北京航空航天大學
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Research Summary

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Outline

- Higher-order Topology in Graphyne Families

Binbin Liu et al., Phys. Rev. B 106, 035153 (2022).
Xu-Tao Zeng, **Binbin Liu,** et al., arXiv: 2302.13090. (Submitted to PRB.)

- Non-centered Inversion Symmetry in Momentum Space

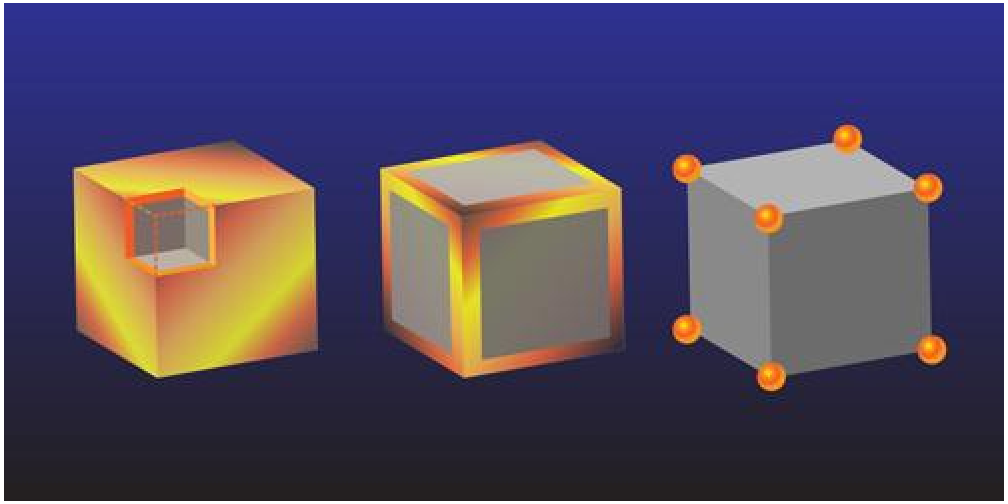
Binbin Liu†, et al. (To be submitted to PRL.)

- Large Bilinear Magnetoresistance (BMR) from Rashba Spin-Splitting on the Surface of a Topological Insulator

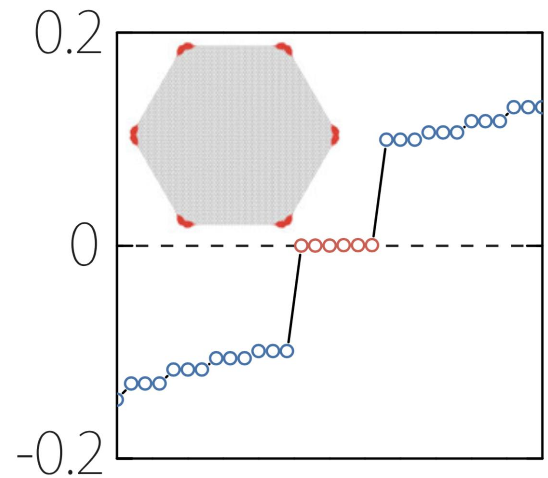
Wang Yang*, **Binbin Liu*,** et al., Phys. Rev. B 106, L241401 (2022).

Higher-order Topology in Graphyne Families

Introduction



3D Higher-order TI



2D Second-order TI

Real Chern number (PT)

$$(-1)^{\nu_R} = \prod_{i=1}^{4} (-1)^{\lfloor (n_-^{\Gamma_i}/2) \rfloor}$$

Real Chern insulator / Stiefel - Whitney insulator

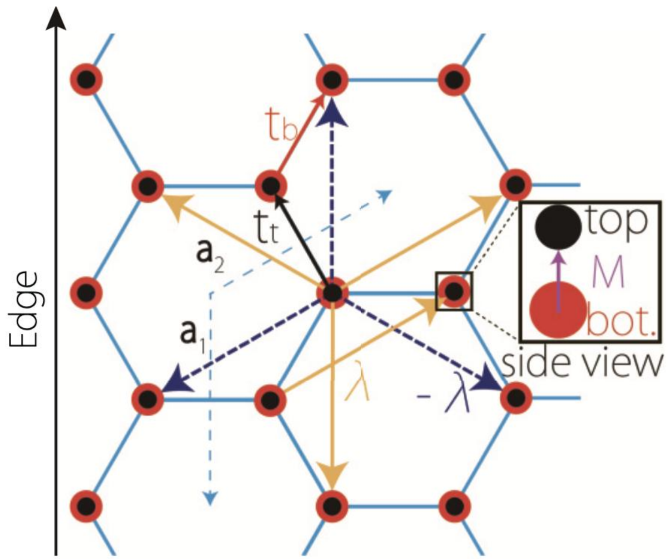
Fractional Charge (Crystalline)

$$Q^{(2)}_{corner} = \frac{e}{4}\left[-n^X_{C_2} - n^Y_{C_2} + \left(n^M_{C_2} + n^\Gamma_{C_2}\right)\right] \mod e$$

