CURRICULUM VITAE OF MATTEO ZACCANTI

(Last update 01/03/25)

PERSONAL INFORMATION

ORCID ID: 0000-0001-6214-4921
web site: http://quantumgases.lens.unifi.it/exp/crli
E-mail: zaccanti@lens.unifi.it; matteo.zaccanti@ino.it

PERSONAL SKILLS AND COMPETENCES

Mother tongue	Italian
Other languages	English, French (excellent), German (Good), Spanish (Basic)
Social skills	20-year long experience in teamwork within international and multicultural environments. Excellent attitude in motivating a whole team to pursue ambitious goals. Excellent skills in establishing contacts and collaborations with other scientists worldwide.
Organisational skills	Project leadership (since 2010). 14-year long experience in organizing international research projects, coordinating activities in research labs and training of young scientists. Administration of research projects and budgets (since 2011).
Technical skills	20-year long experience in experimental AMO Physics and ultracold gases: optics & lasers, high & ultra-high vacuum systems, electronics, computer programming (Mathematica, C++, Origin, LABView, MS Office), data acquisition & analysis.
Artistic skills	Esame di Armonia, Conservatorio di Siena (1998) 5th year of Clarinet class, Conservatorio di Siena (1997) Licenza di Solfeggio, Conservatorio di Firenze (1996)

EDUCATION AND ACADEMIC CAREER

Since 2018: CNR-INO Senior researcher (Primo ricercatore), and associated to LENS, University of Florence, Italy.
Since 2014: National Academic Qualification as Associate Professor.
2012 – 2018: CNR- INO researcher, and associated to LENS, University of Florence, Italy.
2011 – 2012: Lise Meitner Fellow of Austrian Academy of Sciences at IQOQI, Innsbruck.
2010 – 2011: Senior Scientist at IQOQI, Innsbruck, Austria.
2008 – 2010: Project researcher at CNR-INFM, LENS and University of Florence, Italy.
2008: PhD in Atomic and Molecular Spectroscopy at LENS, University of Florence, Italy.
2004: Master in Physics at the University of Pisa, Italy.

FELLOWSHIPS AND AWARDS

2017: FARE Grant from Italian MIUR (P-HELiCS, #R168HMHFYM)
2014: ERC Starting Grant (PoLiChroM, #637738)
2011: Lise Meitner Fellow of Austrian Academy of Sciences, with a proposal ranked in the top 5% of the field (#M1318-N20)
2009: “Gilberto Bernardini” prize of the Italian Physical Society.

REFEREE ACTIVITY

Nature, Science, Nature Physics, Nature Communication, Reports on Progress in Physics, Phys. Rev. Lett., Phys. Rev. A, European Physics Journal.

MEMBERSHIP OF SCIENTIFIC SOCIETIES

(2006 –2010) Italian Physical Society.
(2010-2012) Austrian Academy of Sciences.

SCIENTIFIC OUTPUT

>40 high impact, peer-reviewed publications, seventeen of which with more than 100 citations/item. These include 2 Nature, 2 Science, 3 Nature Physics, 1 Nature Reviews Physics, 1 Reports of Progress in Physics and 12 Phys. Rev. Letters.
Web of Science (March 2025): 4950 citations (average 112 cit./ item), h-index: 28.
Google Scholar (March 2025): 7650 citations, h-index: 30.
During my career I attended more than 50 invited talks at international conferences and workshops, including BEC-Sant Feliu and DAMOP conferences, and I established strong collaborations with several world-leading experts on quantum gases: G. Bruun, S. Giorgini, R. Grimm, P. Julienne, W. Ketterle, J. Levinsen, P. Massignan, M. Modugno, M. Parish, D. Petrov, T. Pfau, A. Recati, L. Santos, A. Simoni, S. Stringari, M. Tomza, W. Zwerger among others.

