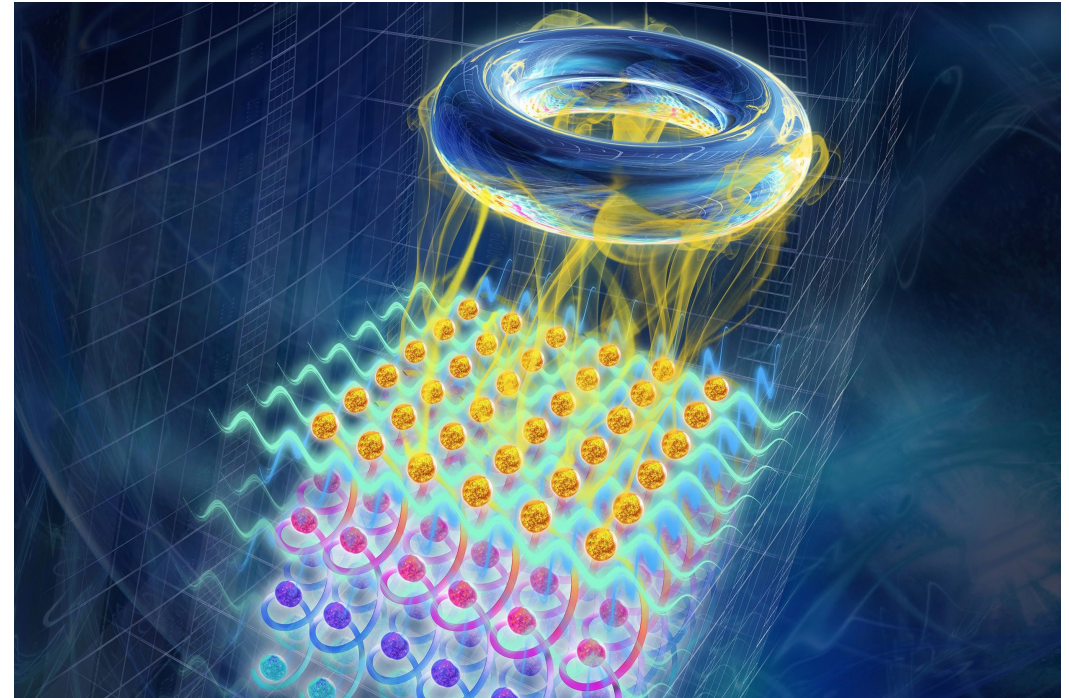


Applications of Generalized Symmetries to Quantum Matter

Interests: Generalized symmetries, anomalies and topological aspects of quantum field theories and quantum lattice models.

Goal: Develop new methods based on these concepts to study phase diagrams of correlated quantum matter.



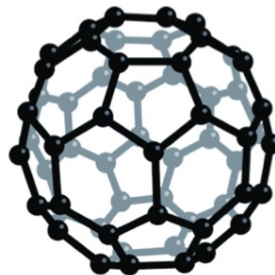
Global Symmetry:

Useful as:

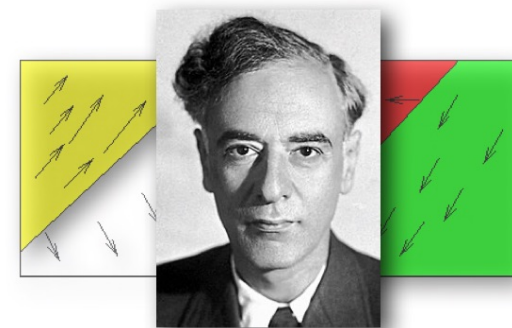
- i) As an organising principle for states and operators
- ii) Constrains low-energy physics/dynamics

| | I | II | III | | |
|------------------------|--|---|---|--|--|
| mass charge spin | $\approx 2.2 \text{ MeV}/c^2$ 2/3 1/2 | $\approx 1.28 \text{ GeV}/c^2$ 2/3 1/2 | $\approx 173.1 \text{ GeV}/c^2$ 2/3 1/2 | 0 1 1 | $\approx 124.87 \text{ GeV}/c^2$ 0 0 |
| QUARKS | u up | c charm | t top | g gluon | H higgs |
| | $\approx 4.7 \text{ MeV}/c^2$ -1/3 1/2 | $\approx 96 \text{ MeV}/c^2$ -1/3 1/2 | $\approx 4.18 \text{ GeV}/c^2$ -1/3 1/2 | 0 1 1 | |
| | d down | s strange | b bottom | γ photon | |
| LEPTONS | $\approx 0.511 \text{ MeV}/c^2$ -1 1/2 | $\approx 105.66 \text{ MeV}/c^2$ -1 1/2 | $\approx 1.7768 \text{ GeV}/c^2$ -1 1/2 | 0 1 1 | $\approx 91.18 \text{ GeV}/c^2$ 0 1 |
| | e electron | μ muon | τ tau | Z Z boson | |
| | 0 1/2 | 0 1/2 | 0 1/2 | $\approx 80.379 \text{ GeV}/c^2$ 1 1 | |
| | ν_e electron neutrino | ν_μ muon neutrino | ν_τ tau neutrino | W W boson | |
| | 0 1/2 | 0 1/2 | 0 1/2 | | |
| | | | | | SCALAR BOSONS vector bosons |

