

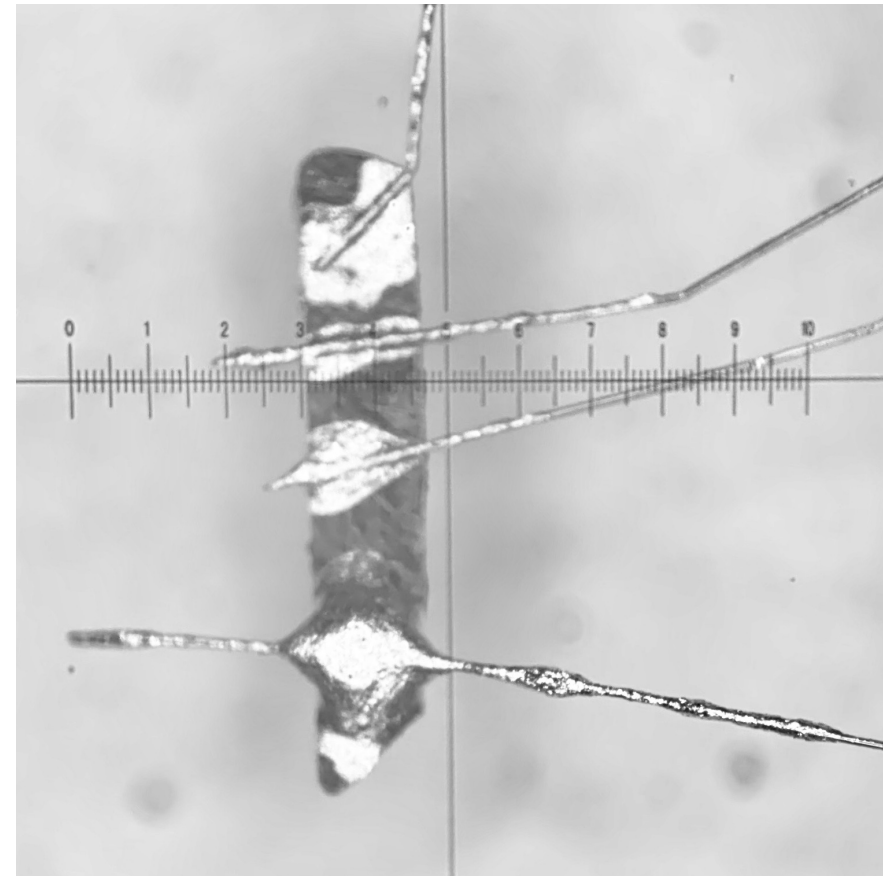
Magic Without a Twist

The Dark Space

Spenser Talkington • UPenn Physics Department

Darkness

- The goal of a PhD is to shed light on a topic
 - New materials enable higher quality life
 - I'm working to illuminate the physics of the Dark Space for the control and discovery of new materials with exotic properties
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- *“Darkness cannot drive out darkness: only light can do that.”*
 - Martin Luther King Jr.



