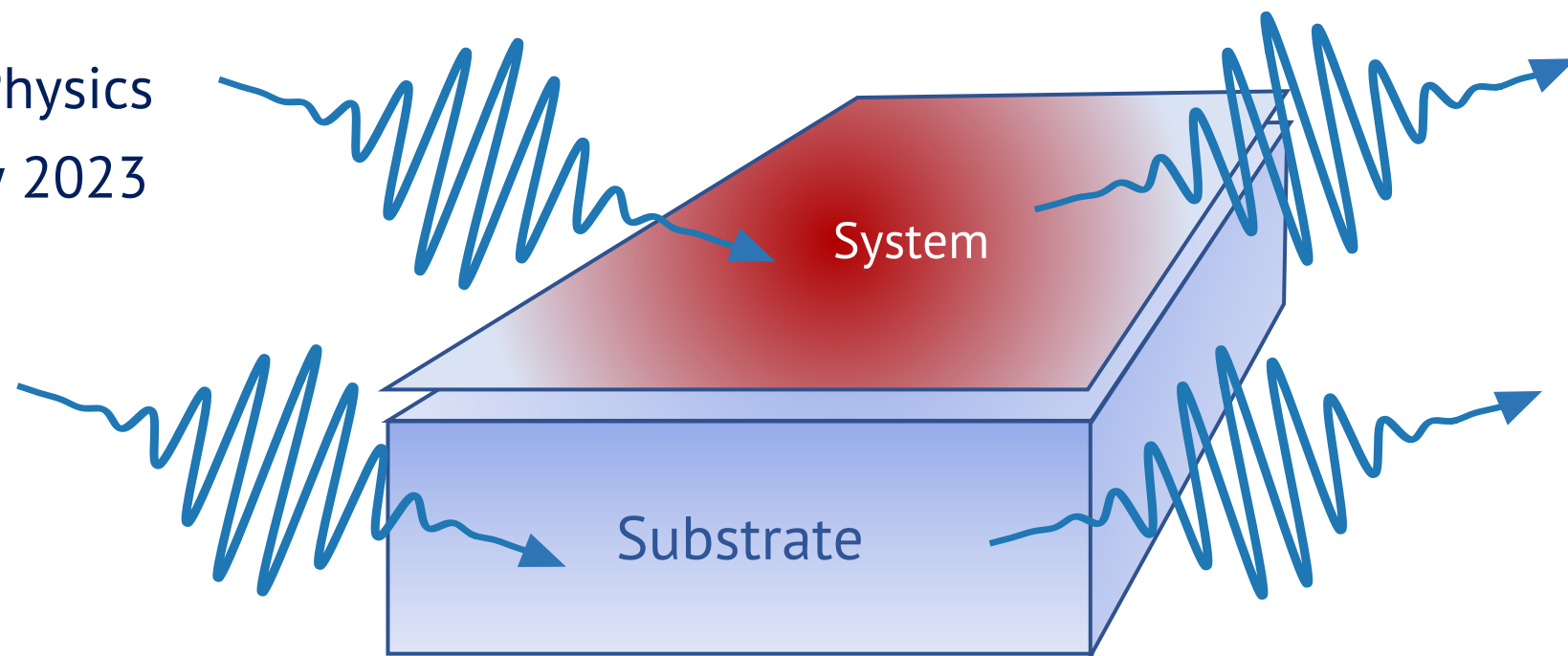


# Driving the Dark State: The Bloch Ness Monster

Spenser Talkington • UPenn Physics  
Graduate Student Visiting Day 2023  
24 March 2023