Quadrupole insulator / TCI

$$\boxed{C_{6z} \quad Q^{(2)}_{corner} = e\frac{\nu_R}{2}.}$$

SOTI models

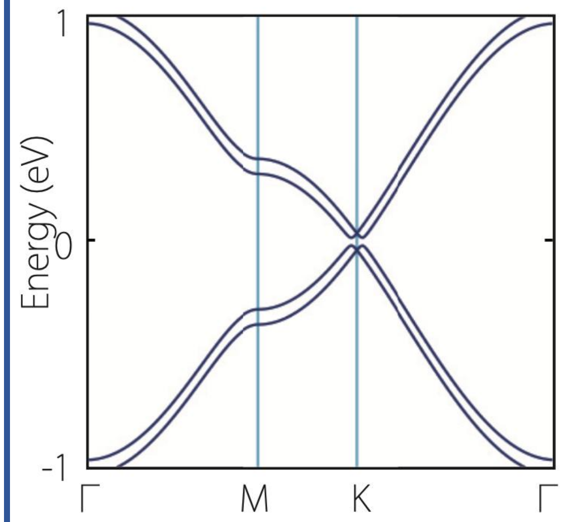


2D model

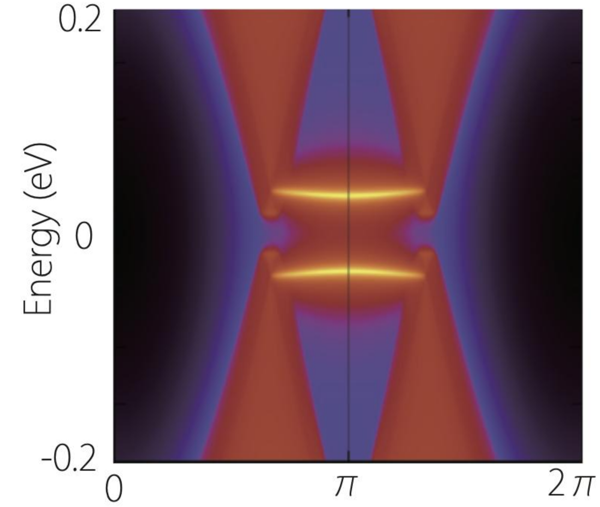
$$\mathcal{C}_{2z}\mathcal{T} \qquad \mathcal{C}_{6z} \text{ and } \mathcal{C}_{2y}$$

$$\nu_R = 1.$$

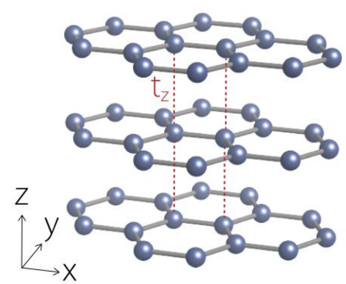
$$H^{\mathrm{4BTB}}(\mathbf{k}) = \begin{bmatrix} G_t & \boxed{M\sigma_0} + iS \\ \boxed{M\sigma_0} - iS & G_b \end{bmatrix}$$



Bulk bands



Edge spectra



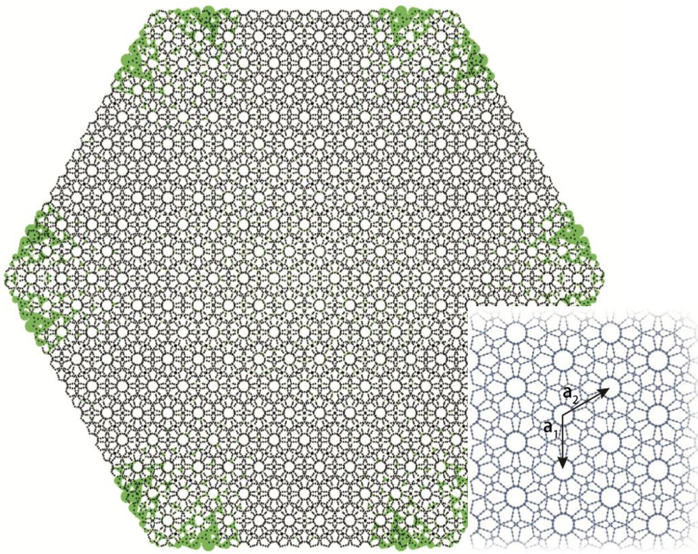
3D model

$$\mathcal{H}_{\mathrm{3D}} = \mathcal{H}_{\mathrm{2D}} + 2t_z \cos k_z \sigma_z \tau_0$$

