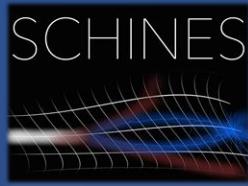


Guided accumulation of active particles by topological design of a second-order skin effect

L. S. Palacios, S. Tchoumakov, M. Guix, I. Pagonabarraga, S. Sánchez and A. G. Grushin

arXiv:2012.14496

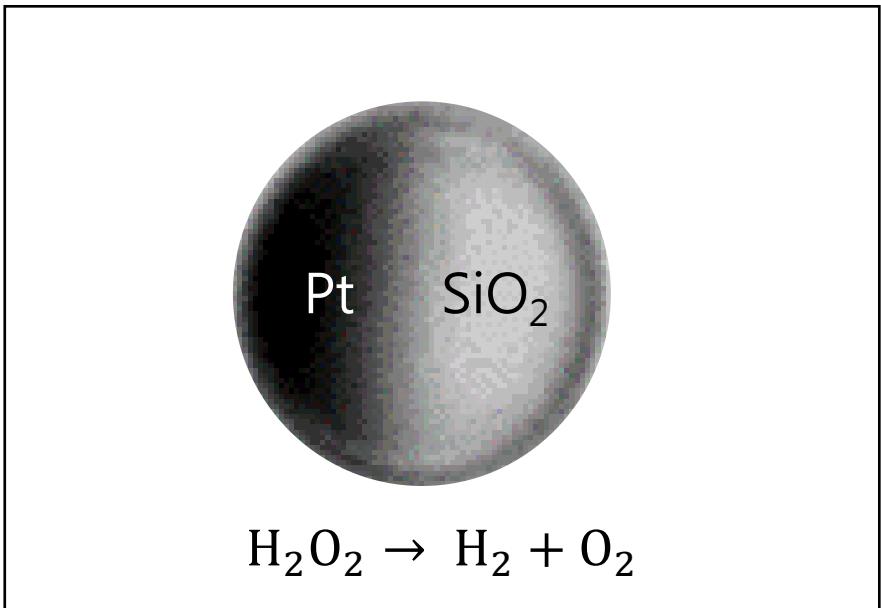


serguei.tchoumakov@neel.cnrs.fr

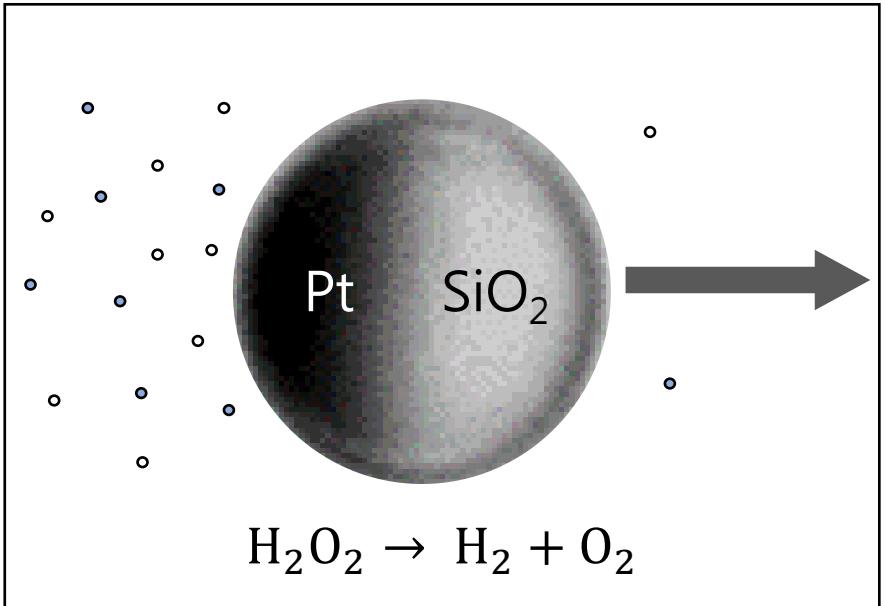
Active particles are a platform to explore non-Hermitian dynamics



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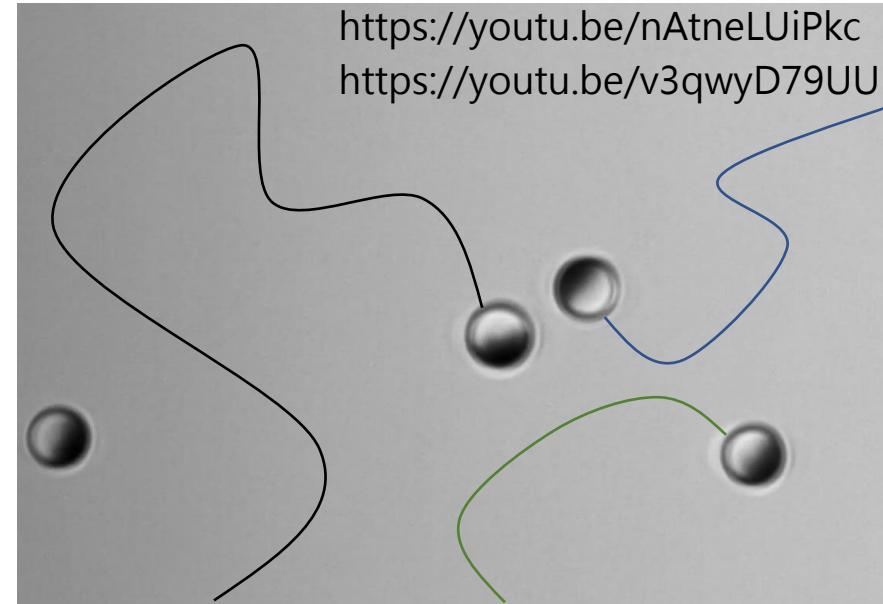
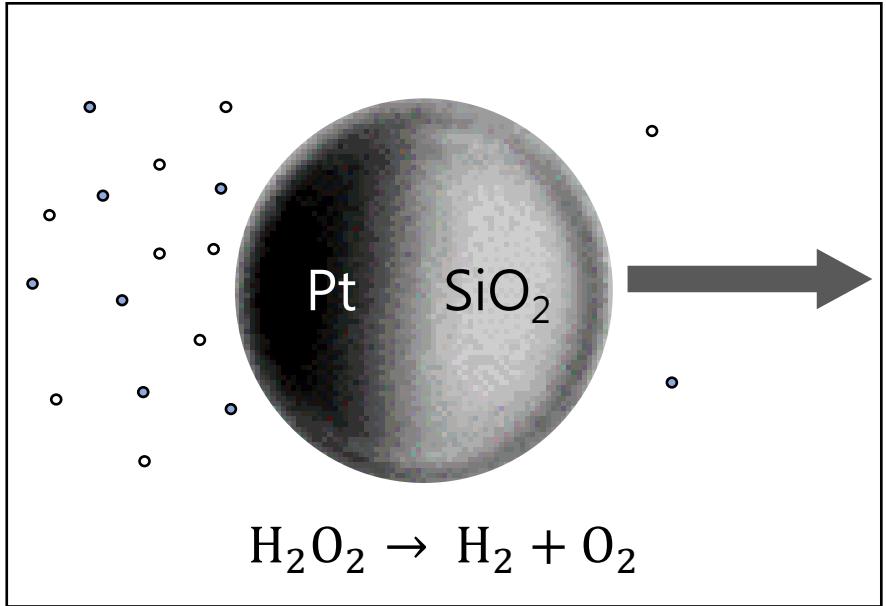
Active particles are a platform to explore non-Hermitian dynamics



$$m \frac{d\boldsymbol{v}}{dt} = \sum_i \boldsymbol{F}_i$$

random forces

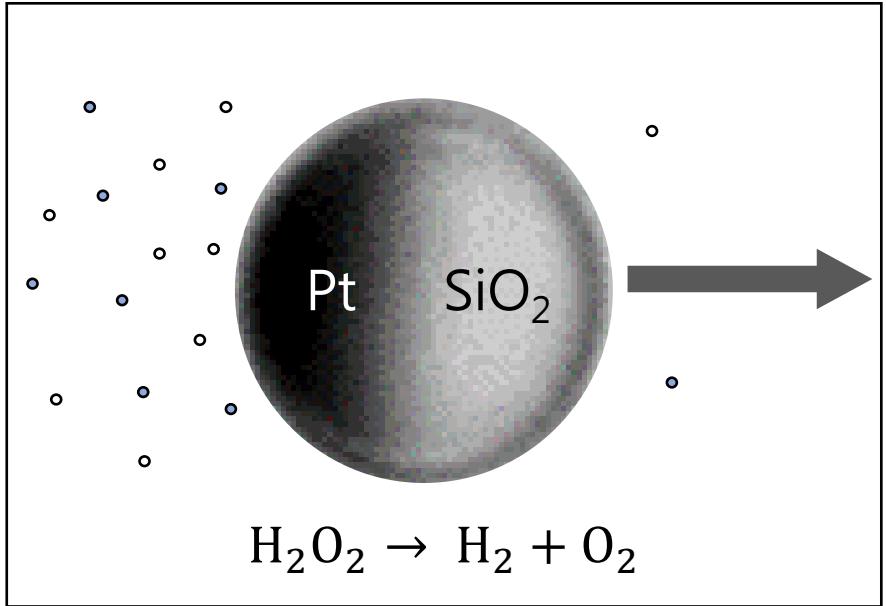
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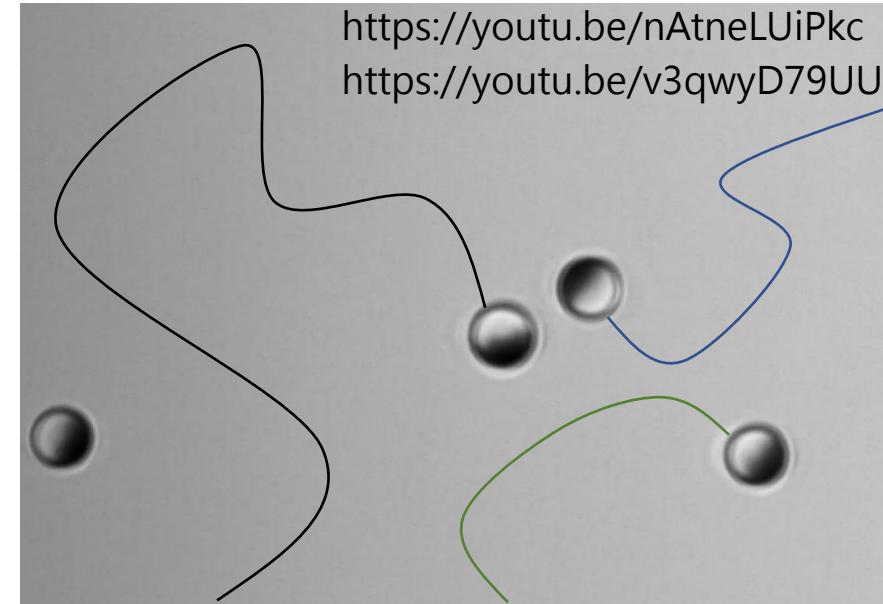
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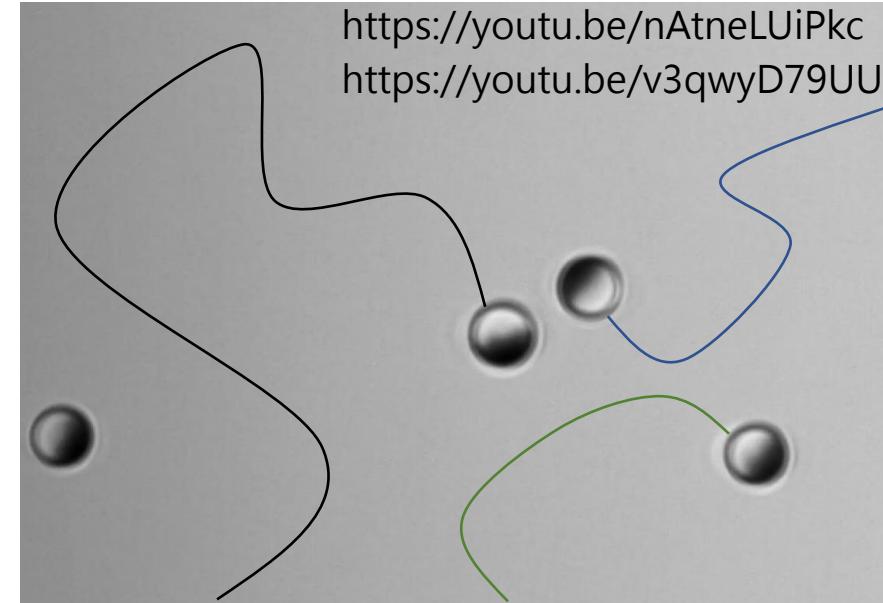
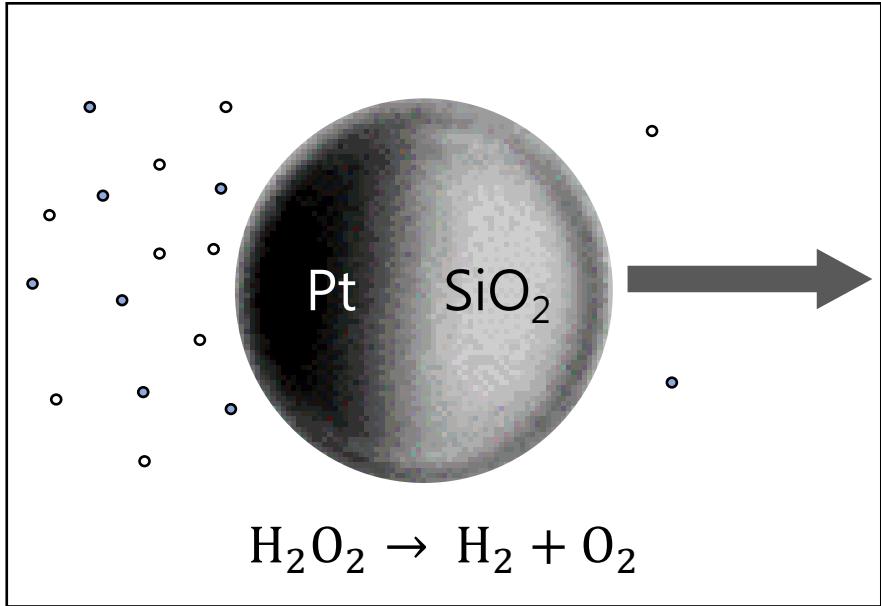
$$m \frac{d\boldsymbol{v}}{dt} = \sum_i \boldsymbol{F}_i$$

random forces



$$\frac{\partial P(\boldsymbol{x}, t)}{\partial t} = \boldsymbol{W}(\boldsymbol{x}, \boldsymbol{x}') \cdot P(\boldsymbol{x}', t)$$

