Entropy spikes as a signature of Lifshitz transition in the Dirac materials

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Entropy is an important fundamental property of many-body systems. It governs their thermodynamics, heat transfer, thermoelectric and thermo-magnetic properties. On the other hand, the entropy was always hard to be directly measured experimentally. It has been revealed very recently that the entropy per particle, $\partial S/\partial n$, where $n$ is the electron density, can be experimentally studied\textsuperscript{1}.

We demonstrate theoretically that the characteristic feature of a 2D system undergoing $N$ consequent Lifshitz topological transitions is the occurrence of spikes of entropy per particle $s$ of a magnitude $\pm \ln 2/(\Delta - 1/2)$ with $2 \leq \Delta \leq N$ at low temperatures.

We derive a general expression for $s$ as a function of chemical potential, temperature and gap magnitude for the gapped Dirac materials. Inside the smallest gap, the dependence of $s$ on the chemical potential exhibits a dip-and-peak structure in the temperature vicinity of the Dirac point. The spikes of the entropy per particles can be considered as a signature of the Dirac materials. These distinctive characteristics of gapped Dirac materials can be detected in transport experiments where the temperature is modulated in gated structures.

Fig.1: The entropy per electron $s$ as functions of the chemical potential $\mu$ and $\Delta_i$ in the units of $\Delta_{SO}$. The temperature $T = 0.3\Delta_{SO}$. Left panel: 3D plot. Right panel: Contour plot.

Kuntsevich, A. Y., Pudalov, V. M., Tupikov, I. V. & Burmistrov, I. S. Strongly correlated two-dimensional plasma explored from entropy measurements. Nat. Commun. 6, 7298, doi:10.1038/ncomms8298 (2015).