Can be readily realized in **Graphyne families**!

SOTI in Graphyne Families

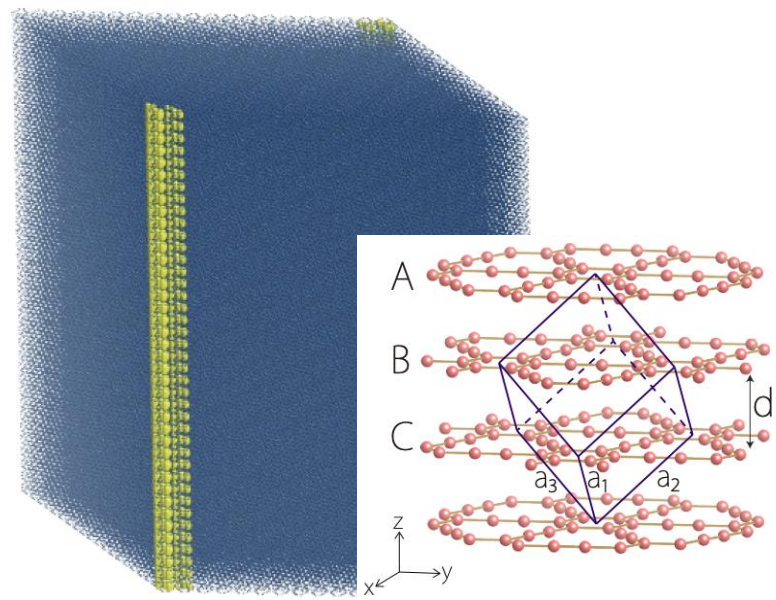
Moiré α-Graphyne (tbGPY)



General way to SOTI phase in moiré materials

B. Liu et al., Phys. Rev. B 106, 035153 (2022).

Bulk γ-Graphyne Nat. Synth. 1, 449 (2022).



The first 3D RCI material

X.-T. Zeng, **B. Liu,** et al., arXiv: 2302.13090.

2D SOTI & RCI: Graphdiyn(PRL 2019), tbGPY (PRB 2022)
SO real nodal-line semimtal: 3D graphdiyn (PRL 2022)
3D SOTI & RCI: bulk γ-graphyne (arXiv 2023)

Non-centered Inversion Symmetry in Momentum Space

Projective Symmetry

Projective symmetry argebra.

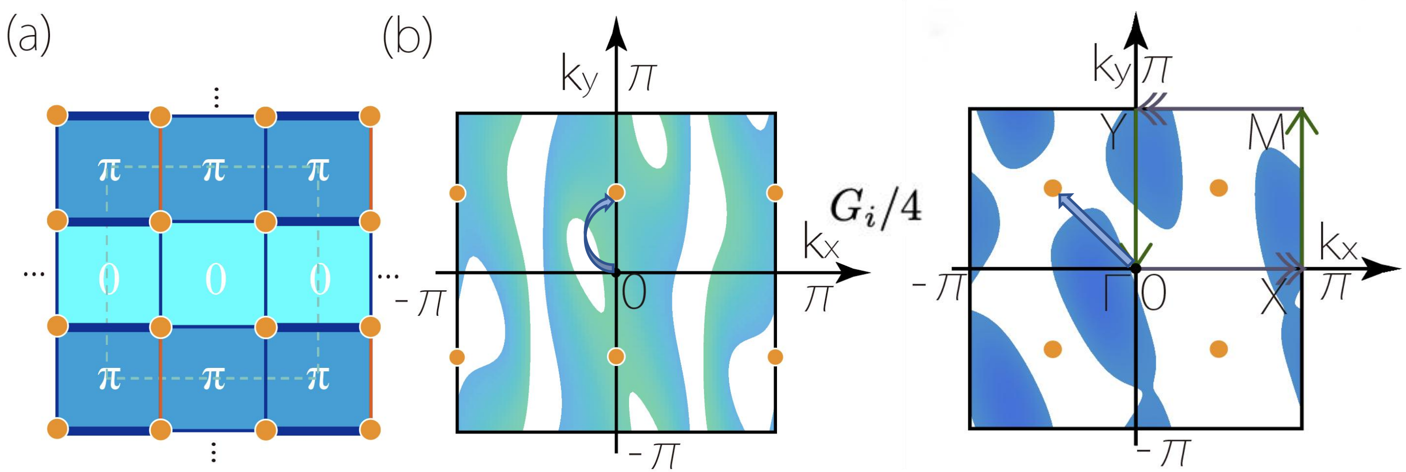
$$(PL_i)^2 = \theta \qquad \theta = \pm 1$$ Cohomology invariant