Active particles are a platform to explore non-Hermitian dynamics



$$m \frac{d\boldsymbol{v}}{dt} = \sum_i \boldsymbol{F}_i$$

random forces

$$i \frac{\partial P(x, t)}{\partial t} = \boxed{iW(x, x')} \cdot P(x', t)$$

Schrödinger-like equation

$$\int dx W(x, x') = 0 : \text{not Hermitian}$$

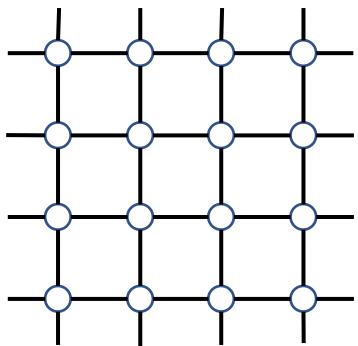
The topological origin of the non-Hermitian skin-effect

$$i \frac{\partial P(x, t)}{\partial t} = i W(x - x') \cdot P(x', t)$$

The topological origin of the non-Hermitian skin-effect

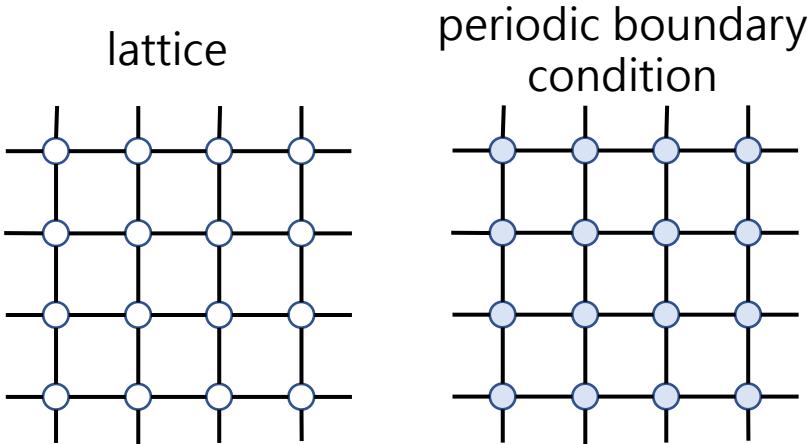
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lattice



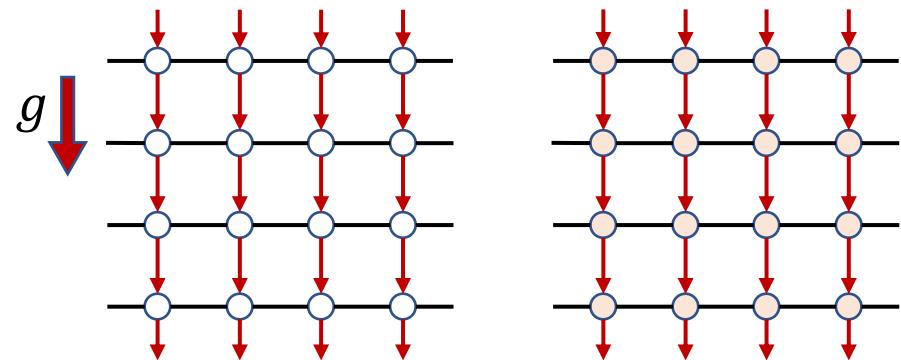
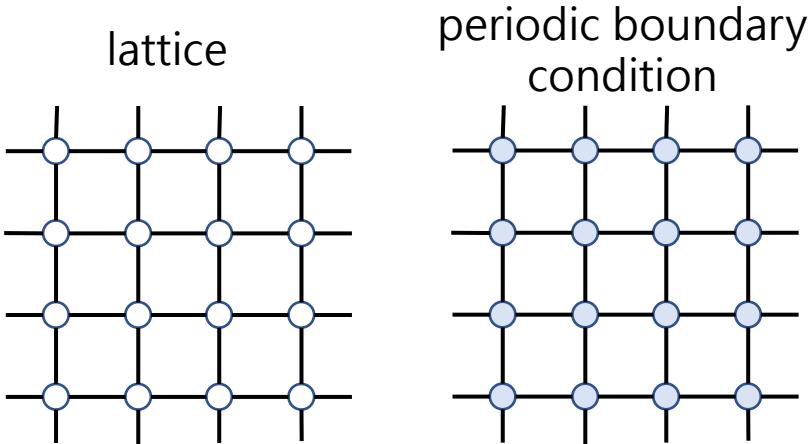
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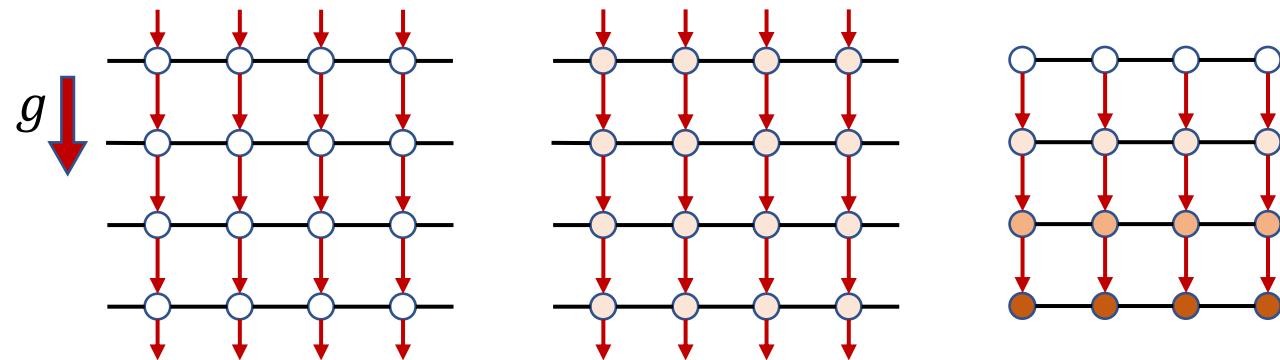
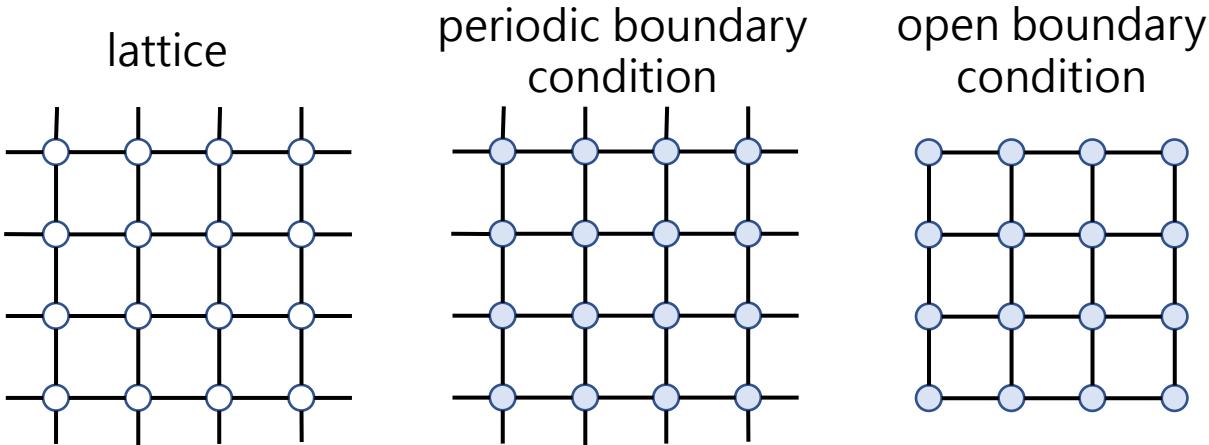
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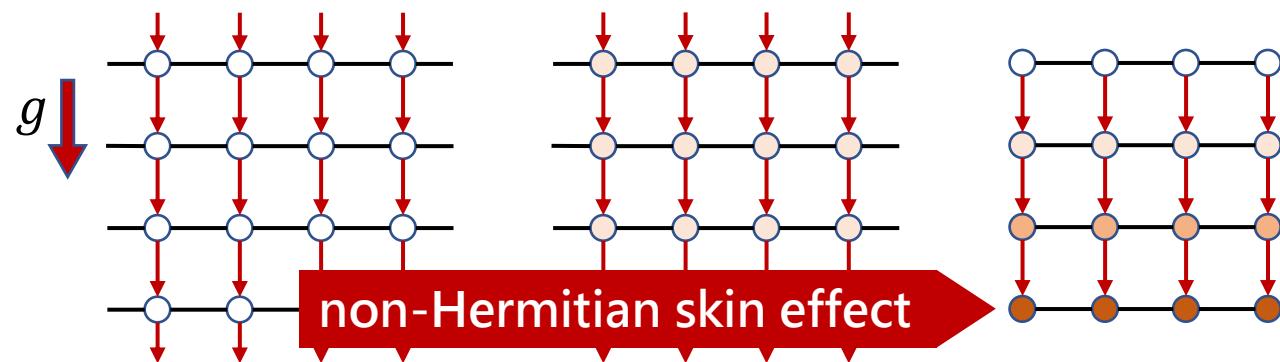
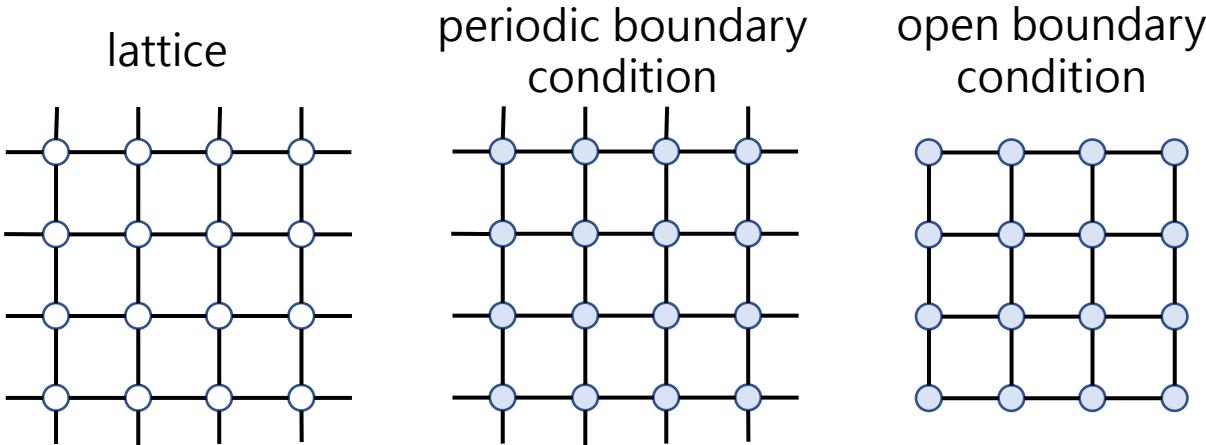
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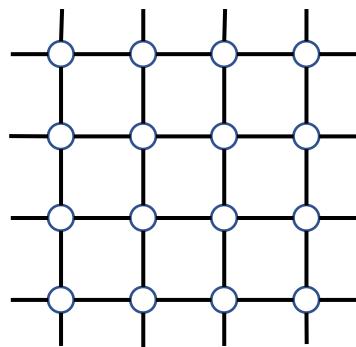
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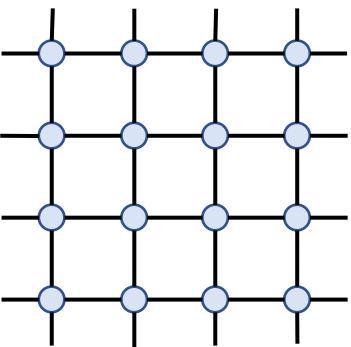
Fourier