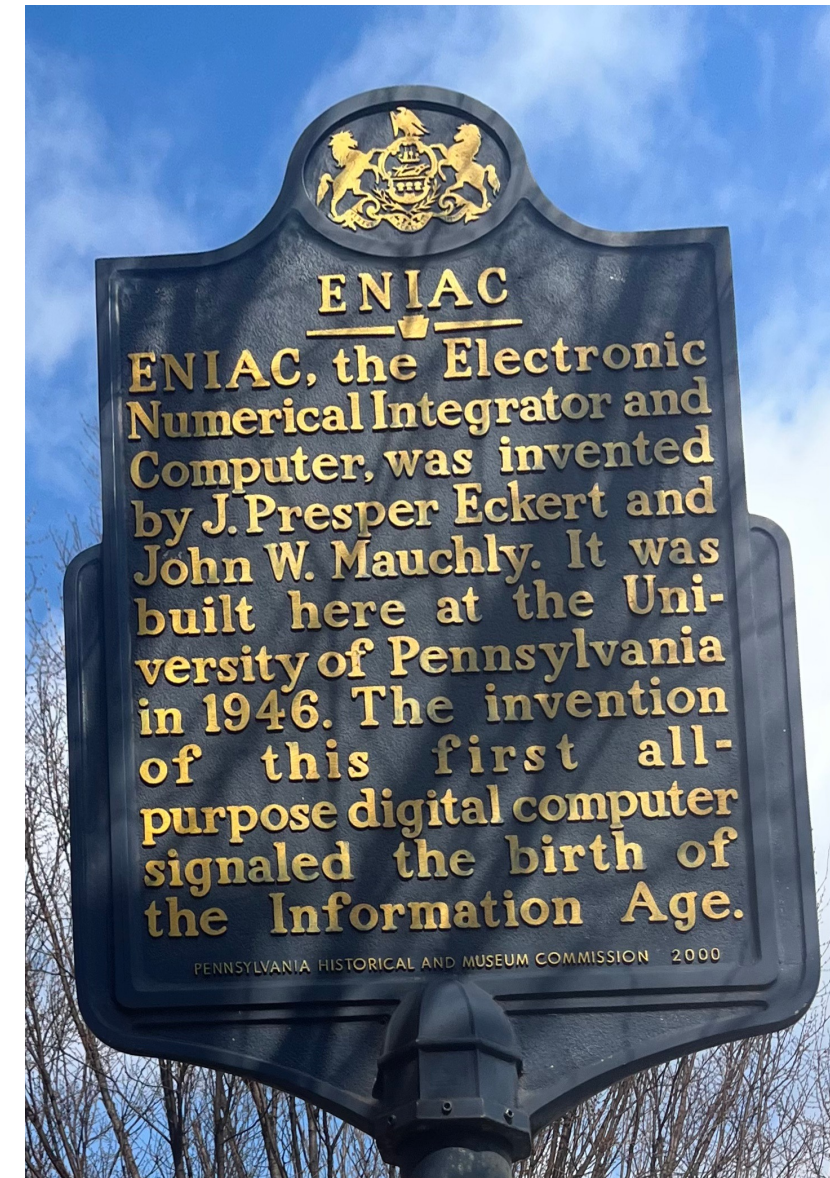
The Ages

- Stone Age
 - Bronze Age
 - Iron Age
 - Silicon Age
- Control over the structure and properties of materials changes the standard of living