$$PL_iP = -L_i^{-1} = e^{i(k_i+G_i/2)a_i}$$

$$\mathcal{P}_i = P\mathcal{L}_{G_i/2}$$

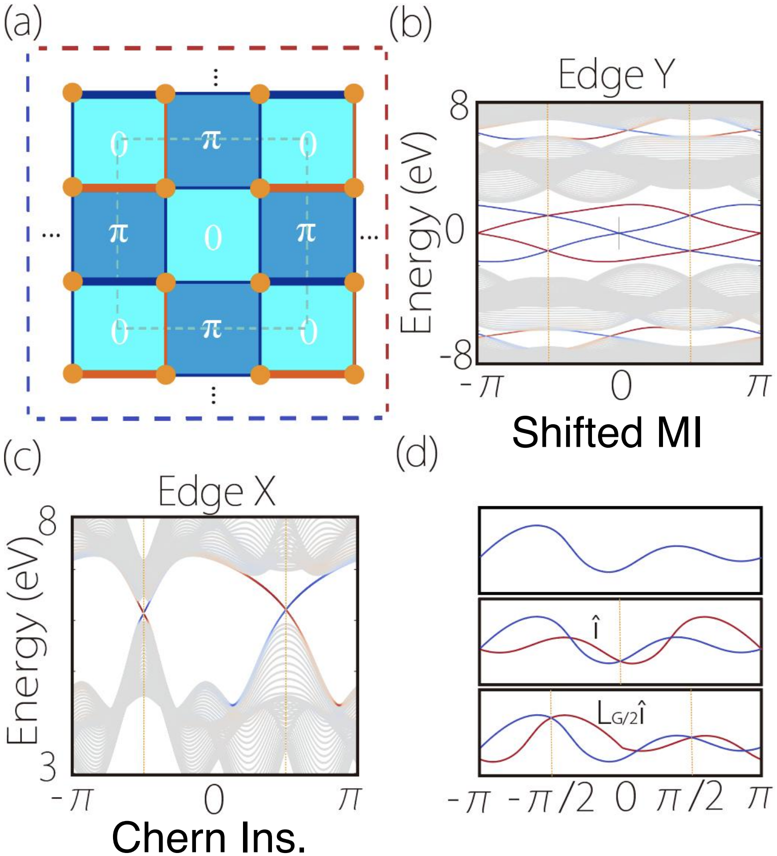
Half reciprocal lattice translation

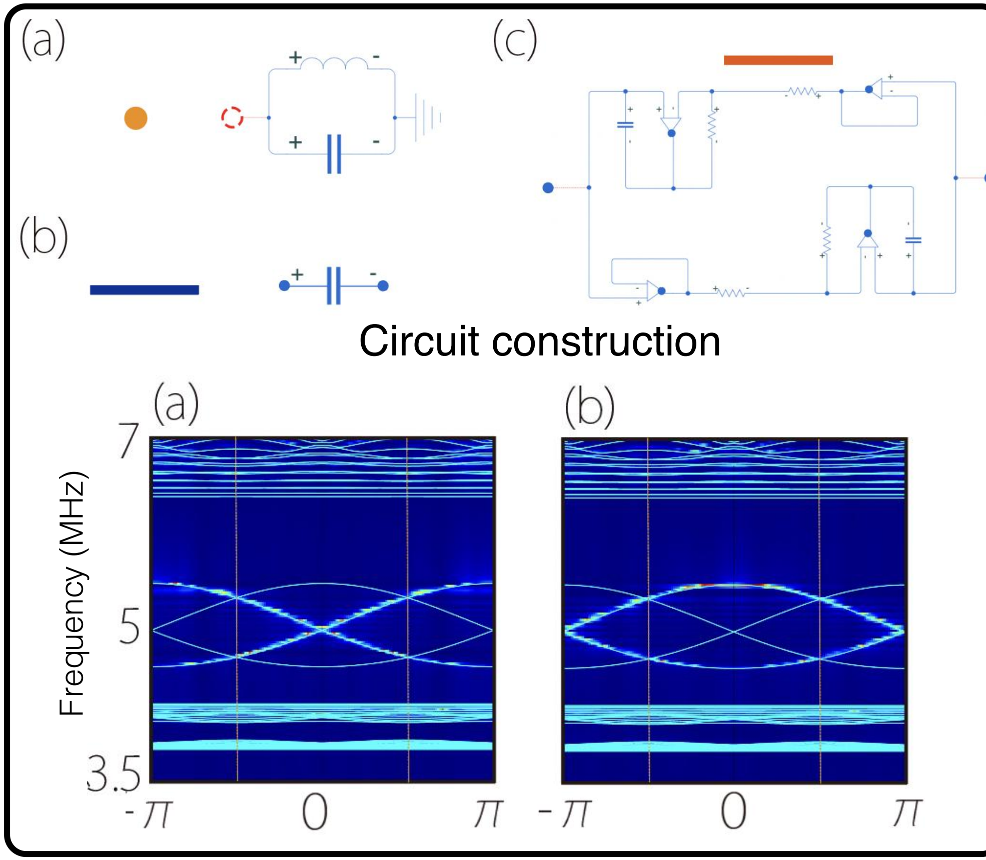
$$UH_i(-\mathbf{k}_{rest}, -k_i + G_i/2)U^\dagger = H_i(\mathbf{k}_{rest}, k_i)$$

