J. Meier, *et al*. (in prep)

Influence of interactions

Influence of effectively *attractive* interactions

“Max” excited state ($\varphi = \pi$):
starts at potential maximum – interactions bring it closer in energy to the other wells



more likely to delocalize!

F. A. An, E. J. Meier, *et al*. (in prep)

Excited state for U < 0 → Ground state for U > 0

At single-particle level: $H \rightarrow -H$

effectively for: $\varphi \rightarrow \varphi + \pi$

$\alpha \rightarrow -\alpha$

To negate entire Hamiltonian would require : $U \rightarrow -U$

→ the localization properties for some parameters $\{\varphi, \alpha, U\}$ should be equivalent to those for $\{\varphi + \pi, -\alpha, -U\}$

Our interactions are effectively ***attractive***, however we can probe physics related to ***repulsive*** interactions by reversing the rest of the Hamiltonian (a feature of not studying the thermodynamic ground state)

F. A. An, E. J. Meier, *et al*. (in prep)

Outlook

Some possible directions for exploration

squeezing / higher-order correlations

- can access richer physics by measuring the off-diagonal correlations between different sites, not just their mean occupations

flat-band physics with interactions

- exploration of “sawtooth” and other flat-band lattices

increased control over interactions

- switching over to ^{39}K for broad Feshbach resonance

access multiple internal states

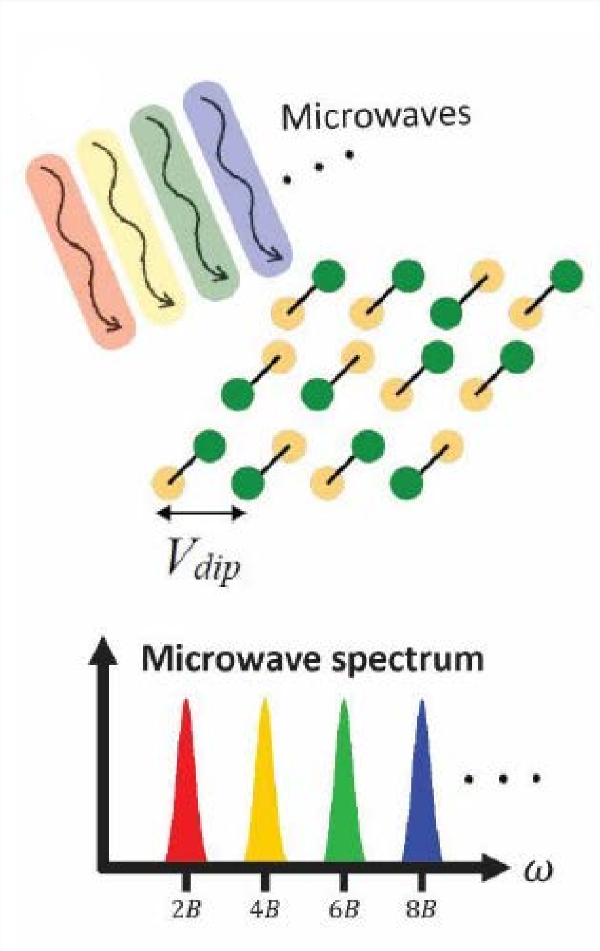
- allows access to local loss (w/ resonant light removing from one state) and the creation of synthetic U(2) gauge fields

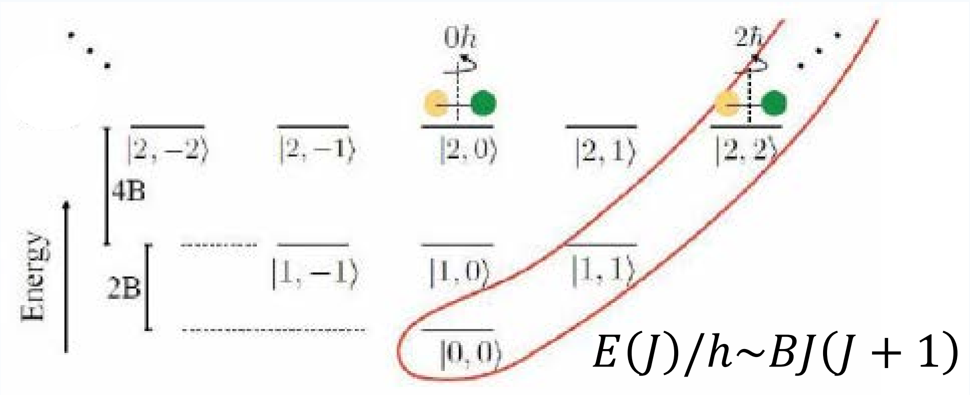
synthetic dimensions for boson sampling

- can the realization of random Hamiltonians in synthetic lattices be useful for certifying quantum supremacy?