PROJECT COORDINATION

2022-present: Integrated infrastructure initiative in Photonic and Quantum Sciences' I-PHOQS (Coordinator of the activity 5.2, funded with 450.000 euro).
2020-2022: EU H2020 Marie Skłodowska-Curie Grant (Supervisor, fellowship to A.Ciamei), CriLiN – "An Quantum Simulator with long-range, multi-body interactions", funding: 183.473 euro.
2015 – 2020: ERC Starting Grant (Principal Investigator), "Superfluidity and ferromagnetism of unequal mass fermions with two- and three-body resonant interactions", funding: 1.495.000 euro.
2017-2020: FARE Grant (Principal Investigator), "P-wave Superfluidity in heteronuclear Lithium-Chromium ultracold Fermi mixtures", funding: 116.610 euro.
2011-2012: Lise Meitner Fellowship (Principal Investigator), "Radiofrequency spectroscopy on K-Li Fermi mixtures", project ranked in the top 5%.

SUPERVISION OF UNDERGRAD AND PhD STUDENTS

2015 – 2024 Postdocs: A. Trenkwalder, M. Jag, A. Ciamei (Marie-Curie Fellow), C. Simonelli, M. Schemmer. PhD Student: E. Neri, S. Finelli, B. Restivo. Master Students: B. Restivo, A. Cosco, S. Finelli, I. Goti, M. Seminara, E. Neri, F. DiNoia, Florence University.
2013 – 2014 PostDocs: A. Burchianti, J. Seman (co-sup. Dr. G. Roati). PhD Student: G. Valtolina (co-sup. Dr. G. Roati), Scuola Normale Superiore, Pisa. Master Students: A. Morales (co-sup. Dr. G. Roati), University of Rome "La Sapienza". E. Neri, Florence University.

TEACHING ACTIVITY

(2022) Lecturer at the E. Fermi School, Varenna, Course 211 "Quantum Mixtures with Ultra-Cold Atoms"
(2022) Lecturer in the course "Seminars in Condensed Matter Physics", within the PhD program at Scuola Normale Superiore, Pisa.
(2016-2018) Lecturer of "Ultracold Gases" (with Prof. M. Fattori), Florence University.
(2014-16) Lecturer of "Cold Collisions in Low Dimensions" at Florence University (with Dr. F. Minardi)
(2010-11) Lecturer of "Atomic and Molecular Physics" at Innsbruck University (with Prof. H.-C. Nagerl).
(2011) Lecturer in the Advanced School of Science "Modern Trends in Quantum Matter: Cold Atoms and Molecules", Sao Carlos, Brazil.

MAJOR SCIENTIFIC ACHIEVEMENTS

-Feshbach spectroscopy of potassium-rubidium systems and study of tunable Fermi-Bose mixtures (2006).
-Production of the first Bose-Einstein condensate of 39K atoms with tunable interactions (2007).
-Realization of atom interferometry with non-interacting Bose gases (2008).
-Observation of Anderson localization of matter waves (2008).
-Study of the localization/delocalization transition in interacting, disordered Bose fluids (2009).
-Observation of an Efimov spectrum in an atomic Bose gas (2009).
-Observation of sub-diffusive dynamics of a disordered Bose gas (2011).
-Observation of collisional hydrodynamic expansion of a strongly interacting Fermi mixture (2011).
-Observation of repulsive and attractive Fermi polarons (2012).
-Study of few-body physics in mass-imbalanced fermion systems (2012-2014).
-Study of Josephson tunneling and dissipative dynamics in Fermi superfluids (2015-2019).
-Disclosure of a ferromagnetic instability in a strongly repulsive Fermi mixture (2017).
-Observation of repulsive Fermi polarons in imbalanced Fermi mixtures (2017).
-Disclosure of heterogeneous phases and quantum emulsions in repulsive Fermi mixtures (2018-2020).
-Realization of the first degenerate Fermi mixture of chromium and lithium atoms worldwide (2022).
-Investigation of Feshbach resonances and scattering properties of ultracold Cr-Li mixtures (2022).
-Realization of a high phase-space density gas of paramagnetic LiCr Feshbach molecules (2024).

RESEARCH ACTIVITY

My research encompasses frontier experiments on ultracold atomic gases, which I exploit as quantum simulators for a wealth of phenomena representing some of the key issues of contemporary physics. My current interests focus on superfluid and magnetic properties of strongly correlated fermions, impurity and few-body physics, quantum transport and many-body dynamics in ultracold Fermi mixtures, quantum gases of ultracold molecules. My past research activities also covered disordered Bose gases and atom interferometry.