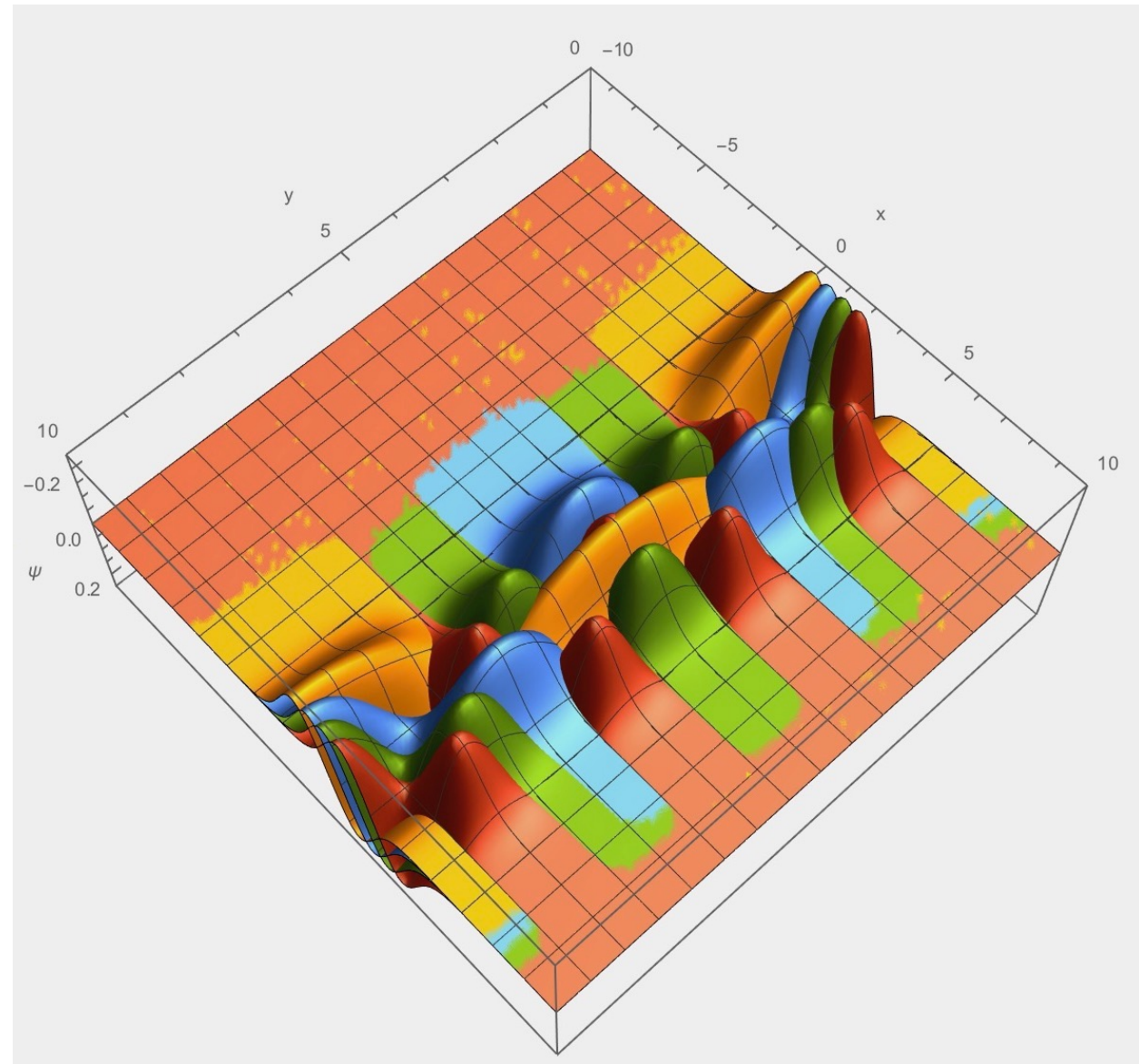
Control Over Materials

- 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



What's Next

- Quantum Mechanics governs the properties of materials
- Single particle
 - Stone, Bronze, Iron, Silicon
 - Topology, *a la* Kane and Mele
- Many particle
 - Superconductivity, *a la* Schrieffer
 - Quantum computers
 - Simulations of real molecules

