2D Majorana fluids: Quantized transport, universal statistics, and instabilities at the surface of a topological superconductor

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**Quantum Topology in Materials**

**Topological phases in materials physics:**
Quantum holography in condensed matter
- Bulk electronic structure is insulating, “knotted”
- Knots unties at the surface: metallic surface states with anomalous properties

**Integer quantum Hall effect**
K. von Klitzing 1980, Noble Prize in Physics 1985
- Electrons in a quantum well, large magnetic field
- Anomalous “chiral” edge state
- Topologically quantized Hall resistance

$$R_H = \frac{h}{e^2}, \quad \nu \in 1, 2, \ldots$$

**Surface and Heat Transport in a 2D Majorana Fluid**

**Surface Majorana fluid can carry spin or heat**
In 2D, wave interference dominates transport; quantum conductance corrections due to
- Multiple scattering off of impurities
- Scattering off of impurity-induced density ripples

**Interaction (Altshuler-Aronov) corrections to second order:**

**Universal transport: Disorder has no effect?**
- Ordinary 2D electron gas: arbitrarily weak disorder localizes all wavefunctions
- Anderson insulator: localized states cannot carry current

**Disorder and interactions; Delocalization and Instabilities**
- Surface Majorana states cannot be localized by disorder (topological protection)
- Despite featureless density, Wavefunctions are extended, but highly inhomogeneous and rarified

**Universal wavefunction statistics can be obtained exactly using 2D conformal field theory**
- Nesting of different wavefunctions (overlapping probability peaks): Fluctuations enhance interactions

**Result: Not always protected. Even weak disorder and interactions can destroy some surface states**

**New Topological Phases in 2D, 3D**
- Topology without a magnetic field Kane and Mele 2005
- 3D Topological insulators with 2D Dirac surface states
- Surface states mapped with optics (photoemission)

**Anomalous surface time-reversal symmetry:**
- Majorana fluid remains ripple-reversal symmetry: Even with dirt

**Spin, heat conductivities encode topology:**

$$\sigma_s = \frac{|\nu|}{\pi h} \left( \frac{\hbar}{2} \right)^2, \quad \kappa = \frac{|\nu|}{\pi h} \left( \frac{\hbar}{3} \right) \gamma, \quad \gamma \in 1, 2$$

**Result: All corrections vanish**
Xie, Chou, Foster 2014

**Non-zero modes:**

4) H.-Y. X., Y.-Z. C., and M.S.F., arXiv:1405.7730

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**Figures:**
- Topological phases in materials physics
- Universal transport: Disorder has no effect?
- New Topological Phases in 2D, 3D
- Surface and Heat Transport in a 2D Majorana Fluid
- Universal transport: Disorder has no effect?