Non-Hermitian Skin Effect and Electronic Nonlocal Transport

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Non-Hermitian physics: just a new perspective

Lead $\xrightarrow{\Gamma}$ Central

$$H_L \to g_L = \frac{1}{\omega - H_L} \to \Sigma = \Gamma^\dagger g_L \Gamma$$

$$H_C \to G = \frac{1}{\omega - H_C - \Sigma}$$

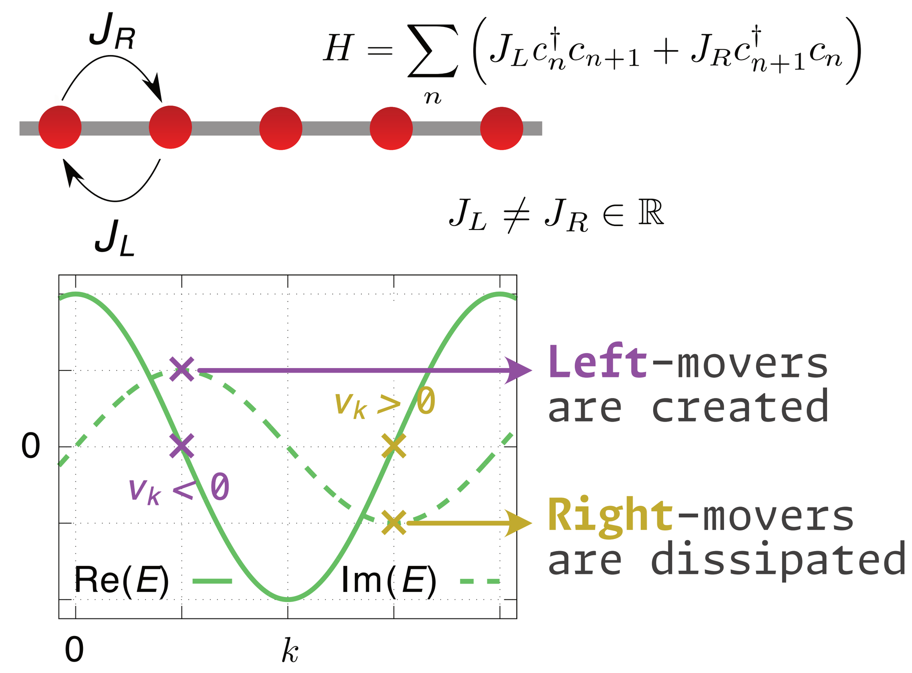
$$\Sigma = \Sigma(\omega = 0) \Rightarrow \boxed{H_{\text{eff}} = H_C + \Sigma \text{ is non-Hermitian!}}$$

Topology of H_C includes symmetries of Central
Topology of H_{eff} includes symmetries of the whole system!

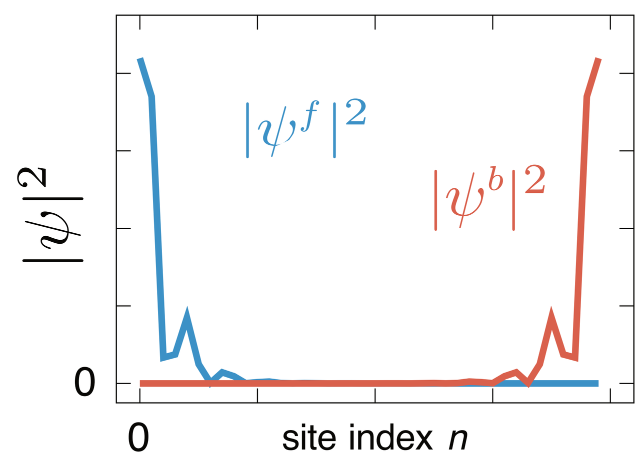
Non-Hermitian Skin Effect

Gohsrich *et al*, EPL 150, 60001 (2025)

Hatano-Nelson model:

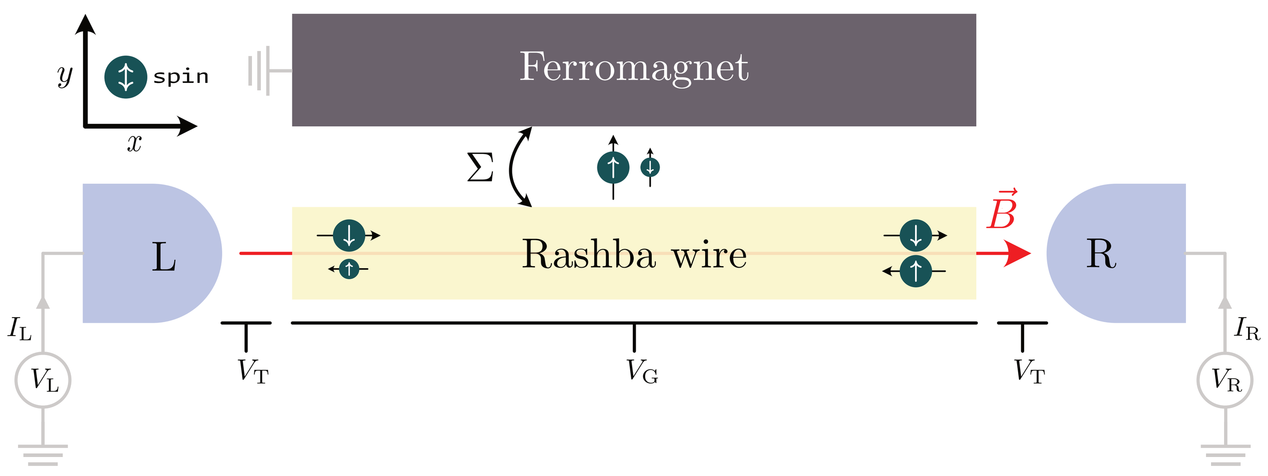


$H\,|\psi^f\rangle = E\,|\psi^f\rangle$
$\langle\psi^b|\,H = \langle\psi^b|\,E$ $\quad \langle\psi_m^b|\psi_n^f\rangle = \delta_{mn}$