Standard Model



Crystallography

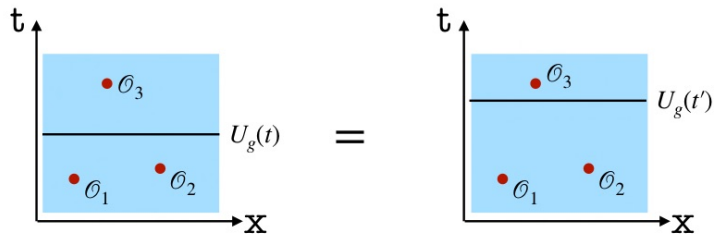


Landau Classification

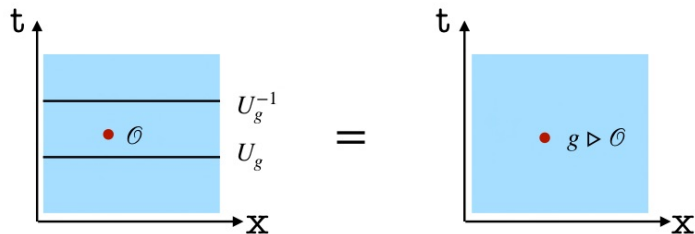
Global Symmetry **old** and **new**

Conventional picture

- Symmetry operators commute with the Hamiltonian.



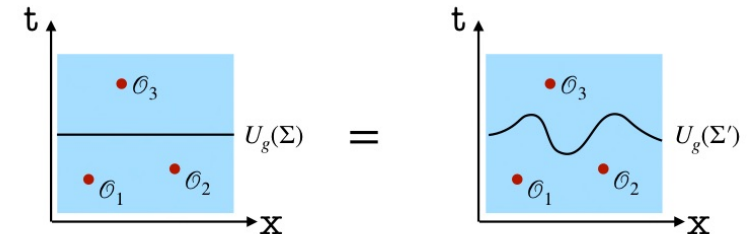
- Symmetry operators act on local operators by conjugation.



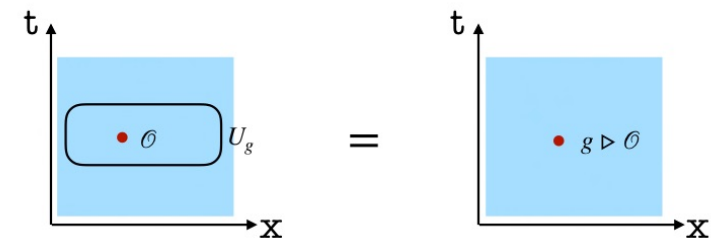
- Symmetry operators satisfy group like fusion rules.

Modern picture

- Symmetry operators are topological.

