PERSONAL INFORMATION

NAME	Maria Vittoria Mazziotti
ADDRESS	Via Iazzano n°34, 04020, Itri (LT), Italy
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NATIONALITY	Italian
DATE OF BIRTH	28/04/1983
ID ITALIAN FISCAL CODE	MZZMVT83D68D708S

EDUCATION

06/05/2021
PhD in Physics at Roma Tre University, Rome, Italy
Titled: Multicomponent superconductivity at the unconventional Lifshitz transition in a three-dimensional heterostructures with tunable Rashba spin-orbit coupling
Supervisor: prof. Roberto Raimondi
with maximum mark 110/100
Roma Tre University
01/10/2017 - 31/12/2020

25/11/2015
Master's degree
Laurea in Physics
110/110
La Sapienza University
01/10/2011 - 25/11/2015

29/06/2002
High school diploma
89/100
Liceo classico Vitruvio Pollione, Formia
01/10/1997 - 29/06/2002

WORK EXPERIENCE AND ACTUAL POSITION

01/01/2021 – today
Research associate at RICMASS research center to study of high critical temperature superconductors in the presence of a tunable Rashba spin-orbit coupling
RICMASS, Roma International Center for Materials Science

01/04/2016 – 01/10/2017
Research associate at RICMASS research center
RICMASS, Roma International Center for Materials Science

26/11/2015 – 01/04/2016
Researcher at CLC research group of Theoretical Physics
Working with prof. Sergio Caprara at the Physics Department of *La Sapienza* University
La Sapienza University

TEACHING EXPERIENCE

01/03/2019 – 01/09/2019
Physics 1 exercises at the Engineering Department of the Roma Tre University
Roma Tre University

01/03/2019 – 01/09/2019
Atomic and Molecular Physics exercises at the Mathematic and Physic
Department of the Roma Tre University
Roma Tre University

01/09/2018 – 01/02/2019
Analysis 1 exercises at the Mathematic and Physic Department of the Roma Tre University
Roma Tre University

01/09/2018 – 01/02/2019
Chemistry exercises at the Mathematic and Physic Department of the Roma Tre University
Roma Tre University

01/03/2018 – 01/09/2018
Physics 1 exercises at the Engineering Department of the Roma Tre University
Roma Tre University

07/11/2016 – 10/06/2017
Physics teacher
Istituto di Istruzione Superiore E. Fermi, Gaeta

07/11/2016 – 08/06/2017
Physics teacher
I.P.I.A. E. Fermi, Formia

OTHER ACTIVITIES

- In the period of March-June 2020 I attended the Academic English course at the University of Roma Tre Linguistic Center obtaining the B2 + level of QCER
- In April 2020 I followed a webminar on the use of Mathematica software
- On 14 July 2020 I obtained 29 CFU in the following disciplines: Antropologia Culturale (9 CFU), Didattica Speciale (9 CFU) and Psicologia dell'Apprendimento (9 CFU)

PUBLICATIONS

1. M. V. Mazziotti, A. Valletta, R. Raimondi, A. Bianconi
   Multigaps superconductivity at unconventional Lifshitz transition in a 3D Rashba heterostructure at atomic limit
   Phys. Rev. B 103, 024523 (2021)

2. M.V. Mazziotti, T. Jarlborg, A. Bianconi, A. Valletta
   Room temperature superconductiity dome at Fano resonance in superlattice of wires
   EPL (Europhysics Letters) 134, 17001 (2021)

3. G. Campi, M. V. Mazziotti, A. Valletta, G. Ravagnan, A. Marcelli, A. Perali, A. Bianconi
   Metastable states in plateaus and multi-wave epidemic dynamics of Covid-19 spreading in Italy
   Scientific Reports doi: 10.1038/s41598-021-91950-5 (2021)

4. M. V. Mazziotti, N. Scopigno, M. Grilli, S. Caprara
   Majorana fermions in one-dimensional structures at $LaAlO_3/SrTiO_3$ oxide interfaces
   Condens. Matter 3(4), 37 (2018)

5. M. V. Mazziotti, A. Valletta, G. Campi, D. Innocenti, A. Perali, A.Bianconi
   Possible Fano Resonance For High T_c Multi-Gap Superconductivity In P-Terphenyl Doped By K At The Lifshitz Transition
   Epl (Europhysics Letters) 118, 37003, (2017)

AWARDS

EPL (Europhysics Letters) Prize of European Physics Society for the best poster presented at the International Conference Superstipes 2017, Ischia, Italy, 4-10 June 2017

CONGRESSES AND CONFERENCES

• I presented a poster High T_C in the organic superconductor K_x p-Terphenyl by Fano resonances in superconducting gaps at the Lifshitz transition, during the **International Conference Superstripes 2017** (Ischia, Italy, 4-10 June 2017) and I have obtained the EPL Prize for the best poster.

