Aniello Quaranta

europass

ABOUT ME

Postdoctoral researcher in particle physics with applications to cosmology and astrophysics, experienced in theoretical modeling and analysis. Expert in quantum field theory in curved spacetime and semiclassical Einstein equations, with emphasis on their application to the study of the dark components of the universe. Proven track record of publishing in high impact journals over six years (three as PhD student and three as postdoc) of research activity. Passionate about advancing our understanding of the universe through innovative research and interdisciplinary approaches.

WORK EXPERIENCE

01/03/2022 – CURRENT Fisciano (SA), Italy

Physics researcher University of Salerno

Postdoc position for research in particle physics amd cosmology.

Supervisor: Prof. Antonio Capolupo
Title of the project: "Quantum field theory and physics of the dark universe"

Activities include:

- Theoretical models building
- Theoretical and formal analysis
- Phenomenological analysis and data visualization
- Manuscript writing and editing, activity as corresponding author
- Referee activity

Responsibilities include:

- Assisting and supervising junior colleagues
- Providing assistance for PhD and master theses writing
- Participating in exam commissions

Business or Sector Professional, scientific and technical activities | **Department** Department of Physics "E. R. Caianiello", University of Salerno | **Website** www.unisa.it

EDUCATION AND TRAINING

01/11/2018 – 02/12/2021 Fisciano (SA), Italy

Ph.D in theoretical particle physics University of Salerno

PhD research was focused on dark matter, both from the particle physics perspective (axions, dark photons etc.) and concerning alternative explanations in terms of quantum field theory effects (condensed vacuum). The PhD comprised nine works published in high impact journals.

PhD supervisor: Prof. Antonio Capolupo

Website www.unisa.it | **Field of study** Physics | **Final grade** Excellent | **Level in EQF** EQF level 8 | **National classification** 8 | **Thesis** Particle physics and quantum field theory approaches to dark matter

01/10/2015 – 20/09/2018 Fisciano (SA), Italy

Master's degree in physics University of Salerno

Extensive analysis of the Hawking-Unruh effect, with generalization to some extended theories of gravity (Brans-Dicke, f(R)).

Supervisors: Proff. Gaetano Lambiase and Antonio Capolupo

Website www.unisa.it | **Field of study** Physics | **Final grade** 110 Cum Laude | **Level in EQF** EQF level 7 | **National classification** 7 | **Thesis** QFT IN CURVED SPACETIMES: THE UNRUH AND HAWKING EFFECT AND THEIR CONSEQUENCES

LANGUAGE SKILLS

MOTHER TONGUE(S): Italian

Other language(s):

English

Listening C1
Spoken production C1
Reading C1
Spoken interaction C1
Writing C1

Levels: A1 and A2: Basic user; B1 and B2: Independent user; C1 and C2: Proficient user

DIGITAL SKILLS

Microsoft Office package: Microsoft Word, Excel, PowerPoint, Access | Microsoft Office | Microsoft Word | Microsoft Powerpoint | Microsoft Excel | Google Drive | Organizational and planning skills | Mathematica Wolfram

NETWORKS AND MEMBERSHIPS

2019 – CURRENT

ISTITUTO NAZIONALE DI FISICA NUCLEARE (INFN)

Specific initiative of the National Institute of Nuclear Physics (INFN): QGSKY, Group Four, research line: Quantum Universe, participation as a member.

2019 – CURRENT

(FARB Project) University of Salerno

Participation in the University Research Fund (Farb) 2019 (formerly 60%), research title: Physics of gravitation, astroparticles, and quantum field theory. Supervisor: Gaetano Lambiase.

CONFERENCES AND SEMINARS

16/09/2024 – 20/09/2024 Castiglioncello (Italy)

DICE 2024

Presentation of "Quantum reference frames and particle mixing".

Link https://osiris.df.unipi.it/~elze/DICE2024.html

14/09/2023 Institut Ruđer Bošković, Bijenička cesta 54, 10000 Zagreb, Croatia.

Invited Talk

Invited Talk "QFT of neutrino mixing in curved spacetime".

10/07/2023 – 14/07/2023 Chania, Crete (Greece)

SigmaPhi 2023

Presentation of "Axion-like particles and fifth force with neutron interferometry".

Link http://www.sigmaphi.polito.it/index.php?option=com_content&view=article&id=223:sigmaphi2023-round-table&catid=25:news-2023&Itemid=121

Castiglioncello (Italy)

DICE 2022

Presentation of "Fermion mixing in curved spacetime".