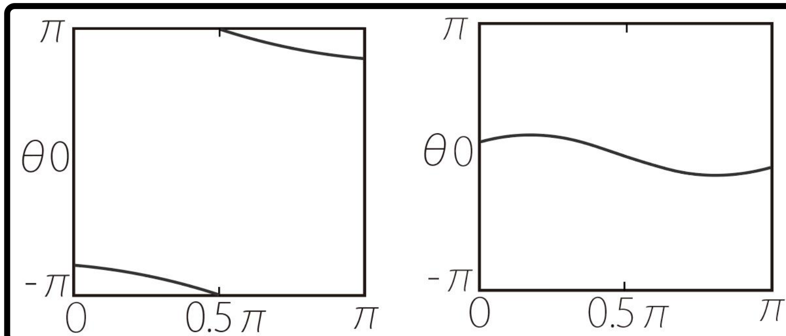


Inversion centers: ***Quater*** reciprocal lattice translation

Topological States & Simulations





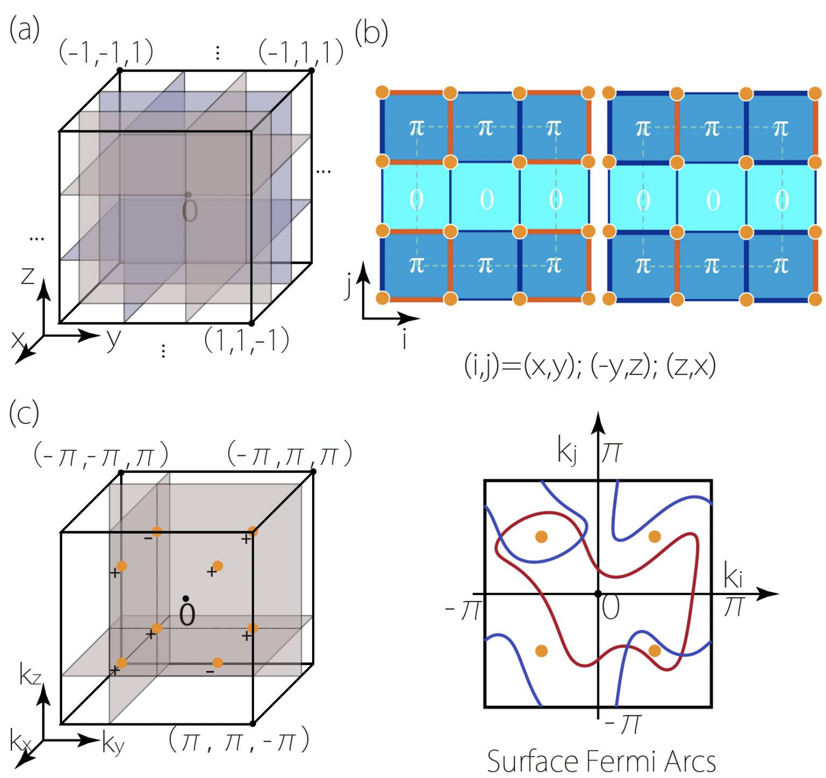


$$\nu = \frac{1}{2\pi}[\gamma(0) + \gamma(\pi)] \quad \mathrm{mod}\ 2$$
$$= \zeta \quad \mathrm{mod}\ 2$$

