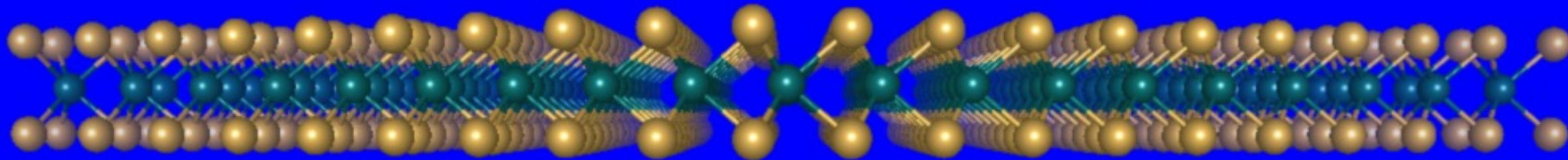


# Two-dimensional excitonic insulators

@ CMD30 - FisMat2023



**MiniColloquium at the  
Conference of the Condensed Matter Division  
of the European Physical Society**

**4 - 8 September 2023  
Politecnico, Milano, Italy**

<https://eventi.cnism.it/cmd30-fismat>

# WTe<sub>2</sub>

- Experimental data
  - Cusp in conductivity
  - Jump in chemical potential
  - Collapse of STM gap with doping
  - Lack of universal CDW
  - Movement of bands in ARPES
- Theoretical picture
  - Monolayer – possible spin density wave
  - Bilayer- emerging model
  - Anomalous plasmon dispersions

# Bilayers and quantum wells

- Evidence of correlated phases in moiré graphene heterostructures
- Mapping BEC-BCS regime in graphene heterostructures
- Dissipationless transport in graphene heterostructures
- Checkerboard insulators in quantum wells- with future work to attain a supersolid phase

# Correlated phases in TMD heterostructures

- Mott-Hubbard insulators
- Zoo of correlated phase diagrams in TMD heterostructures
  - Exciton sensor, polaron sensing
- Relation between trions and g-factors in TMD heterostructures
- Exciton-polariton systems as a platform to explore non-reciprocal phase transitions

# Ta<sub>2</sub>NiSe<sub>5</sub>

- Experimental data illustrating role of electronic correlations in driving phase transition
- Theoretical models capturing system
  - Describe new ways to interpret different gap measurements from experiments
  - Proposals for role of collective modes in determining quantitative chicken and egg problem
- Discussion of how different broken symmetries contribute to an EI

# Theory proposals

- Importance of role of screening
- Routes for using high throughput to identify EI candidates
- Proposals for topological excitonic insulators
- Role of disorder in EI collective modes
- Experimental probes to determine EI phases
  - Destruction of EI
  - Josephson junction
  - Exciton-polarons

# Where are we now?

- New possibilities for topological excitonic insulators
- New dimensions of control
  - Layer stacking
  - Moiré
- New dimensions of control and sensitivity
  - Experimental control: optical properties
  - Role of gating: what is an excitonic insulator in the presence of free carriers?
  - ??

---

# Questions I

- Is it possible to have a CDW that does not couple to the lattice?
- Could bilayer graphene be an overlooked EI?
- What are important parameters to screen for in theory searches for new EI candidates?
- Is there a scenario where an EI could have real-world applications?



# Questions II

- What are experimental probes for superfluidity?
  - Counterflow
  - Josephson junctions
  - Coherence in optical emission
  - Collective modes
  - Nonequilibrium probes
  - Compressibility
  - Thermal transport/second sound
- Limits: poor contacts, ground-state physics, quadrupole symmetries, excitons with finite  $q$ ....

---

# Questions III

- How does a topological EI differ from topologically trivial EI?
- How can one create a taxonomy of different EI phases – to clearly distinguish what properties one could expect to see in different phases?