# How Do We Characterize Civilization?

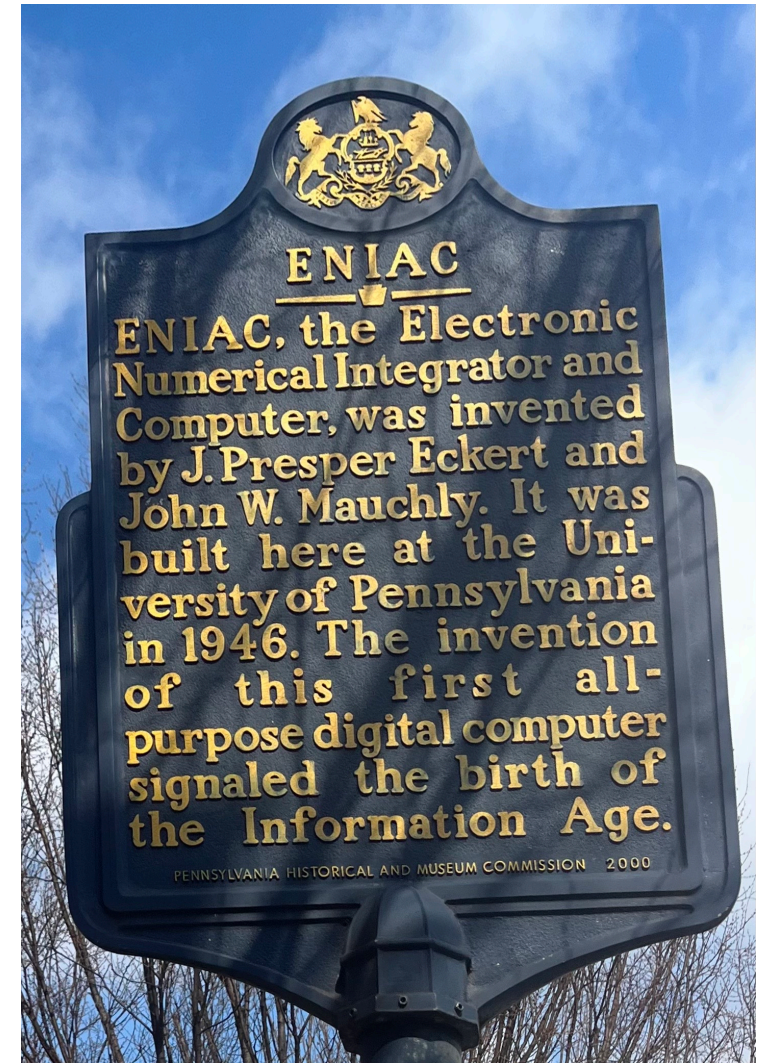
- With Ages
  - Stone Age
  - Bronze Age
  - Iron Age
  - Silicon Age



- Control over the structure and properties of materials changes the standard of living

# Can We Control Materials?

- Modern life is enabled by digital devices
- The first general-purpose digital computer was made at Penn
- The enormous growth from there was made by mastering the physics of silicon
- Quantum Mechanics governs the properties of materials