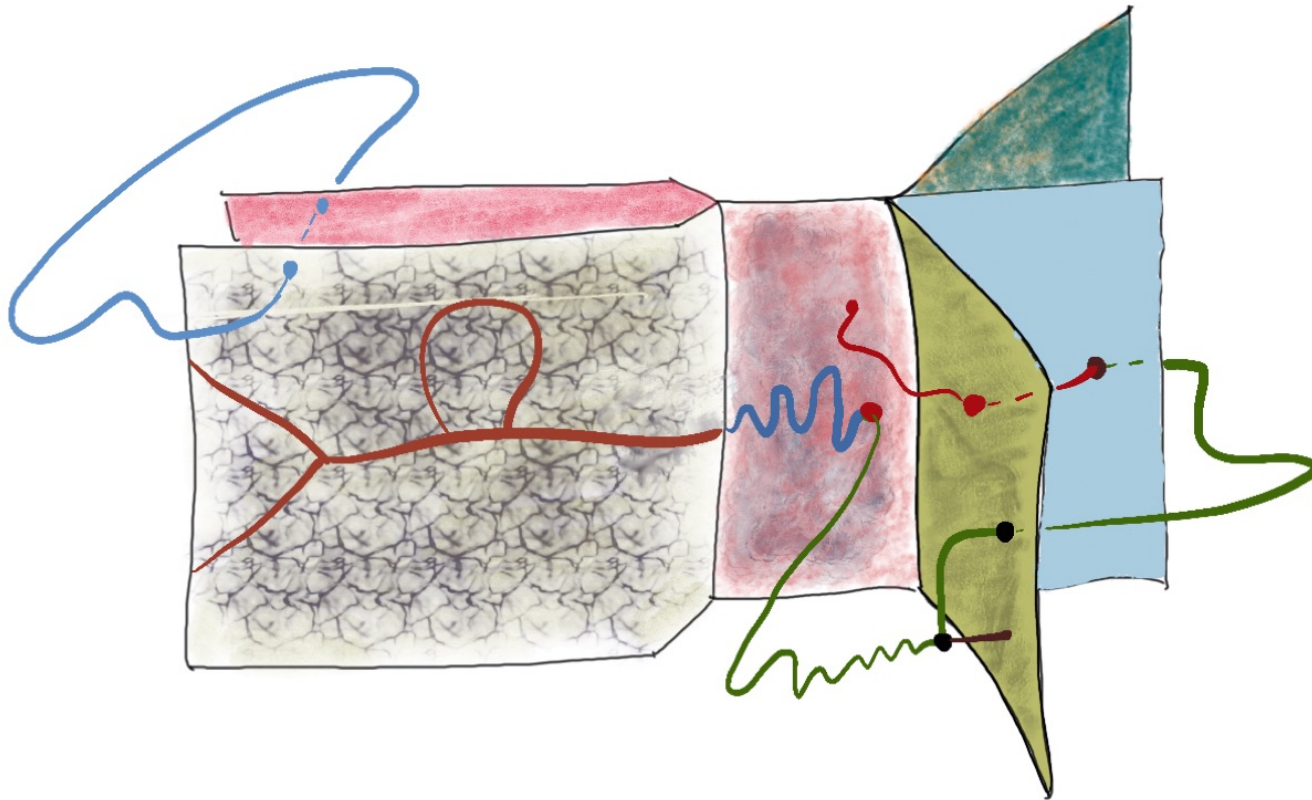


- Symmetry operators act on local operators by linking.



- Symmetry operators need NOT satisfy group like fusion rules.

Generalized symmetries



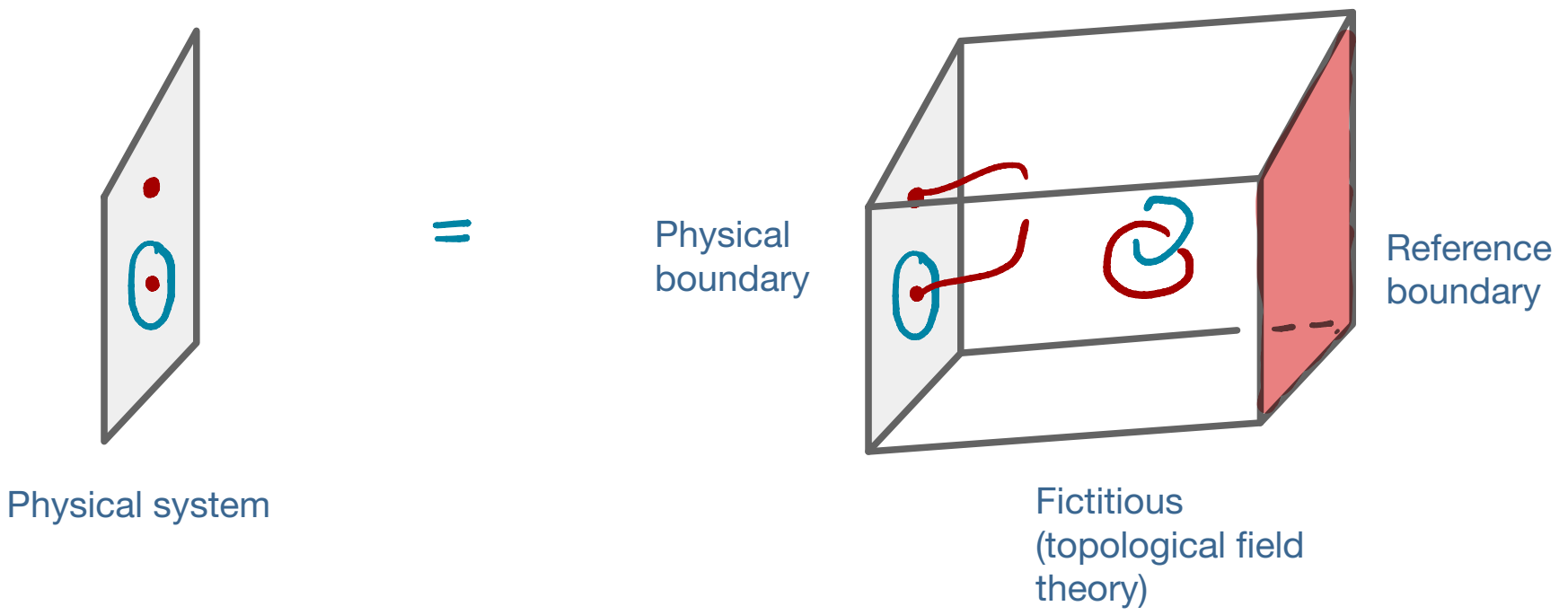
Examples: Many recent realizations of theories with generalized theories e.g., Lattice gauge theories, QCD, Topological orders, spin liquids, ...

Why? Can extend Landau's paradigm, constrain strongly coupled theories, new insights for topological quantum computation.

Mathematical description:
Higher Fusion Categories

Holographic Symmetry

Recall (1) $\bigcirc_{U_g} = \text{irregular shape}_{U_g}$; (2) $\bigcirc_{U_g}^{\bullet} = g \triangleright 0 \bullet$



Why useful? Organizes spectrum of symmetry charges, quantum dualities, provides a full classification of phases of symmetric matter.

Many many unexplored interested puzzles!