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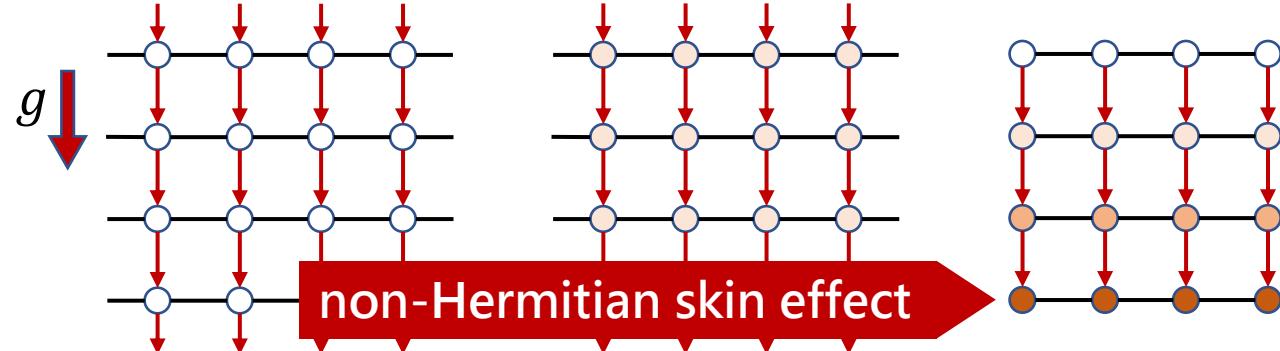
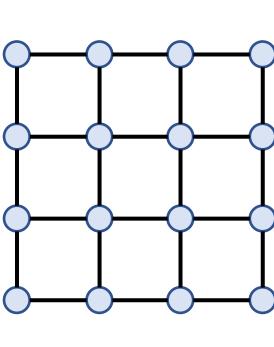
lattice



periodic boundary condition



open boundary condition

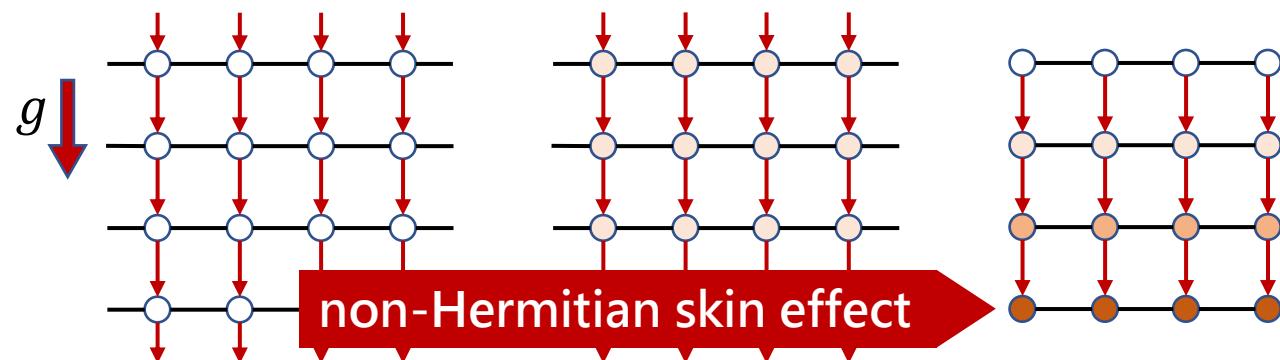
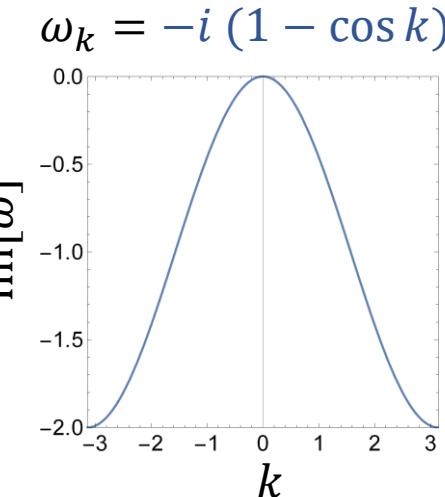
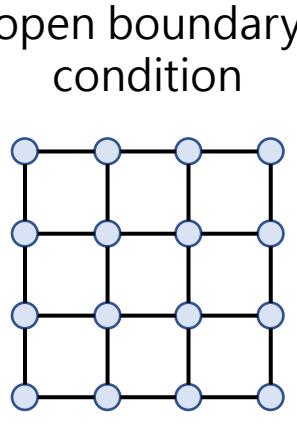
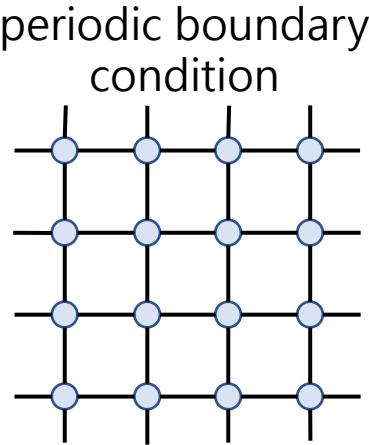
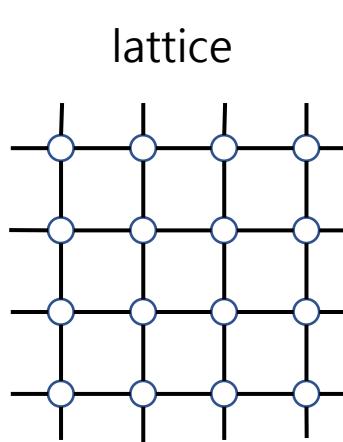


The topological origin of the non-Hermitian skin-effect

$$i \frac{\partial P(x, t)}{\partial t} = i W(x - x') \cdot P(x', t)$$

Fourier

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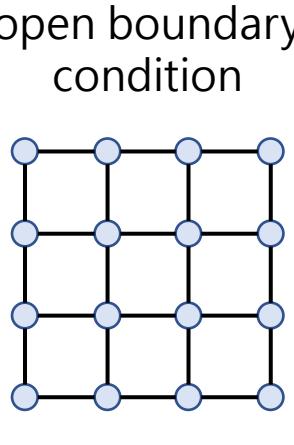
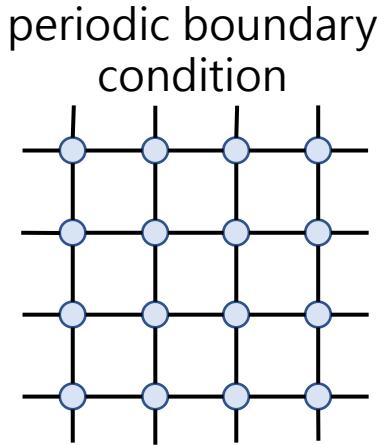
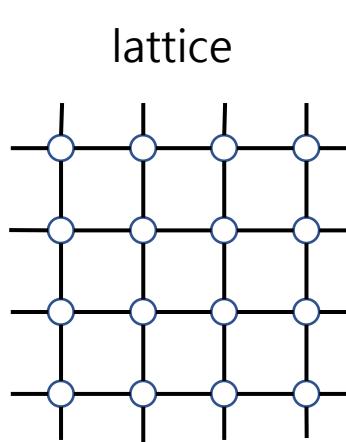


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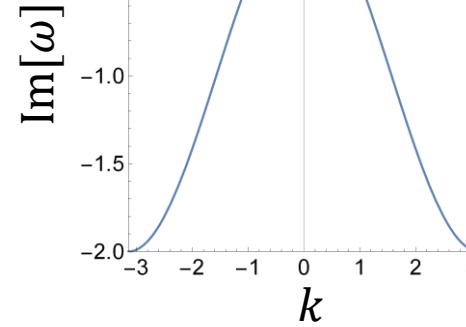
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Fourier

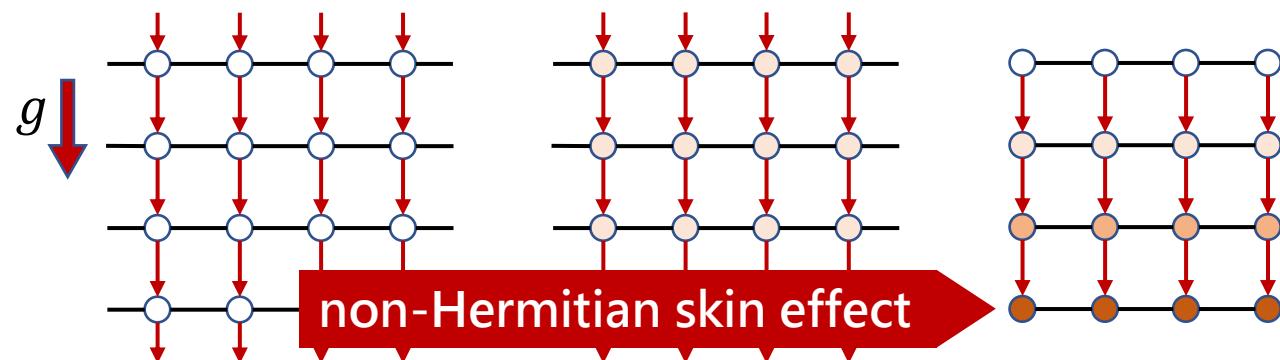
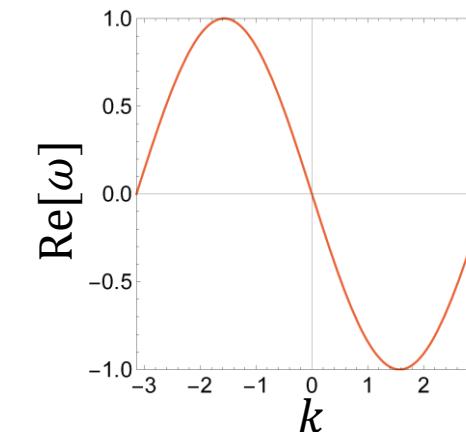
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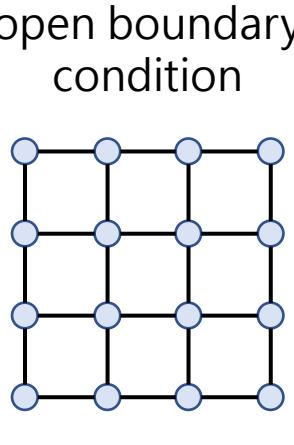
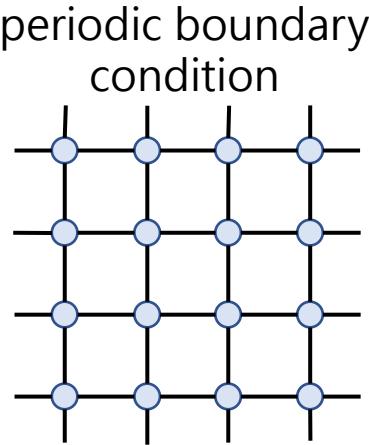
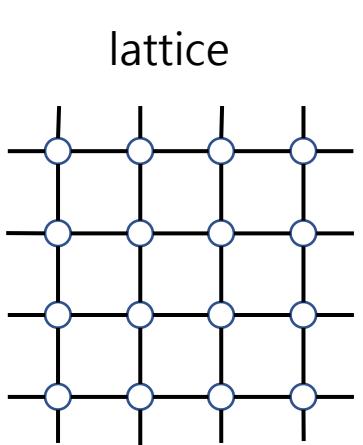


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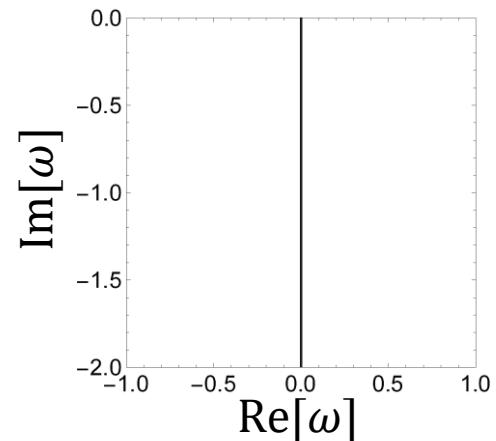
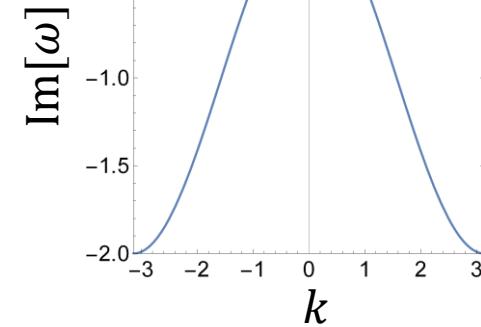
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Fourier

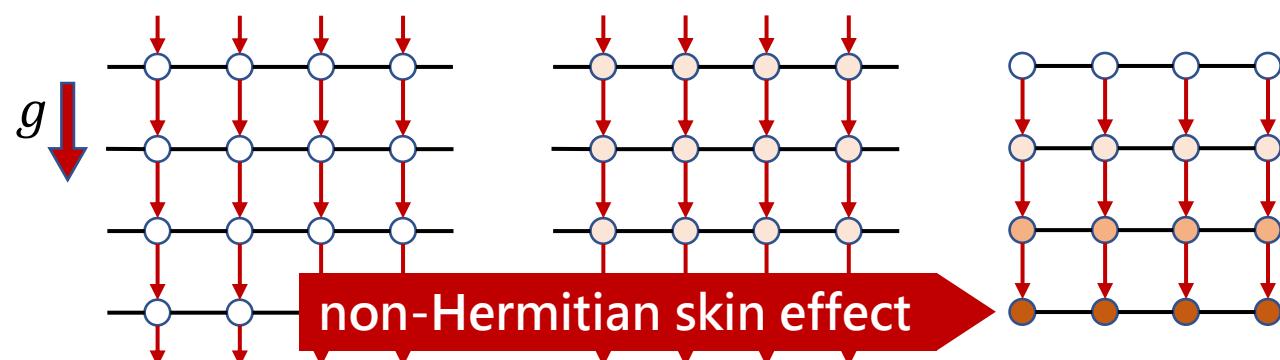
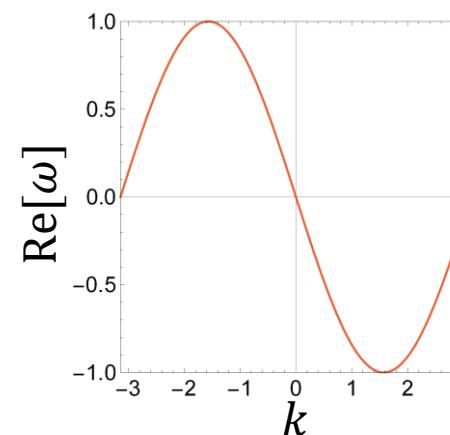
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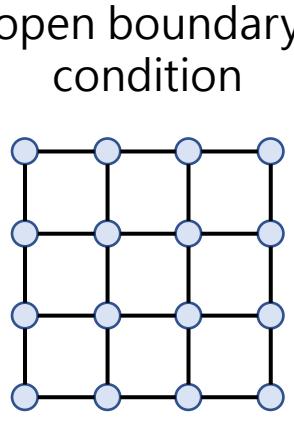
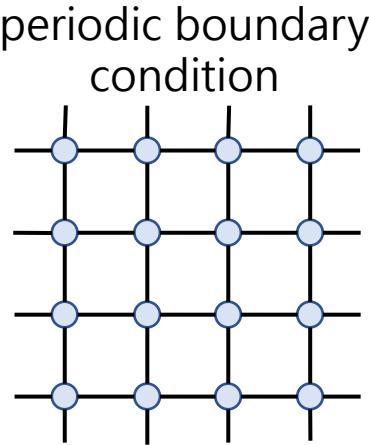
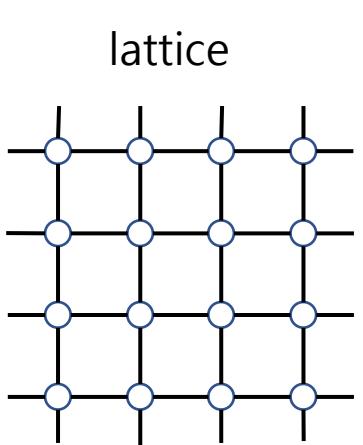