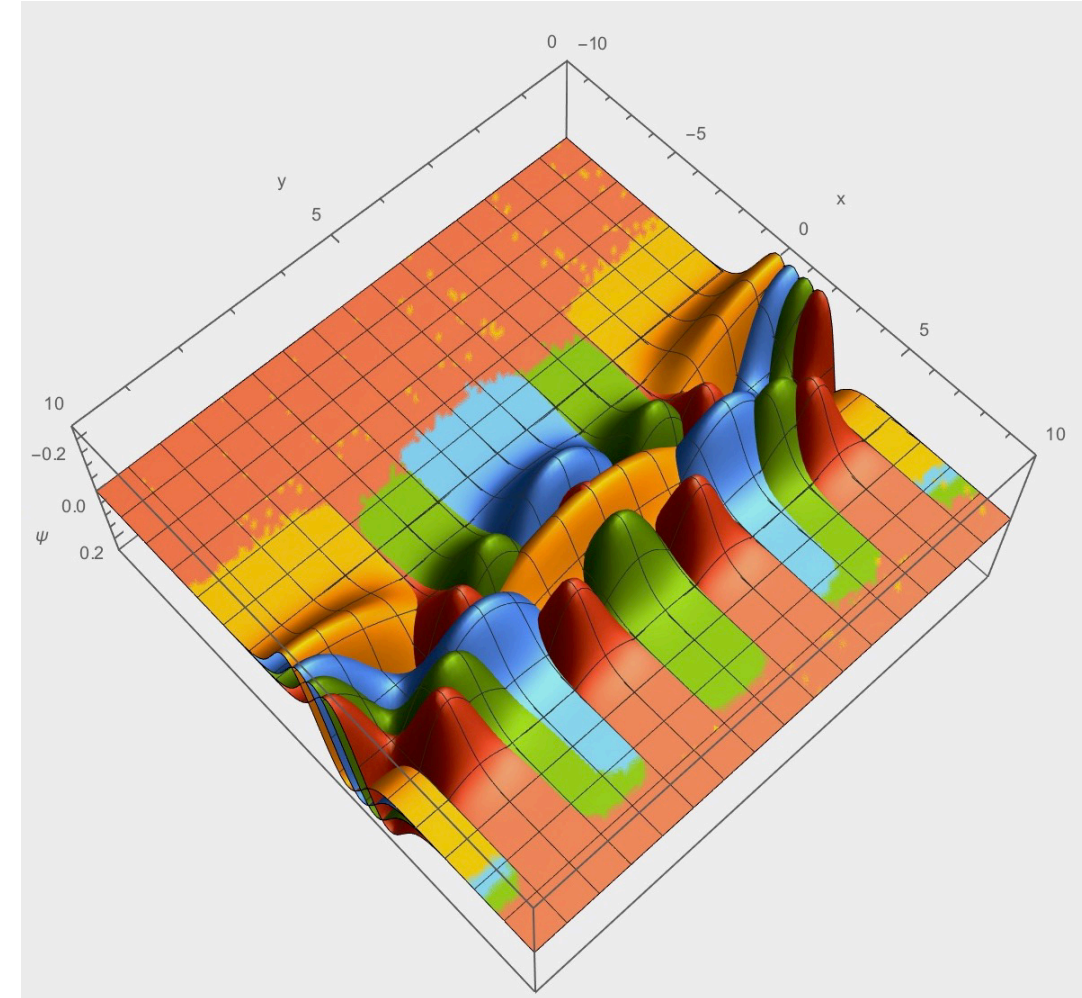




# What does Quantum Mechanics give us?

1

- Single particle
  - Stone, Bronze, Iron, Silicon
  - Topology, *a la* Kane and Mele (Penn)
- Many particle
  - Superconductivity, *a la* Schrieffer (Penn)
  - Quantum computers
  - Simulations of real molecules
- This isn't all there is: the systems we want to consider are usually not isolated from their environment





# What is Ness?

- We need to consider dissipation!
- In equilibrium we have

$$\rho_{\text{eq}} = \frac{e^{-\beta H}}{\text{Tr}(e^{-\beta H})}$$



- In non-equilibrium systems consider the long-time steady state (NESS)

