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Many-body Interactions and Vortex Matter in Multi-condensate Superconductors

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Inter-type (IT) or critical superconductivity appears in a finite interval between the types I and II amending the standard classification. Existence of the IT superconductivity is a generic property of the BCS pairing mechanism and is related to the infinite degeneracy of the Bogomolny point. At lower temperatures the degeneracy is removed. This leads to many unconventional properties of the superconductor mixed state, which defines a separate IT superconductivity type. Its magnetic properties cannot be described as a mixture of those in type I or II superconductors [1]. IT domain is small in single-band materials but increases considerably in multi-condensate superconductors, the increase is largest when one of the superconducting bands is shallow.

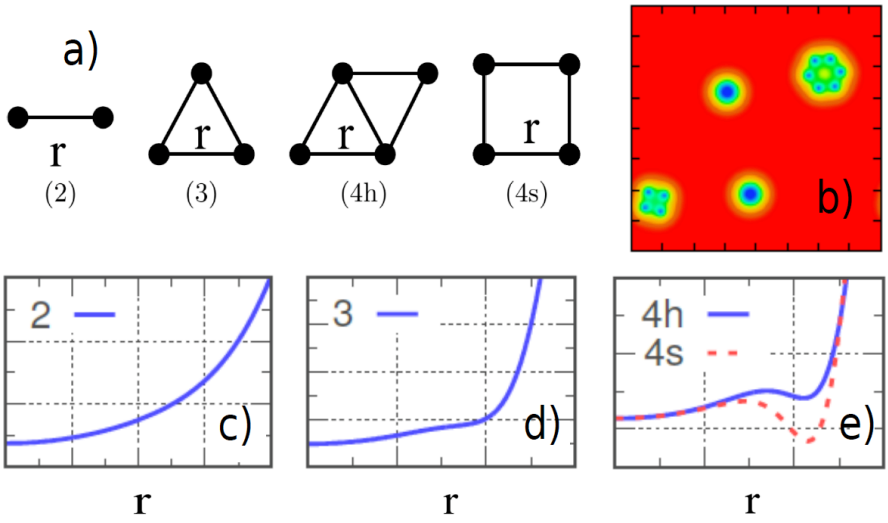

Figure: a) vortex configurations, b) giant vortices and vortex clusters in the IT domain, c) – e) vortex interaction potential that corresponds, respectively, to 2-, 3- and 4-vortex configurations in panel a).

Analysis of the vortex interactions in the IT domain reveals that they have a considerable many-body (many-vortex) component. Such many-body interactions play a crucial role in the formation of the vortex matter in the mixed state stabilizing multi-vortex clusters. Properties of the vortex-vortex interactions depend strongly on the number of vortices in a cluster. The interaction is fully attractive in small clusters and is non-monotonic in larger ones [Figures c)-e)]. This dependence on the cluster size gives rise to that large vortex clusters are stable, while smaller ones collapse into giant multi-quanta vortices [Figure b)]. This tendency becomes more noticeable close to the boundary of the IT domain. This observation demonstrates an existence of a special type of vortex matter shaped by many-vortex interactions. Similar vortex behavior and clustering is observed in nano-size superconductors [3].

[1] A. Vagov, A. A. Shanenko, M. V. Milosevic, V. M. Axt, V. M. Vinokur, J. A. Aguiar, Phys. Rev. B **93**, 174503 (2016).
[2] S. Wolf, A. Vagov, A. A. Shanenko, V. M. Axt, and J. Albino Aguiar, Phys. Rev. B **96,** 144515 (2017).
[3] W. Cordoba-Camacho, R.M. da Silva, A. Vagov, A.A. Shanenko, and J. Albino Aguiar, under consideration.