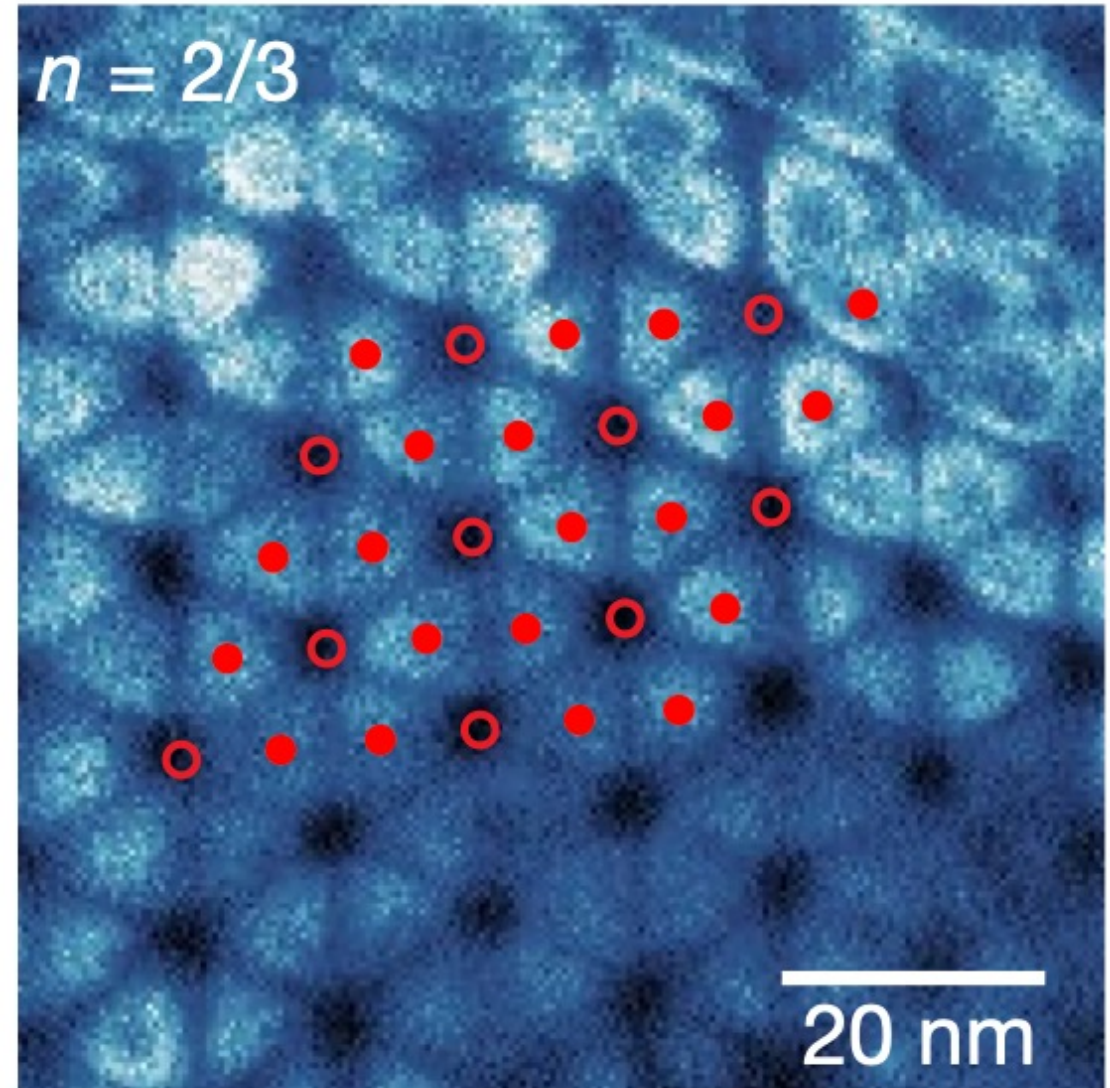


The Magic of Flat Bands

- Electrons live in quantized energy states, where states with different momenta form a band

$$\text{Energy} = E_{\text{Kinetic}} + E_{\text{Potential}}$$

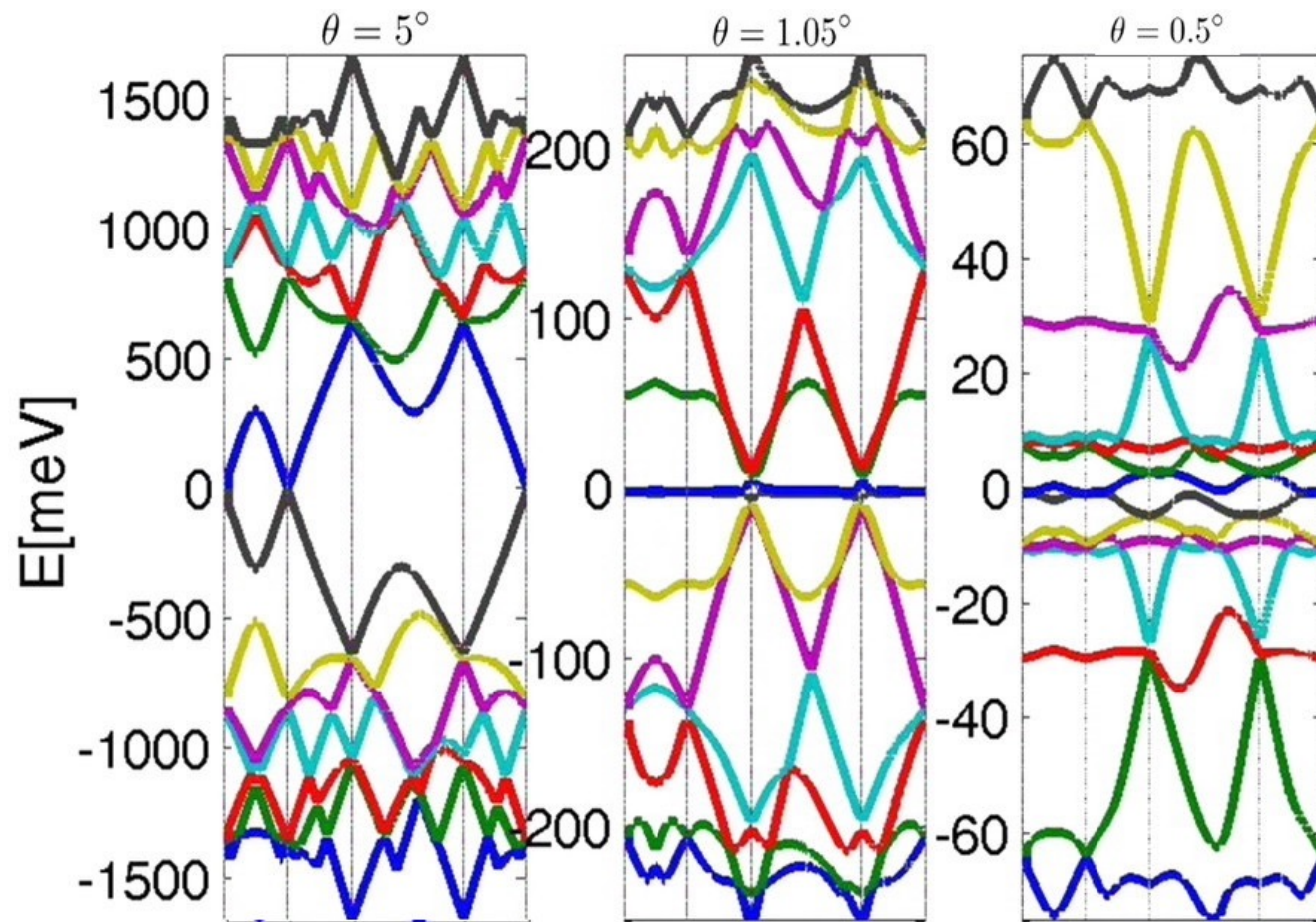
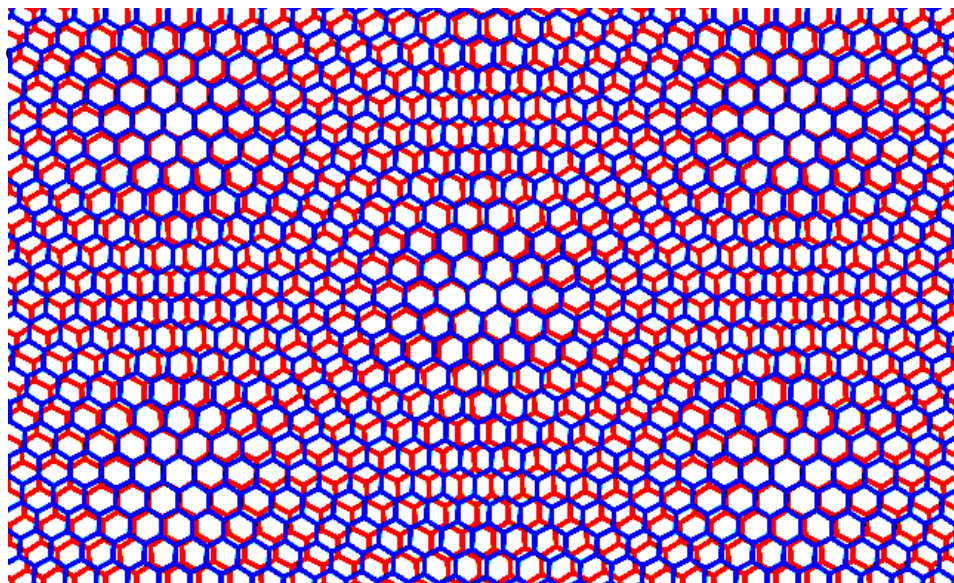
- Usually $E_{\text{Kinetic}} = \frac{1}{2}mv^2$ but when it is zero, magic ensues:
 - Fractionalized states
 - Superconductivity
 - Magnetic and charge orders