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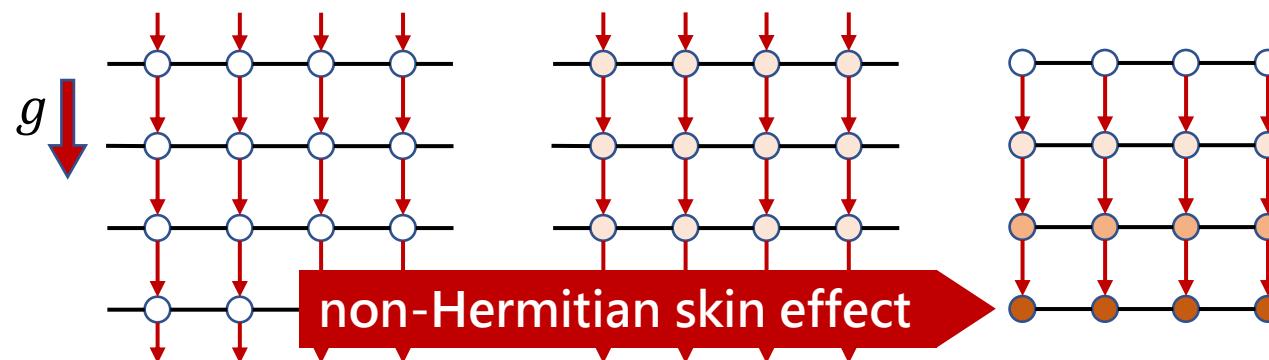
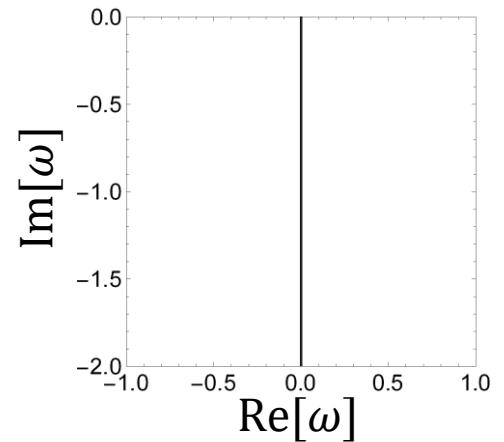
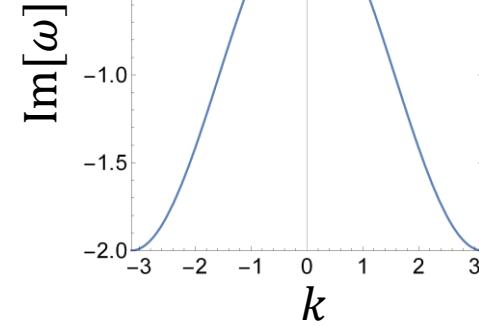
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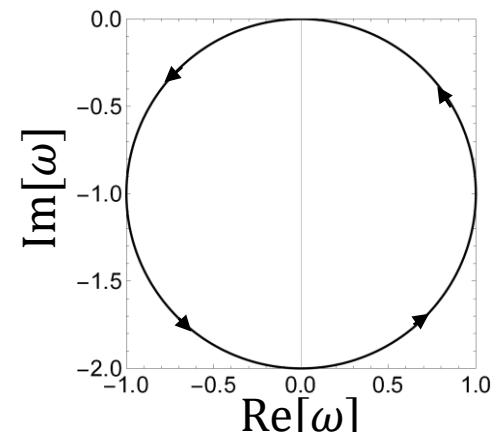
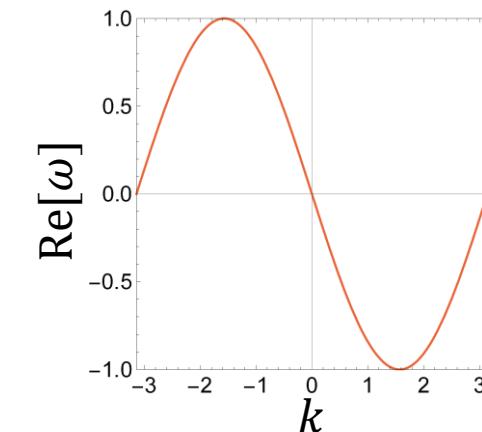
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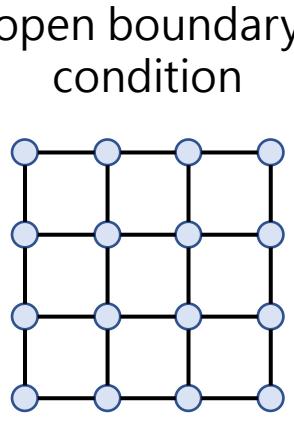
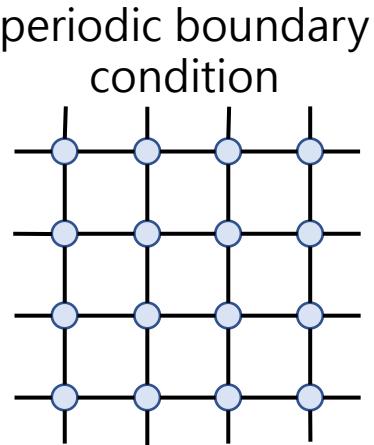
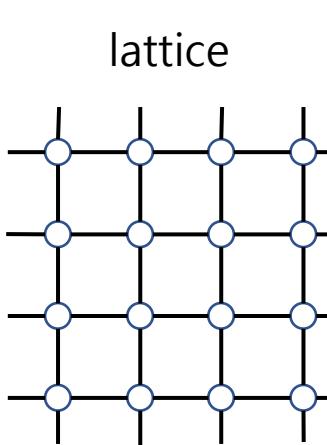


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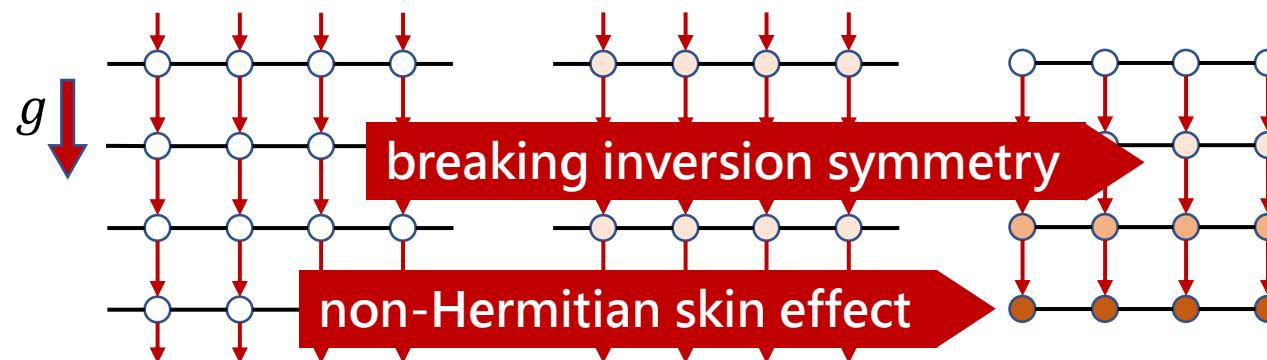
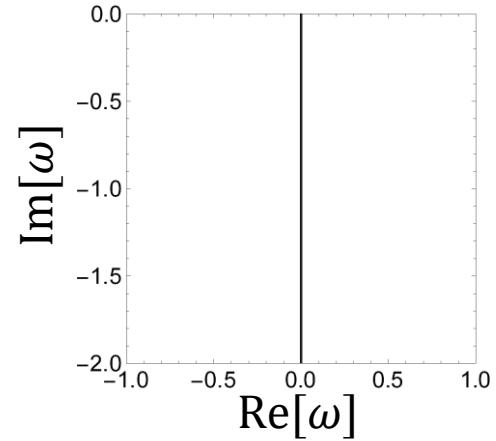
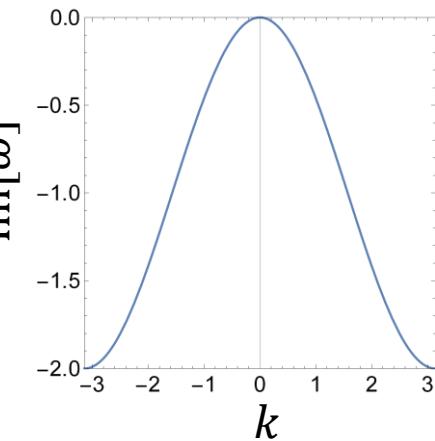
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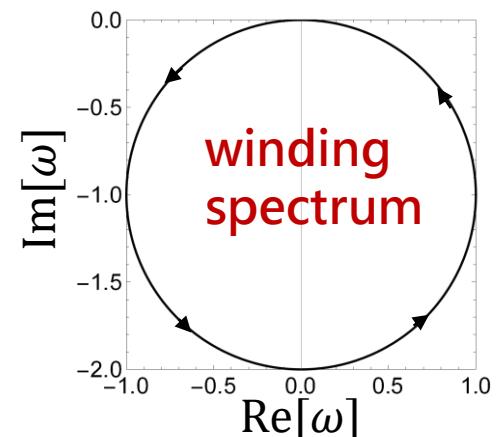
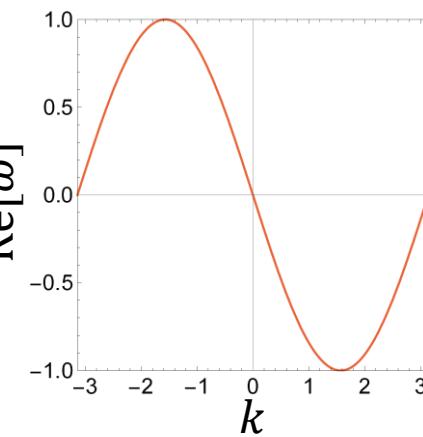
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Im[ω]



$$\omega_k = \delta \sin k - i (1 - \cos k)$$

Re[ω]



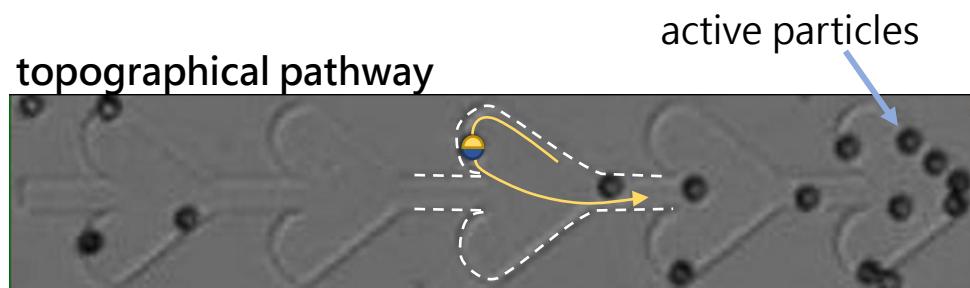
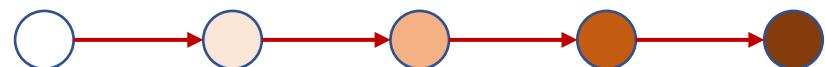
Non-Hermitian skin-effect without breaking inversion symmetry

Breaking inversion symmetry
⇒ non-Hermitian skin-effect



Non-Hermitian skin-effect without breaking inversion symmetry

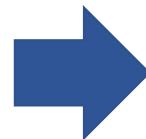
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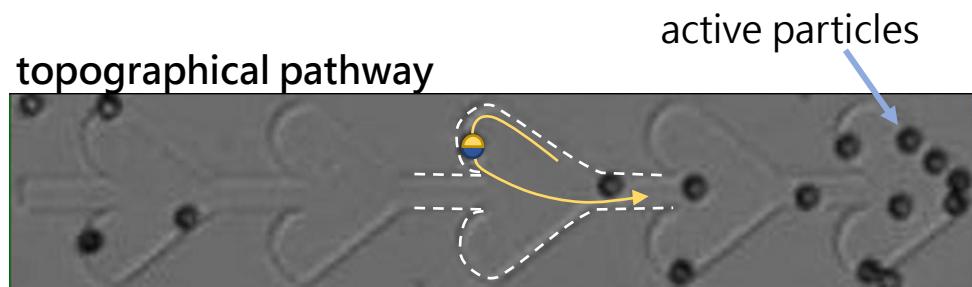
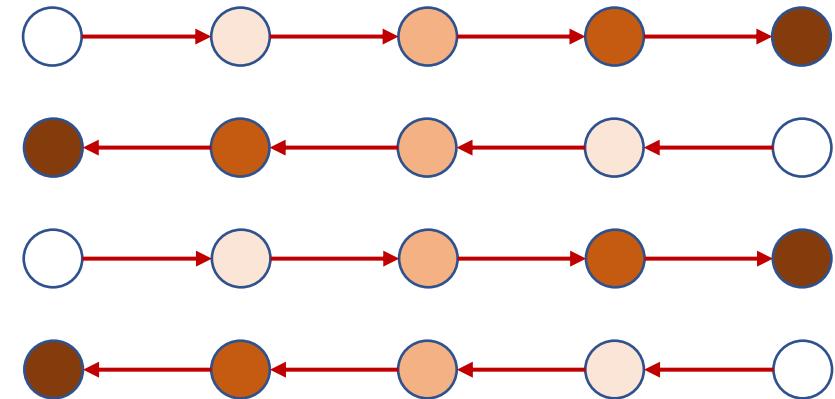
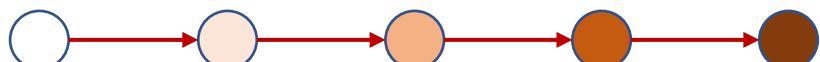
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Non-Hermitian skin-effect without breaking inversion symmetry

Breaking inversion symmetry
⇒ non-Hermitian skin-effect



Preserved inversion symmetry
⇒ second-order non-Hermitian skin-effect ?