$$(-1)^{\nu} = \prod_{j=a,b} \prod_{i}^{N} \lambda_i(\Gamma_j)$$

Topological invariant

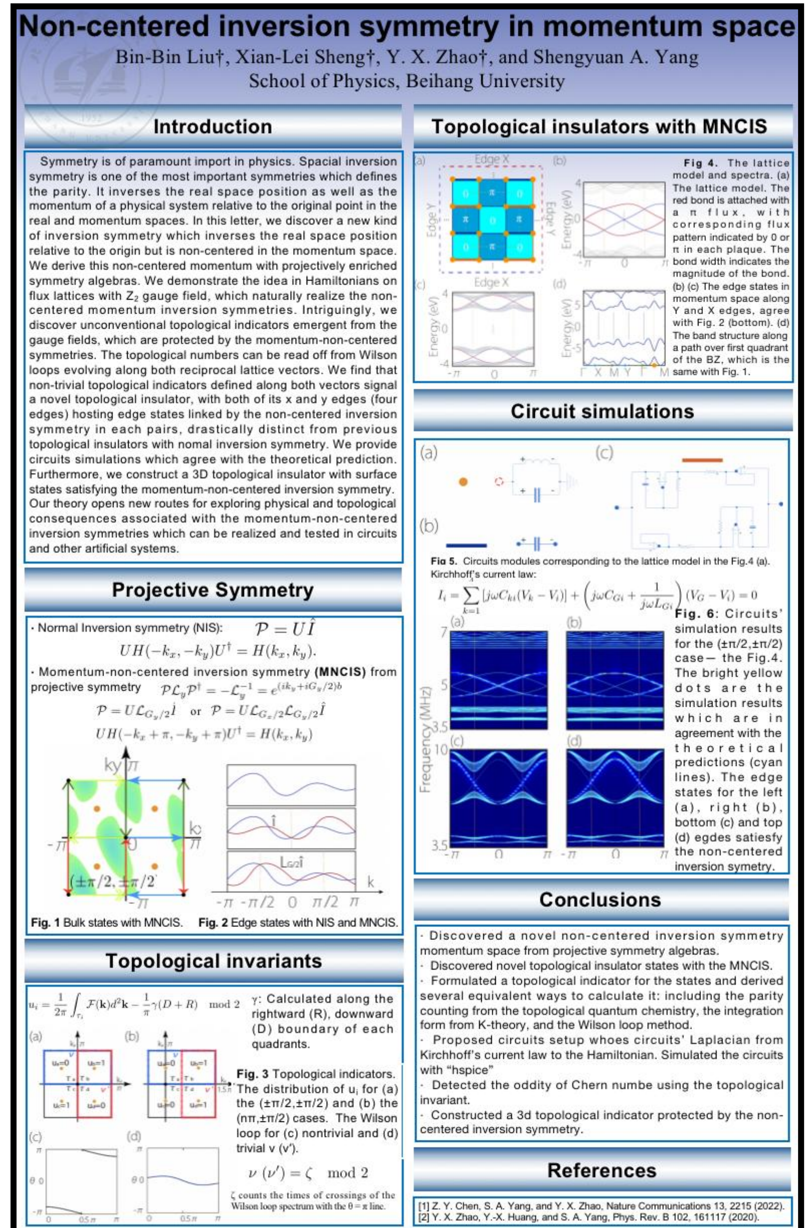
Extending to 3D



$$\boxed{\mathcal{P}^{3D}_{xyz} = U_{3D}\mathcal{L}_{G_x/2}\mathcal{L}_{G_y/2}\mathcal{L}_{G_z/2}\hat{I}_{xyz}}$$

To be submitted to PRL.