• I presented a poster, Possible Fano resonance for high-T_C multi-gap superconductivity in p-Terphenyl doped by K at the Lifshitz transition, during the **International Conference on Fluctuations and Highly Non Linear Phenomena in Superfluids and Superconductors** (San Benedetto del Tronto, 6-8 September 2017) and I received a Springer book for the Springer Nature Award

• I held a talk, BEC-BCS cross-over in multi-condensate superconductors at the Lifshitrz transition in arrays of weakly interacting quantum wires, during the **International Conference on Multi-Condensate Superconductivity and Superfluidity in Solids and Ultracold Gases** (14-18 May 2018 Trieste, Italy)

• I presented a poster, Superconductivity in the BEC-BCS crossover near a topological Lifshitz transition in organic superconductors, during the **International Frontieres of Condensed Matter Physics School** (Rome - Frascati National Laboratory, 11- 15 June 2018)

• I held a talk, Unconventional superconductivity near a topological Lifshitz transition in arrays of not connected wires, during the **Workshop Majorana Fermions and Topological Materials Science** (Erice, 21-27 July 2018)

• I held a talk, Numerical solution of Bogoliubov equation in a superlattice of superconducting wires in organics superconductors: the effect of electron hopping between wires, during the SUPERSTRIPES 2019 **International Conference "Quantum physics in Complex Matter: Superconductivity, Magnetism and Ferroelectricity "** (Ischia, Italy, 23-29 June 2019)

• I attended the Ugo Fano Prize 2019 and **Ugo Fano Symposium** "Majorana Fermions and Quantum Matter for Quantum computing" (Roma, Italy, 20 December 2019)

• I held a talk, Superconducting Dome in Multigap Superconductivity near a Topological Lifshitz transition, during the SUPERSTRIPES 2019 **International Conference "Quantum Complex Matter 2020"** (Frascati, Italy, 08 - 12 June 2020)

• I attended the **workshop "Topological Superconductivity in Quantum Materials"** (19-22 October 2020)

• I held a talk, Superconducting dome in multigap superconductivity near unconventional topological Lifshitz transitions, during the **Russian-Italian Science-Culture Meeting "Frontiers in Quantum Materials for Quantum Computing"** (Italy, 26 - 27 October 2020).

• I held a talk, Multicomponent superconductivity at the unconventional Lifshitz transition in a three-dimensional heterostructure with tunable Rashba spin-orbit coupling, during the **Quantum Complex Matter 2021 Symposium (**Frascati-Rome, June 7-9, 2021).

SCIENTIFIC STATEMENT

The aim of the work presented in my PhD thesis has been to investigate theoretically and numerically the electronic structure and the superconducting properties of a nanostructured superlattice of quantum layers in the presence of RSOC. We have described the unconventional Lifshitz transition in a 3D superlattice of metallic layers characterized by the length of the circular nodal line increasing with RSOC in the negative helicity states of the spin-orbit split electron spectrum. Here we have been able to provide the theoretical description of tuning multigap Bogolioubov-de Gennes superconductivity near the bottom of the upper subband with the negative helicity shifted by the RSOC. Our theory overcomes the limitations present so far due to common BCS approximations used in previous theoretical works on superconductivity in the presence of spin-orbit interactions which mostly describe superconductivity only at very high Fermi energy. We have shown the key role of quantum configuration interaction between the gaps in the self-consistent mean-field equation which need the calculation of the exchange interactions between singlet pairs in subbands with different quantum number and different helicity. The exchange interactions are local contact interactions which have been shown to be essential in condensation phenomena in fermionic quantum ultracold gases. In our theory the contact interactions are in action together with phonon exchange Cooper pairing. The key result of this work has been the calculations of the overlap of the electron wavefunctions by solving the non-relativistic Dirac equation in order to account for the spin-orbit coupling.

