Codes for *Projected Topological Branes*

Archisman Panigrahi

Preprint Link: https://arxiv.org/abs/2112.06911
Journal: Submitted for peer review in Communications Physics.

Note: These Mathematica notebooks use relative file paths, which usually work in GNU/Linux operating systems. If you are using a different operating system (especially Windows), you may have to edit the notebooks to use absolute file paths to import and export the .dat files.

Table of Contents

1. Projected Quantum Anomalous Hall Insulator (QAHI) – We have implemented the spinless Bernevig-Hughes-Zhang (BHZ) model of QAHI on a square lattice, and its projected branes

`QAHI/SquareLattice_PTB_QAHI.nb` – Implements and diagonalizes the Hamiltonian of this system on a square lattice and its projected branes. Then it exports the energy eigenvalues and the probability density of the eigenvectors closest to zero energy to .dat files in the directory `QAHI/data`.

`QAHI/EnergySpectra_QAHI.nb` – Imports the dat files from `QAHI/data` and generates plots, which have been used in Fig. 2 of the main manuscript.

2. Projected Quantum Anomalous Hall Insulator (QAHI) with line dislocation – We have implemented the spinless Bernevig-Hughes-Zhang (BHZ) model of QAHI on a square lattice with an edge dislocation. The projected branes contain the dislocation center as well.

`Dislocation_QAHI/SingleDislocation_PTB_QAHI.nb` – Implements and diagonalizes the Hamiltonian of this system on a square lattice with an edge dislocation, and generates the eigenvalues and the probability density of the eigenvectors closest to zero energy. Then it exports them to the directory `Dislocation_QAHI/data`.

`Dislocation_QAHI/data/dislocationMelting/DislocationLDoSPlots.nb` – Imports the .dat files from `Dislocation_QAHI/data/dislocationMelting/` and plots the probability densities of the corresponding eigenvectors on a line.

`Dislocation_QAHI/data/Energy_Eigenvalues/EnergySpectra_QAHI_dislocation.nb` – Imports the energy eigenvalues from `Dislocation_QAHI/data/Energy_Eigenvalues` and plots them.

3. Local Chern Number – We calculate the local Chern number of the spinless BHZ model on each site of a square lattice, and its corresponding PTB. To get the value of the local Chern number in the bulk of the system (to remove the edge effects), we draw a line through the middle of the lattice and calculate the local Chern number on the sites along this line. Similarly, for the calculation of the local Chern number on PTB, we draw a line going through the middle of the brane, and calculate the local Chern number of the projected Hamiltonian on the sites closest to that line.

`Local_Chern_Number/Local_Chern_Number_QAHI.nb` – Implements Local Chern Number of the spinless BHZ model on a square lattice and exports the values to `Local_Chern_Number/data`.

`Local_Chern_Number/Make_Plots_Local_Chern_Number_squarelattice.nb` – Imports the values of the local Chern number from the dat files in `Local_Chern_Number/data`, and plots the local Chern Number of the square lattice along a line going through the middle of the lattice.

`Local_Chern_Number/Local_Chern_Number_QAHI_projected_Brane.nb` – Implements Local Chern Number of the spinless BHZ model on PTB and exports the values to `Local_Chern_Number/dataPTB`.

`Local_Chern_Number/Make_Plots_Local_Chern_Number_projected_Brane.nb` – Imports the values of the local Chern number from the dat files in `Local_Chern_Number/dataPTB`, and plots the local Chern Number of the PTB along a line going through the middle of the brane.

4. Weyl Semimetal (WSM) – We have implemented the Weyl Semimetal on a 3D lattice as well as on its projected branes. We have also taken the momentum in one direction (along z axis) to be a good quantum number, and implemented Fermi Arcs, on the parent system, as well as on the projected brane.

`WSM/WSM_SquareLattice_BandStructure_PTB.nb` – Generates the band structure of WSM on a PTB, treating the momentum along the z direction as a good quantum number.

`WSM/WSM_3D_real_space_PTB.nb` – Generates Fermi Arc in effectively two dimensional PTB, where the parent Hamiltonian is plotted in three dimensional (real) space. The dat files are stored in `WSM/RealSpaceFermiArcPlots/`.

`WSM/WSM_momentum_space_Fermi_Arc_parent_lattice.nb` – Implements the Hamiltonian in real space along x and y axis, while treating the momentum along the z axis as a good quantum number. Fermi Arc states are obtained when - $\pi/2 < k_z < \pi/2$.

`WSM/WSM_momentum_space_Fermi_Arc_PTB.nb` – Implements the Hamiltonian in real space along x and y axis, while treating the momentum along the z axis as a good quantum number. Then the Hamiltonian is projected on a brane. Fermi Arc states of the projected Hamiltonian are obtained when -$\pi/2 < k_z < \pi/2$. Although the system is effectively 2D (one direction in real space, and the z direction is implemented in momentum space), it continues to show Dirac Points with linear band touching. The resulting .dat files are exported to `WSM/MomentumSpaceFermiArcPlots`.

`WSM/MomentumSpaceFermiArcPlots/MomentumSpaceFermiArcPlots.nb` – Generates momentum space Fermi Arc plots from the dat files in `WSM/MomentumSpaceFermiArcPlots`.

`WSM/RealSpaceFermiArcPlots/RealSpaceFermiArcs.nb` – Generates real space Fermi Arc plots for PTB (where the x-y plane is projected to a brane, whereas k_z remains a good quantum number) from the dat files in `WSM/RealSpaceFermiArcs`.

5. Landau Levels –

`Landau_Levels/MagneticField_SquareLattice_QAHI.nb` – We take the same model of WSM, but introduce a constant magnetic field in the z direction. The magnetic field is realized by the standard Peierls substitution, where the hopping amplitudes gain an appropriate phase factor. The Hamiltonian is implemented in real space along the x and y axes, whereas the momentum along the z axis is treated as a good quantum number. As the band-structure is plotted against k_z , the lowest Landau levels can be visualized.

`Landau_Levels/MagneticField_SquareLattice_QAHI_PTB.nb` – The same as above, but the Hamiltonian (previously implemented in real space in the x-y plane) is now projected to a brane in the x-y plane, whereas k_z remains a good quantum number. The lowest Landau levels can still be visualized (shown in red in the plot).

6. Chiral Anomaly –

`Chiral_Anomaly/ChiralAnomaly_PTB.nb` – We introduce a singular magnetic flux tube in the center of the projected brane, and calculate the accumulated charge around it. Here, the Hamiltonian is implemented on real space along the x-y plane, and k_z is taken to be a good quantum number. The calculation is done for several values of k_z uniformly chosen from $(-\pi,\pi)$, and the resulting value of the accumulated charge is averaged over all values of k_z. This calculation is repeated after changing the value of the magnetic field.

`Chiral_Anomaly/ChiralAnomaly_PTB.nb` - The data (generated by `ChiralAnomaly_PTB.nb`) for the excess charge and the magnetic field is manually collected in this notebook. The excess charge is plotted against the magnetic flux (in the units of the magnetic flux quantum), for both rational and irrational slopes of the brane. Finally, the slope of the resulting plot is compared against the theoretical value, $\pi/2$.