Synthetic lattices on a molecule

Similar idea, but with molecules (strongly correlated)





Rotational states are almost perfect "clock" states [same hyperfine quantum numbers, singlet state]

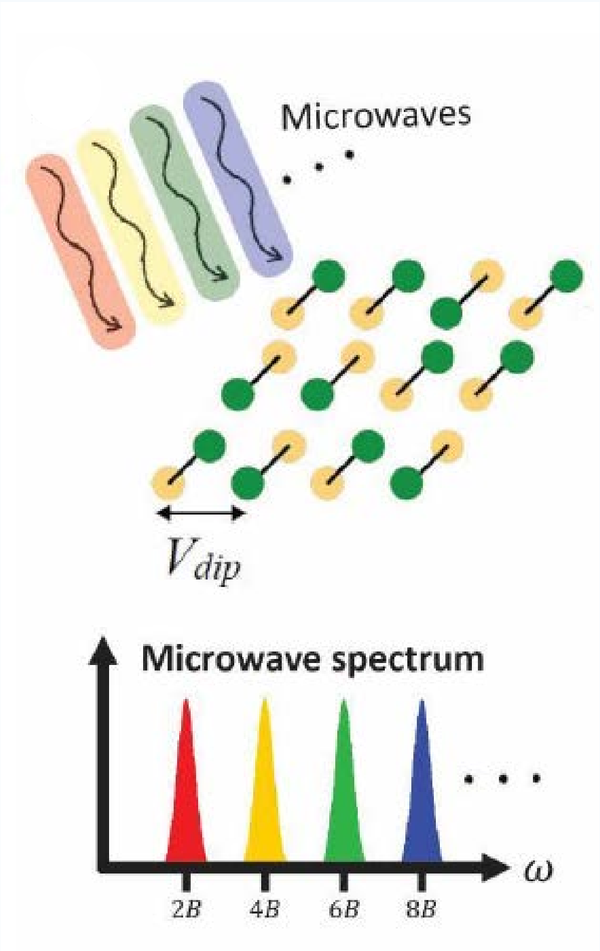
Families of states have common "magic" polarization

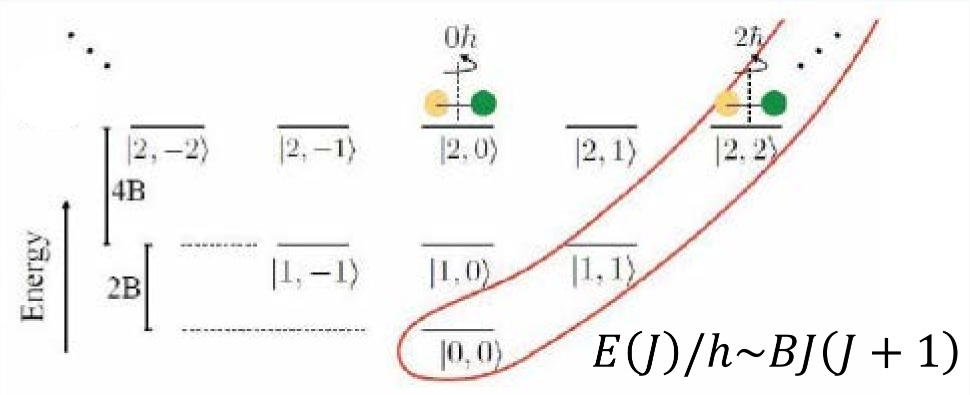
Can use full manifold of states (J_{max}^2 states)