As a first step, we have shown that resonant and crossover phenomena in the normal state are amplified when the transverse energy dispersion of electrons in the superlattice is of the same order of magnitude of the energy cut-off of the effective pairing interaction. Under these conditions the introduction of a RSOC, of amplitude of the order of the 3D superlattice period, creates a completely unexpected variation in the topology of the Fermi surface, especially for the negative helicity band. In particular, the RSOC induces an unconventional Lifshitz transition with an associated extended van Hove singularity. For the non-BCS superconducting phase we have solved the Bogoliubov-de Gennes equation for the multiple gaps numerically. The unusual complexity in the properties of the normal phase is reflected in an amplification of the gap and the critical temperature in precise energy ranges. We have found that the enhancement of the superconducting parameters takes place when the chemical potential is tuned around the Lifshitz transition.

The most interesting aspects that emerged from my PhD thesis are the possibility of to vary the RSOC by varying the parameters of the model and the possibility to obtain a critical temperature typical of high T_C compounds by suitably and parallel varying the parameters that define the superconducting phase, the RSOC coupling and the geometry of the heterostructure of quantum layers. This allows us to provide precise indications for any experimental tests and practical applications. In a second phase of our work, we have, indeed, seen that by choosing a RSOC of the order of the cut-off energy and greater than the dispersion of the second subband and keeping the lattice periodicity fixed, it is possible to suitably vary the electron-phonon interaction constant in order to reach critical temperatures of the order of 208 K. Furthermore, our work shows how by adding the spin degree of freedom in the equations describing the system as well as being able to model the behaviour of real systems in a more realistic way, it is possible to justify the most recent results on superconductors at room temperature in a week coupling regime.

In such a context it might be interesting to extended the study of the thermal fluctuations in order to include the realistic electronic structure of the superlattice in the 3D-2D dimensional crossover, subject of this thesis. This involves going beyond the parabolic-band approximation used in previous work. To this end, as a preliminary study, it is possible to consider an analytical fit-model of the

superlattice bands. Another aspect that should be analysed is the extension of the Ginzburg-Landau theory in the presence of fluctuations for multiband systems. The next step could be to study the effect of thermal fluctuations in a multiband superconductor in the presence of a spin-orbit coupling (SOC). This greatly complicates an already controversial problem, but it could open up the possibility to study entirely new and fascinating phenomena. The theory of GL in the presence of a Rashba spin-orbit interaction (RSOC) has been investigated in several papers. It is emphasized that for such systems there are two transition temperatures the higher of which is the conventional critical temperature, T_C, while the lower one, T, corresponds to the crossover from a mixed singlet-triplet phase, at lower temperatures, to only a spin-singlet or spin-triplet (depending on the sign of the inter-band scattering potential) phase at higher temperatures. Currently, the problem of superconducting fluctuations in the presence of SOC has been addressed only for single-band systems, where the fluctuations with SOC are studied in BCS-BEC crossover, an important aspect for our work. In fact, the crossing of a shape-resonance and the passage of the chemical potential through a Lifshitz transition determines the tuning of the superlattice through this crossover. In several works the BCS-BEC crossover in the presence of RSOC was analysed. It has been shown that the SOC causes fluctuations to mediate an attractive pairing coupling, strongly dependent on the momentum and the spin, in the channel with odd-parity (p- or f-wave). Contrary to what was expected, the addition of a transversal Zeeman field does not destroy the superconductivity, but it suppresses the s-wave coupling promoting a coupling with odd-parity that increases as the SOC increases. This behaviour supports an unconventional topological superconductivity. As underlined in different works for sufficiently large SOC the singlet contribution improves in the BCS channel, but is suppressed in the BEC channel, therefore, as the spin-orbit coupling increases the system passes from a BCS-EC superfluid to a condensate BEC. The above leads, as a major effort, to the need to develop a new theoretical and computational research project aimed at the study of BCS-BEC fluctuations and the crossover phenomena in the presence of multiband systems, such as those generated by a superlattice, and at the same time, in the presence of spin-orbit coupling and, possibly, in the presence both parallel and transverse Zeeman magnetic fields. This will be a promising future development of the work of my thesis.
An other possible extension of the my PhD work could be to study the effect of both a parallel and a transversal Zeeman magnetic field and to see if and under what conditions it is possible to obtain topological zero-energy edge states, the Majorana fermions, object of my master's thesis work

COMPETENCES

- **English language**
- **French language**
- **Knowledge of Windows, Linux and Unix**
- **Knowledge of programming languages C, C++, FORTRAN 90, HTML**
- **Knowledge of Mathematica and Matlab software**

Roma, 14/06/2021

MARIA VITTORIA MAZZIOTTI