$$\frac{d\rho_{\text{ss}}}{dt} = 0$$

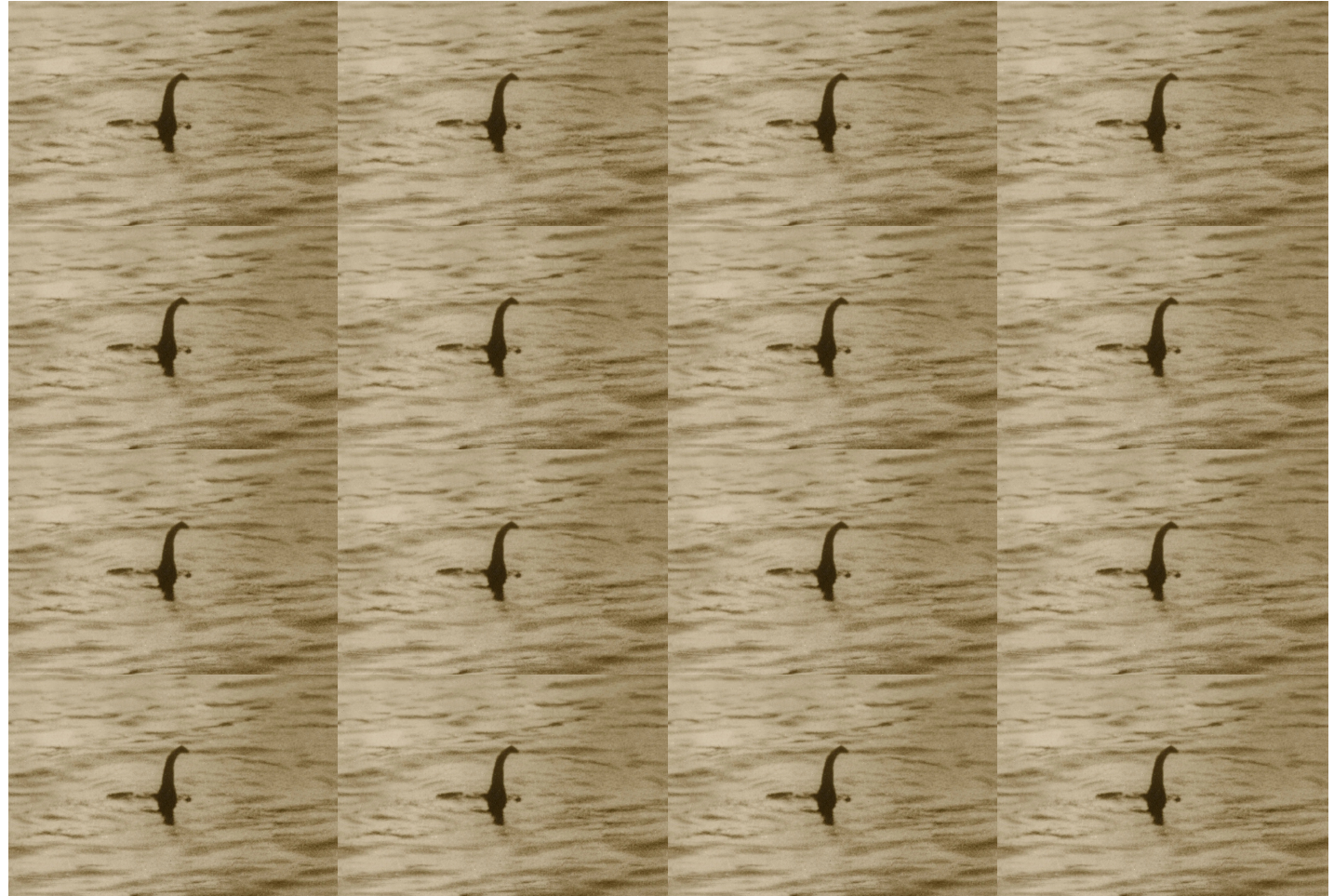


# What is Bloch?

- In quantum matter we consider systems with many degrees of freedom
- How to simplify?
  - Use symmetry
- Discrete translations

$$\psi(\mathbf{x}) = e^{i\mathbf{k}\cdot\mathbf{x}} u(\mathbf{x})$$

- For periodic  $u(\mathbf{x})$
- Bloch's theorem



# Is Nessy Boring?

- The vacuum can be a NESS

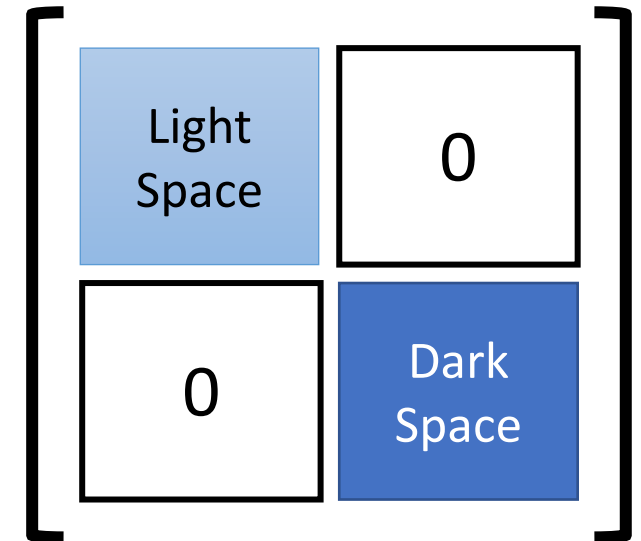
$$\frac{d|\text{vac}\rangle\langle\text{vac}|}{dt} = 0$$

- Does dissipative time evolution lead you there?
- Not necessarily!
- Long lived dark states can evade the vacuum