POSTER

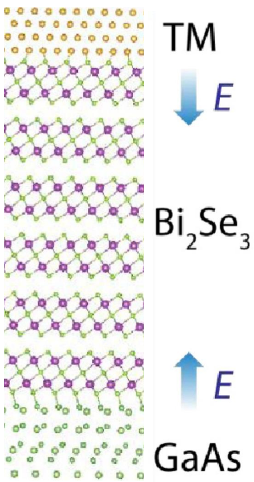


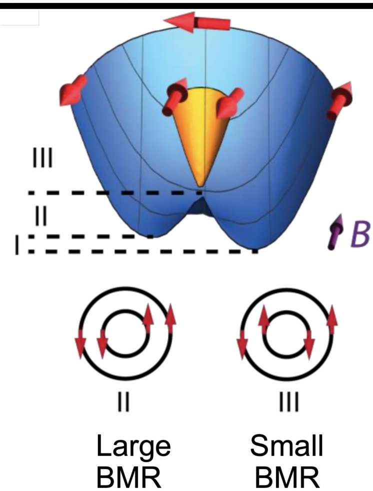
Large BMR in Rashba States on the Surface of a TI

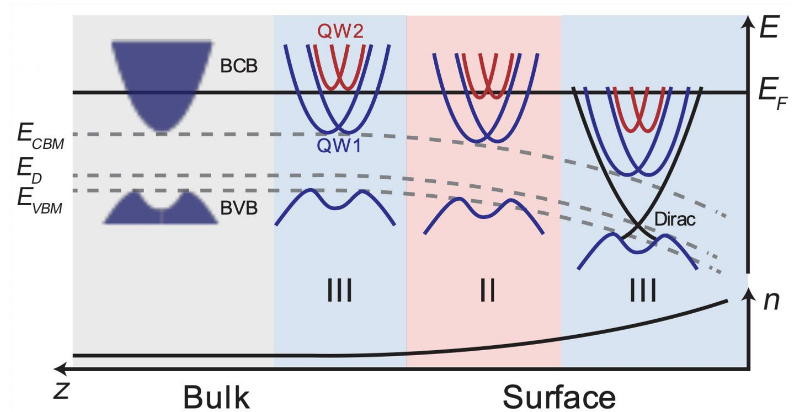
Explaining the Large BMR

$$\boxed{R(I,B) = R_0[1 + \beta B^2 + \gamma \boldsymbol{I} \cdot (\boldsymbol{P} \times \boldsymbol{B})]}$$