Nature 597, 650 (2021)

Controlling Magic

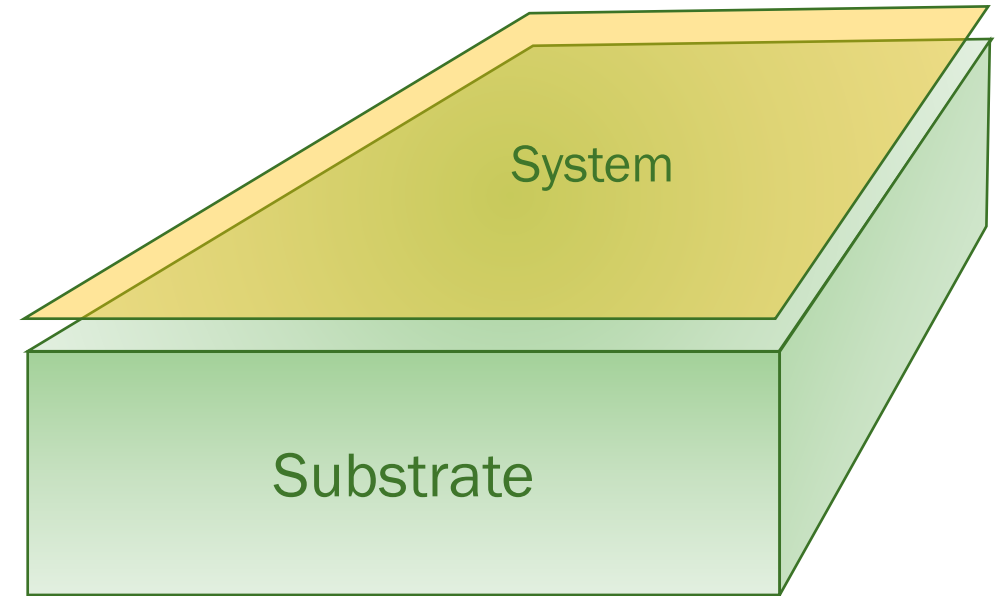
- Control over two dimensional materials has emerged over the last decade