(2005-2010) First as a PhD, and later as a junior post-doc at LENS, University of Florence, under the supervision of Prof. G. Modugno within the Quantum Gases Group led by Prof. M. Inguscio, I performed pioneering investigations of ultracold Bose-Fermi and Bose-Bose quantum mixtures of potassium and rubidium atoms. Thanks to the discovery of interspecies magnetic Fano-Feshbach resonances in such heteronuclear systems, I was able to tune the interatomic interactions driving the mixture into the resonant regime, where I accessed notable phenomena, such as interaction-induced collapse and phase separation, and heteronulear molecule formation. This bi-atomic system is nowadays employed in many laboratories worldwide for advanced studies of quantum Bose-Fermi and Bose-Bose mixtures and, most notably, for the realization of quantum gases of ground-state polar molecules, see e.g. K.K. Ni *et al.*, Science 322, 231 (2008).
Building on the knowledge gained both on the interspecies scattering properties of all K-Rb isotopic pairs, and on making and probing such heteronuclear mixture in the ultracold regime, I could then realize a novel kind of Bose-Einstein condensate of potassium (^{39}K) atoms with tunable interactions, based on sympathetic cooling with the rubidium component. With the ^{39}K condensate, prepared in the regime of vanishing interatomic interactions, I first demonstrated the realization of ultra-precise atom interferometers based on quantum gases, a possible new standard for the quantum sensors of tomorrow. Additionally, this ultracold, non-interacting Bose gas allowed me to observe for the first time the Anderson localization of matter waves by disorder, a phenomenon that is believed to lay at the heart of the insulating transitions in metals and superconductors, but which was never observed directly before for matter waves. This work is nowadays internationally recognized as a breakthrough achievement, both in and out the cold-atom physics community, see also Physics Today 62, 30 (2009). The possibility of finely tuning the interactions between ultracold ^{39}K atoms allowed me also to explore, through quantum transport and correlation measurements, the delocalizing role of a weak repulsive interaction on a disordered Bose gas, something that was again believed to play a major role in the conduction properties of real material, but which could not be studied in detail so far (see e.g. Nature Physics 6, 328 (2010)).
During this period, I also coordinated a pioneering study of few-body physics within a strongly-interacting Bose gas, which led to the first observation in nature of a spectrum of three-body Efimov states, and to experimentally test the distinctive spectral properties of such exotic few-body clusters. Unveiling such a fundamental quantum-mechanical phenomenon – originally predicted in the early 70's in the context of nuclear physics but never observed before – represented an absolute breakthrough for the cross-disciplinary community of few-body systems (see the commentary by V. Efimov, Nature Physics 5, 533). This study has now opened a new worldwide frontier in the research on quantum physics (see e.g. Physics 3, 9 (2010)).

In light of the important achievements obtained within this period – which led to top-level publications including 1 Nature, 2 Nature Physics and 3 Physical Review Letters, and that altogether are nowadays cited more than 4000 times – I was awarded with the "Gilberto Bernardini" Prize of the Italian Physical Society (2009). Furthermore, I attended as an invited speaker several international and prestigious conferences which, among others, include DAMOP (State College, Pennsylvania 2008), ETOPIM8 (Rethymnon, Crete 2009), the ITAMP Interdisciplinary Workshop "Efimov States in molecules and nuclei: Theoretical methods and new experiments" (Accademia dei Lincei, Rome 2009), and the Laser Physics '10 conference (Foz du Iguazu, 2010).

(2010-2012) Thanks to the international visibility gained from the breakthrough results achieved within my 2006-2010 research period– especially through my first authorship in the "Observation of an Efimov spectrum in an atomic system", and the attendance as invited speaker of the ITAMP Workshop on Efimov Physics at the Accademia dei Lincei in Rome mentioned above – I received offers for Senior Postdoc positions by various research groups worldwide. Among them, at the beginning of 2010 I opted to join the FeLiKX Lab at the Center for Ultracold Atoms and Quantum Gases in Innsbruck, under the supervision of Prof. R. Grimm – one among the leading scientists that opened the research area of strongly-interacting Fermi gases, and who pioneered the experimental investigation of the so-called BCS-BEC crossover of fermionic superfluidity.