Monster vacuum



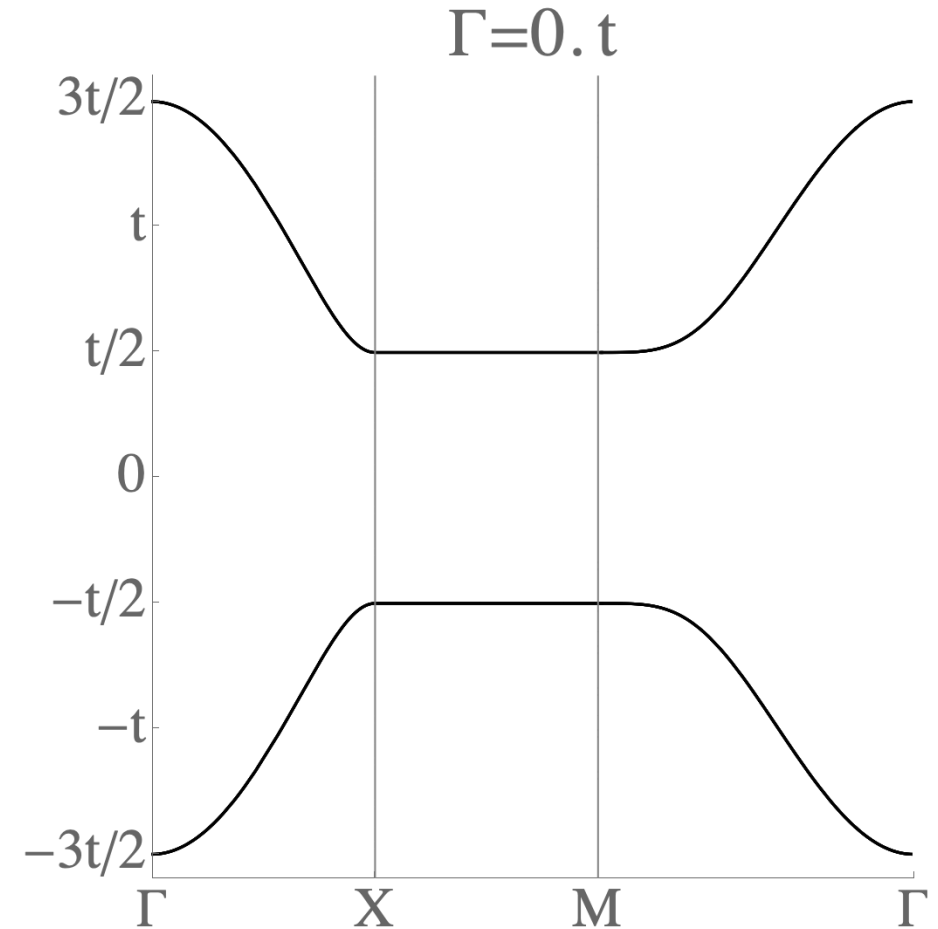
Monster





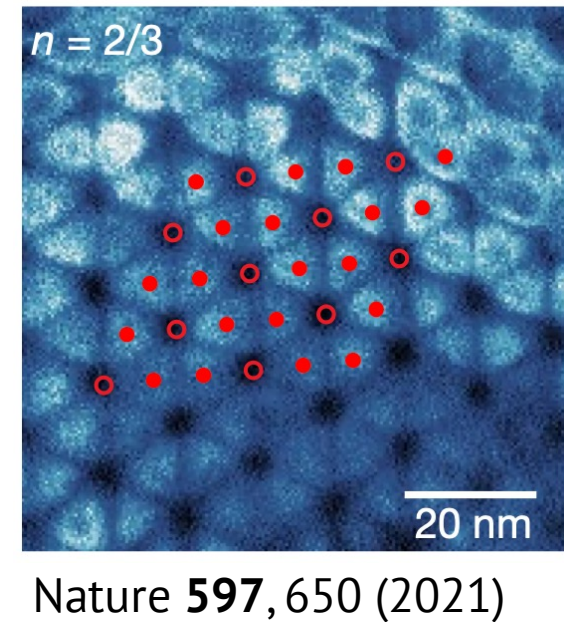
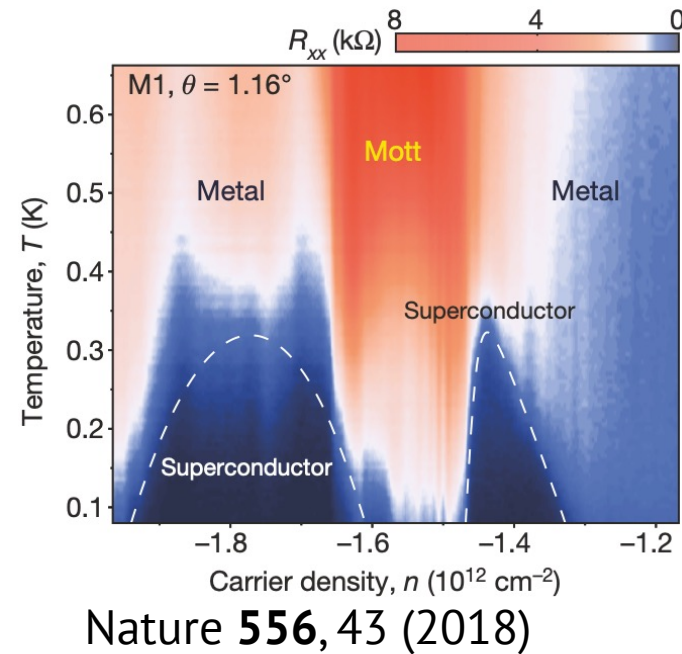
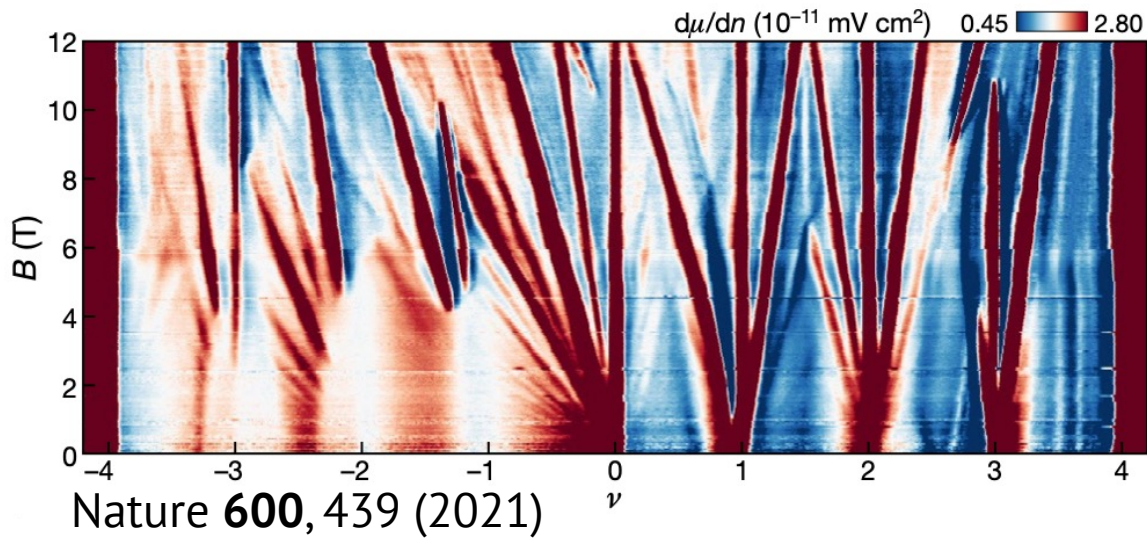
# Is Bloch Ness Magical or Just Mythical?