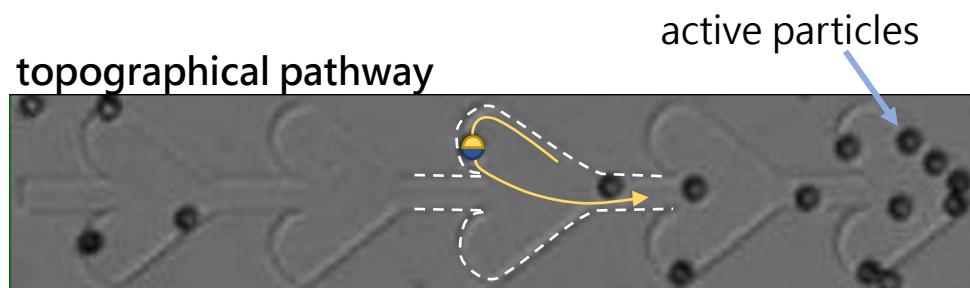
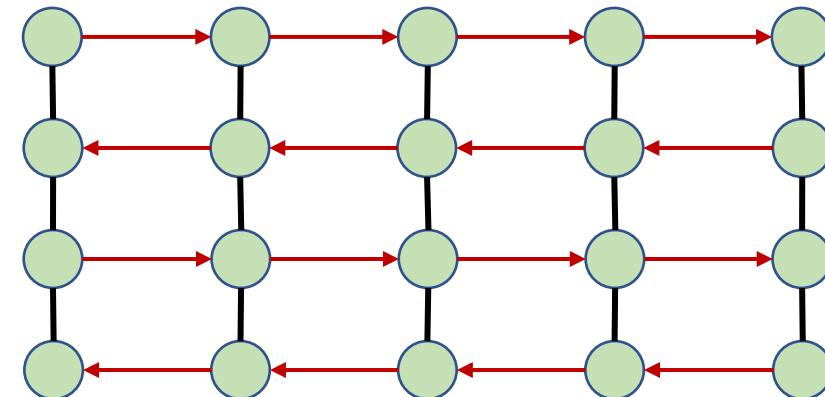
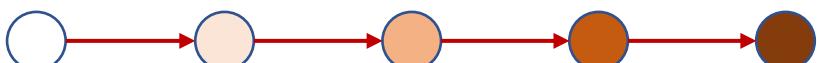
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Breaking inversion symmetry
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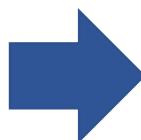
Preserved inversion symmetry
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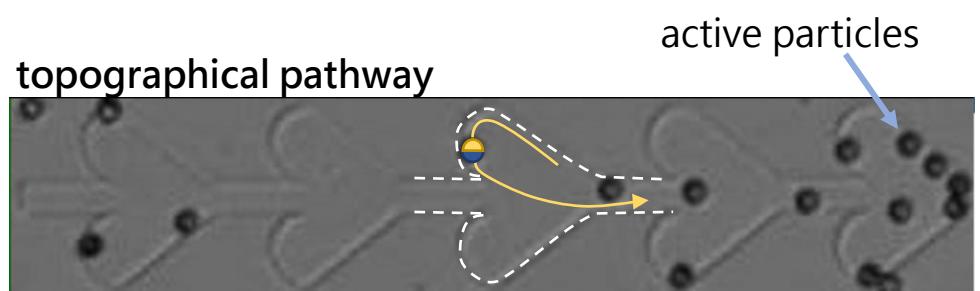
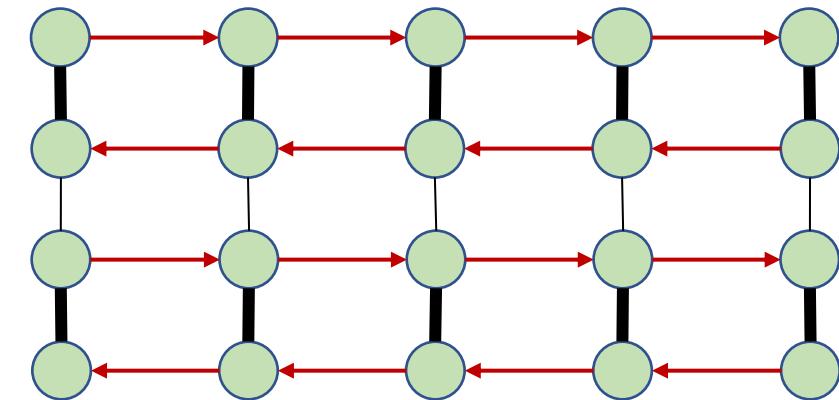
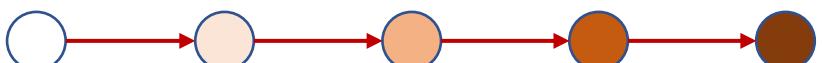
J. Katuri et al., ACS Nano 12 2018

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Breaking inversion symmetry
⇒ non-Hermitian skin-effect

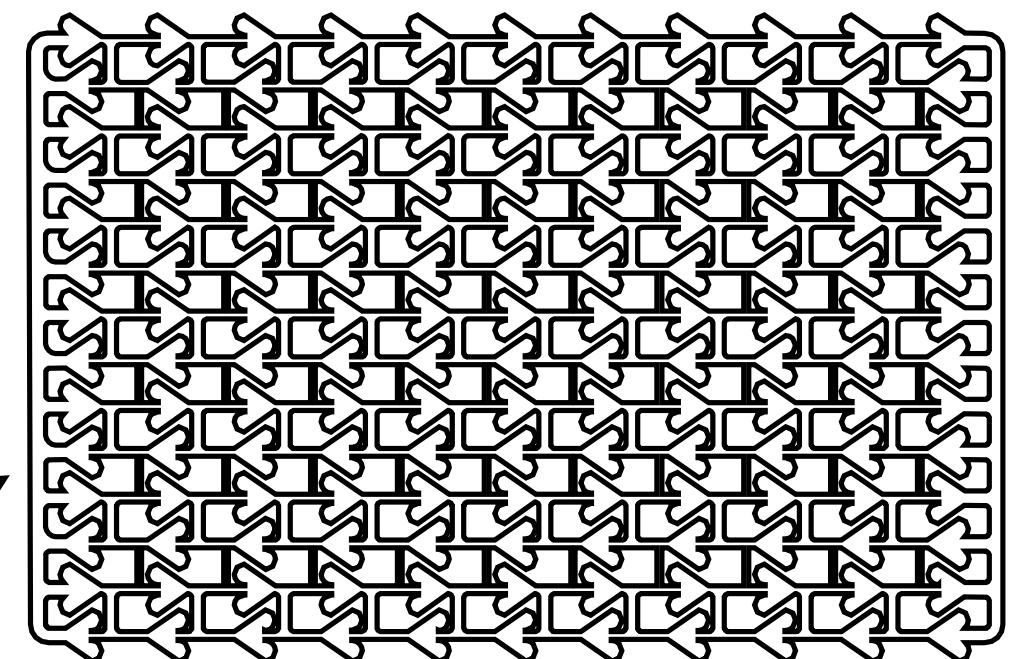


Preserved inversion symmetry
⇒ second-order non-Hermitian skin-effect ?



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trivial device

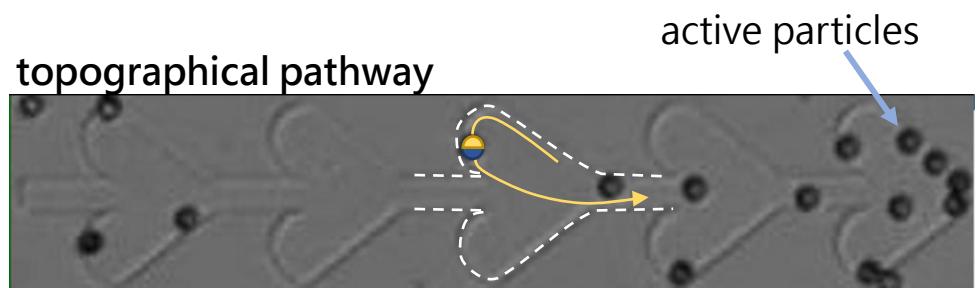
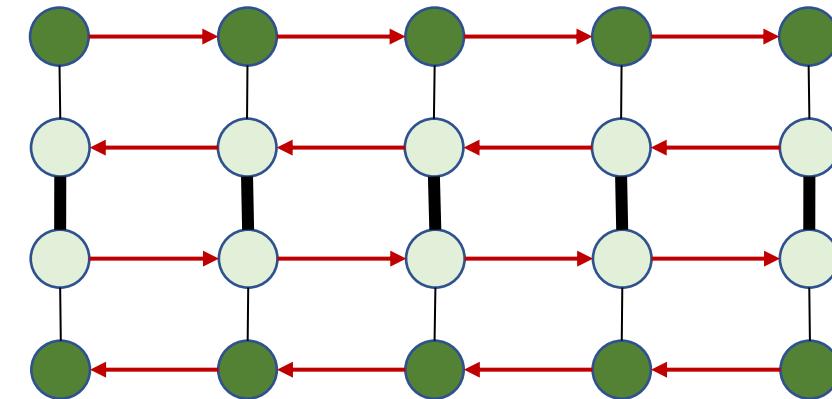
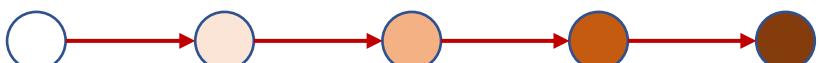


Non-Hermitian skin-effect without breaking inversion symmetry

Breaking inversion symmetry
⇒ non-Hermitian skin-effect

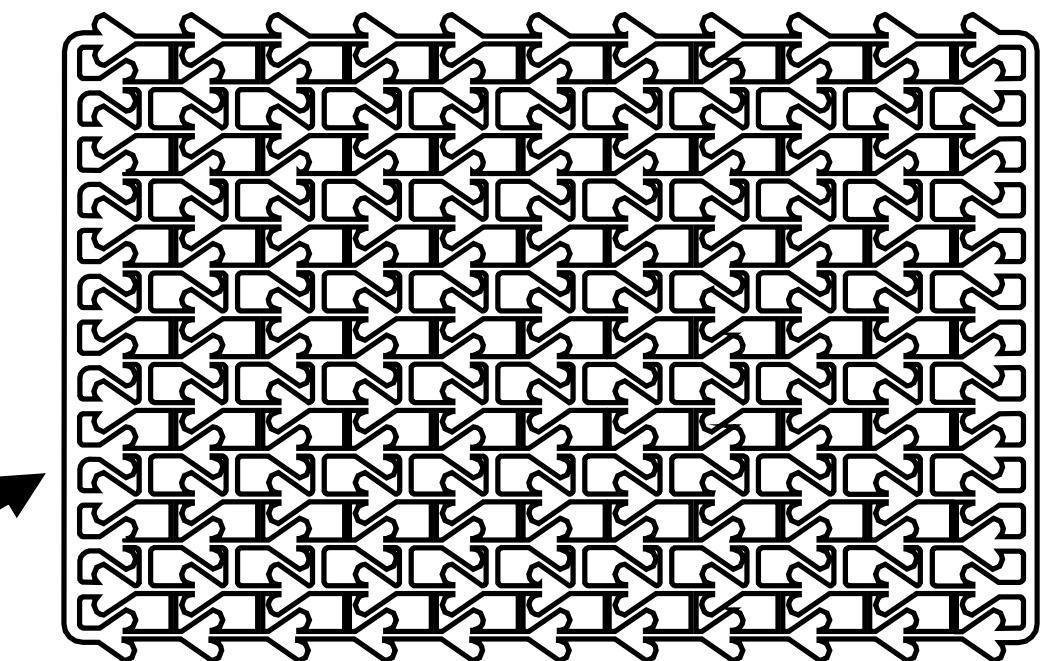


Preserved inversion symmetry
⇒ second-order non-Hermitian skin-effect ?



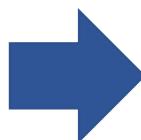
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topological device

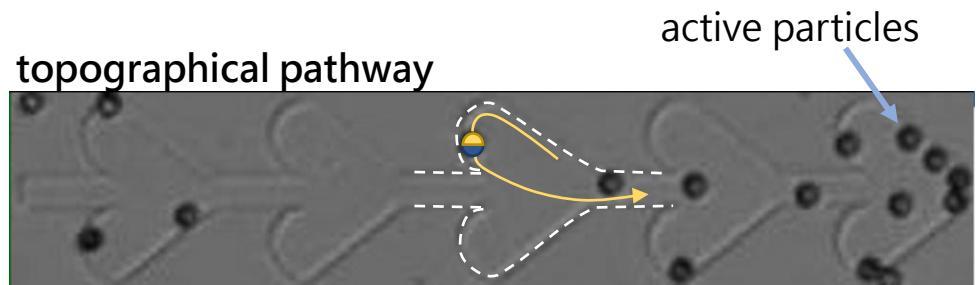
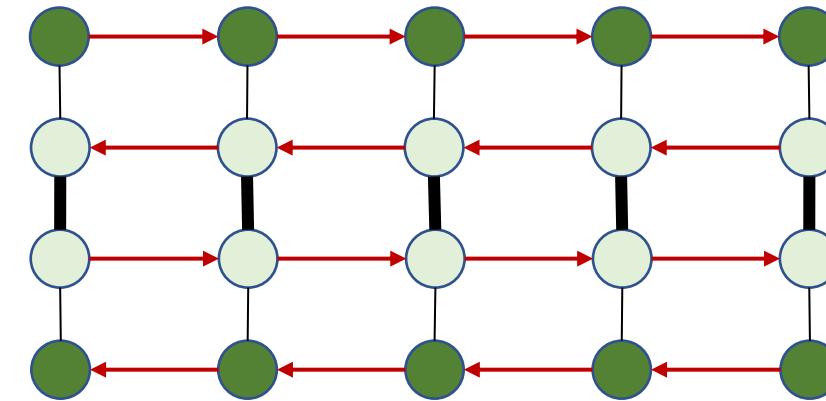
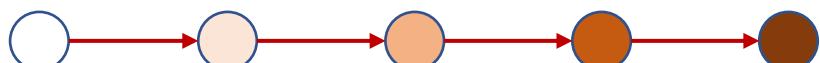


Non-Hermitian skin-effect without breaking inversion symmetry

Breaking inversion symmetry
⇒ non-Hermitian skin-effect

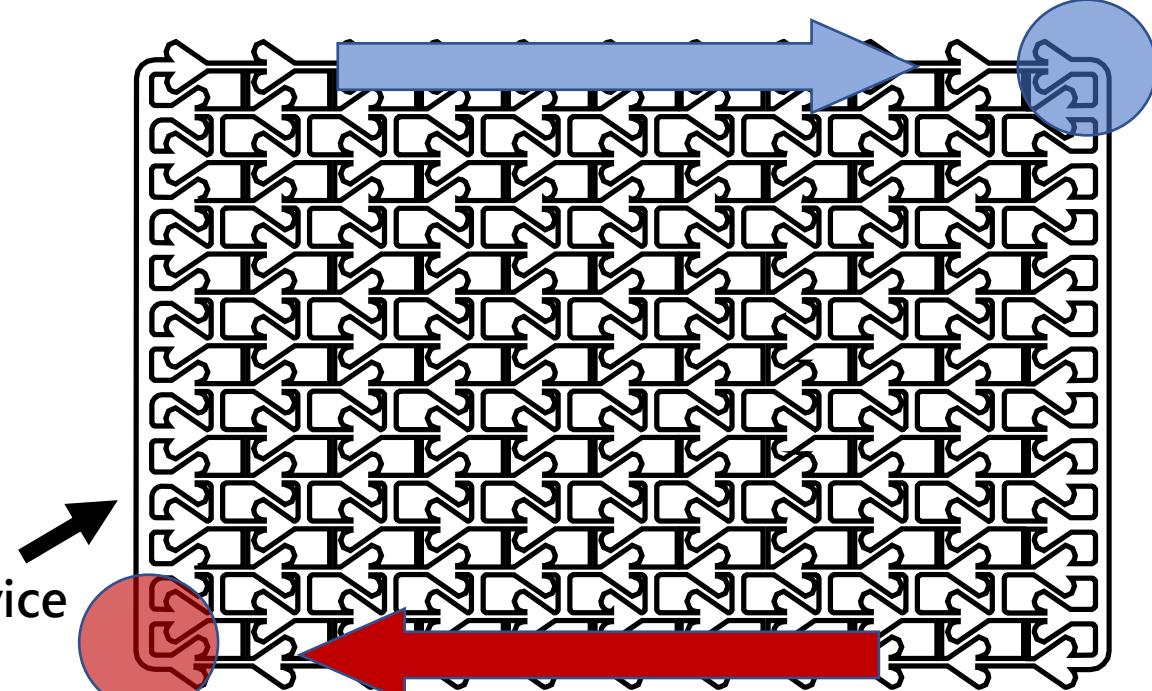


Preserved inversion symmetry
⇒ second-order non-Hermitian skin-effect ?