This allowed me to further expand my expertise in the field of ultracold gases and quantum mixtures, focusing on the exploration of few- and many-body regimes of highly-correlated ultracold fermionic systems. In particular, first as a research associate of the Institute for Quantum Optics and Quantum Information (IQOQI), and later on as a Lise-Meitner fellow of the Austrian Academy of Sciences (Project Number M 1318-N20, proposal ranked in the top 5% of the field), I led an experimental team devoted to the investigation of strongly-interacting mixtures of two different Fermi gases of ^{40}K and of ^{6}Li atoms. Following a detailed characterization of the scattering properties and Feshbach resonances of such a mass-imbalanced fermionic system – which allowed me to establish a fruitful collaboration with the world-renown theory group of Prof. P. Julienne at NIST (see Naik *et al.*, Eur. Phys. J. D 65, 55 (2011)) – my team succeeded to observe, for the first time, the collision-driven hydrodynamic expansion of the system, a hallmark that, indeed, strongly-interacting conditions could be accessed in such a novel heteronuclear Fermi mixture.

Following the implementation of my Lise Meitner proposal, I then performed the first, thorough experimental characterization of the so-called Fermi polarons, the fundamental building blocks of Landau's Fermi liquid. Embedding a few potassium "impurity" atoms within a degenerate lithium Fermi gas – acting as a quantum bath with which the impurities resonantly interact – and pioneering the development of new radio-frequency spectroscopy protocols, we could unveil the full energy spectrum of both attractive and repulsive Fermi polarons and, even more importantly, we could probe their stability and coherence properties for the first time. The results of this study, published in Nature with myself as corresponding author, have represented a fundamental breakthrough in the field of ultracold gases (see also News & Views in Nature 485, 588 (2012)). Besides representing a textbook experiment probing the properties of Landau's Fermi liquids within highly-correlated ultracold matter, this work has opened up the way to the investigation of superfluid and magnetic phases with mass-imbalanced Fermi mixtures. Most importantly for my future career, this study represented a unique opportunity for me to emerge as an expert in the cross-disciplinary field of impurity physics, and to establish fruitful and yet active collaborations with world-renown theorists of highly-correlated fermionic matter. In particular, together with Profs. G. Bruun (Aarhus) and P. Massignan (Barcelona) co-authoring the work, I was later invited to write a Reports on Progress in Physics review article on Fermi polarons and related phenomena, which represents nowadays one of the most representative reviews on this topic, both in and out the cold-atom community.

During the latest time of my Postdoc period in Innsbruck, I focused on a study of few-body properties of mass-imbalanced fermionic systems under strongly-interacting conditions. Also building on my previous expertise on few-atom problems gained as a junior postdoc in Florence, I discovered a novel kind of "non-Efimovian" three-body effect. Specifically, my team was able to disclose a resonant attraction between K atoms and weakly bound KLi dimers – a few-body elastic phenomenon that solely arises from the large mass asymmetry of our mixture components and from their fermionic nature, and that qualitatively differs from what previously observed in equal-mass systems. Besides the importance of such discovery for the entire few-body physics community, this study was fundamental for me to devise my future research plans, see below. It also enabled me to establish a very strong collaboration with two top-level theorists in the field, Dr. D. Petrov (Orsay) and Prof. J. Levinsen (Monash), respectively.