- Non-equilibrium steady states can be dominated by flat band dark states
- Example
  - QWZ model of a 2D Chern insulator
  - Couple to a superconducting substrate
- Our previous work
  - Long lived flat bands form in the dark space of the dissipation operator
  - Derived symmetry-based conditions for the existence of long-lived flat bands
  - PRB **106**, 161109 (2022)



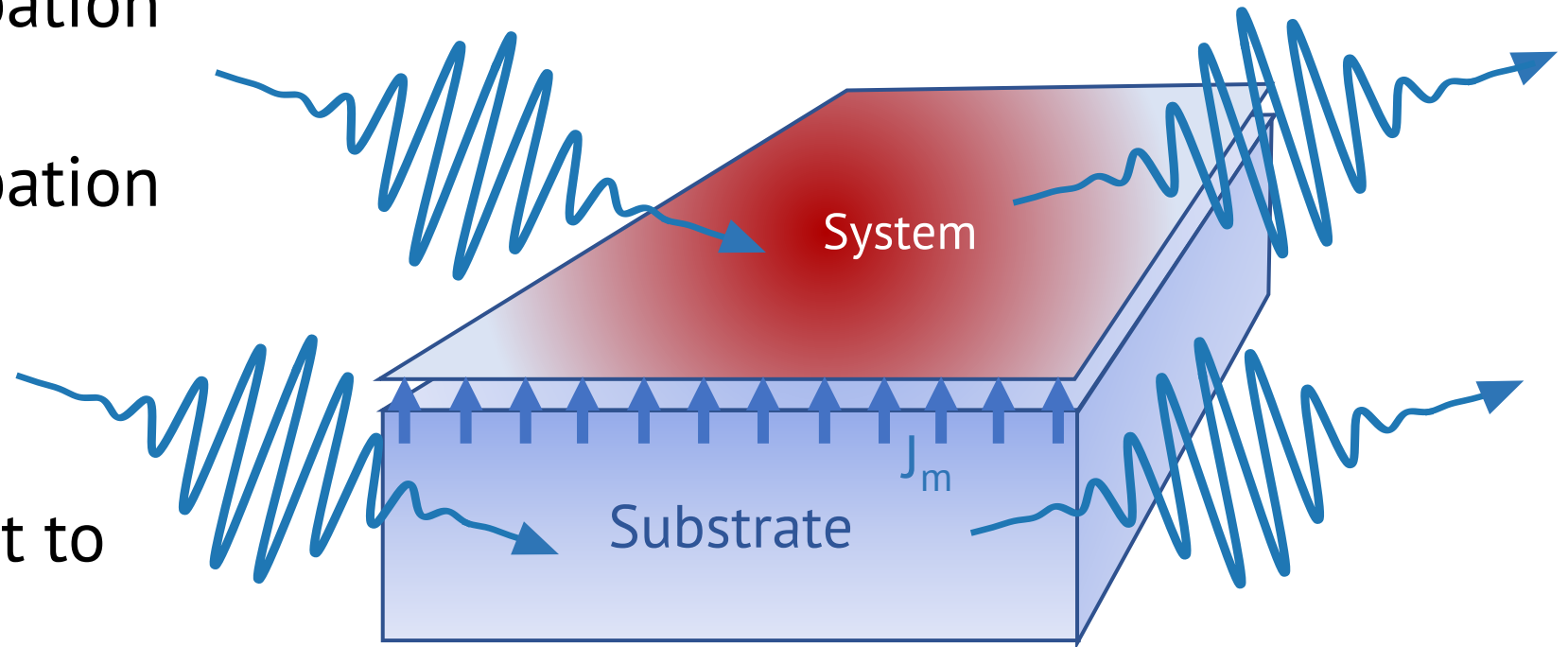
# What's Magical About Flat Bands?