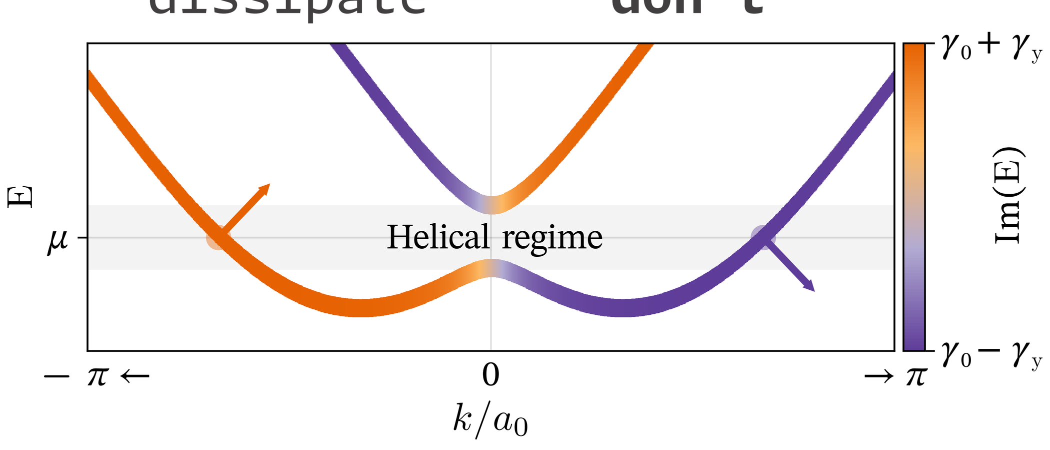


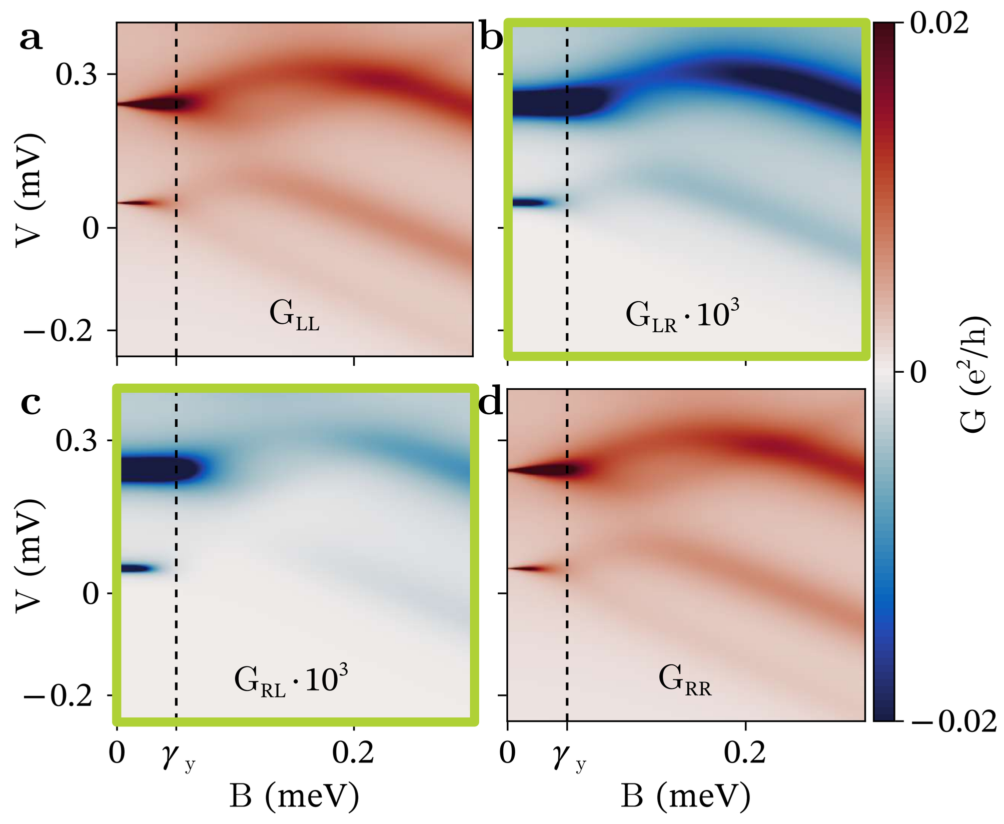
NH Skin Effect:
Forwards (backwards) eigenstates localize on the left (right) side

Hybrid semi-ferro wire: nonreciprocal conductance



Left-movers dissipate
Right-movers **don't**





Spin-dependent dissipation + Spin-momentum locking = Directional dissipation

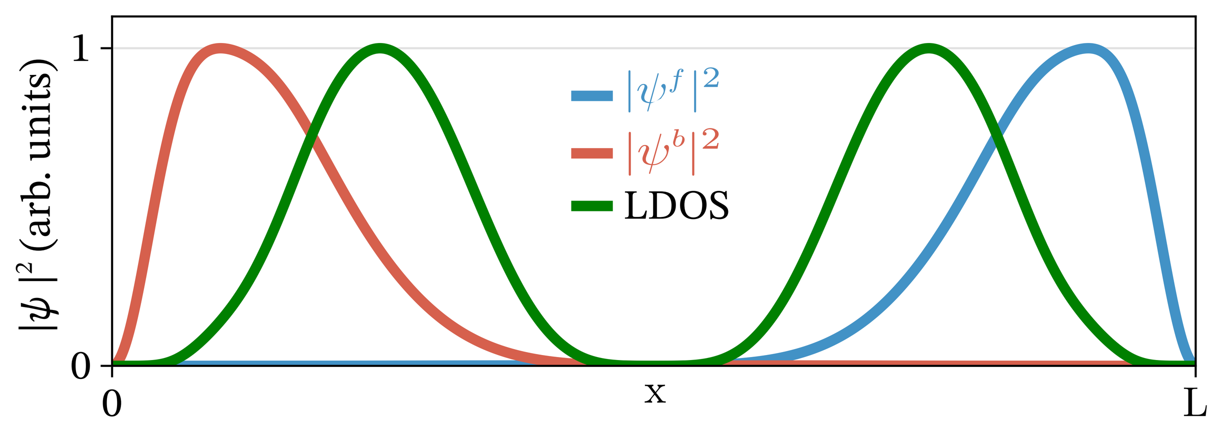
Nonreciprocal conductance is a manifestation of the NH Skin Effect