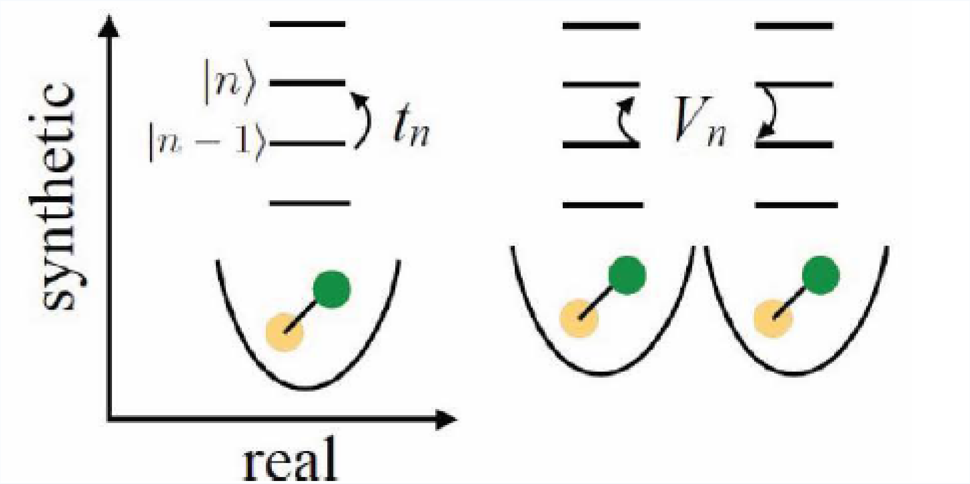
B. Sundar, BG, and K. R. A. Hazzard, arXiv:1708.02112 (2017).

Synthetic lattices on a molecule

Similar idea, but with molecules (strongly correlated)







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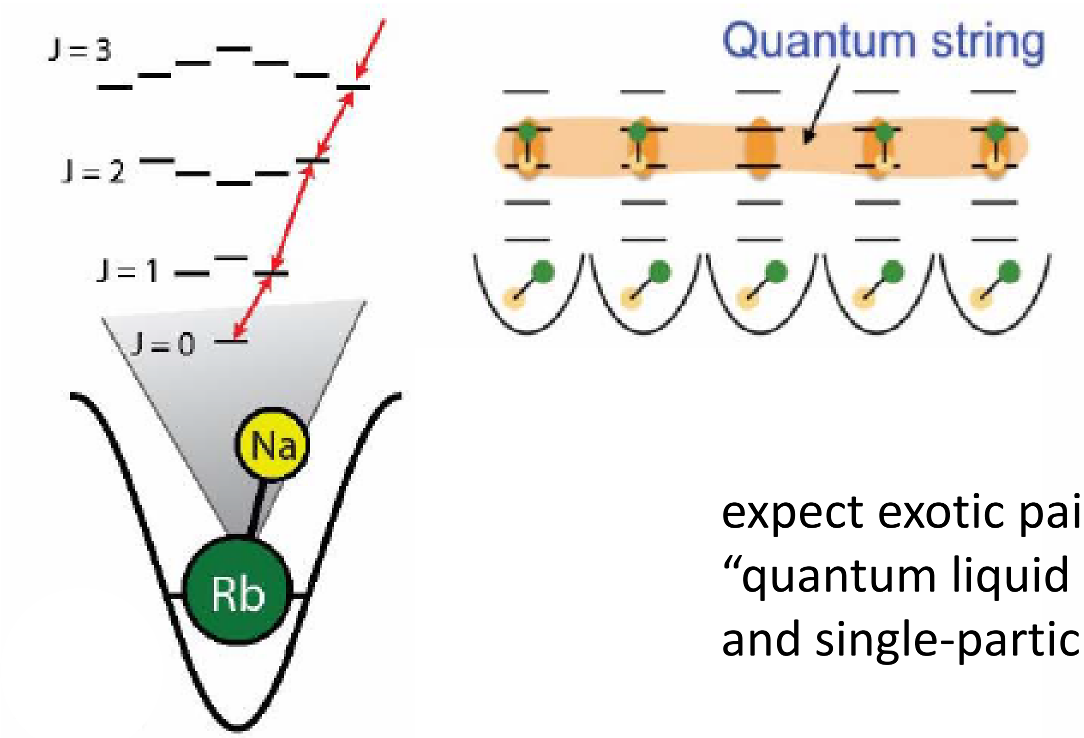


expect exotic pairing phenomena,
“quantum liquid crystal”-like strings,
and single-particle control as in our MSLs

