**Common behavior of the scaled condensation energy for both high-$T_c$ and conventional superconductors**

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It is generally accepted that conventional superconductors have nothing in common with unconventional superconductors, since unconventional superconductors are metals with flat bands in the absence of quasiparticles. On the other hand, experimental facts show that both types of superconductors have common properties, have quasiparticles and exhibit the common scaling behavior of the scaled condensation energy $E_\Delta/\gamma$ [1], here $E_\Delta$ is the condensation energy and $\gamma$ is the Sommerfeld coefficient of electronic heat capacity. These facts pose a challenging puzzle for condensed matter researchers. As a result, an acute problem arises of revealing theoretically substantiating experimentally observed scaled condensation energy $E_\Delta/\gamma$ applicable to conventional and non-conventional superconductors [1]. Our theoretical consideration is based on the experimental paper that examines a representative subset of cuprates under optimal doping without any pseudogap [1]. For the first time, we have demonstrated that the universal scaling of the condensation energy $E_\Delta/\gamma = N(0)\Delta_1^2/\gamma$ applies equally to conventional and unconventional high-$T_c$ superconductors. Our explanation is based on the general property of superconductors: Bogoliubov quasiparticles act in conventional and unconventional superconductors, while the corresponding band is only deformed by the unconventional superconducting state [2]. These observations suggest that the unconventional superconducting state can be considered BCS-like in some cases, as predicted in [3]. Our theoretical observations are in good agreement with experimental facts.

## References

[1] J.S. Kim, G.N. Tam, and G.R. Stewart, *Universal scaling law for the condensation energy across a broad range of superconductor classes*. Phys. Rev. B **92**, 224509 (2015).

[2] V.R. Shaginyan, A.Z. Msezane, M.Ya. Amusia, and G.S. Japaridze, *Effect of superconductivity on the shape of flat bands*. EPL, **138**, 16004 (2022).

[3] V.R. Shaginyan, M.Ya. Amusia, A.Z. Msezane, and K.G. Popov, *Scaling behvior of heavy-fermion metals*. Phys. Rep. **492**, 31 (2010).