The important achievements obtained from my research activity developed during this period – which led to top-level publications, including 1 Nature, 1 Reports on Progress in Physics and 2 Physical Review Letters, and altogether cited more than 1500 times – were fundamental to boost my career development under several perspectives. First, thanks to scientific results I obtained, I was invited to prestigious international conferences, workshops and schools, such as the SFB Meeting of the Austrian Physical Society (Innsbruck, 2011), the Advanced School of Science "Modern Trends in Quantum Matter: Cold Atoms and Molecules" (Sao Carlos, 2011), the "Theory of Quantum gases and Quantum Coherence" conference (Lyon, 2012), and the ITAMP Interdisciplinary Workshop "Research Frontiers in Ultra-Cold Atoms and Molecules: Unequal Mass Mixtures and Dipolar Molecules" (Cambridge MA, 2012). Second, the Lise Meitner Fellowship significantly increased my visibility within the international community, and offered me a perfect training for the administration of research projects and budgets. Third, thanks to the extremely positive assessment and trust I gained with Prof. R. Grimm, I had the opportunity to lead a competitive research team within the unique IQOQI infrastructure, with complete freedom to define the research line in the lab, and the responsibility of training Master and PhD students, as well as junior postdocs. Last but not least, my Innsbruck experience within the stimulating IQOQI environment allowed me to get in touch on a daily basis with world-leading scientists of the AMO Physics community – such as Profs. R. Blatt, P. Zoller, H.C. Nagerl and F. Ferlaino just to mention a few – and to greatly increase my professional skills, both technical and theoretical, in the field of ultracold atomic mixtures and highly-correlated quantum matter, enabling me to reach full independence as a senior scientist.

(2013-present) Despite having the opportunity of being hired as a permanent Senior Scientist at IQOQI, in November 2012 I opted to move myself and my family back to Italy, where I joined CNR-INO as a permanent researcher (Ricercatore CNR III livello). Among other possibilities, here I decided to join the newly-created LITHIUM lab at LENS, led by my long-lasting collaborator Dr. G. Roati, and targeted at BCS-BEC crossover studies based on homonuclear ^{6}Li Fermi mixtures. As the co-PI of the Lithium lab, and thanks to my technical skills and expertise gained in Innsbruck on strongly-interacting fermions, within a few months I was able to produce large superfluid samples, as well as deeply degenerate Fermi gases, by devising and optimizing an all-optical protocol (see Burchianti *et al.*, Phys. Rev. A 90, 043408 (2014)), nowadays followed by several labs worldwide. With the fully-operative LITHIUM machine, I successfully supervised, in close synergy with Dr. G. Roati, fundamental studies on highly-correlated fermions at ultralow temperature, covering different cross-disciplinary topics. These encompass superfluid quantum transport phenomena, impurity physics, and out-of-equilibrium dynamics of repulsive Fermi gases across a ferromagnetic phase transition. My commitment to the LITHIUM lab enabled scientific breakthroughs that have led more than ten top-level publications, including 2 Science, 1 Nature Physics, and 6 Physical Review Letters (among the latter ones, 2 Editors' Suggestion), altogether being cited more than 1300 times. The achieved results have allowed me to further strengthen my international visibility in the scientific community, also thanks to more than 30 invitations to international conferences, workshops, and top-level universities: Among others, I mention that I was invited to present our results in the BEC Conference (Sant Feliu, 2018), the most prestigious workshop of the whole community of ultracold quantum gases. These research activities also allowed me to establish new important and fruitful collaborations with world-renown scientists. In particular, these include the one with the 2001 Nobel Laureate Prof. W. Ketterle (MIT) – which led to two scientific papers on the physics of repulsive Fermi gases (one Physical Review A, and one Physical Review Letters), both with myself as last author. Additionally, it is worth mentioning my collaboration with the top-level theorist Prof. W. Zwerger (TUM University) on Josephson tunneling, with whom I developed an analytic model that sheds light on the subtle link between the Josephson critical current and the condensate density of fermionic superfluids – able to reproduce our experimental findings with remarkable accuracy throughout the BCS-BEC crossover.

