MAP-fis Essay Proposal, 2013-2014

(*please write in English*)

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Title

Josephson junctions arrays with frustrated multiband superconducting elements

Area

(*Materials, Optics, Condensed Theory, High Energy Theory,....*);

Condensed Matter Theory

Summary of Proposal

The aim of this proposal is the study of the Josephson junctions arrays with multiband superconducting elements.

Josephson junction (JJ) arrays have been extensively studied in the last decades. These studies have been to large extent motivated by the close analogy with classical spin systems [1] but more recently by the possible relevance of these systems to quantum computation [2–4].

In particular, it has been suggested that in JJ arrays with particular geometries it is possible to implement topologically protected qubits [10, 11] (qubits protected against the decoherence and entanglement with the environment).

In the case of a JJ array with multiband superconducting elements, besides the usual Josephson tunnelings, one must consider the interband tunnelings [5], which effectively modify the geometry of the JJ array. In fact, a multiband superconductor can be regarded as a simple realization of a short

JJ array. The interband pairings are equivalent to Josephson tunnelings and for example, a three-band superconductor is analogous to a triangular circuit of asymmetric JJs. Frustration in this case has been addressed only very recently [6–8] and it occurs if one or several interband interactions are repulsive since a repulsive interband interaction in a multiband superconductor plays a similar role to that of a π-junction in a Josephson junction array [9]. Another superconducting system equivalent to a triangular JJ array is a single JJ between a two-band superconductor and a single-band s-wave superconductor. In this system, chiral states have also been predicted in the absence of magnetic flux if the two-band superconductor is in a sign-reversed state [5, 7]. Such a sign-reversed two-band scenario, the so-called s± state, has been recently proposed in the context of the iron-based superconductors [10].

Frustration in a multiband superconductor leads to rather unusual features as a consequence of the intrinsic chirality of the superconducting state. One example is the existence of new mixed phase-density collective modes in the state with broken time-reversal symmetry [12, 13].

The signature of frustrated multiband superconductivity in the context of JJ arrays is an open problem, both in the classic and quantum limits of the JJ arrays. The classic limit corresponds to the high capacitance limit of the JJs. In this limit, we have recently found that in particular geometries of the JJ arrays, a new type of chirality occurs, leading to unusual features such as supercurrent blocking and plateaus in the energy versus magnetic flux profiles [11].

To conclude, the objectives of this Essay Proposal are:

1) The analytical study of short JJ arrays with quasi-2D multiband superconducting elements in the high capacitance limit, addressing in particular the temperature versus in-plane magnetic field phase diagram.

2) The analytical and numerical study of the classical behavior of geometrically frustrated JJ arrays with multiband elements.

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References

(*to allow students first look at topic*)

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