J. Katuri et al., ACS Nano 12 2018

topological device



Active particles propagate faster on the edges

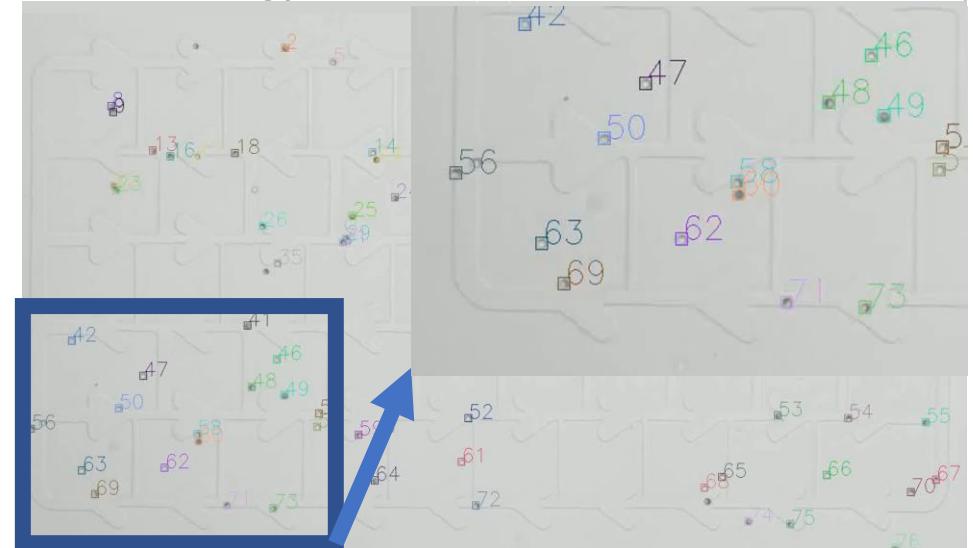
trivial circuit  topological circuit

Active particles propagate faster on the edges

arXiv:2012.14496

trivial circuit \longleftrightarrow topological circuit

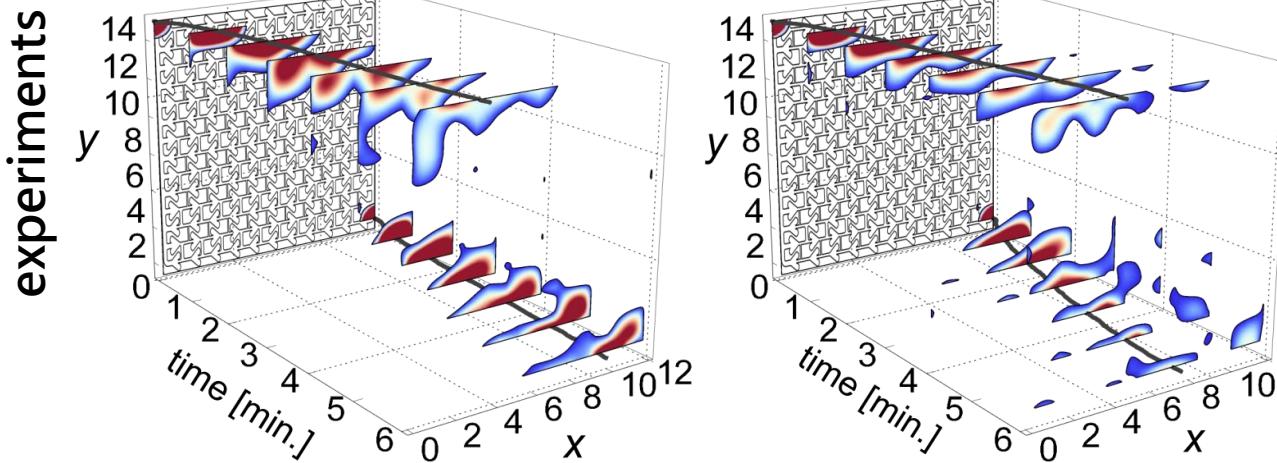
Methodology : track active particles individually



Active particles propagate faster on the edges

arXiv:2012.14496

trivial circuit \longleftrightarrow topological circuit



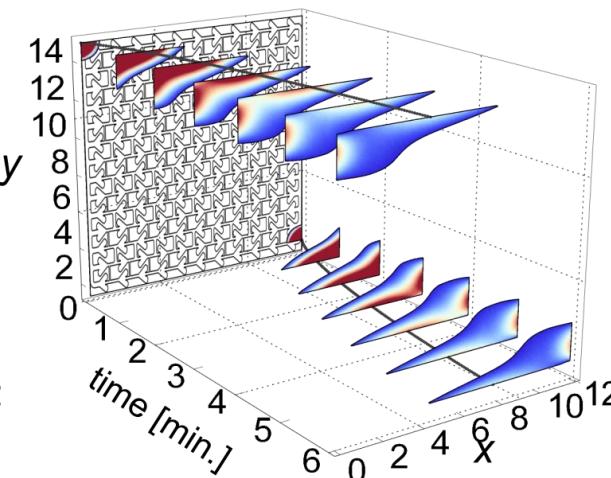
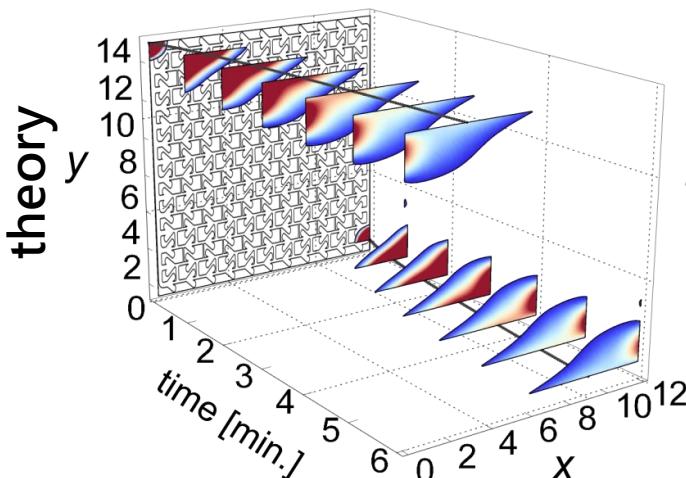
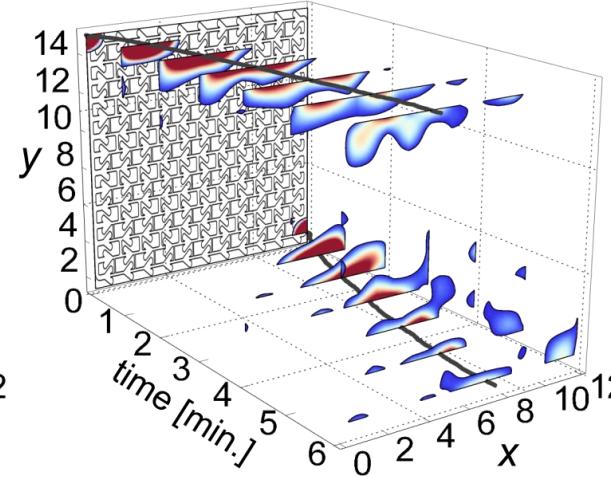
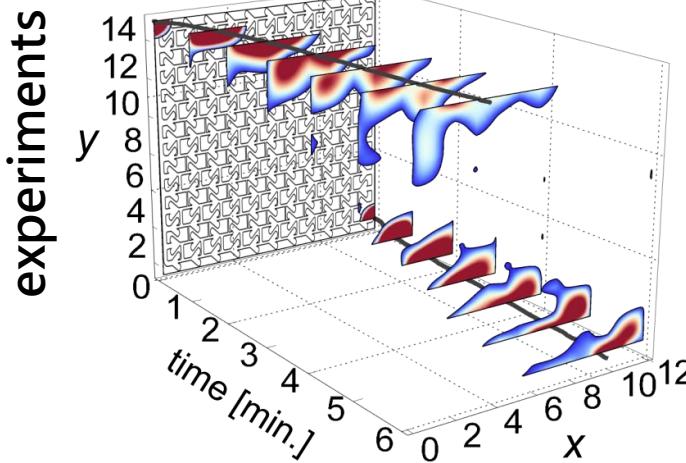
Methodology : track active particles individually



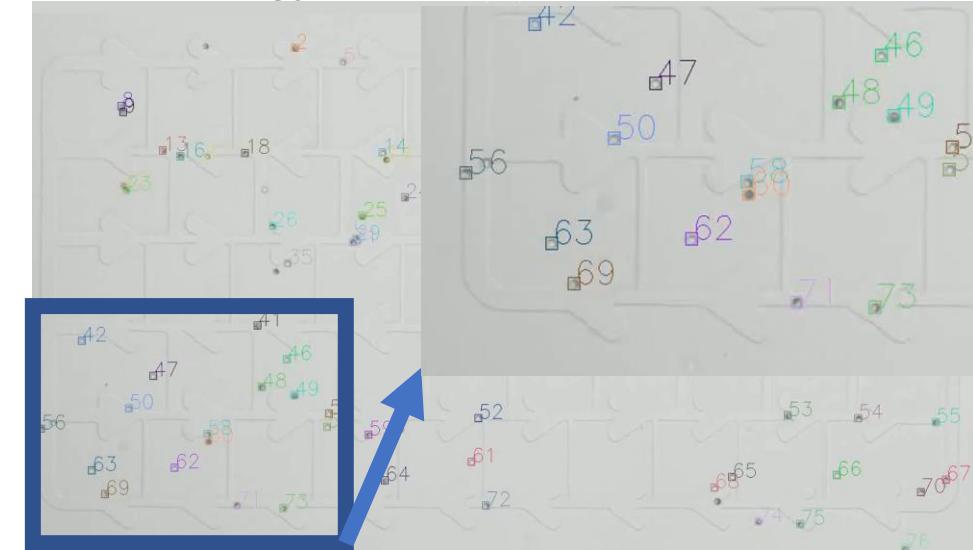
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trivial circuit \longleftrightarrow topological circuit