- Dominant Coulomb Interaction + Fractional Filling = Interesting Physics
  - Fractionalized states
  - Superconductivity
  - Charge orders
  - And more!



# What's the Response?

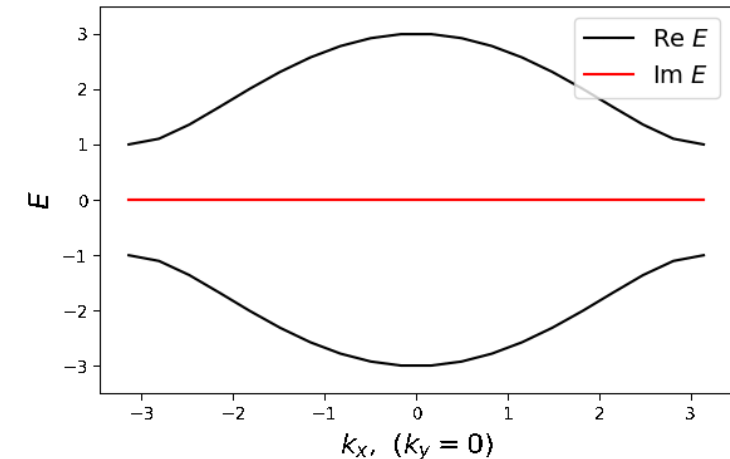
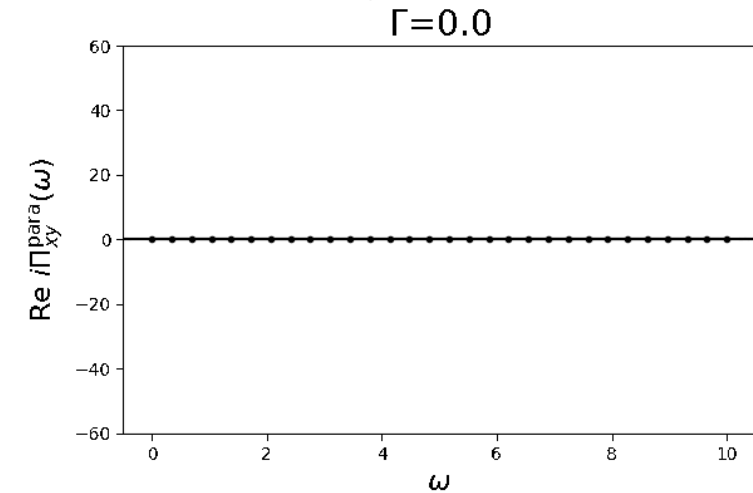
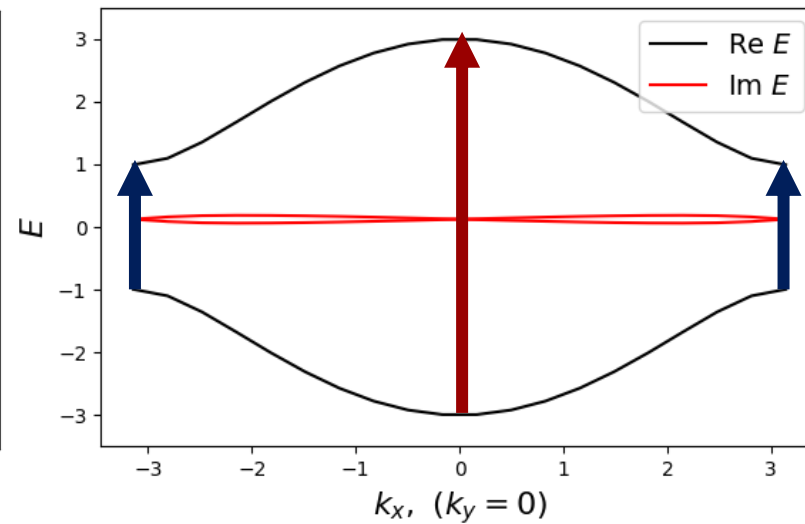
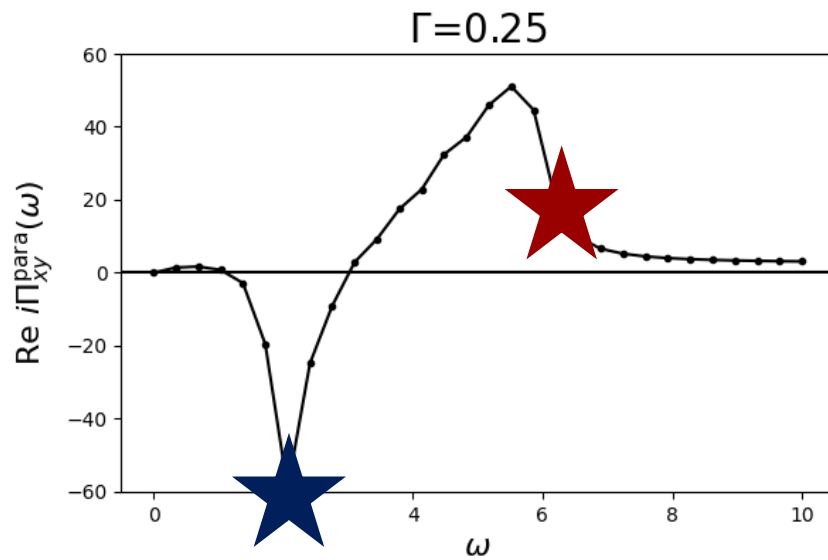
- System to perturbation
- System to perturbation and substrate
- System to perturbation and substrate to perturbation
- Response isn't just to  $H^{\text{NH}}$ , but also the substrate (integrated out to give jumps  $J_m$ )





