Smearing of the quantum anomalous Hall effect due to statistical fluctuations of magnetic dopants

M.E. Raikh*

Department of Physics, University of Utah

Quantum anomalous Hall effect (QAH) is induced by substitution of a certain portion, $x$, of Bi atoms in a BiTe-based insulating parent compound by magnetic ions (Cr or V). Breaking of the time-reversal symmetry induced by the magnetic order results in the lifting of symmetry between the two counterpropagating edge modes. With a single chiral mode per edge, the Hall conductance of the sample becomes nonzero, and the transport resembles the conventional quantum Hall effect. Pioneering experiments on QAH revealed that the “inverted” gaps are narrow, so that the quantization is washed out already at very low temperatures. Motivated by these observations, we calculate the density of in-gap states, $N(E)$, emerging as a result of statistical fluctuations of the composition, $x$, in the vicinity of the transition point, where the average gap, $E_g$, passes through zero. Local gap follows the fluctuations of $x$. Using the instanton approach, we show that, near the gap edges, the tails are exponential, $\ln N(E) \propto -(E_g - |E|)$, and the tail states are due to small local gap reduction. Our main finding is that, even when the smearing magnitude exceeds the gap-width, there exists a semi-hard gap around zero energy, where $\ln N(E) \propto -\frac{E_g}{|E|} \ln \left(\frac{E_g}{|E|}\right)$. The states responsible for $N(E)$ originate from local gap reversals within narrow rings. The consequence of semi-hard gap is the Arrhenius, rather than variable-range hopping, temperature dependence of the diagonal conductivity at low temperatures.

* In collaboration with Yue Zhang