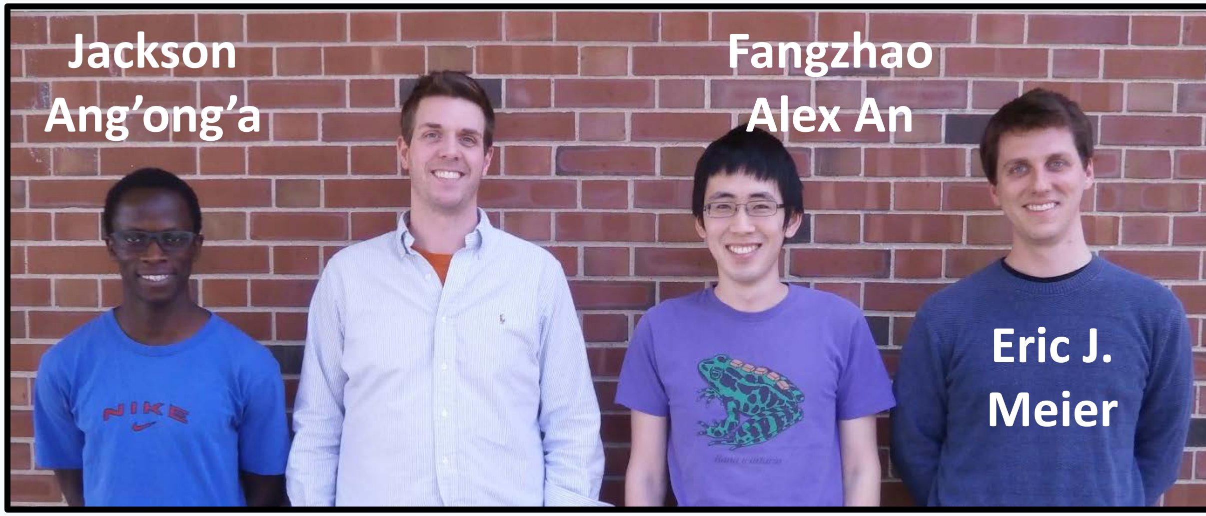
B. Sundar, BG, and K. R. A. Hazzard, arXiv:1708.02112 (2017).

Thanks! Questions?

Acknowledgments

Muyan Du

Michael Highman



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Funding:

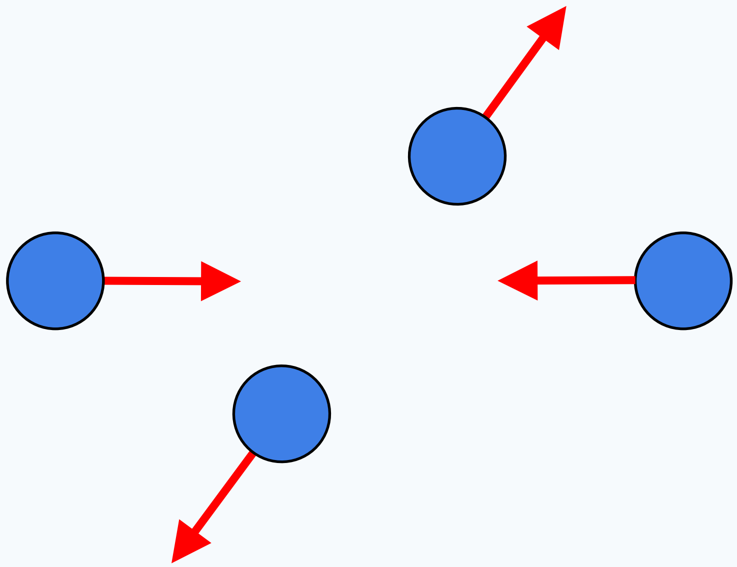



Theory friends & collaborators:

- Pietro Massignan, Maria Maffei, & Alexandre Dauphin (ICFO)
- Kaden Hazzard (Rice University)
- Taylor Hughes (UIUC)
- Smitha Vishveshwara (UIUC)

Elastic scattering "loss"

Momentum & energy conservation allow for pairwise scattering into 4π steradians (i.e. *s*-wave halos)



Elastic loss rate $\sim \boldsymbol{n\sigma v} \ \propto \boldsymbol{n} \ \times \ \boldsymbol{a^2}$

Interaction energy $\sim \boldsymbol{gn} \ \propto \boldsymbol{n} \ \times \boldsymbol{a}$

different scaling with scattering length

→ Ratio can in principle be tuned

Ratio of "bad" to "good" processes:

$$R = 2|k|a \sim 0.1 \quad \text{for} \quad k = 2k_L$$

Trippenbach, Band, Julienne.
PRA **62**, 023608 (2000)