Link https://osiris.df.unipi.it/~elze/DICE2022.html

14/09/2022 – 16/09/2022 Genova (Italy)

Avenues of Quantum Field Theory in curved spacetime

Link http://avenuesingenova.dime.unige.it/

15/06/2022 – 24/06/2022 Erice (Italy)

International school of subnuclear physics

Link https://ettoremajoranafoundation.it/scuola/international-school-of-subnuclear-physics/

17/10/2019 – 18/10/2019 Trieste (Italy)

Workshop Quantum Gravity in the SKY, Quantum Universe

Presentation of "Probing the nature of neutrinos through decoherence and geometric phases".

13/04/2019 – 17/04/2019 Vietri Sul Mare (Italy)

International conference: Current Problems in Theoretical Physics

Presentation of "Dirac and Majorana neutrinos: decoherence, phases and CPT violation".

Link https://conferences.phys.unisa.it/paft19/

TEACHING EXPERIENCE

2023

Master Thesis Supervision

Supervision activity for the Master Thesis in Physics of the students Giuseppe De Maria e Simone Monda.

2021 – 2022

Master Thesis Supervision

Supervision activity for the Master Thesis in Physics of the students Gabriele Pisacane, Raoul Serao e Pia Antonella Setaro.

2020 – 2024

Member of exam committee

Member of the exam committee for the course Elettrodinamica (Electrodynamics) at Department of Physics "E. R. Caianiello", part of the Master's degree in physics at University of Salerno, as "cultore della materia".

2020 – 2024

Member of exam committee

Member of the exam committee for the course Fisica I (Physics I) at Department of Chemistry and Biology "A. Zambelli", part of the Bachelor's degree in Chemistry at University of Salerno, as "cultore della materia".

2019

Tutoring

Tutoring for the course Fisica Generale I (Physics I), 15 hours of lectures (bachelor's degree in physics, University of Salerno).

RESEARCH ACTIVITY

Outline and subjects

I conduct research in Theoretical Physics of Fundamental Interactions, Quantum Field Theory, Theoretical Particle Physics, Cosmology, and Gravitational Physics. This work is carried out within the Theoretical Physics of Fundamental Interactions research group, in collaboration with researchers from the local department ("E. R. Caianiello") as well as with representatives from other universities (both Italian and foreign).

Subjects I have worked in include:

- Quantum Field Theory and non-perturbative interacting field theories. In particular, studies applied to oscillation phenomena in particle physics (neutrinos, axions, mesons).
- Beyond the standard model physics: axions, mirror matter, massive neutrinos, nonlocal field theories - theoretical models and phenomenology.
- Dark matter - particle physics candidates and alternative explanations.
- Black Hole Physics and accretion disks, particle dynamics in black hole metrics
- Structure of the quantum vacuum and condensation effects induced by mixing, curvature, and finite temperature effects. Applications to cosmology and astrophysics, such as the Hawking effect in extended theories of gravitation, oscillations in curved spacetimes and at finite temperature, and potential connections with dark energy and dark matter.
- Particle physics in cosmological contexts, theory of leptogenesis, and the origin of matter-antimatter asymmetry.

- Phases and geometric invariants as tools for detecting particles beyond the Standard Model (axions, mirror matter, fifth force carriers), testing fundamental symmetries (CPT), and determining the fundamental nature of neutrinos. Study of entanglement induced by interactions beyond the Standard Model.
- Atomic analogs in the study of phenomena related to quantum field theory that are challenging to observe experimentally (Hawking-Unruh effect, Dark Matter, and Dark Energy from condensate effects).

Quantum field theory and theoretical particle physics

The studies conducted in this context focus on physics beyond the Standard Model, with particular emphasis on mixing phenomena, condensate effects, field theory in curved spacetimes and in extended theories of gravitation, and finite temperature effects. In all these applications, the development and study of non-perturbative methods play a key role in analyzing interactions. Other studies involve the application of geometric invariants to fundamental physics.

• Mixing phenomena

Oscillation phenomena in particle physics provide evidence for the necessity of physics beyond the Standard Model, even at energy scales that we can experimentally test. These phenomena involve both hypothetical particles, such as the axion in the presence of strong magnetic fields, and already known particles, such as neutral mesons (K, B, D) through the oscillation of their constituent quarks (d, s, b), and, in particular, neutrinos. The oscillations of the latter were first theorized by Pontecorvo and later confirmed experimentally. Among known particles, neutrinos are the least understood, given the numerous open questions related to, among other things, the origin of their mass, their fundamental nature (Dirac or Majorana fermions?), and the origin and proper treatment of flavor oscillations. While the treatment of mixing does not pose difficulties in quantum mechanics, the correct field theory is still a subject of discussion. It is known that the generator of mixing transformations, which links fields with definite masses and those with definite flavor, does not leave the vacuum invariant. This means that fields with definite masses and those with definite flavor operate in different, unitarily inequivalent Fock spaces. The issue of the existence of unitarily inequivalent representations of the canonical (anti-)commutation relations is even more significant when defining field theories in curved spacetimes or at finite temperature. In these cases, there is generally no preferred definition of the quantum vacuum, not even for free fields, since generators related to curvature and the thermal bath do not leave the vacuum invariant. In this context, I have conducted research aimed at determining the correct oscillation formulas and their related phenomenology. My works on the subject include:

"**Neutrinos in curved spacetimes: particle mixing and flavor oscillations**", published in *Phys. Rev. D* **101**, 095022 (2020).
"**Quantum field theory of neutrino mixing in spacetimes with torsion**", published in *Universe* **2024**, 10 (4), 170 (2024).
"**Beyond the MSW effect: neutrinos in a dense medium**", published in *Phys. Lett. B* **820**, 136489 (2021).
"**Testing CPT violation, entanglement and gravitational interactions in particle mixing with trapped ions**", published in *EPJC* **81**, 410 (2021).
"**Boson mixing and flavor oscillations in curved spacetime**", published in *Phys. Rev. D* **106**, 043013 (2022).
"**Neutrinos, mixed bosons, quantum reference frames and entanglement**", published in *Journal of Physics G* **50**, 055003 (2023).

• Non-local field theories

There are many possible avenues for extending the Standard Model. Generalizations can be obtained by adding new fields and particles (such as axions, dark photons, etc.), new fundamental symmetries (supersymmetry), or by making a true paradigm shift (string theories, non-local theories). Among these, non-local field theories extend the possible forms of interactions, considering terms that do not depend solely on the value of the fields and their derivatives at a single point, but on their values over extended regions of spacetime. Examples of non-local theories emerge both in the context of gravitation and in particle physics. Moreover, non-local theories are closely related to string theories, which often predict them as effective theories at low energies. My research in this area resulted in the article:

"**Muon g-2 anomaly and non-locality**", published in *Phys. Lett. B* **829**, 137128 (2022).

Quantum field theory and theoretical particle physics

• Condensation phenomena and non-perturbative QFT

A characteristic of the treatment of particle mixing in QFT is its non perturbative nature and the consequent appearance of a non-trivial vacuum, which has a pair condensation structure of particles and antiparticles. In addition to the particle creation phenomena induced by curvature (Hawking Unruh and Parker effects), non-trivial topology (Casimir), and interactions with intense background fields (Schwinger effect), a condensate vacuum also characterizes spontaneous symmetry breaking and four-fermion interactions (e.g., superconductivity). The study of the spin-spin four-fermion interaction has been incorporated into the article:

"**Fermion condensates induced by axial interactions and cosmological implications**", published in *Journal of Physics G* **51**, 105202 (2024).

• Phases, geometric phases and their application to fundamental physics

The study of phases, and more generally, of geometric invariants in connection with fundamental physics, is a relatively recent field of research with great potential for applications. The most well-known example of a geometric invariant is probably the Berry phase, discovered by Berry in the 1980s for cyclic and adiabatic evolution. Since then, the notion of geometric phase has been refined and generalized to cases where the quantum system's evolution is neither cyclic nor adiabatic (Mukunda-Simon phase). Furthermore, the phase is experimentally accessible through interferometry, making it ideal for highlighting phenomena that would otherwise be difficult to detect. My research has culminated in the articles:

"Probing mirror neutrons and dark matter through cold neutron interferometry", published in *Physics of the Dark Universe* **46**, 101688 (2024).
"Neutron interferometry, fifth force and axionlike particles", published in *EPJC* **81**, 1116 (2021).
"Discerning the nature of neutrinos through decoherence and geometric phases", published in *Universe* **20 20**, 6(11), 207 (2020).

Cosmology and Gravitation

Research in this field has been primarily focused on studying the dark components of the universe (Dark Energy and Dark Matter) and the physics of the early universe (leptogenesis and matter-antimatter asymmetry).

• Dark Matter
Dark matter was originally introduced to explain the rotation curves of galaxies and remains one of the primary subjects of study in cosmology. Numerous hypotheses have been proposed regarding its composition, including compact astrophysical objects (MACHOs, primordial black holes, etc.) and new weakly interacting particles (WIMPs, axions, axion-like particles, etc.). There have also been theories involving modifications of General Relativity (extended gravity theories) and condensate effects induced by mixing (and more broadly, particle creation mechanisms in field theory). My study focused on this latter hypothesis and the potential for experimental validation through the construction of an atomic analogue, as well as through the capture of cosmic background neutrinos. My papers on the subject include:

"Probing quantum field theory particle mixing and dark-matter-like effects with Rydberg atoms", published in *EPJC* **80**, 423 (2020).
"Quantum flavor vacuum in the expanding universe: A possible candidate for cosmological dark matter?" , published in *Phys. Rev. D* **105**, 105013 (2022).
"Neutrino capture on Tritium as a probe of flavor vacuum condensate and dark matter", published in *Phys. Lett. B*. **839**, 137776 (2023).