PNAS 108, 12233 (2011)

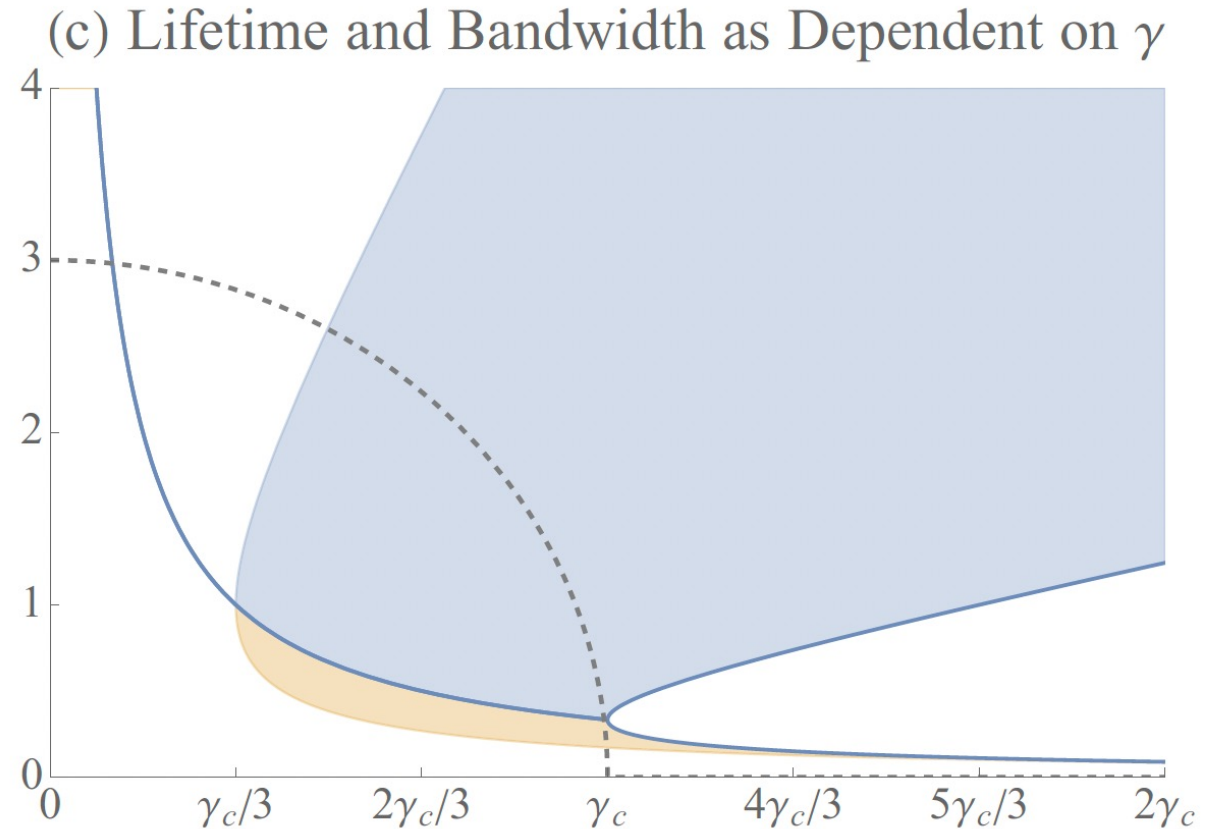
The Dark Space

- Twist angles are messy and unreliable
- Other pathways to controlling flat bands
- Open quantum systems
 - What is it on top of?
 - Leads to gain, loss, and decoherence
- The *Dark Space* are states which are immune to gain, loss and decoherence



Magic in the Dark Space

- Long lived flat bands can form in the dark space of coupling to a superconductor
- Work with M. Claassen
 - Generic conditions for the formation of long-lived flat bands
- Next step: potential energy and many particle physics



PRB 106, 161109 (2022)

The Frontier

- Mastering materials improves our lives
- We have mastered materials governed by single particle quantum mechanics
- There is much to learn and master in many particle quantum mechanics
 - The Dark Space may provide a way to clarify and control the exotic Magic in many particle quantum systems with flat-bands

