

Anomaly indicator of rotation symmetry in (3+1)D topological order

## Fermionic phases of matter on unoriented spacetime

Based on arXiv: 1905.05902

We sometimes consider putting topological phases of matter on **unoriented** spacetime.

Ex.

➤ (1+1)d time-reversal SPT phase w/  $T^2 = 1$

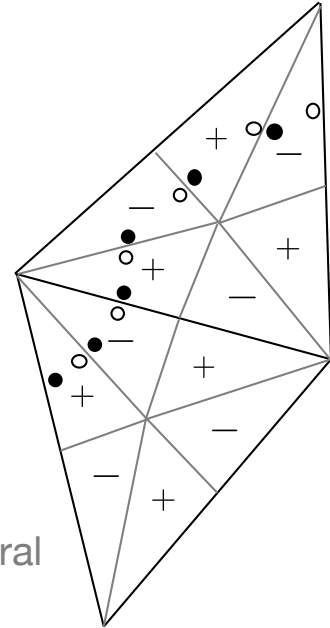
requires  $\text{pin}_-$  structure, and classified by  $\Omega_2^{\text{pin}_-}(\text{pt}) = \mathbb{Z}_8$

generated by  $\mathbb{RP}^2$ ; i.e.,  $Z(\mathbb{RP}^2) = e^{2\pi i\nu/8}$  detects the classification

Important to formulate  **$\text{pin}_{+/-}$  TQFT** on unoriented spacetime!

By extending the lattice construction of spin TQFT by Gaiotto & Kapustin,

we can formulate the  $\text{pin}$  TQFT on lattice, on unoriented spacetime.



Grassmann integral on spacetime

### Applications:

➤ (1+1)d time-reversal SPT phase w/  $T^2 = 1$ ;  $\Omega_2^{\text{pin}_-}(\text{pt}) = \mathbb{Z}_8$

➤ Time-reversal Gu-Wen SPT phase

➤ Gapped boundary for time-reversal Gu-Wen SPT phase (see 1905.05391 & 1905.05902)

➤ Time reversal anomaly of (2+1)d TQFT w/  $T^2 = (-1)^F$ ;  $\Omega_4^{\text{pin}_+}(\text{pt}) = \mathbb{Z}_{16}$