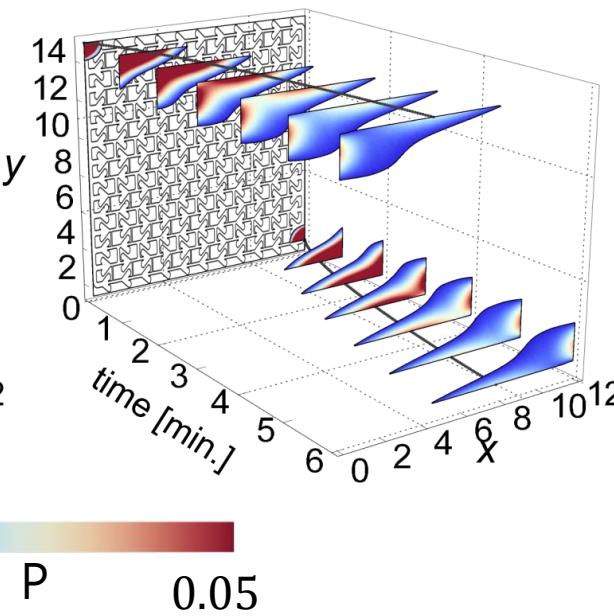
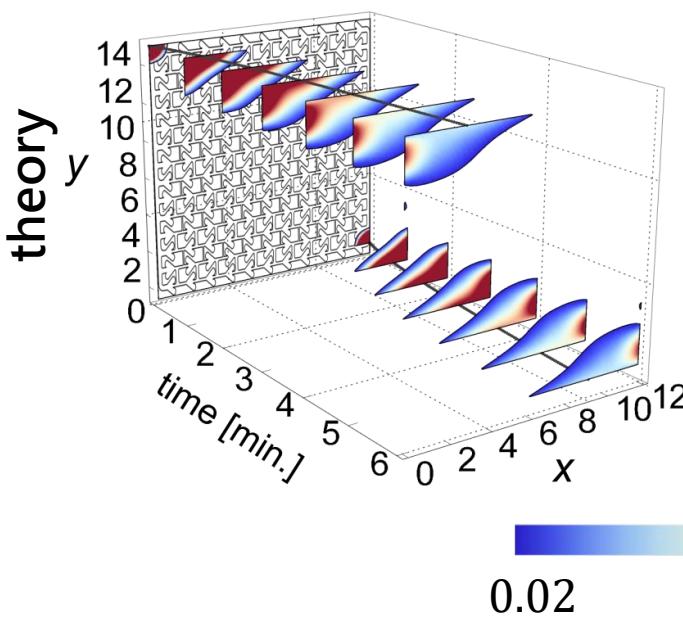
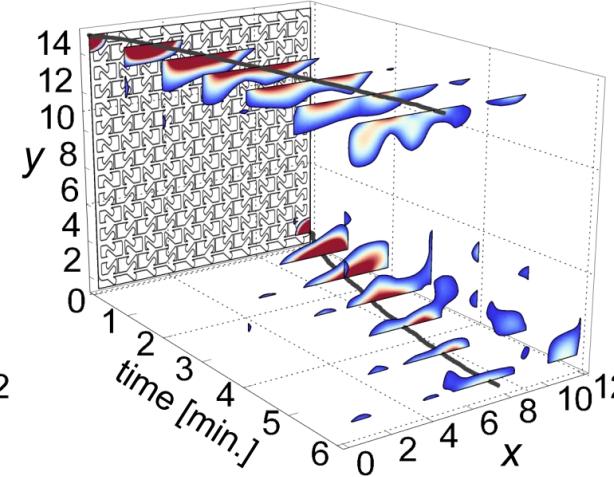
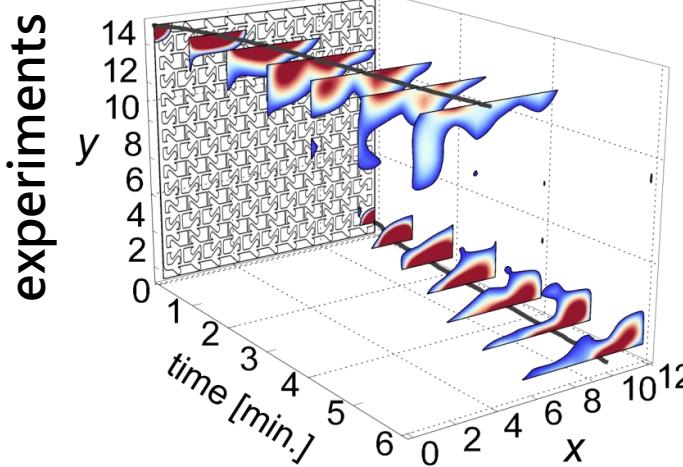
Methodology : track active particles individually



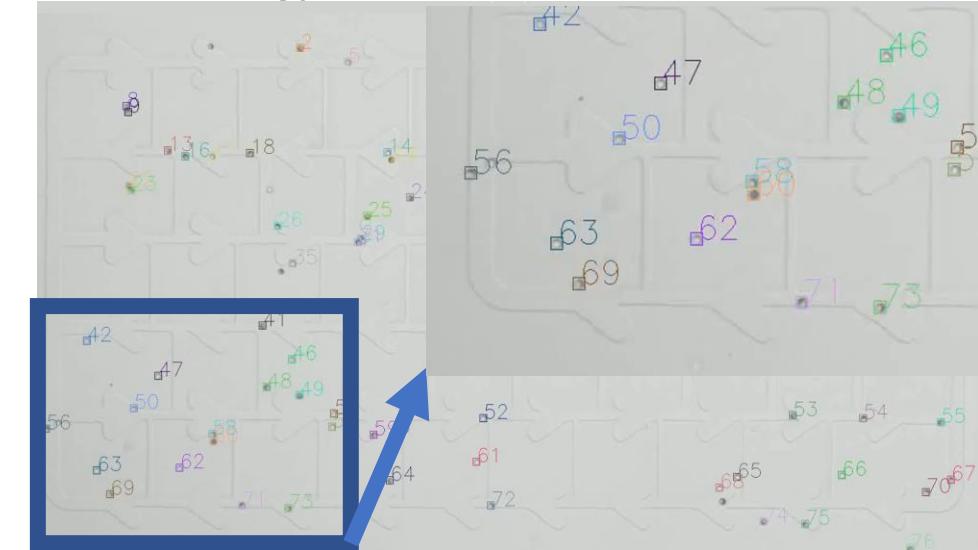
Active particles propagate faster on the edges

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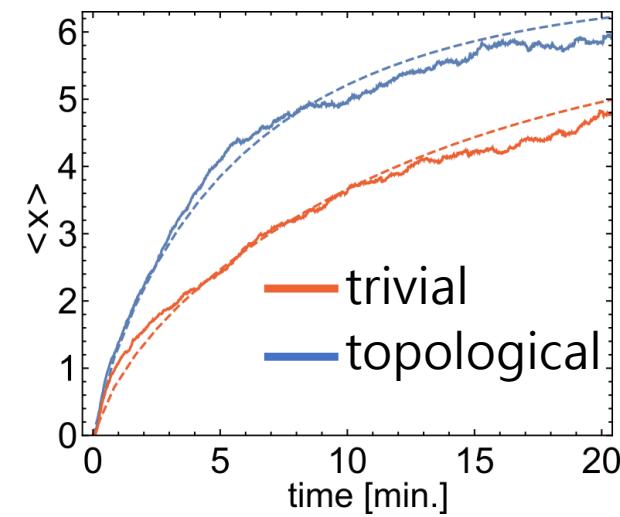
trivial circuit \longleftrightarrow topological circuit



Methodology : track active particles individually



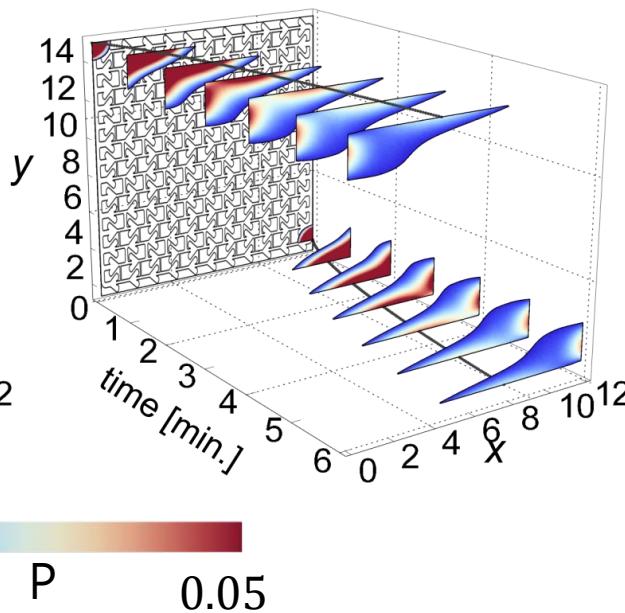
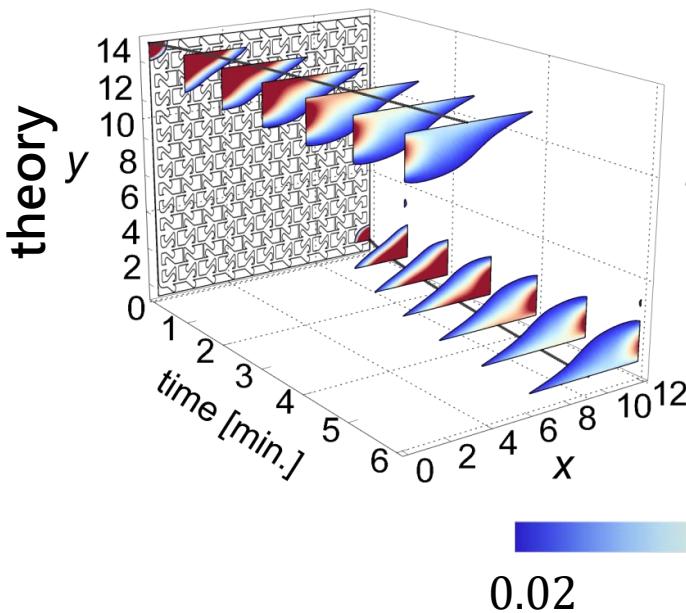
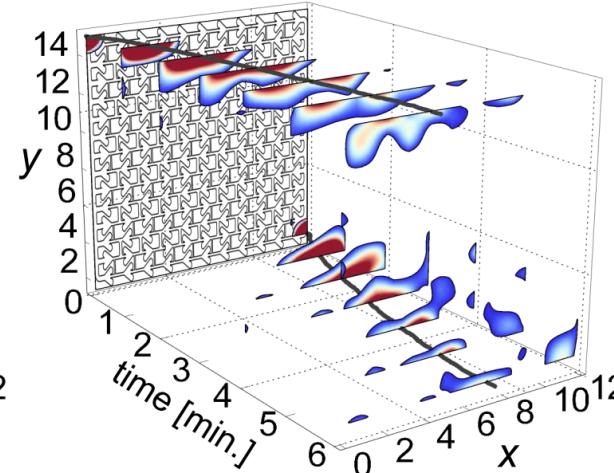
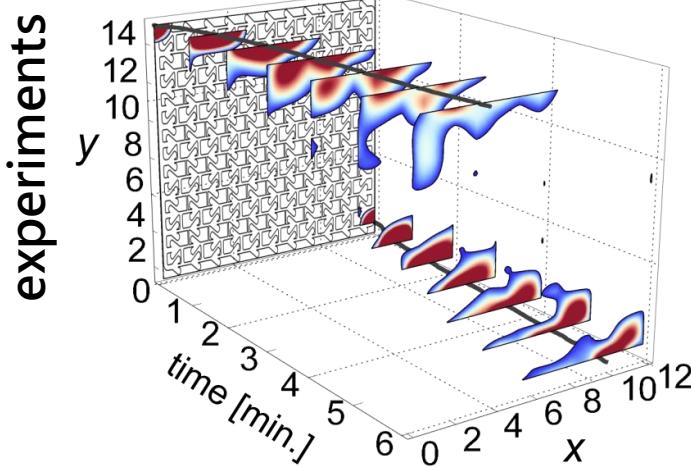
experiment and theory



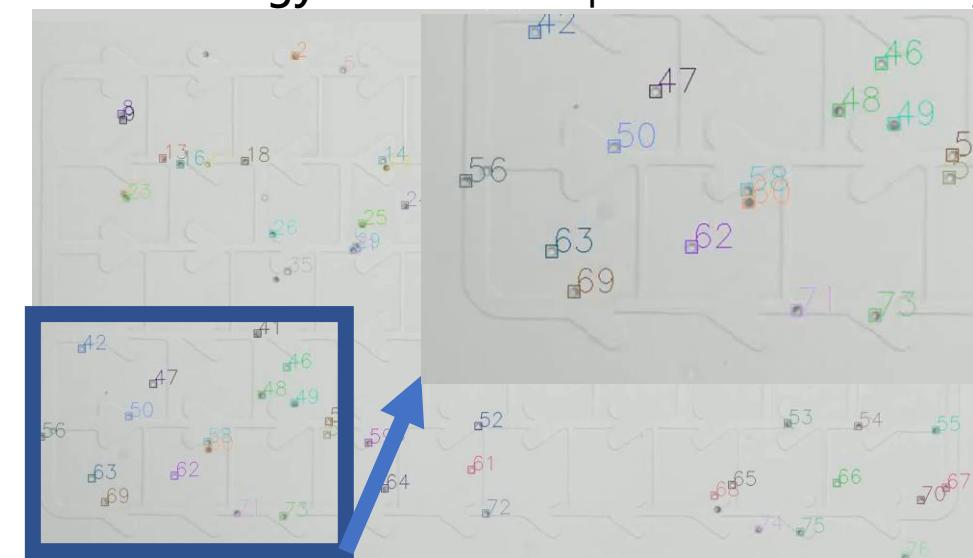
Active particles propagate faster on the edges

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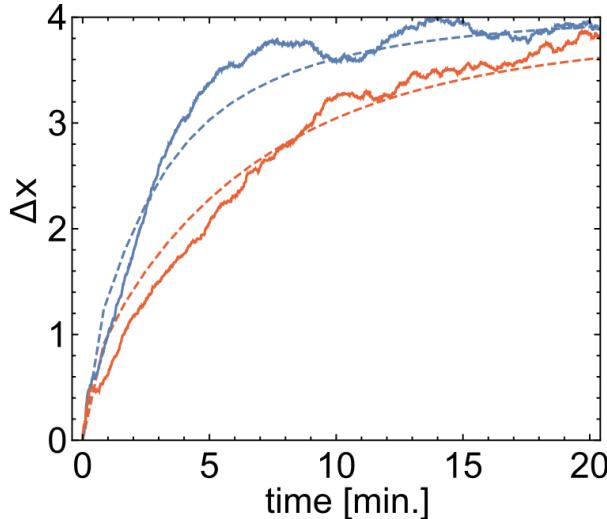
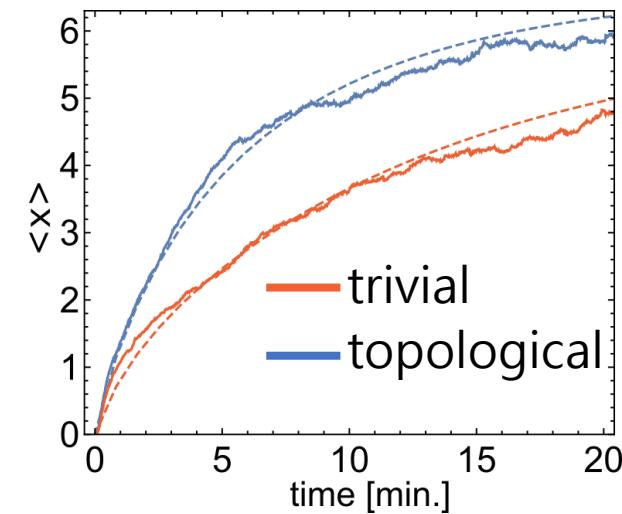
trivial circuit \longleftrightarrow topological circuit



