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Report on thesis by Dmitry Zverevich

In his thesis, Dmitry Zverevich explores the consequences of a putative excitonic transition in a Weyl semimetal. He starts with a minimal model for the free-electron spectrum and electron-electron interaction, which may lead to the excitonic instability. He follows this up with the mean-field analysis, in the spirit of BCS and Keldysh-Kopaev theories, of the emerging collective state. The assumption of an isotropic gap in the exciton insulator phase allows Dmitry to come up with a treatable system of equations for the particle and hole amplitudes in the elementary excitations. Furthermore, he supplements these equations with a plausible boundary condition at the surface of the semimetal and analyzes the spectrum of elementary excitations. The analysis is cumbersome but Dmitry braves through it and arrives at results, which I find quite interesting.

The main Dmitry's finding is that the exciton insulator formed out of the Weyl semimetal is actually a three-dimensional topological insulator. The telltale sign of it is the formation of compressible surface states, on the background of fully gapped electron spectrum in the bulk. The Fermi lines characterizing the surface states are the descendants of the Fermi arcs on the underlying Weyl semimetal. In the semimetal, the end-points of the arcs correspond to the states "sinking" into the bulk. Dmitry's calculation details, how the formation of the exciton gap prevents the sinking from occuring. As the result, in his calculation, the Fermi line traverses the entire two-dimensional Brillouin zone of the exciton insulator's surface.

Dmitry's work satisfies the requirements set forth for a thesis. In future, one may expand the research in a number of directions. First, one needs to investigate whether an isotropic gap solution leading to a fully gapped state in the bulk is indeed the optimal one. Next, one may look at the possible experimental manifestations of the topological nature of the exciton insulator; for example, one may come up with a prediction for the ARPES spectra. Finally yet importantly, one should compare the found results with the existing theory literature.

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