Awarded with an ERC Starting Grant (mid of 2015), and later with a national FARE Grant (from 2017), I also started developing my own group, as the PI of the PoLiChroM lab. The main challenge of this experimental activity was to realize a novel heteronuclear Fermi mixtures by combining the well-known lithium atom with the fermionic isotope of chromium – an atomic species that was almost unexplored in the ultracold regime. The scientific motivation of such a choice was heavily influenced by my past research on lithium-potassium mixtures, and it mainly connects with the exotic few-body phenomenon I disclosed therein. Based on predictions made by my theory collaborator Dr. D. Petrov, lithium-chromium mixtures – thanks to their increased mass asymmetry, relative to the lithium-potassium one – are expected to be a unique platform for the exploration of a new class of "non-Efimovian" few-body states, never observed in any physical system thus far. Most remarkably, theoretical studies foresee that such exotic clusters, in stark contrast with the widely-explored Efimov ones, should exhibit non-trivial topological properties, combined with an exceptional stability against inelastic processes. Hence, besides enabling one to experimentally probe a new kind of few-body physics phenomena, lithium-chromium mixtures could uniquely enable to controllably introduce non-perturbative few-body correlations – besides the standard two-body ones – within strongly-interacting ultracold fermionic matter, thereby opening qualitatively new opportunities in the field of quantum gases and quantum simulation.

Notwithstanding the challenge of producing fermionic chromium in the ultracold regime, and the complete absence of reference literature for lithium-chromium mixtures, since 2020 we could simultaneously create large cold Li-Cr samples in a magneto-optical trap (see Phys. Rev. A, 101, 063602 (2020)). Shortly after – and in spite of the COVID pandemic temporarily slowing down our lab activities – we succeeded to optically trap the two mixture components, and to perform forced evaporative cooling of lithium combined with sympathetic cooling of chromium: Following such an all-optical approach, we could achieve simultaneous quantum-degeneracy of chromium and lithium atoms, with more than 100k atoms per species, at temperatures of about one quarter of the corresponding Fermi temperature for both components. Moreover, we thoroughly investigated the scattering properties of this novel system, uniquely available in our lab worldwide, identifying more than 50 heteronuclear Feshbach resonances. Building on my already well-established collaboration with Prof. A. Simoni, and on his expertise in coupled-channel calculations, a joint experiment-theory effort allowed us to construct a quantum collisional model quantitatively accurate for all Li-Cr isotopic pairs. The discovery of magnetic Feshbach resonances suited to controllably tune the interspecies interaction in this new quantum mixture has, over the last year, allowed us to thoroughly explore the LiCr molecule formation process through magneto-association techniques. This study, in collaboration with the theoretical group of Prof. M. Tomza (University of Warsaw) has resulted in the production of high phase-space density samples of more than 50k bosonic LiCr dimers at 100nK temperatures, featuring phase-space densities exceeding 0.2. These latest results (see arxiv:2402.08337, to be published in PRX Quantum) represent a fundamental achievement under several viewpoints: The ability to create and probe lithium-chromium dimers is a crucial step towards the realization, and disclosure, of more complex few-body cluster states. Attaining molecular Bose-Einstein condensates from lithium-chromium Fermi mixtures would be an absolute breakthrough on its own, that paves the way to the exploration of BCS-BEC crossover physics in presence of a mass imbalance. Last but not least, the availability of producing high phase-space density samples of LiCr Feshbach dimers provides an optimal starting point to realize, via adiabatic optical transfer schemes, the first quantum gas of ground-state paramagnetic polar molecules. In this respect, recent ab initio calculations (by M. Tomza's group), foresee for the LiCr diatomic molecule a large electric dipole moment, exceeding 3.3 Debyes, combined with a large electronic spin, which makes our mixture an ideal system with which to realize quantum gases of doubly-polar molecules.

This latter possibility, supported both by the Integrated infrastructure initiative in Photonic and Quantum Sciences I-PHOQS (of which I am responsible for the A5.2 activity) and by the PE0000023-NQSTI project, has allowed me to establish strong collaborations, both at the international and national level, both in and out INO-CNR: First, with Dr. P. De Natale at CNR-INO & LENS and Dr. G. Santambrogio at INRIM & LENS, combining in a synergic effort the unique ability of my research team in making ultracold samples of weakly-bound LiCr dimers, with the world-renown expertise of De Natale's and Santambrogio's groups on laser physics and molecular spectroscopy; Moreover, I have established strong collaborations and connections on this research topic with Dr. G. Carugno at INFN-Legnaro, Prof. M. Tomza's theory group at the University of Warsaw, and Prof. X. Cui's group at the Institute of Physics of the Chinese Academy of Sciences, Beijing.