• Dark Energy
Dark energy represents another of the great puzzles in modern cosmology, invoked to explain the accelerated expansion of the universe. The nature of dark energy remains unknown, with numerous theoretical possibilities: cosmological constant, new scalar fields, extended theories of gravitation, etc. My work focuses on the potential contribution to dark energy arising from boson mixing, which resulted in the publication:

"Boson mixing and flavor vacuum in the expanding Universe: a possible candidate for the Dark energy", published in *Phys. Lett. B* **840**, 137889 (2023).

• Leptogenesis and Early Universe
Among the open questions in cosmology are the understanding of the early stages of the universe's life and the mechanisms that led to its current form, particularly the origin of the matter-antimatter asymmetry. Among the various theories proposed to explain it, one of the most widely accepted is Leptogenesis, which suggests that the asymmetry originally developed in the lepton sector based on the see-saw mechanism for neutrinos. The research has culminated in the article:

"Consequences of f(T) Cosmology in thermal leptogenesis and gravitino late abundance", published in *Sym metry* **2020**, 12(2), 300 (2020).

• Spacetime and black hole physics
The fundamental, and potentially quantum, nature of spacetime remains an open question in theoretical physics, closely tied to the formulation of a theory of quantum gravity (QG). Some clues about the nature of spacetime come from the connection that developed over the past decades between thermodynamics and geometry, culminating in work on black hole thermodynamics, Hawking radiation, and the derivation of Einstein's field equations from thermodynamic laws applied to causal horizons. My work in this area has focused on formalizing a view of spacetime that is more centered on its causal structure, where the connection with thermodynamics is even more apparent. This led to the publication:

"A background independent notion of causality", published in *International Journal of Geometric Methods in Modern Physics* **21**, 08, 1450159 (2024).

Quantum field theory and applications, entanglement

Very often, the results obtained in field theory and particle physics are difficult to verify experimentally due to the level of precision required. This is the case, for example, with the Hawking-Unruh effect and axions, for which there is still no experimental evidence. In this context, the development of alternative detection methods is of great interest. My study has culminated in the following work:

"Probing axion-mediated fermion-fermion interaction by means of entanglement", published in *Phys. Lett. B*. **840**, 135407 (2020).

BIBLIOMETRIC PARAMETERS

Outline of bibliometric parameters

DATABASE	CITATIONS	h-INDEX
Google Scholar	282	11
Scopus	183	8
Web of Science	160	8

SCIENTIFIC COLLABORATIONS

List of Scientific Collaborations

- Prof. A. Capolupo, Università degli studi di Salerno, dipartimento di Fisica "E. R. Caianiello", Salerno, Italy.
- Prof. S. Capozziello, Università degli studi di Napoli "Federico II", dipartimento di Fisica "E. Pancini", Napoli, Italy.
- Prof. O. Luongo, Scuola di Scienze e Tecnologie, Camerino University, 62032 Camerino, Italy.
- Dr. S. M. Giampaolo, Institut Ruđer Bošković, Bijenička cesta 54, 10000 Zagreb, Croatia.
- Prof. K. Boshkayev, Nazarbayev University, department of Physics, Kabanbay Batyr 53, Astana 010000, Kazakhstan.
- Prof. S. Carloni, DIME, Università di Genova, Via all'Opera Pia 15, 16145 Genova, Italy.
- Prof. S. Vignolo, DIME, Università di Genova, Via all'Opera Pia 15, 16145 Genova, Italy.
- Prof. A. Iorio, Faculty of Mathematics and Physics, Charles University, V Holešovi˘ckách 2, 18000 Prague 8, Czech Republic.
- Prof. B. C. Hiesmayr, University of Wien, department of Physics, Währingerstrasse 17, 1090 Wien, Austria.
- Dr. K. Simonov, Unviersity of Wien, department of Physics, Währingerstrasse 17, 1090 Wien, Austria.
- Prof. G. Lambiase, Università degli studi di Salerno, dipartimento di Fisica "E. R. Caianiello", Salerno, Italy.

REFEREE ACTIVITY

2019 - CURRENT

Referee activity

Referee for The European Physical Journal C
Referee for an ERC Starting Grant 2020 project proposal
Referee for "Advances in High Energy Physics" (2022-2023)
Referee for "International Journal of Geometrical Methods in Modern Physics" (2022-2024).
Referee for "Modern Physics Letters A" (2022-2023).

INTERESTS

CURRENT

Other interests

I actively collaborate with a publishing house, dealing mostly with human sciences, taking care of impagination and design. I am interested in trading of commodities and forex, and in general in economics. I am passionate about music, especially rock music.

DATE

30/12/2024

SIGNATURE