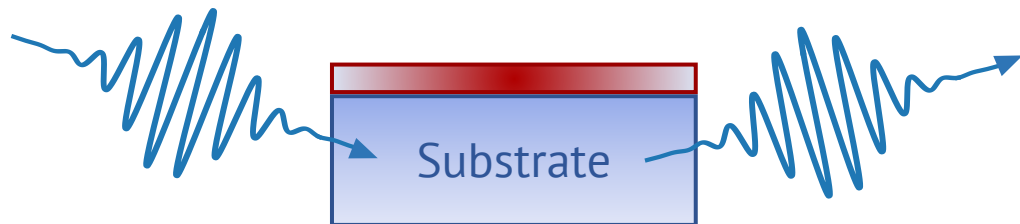
# How Does Nussy Respond to Driving?

- Model with non-zero Chern number for the closed system
- $\sigma_{xy}(0)$  vanishes for open system!
  - Steady state  $\neq$  equilibrium



## Bloch Ness Monster

- Lives in Fermi Sea
- Periodic behavior
- Subject to dissipation
- Flat band magic
- Drive with EM fields



## Loch Ness Monster

- Lives in Loch Ness
- Periodic sightings
- Dissipating likelihood
- Mythical creature
- Drive with remote control



# Why UPenn?

- Professional Development
  - Links to other programs: engineering, chemistry, Wharton
- Quality of Life
  - People are nice
  - Less competition
  - No comp exam
- Ego
  - Top 15 physics PhD program
  - It's an Ivy league school





# Why Philadelphia?

- Size and Location
  - It's a big city (sixth largest in US)
    - But easy to get around
  - An hour train ride from NYC and DC
- Activities
  - Good food
  - Famous museums
  - Good sports teams
  - Largest urban park in US
- You're a grad student
  - The cost of living is low





# Feel free to reach out

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