Rashba Hamiltonian

$$H = \frac{p_x^2}{2m^*} - \mu + \alpha p_x \sigma_y + B\sigma_x$$

Minimal ferromagnet

$$\Sigma = -i\left(\gamma_0 + \gamma_y \sigma_y\right)$$



LDOS is symmetric
Eigenstates are not: **Skin Effect**

Nonreciprocal conductance in terms of forwards-backwards eigenstates

Green's function in biorthogonal basis:

$$G^{\mathrm{R}}(\omega) = \sum_n \frac{|\psi_n^f\rangle\langle\psi_n^b|}{\omega - E_n}$$

$$G_{\alpha\alpha} \sim \mathrm{Im} \sum_n \frac{\langle\psi_n^b|x_\alpha|\psi_n^f\rangle}{(eV - E_n)}$$

Insensitive to localization

$G_{\alpha\alpha}$ is symmetric

$$G_{\alpha\beta} \sim \mathrm{Re} \sum_{nm} \frac{\langle\psi_n^b|x_\beta|\psi_m^b\rangle\,\langle\psi_m^f|x_\alpha|\psi_n^f\rangle}{(eV - E_n)(eV - E_m^*)}$$

Sensitive to localization

$G_{\alpha\beta}$ is nonreciprocal

A non-Hermitian topological phase transition

H_{eff} is in class AI

2-band model: $\mathbb{Z}_2$ invariant

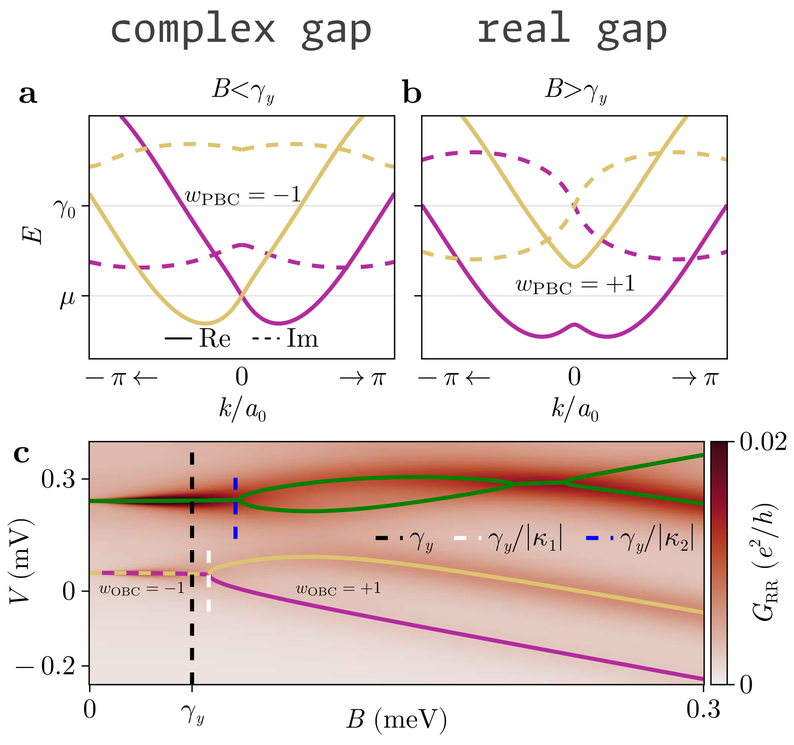
$$w_{\text{PBC}} = \text{sign}\left(B^2 - \gamma_y^2\right)$$

with **P**eriodic **B**oundary **C**onditions

This topological phase transition is an **Exceptional Point** (**black** line)

In the conductance calculation, Exceptional Points (**blue** and **white** lines) are **shifted** due to the change to **O**pen **B**oundary **C**onditions

Phase I: complex gap · Phase II: real gap



Conclusions

1. The **non-Hermitian skin effect** is the **localization** of eigenstates of non-Hermitian *effective* Hamiltonians characterizing **open** quantum systems.
2. A **Rashba** nanowire coupled to a **ferromagnet** exhibits **symmetric local conductance** and **nonreciprocal nonlocal conductance**. It is a **manifestation of the non-Hermitian skin effect**.
3. Our results establish **transport spectroscopy** as a tool to probe **non-Hermitian effects** in open electronic systems.

Full paper:

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