γ ~BMR



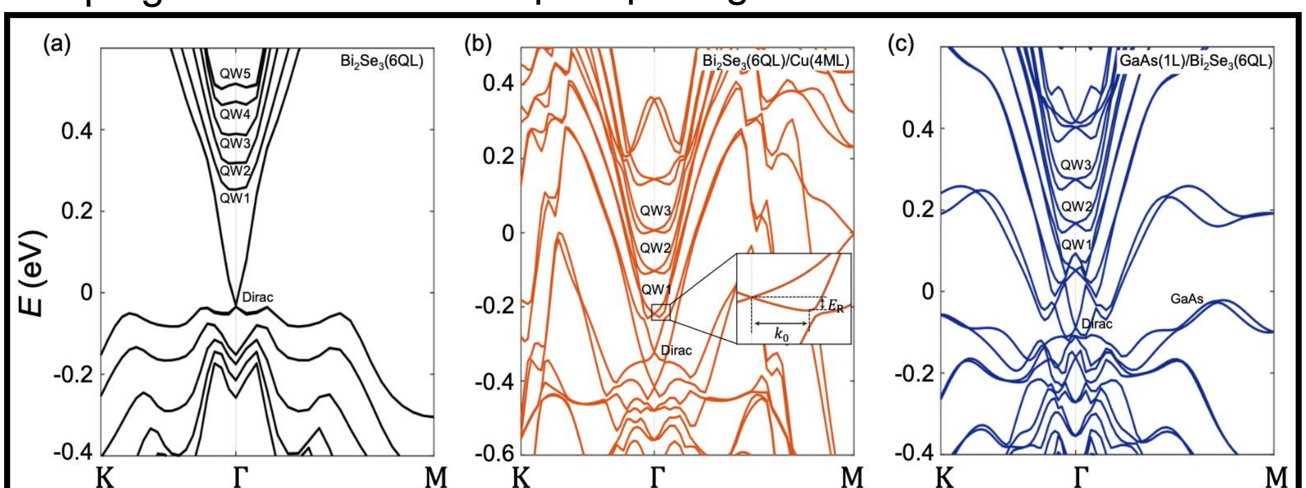




Surface doping

Rashba spin-splitting

Band bending



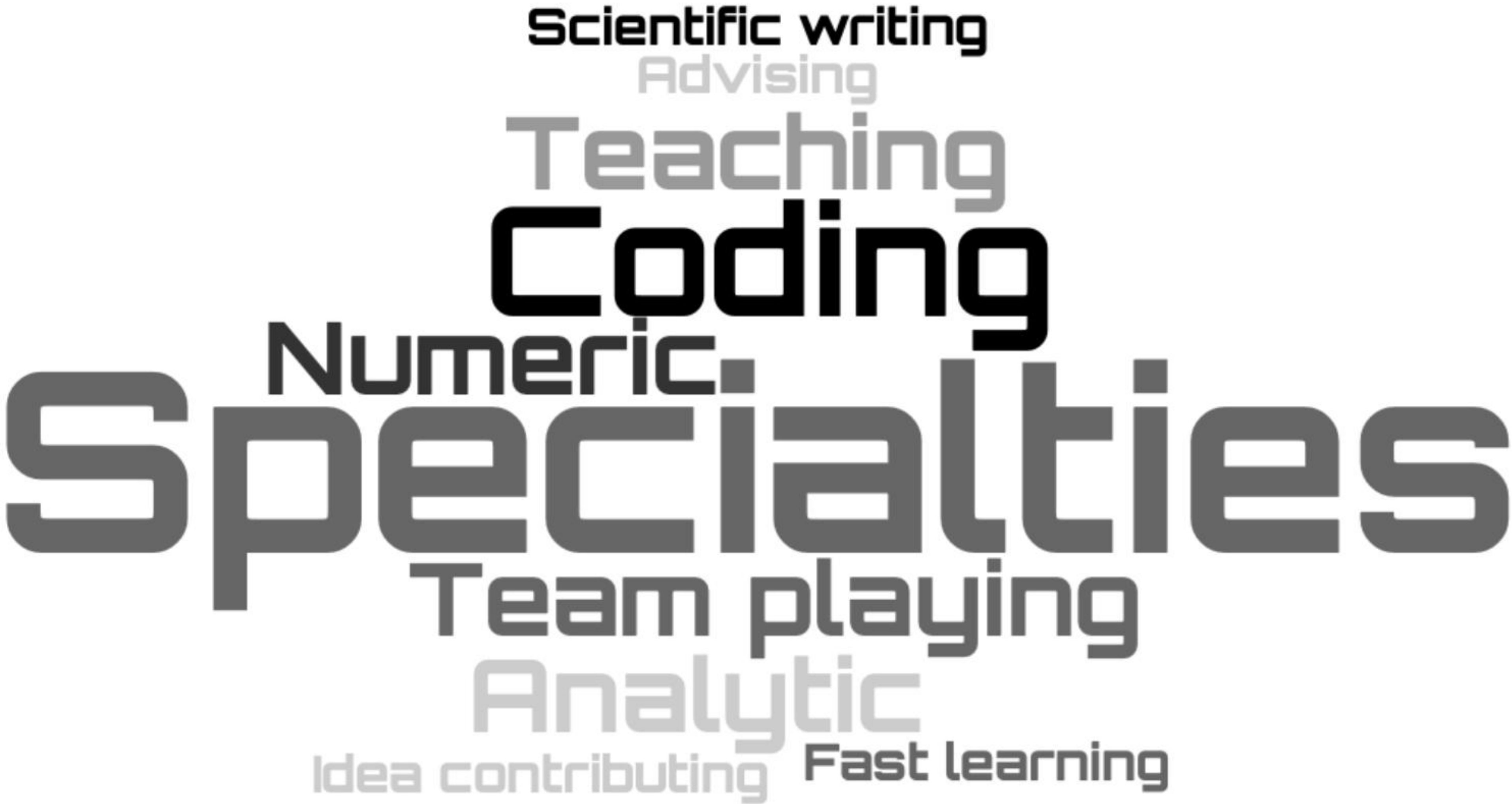
DFT results

PRB, Letter (2022).

Outlooks

nonHermitian
Tensor networks
Complex systems Application
Circuit Hyperbolic fluid
metamaterial
Interests
Topological
Correlated electrons
Topological everything
material

Outlooks


Scientific writing
Advising
Teaching
Coding
Numeric
Specialties
Team playing
Analytic
Idea contributing
Fast learning

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Thank you!

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