Methodology : track active particles individually



experiment and theory



Active particles accumulate at the corners

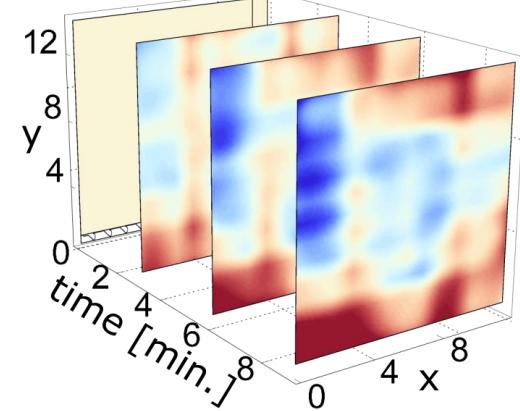
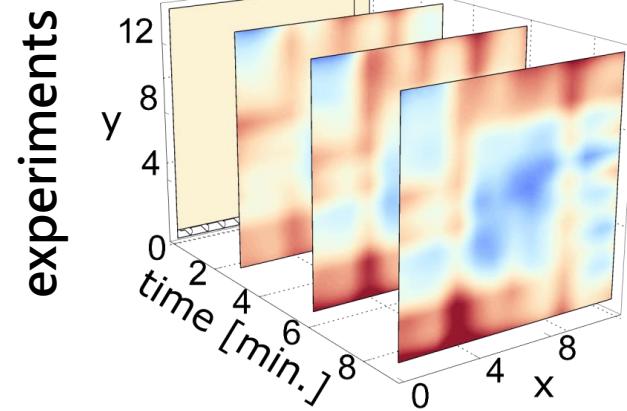
arXiv:2012.14496

trivial circuit  topological circuit

Active particles accumulate at the corners

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trivial circuit \longleftrightarrow topological circuit

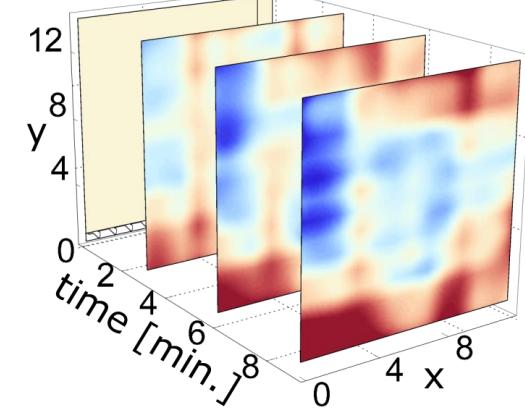
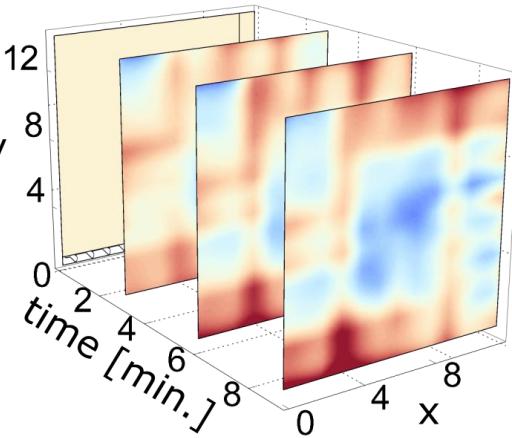


Active particles accumulate at the corners

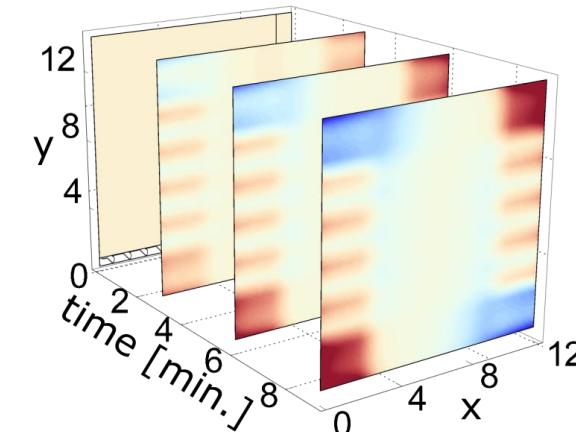
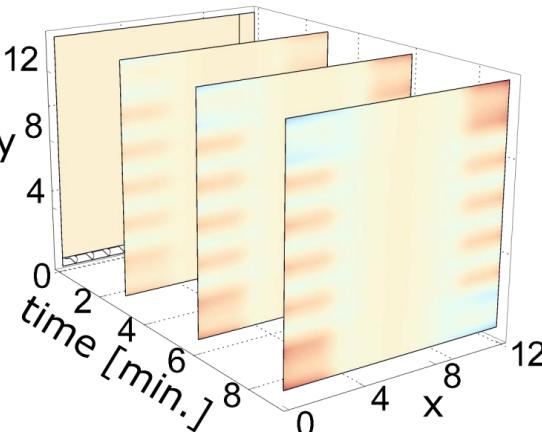
arXiv:2012.14496

trivial circuit \longleftrightarrow topological circuit

experiments



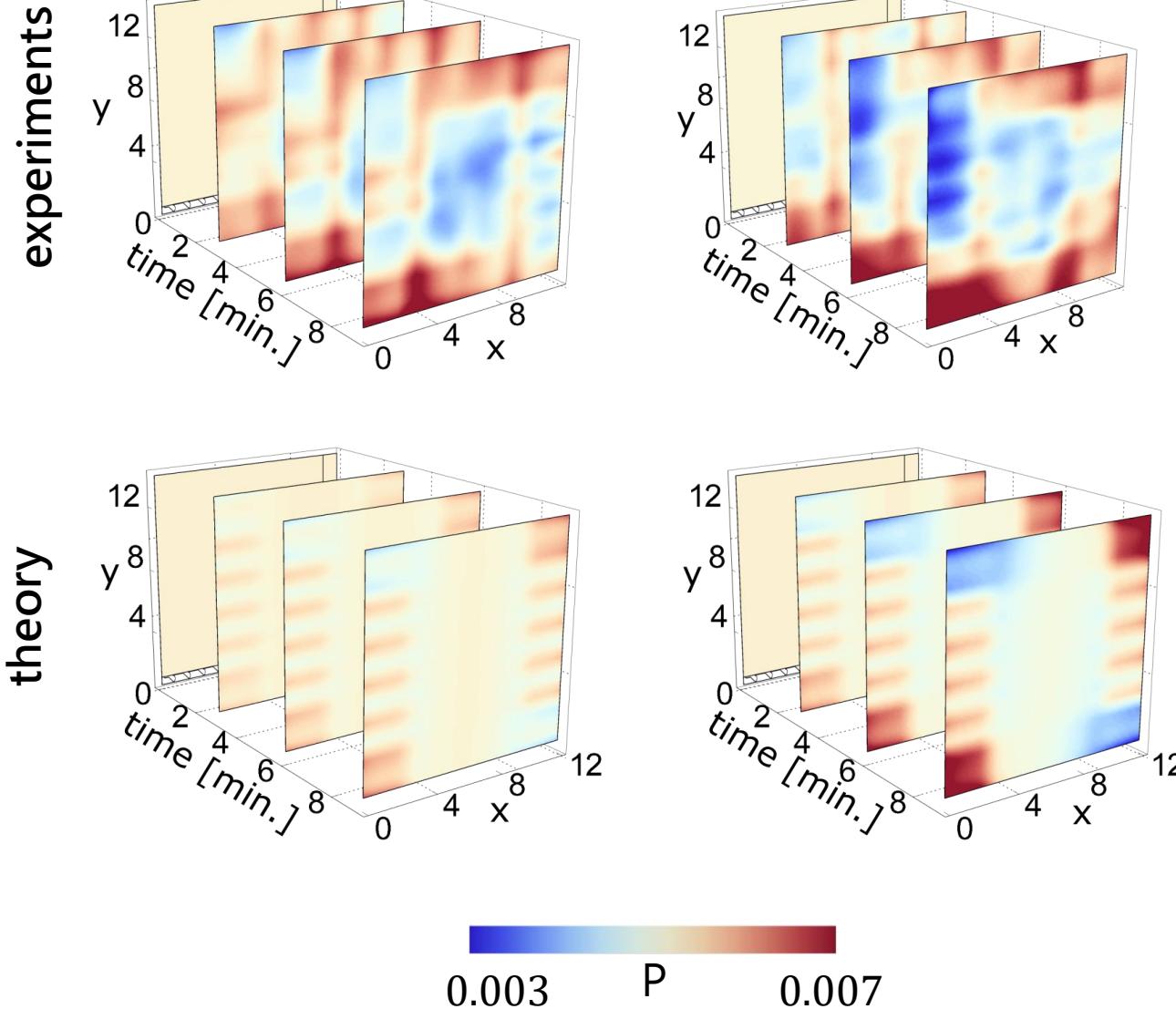
theory



Active particles accumulate at the corners

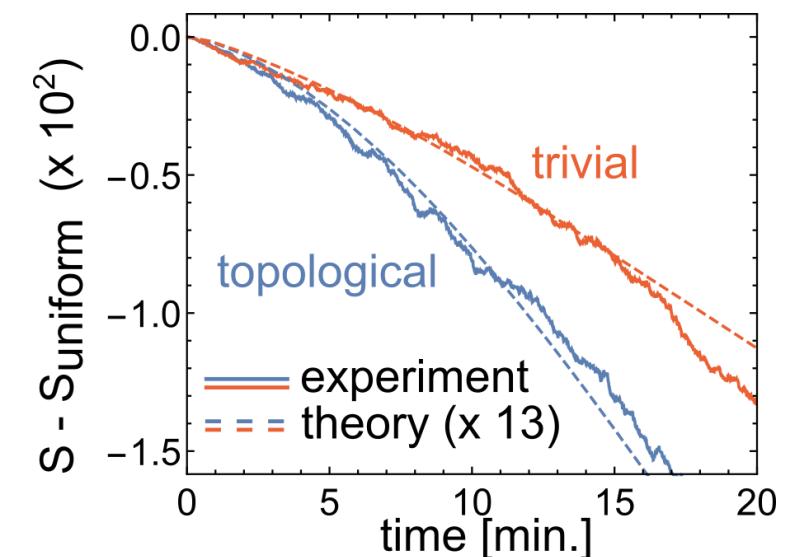
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trivial circuit \longleftrightarrow topological circuit



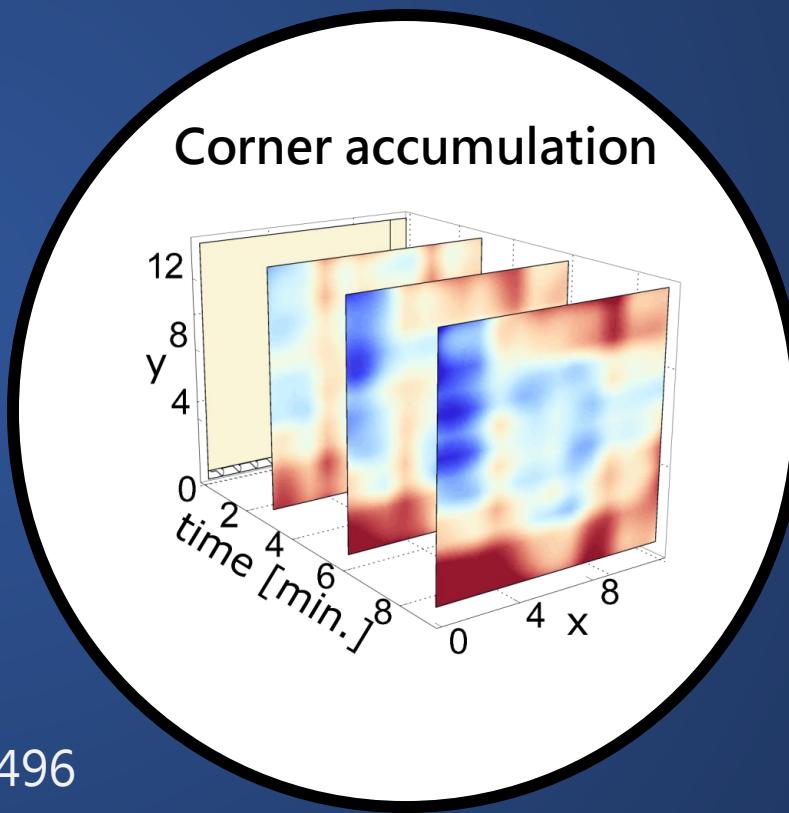
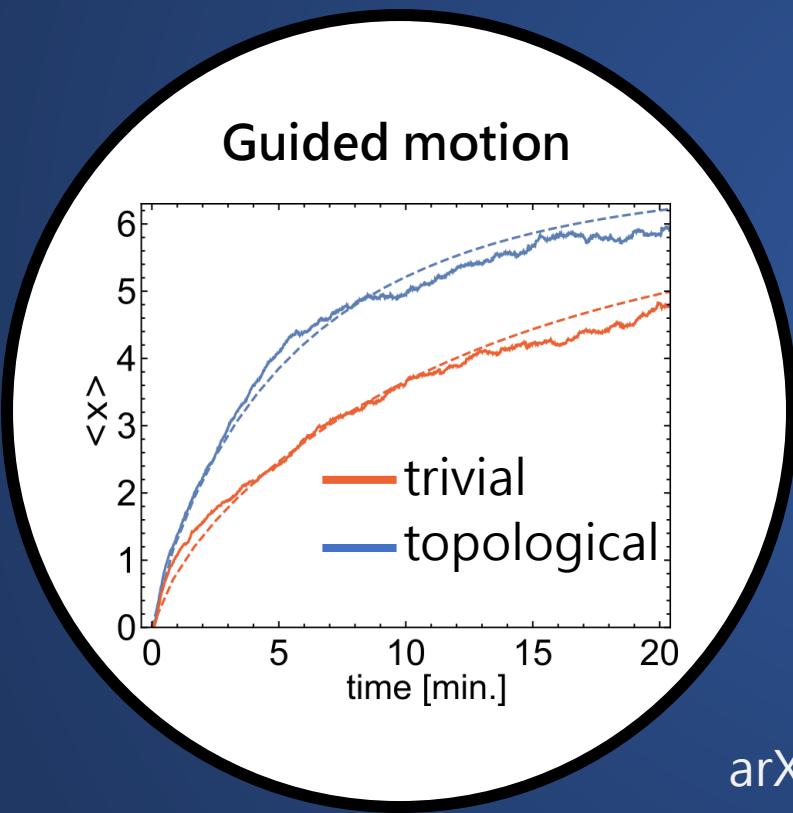
Shannon entropy

$$S = - \sum_x P(x) \ln P(x)$$



Guided accumulation of active particles by topological design of a second-order skin effect

L. S. Palacios, S. Tchoumakov, M. Guix, I. Pagonabarraga, S. Sánchez and A. G. Grushin



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