10 PhD positions in the Doctoral Network 'Quantum and Classical Ultrasoft Matter' (QLUSTER, HORIZON–MSCA–2021–DN, Project ID 101072964).

Despite striking similarities in phenomena, language and even methods employed to study cluster formation and mesophase organization across widely different length scales — from the subatomic to the macromolecular scale — a coherent effort to bring distinct research communities in classical and quantum soft matter together has not been yet undertaken. The scientific objective of the Doctoral Network QLUSTER is to advance the fundamentals in classical and quantum soft matter beyond the state of the art, creating permanent ties between communities that have evolved separately so far, and fostering the transfer of knowledge essential for a broad range of applications. The ambitious research and training programme will address the properties of classical and quantum soft matter systems under a common framework based on the underlying ultrasoft interactions of the constituents. Ultrasoftness is the key factor leading to the observed complexity in the dynamics, structure, and response to external drives of these different entities (complex polymers, soft colloids, Rydberg atoms in optical lattices, vortex matter in superconductors, etc). QLUSTER comprises a unique theory/experiment balanced team of specialists in quantum optics, polymer physics and macromolecular chemistry among others, and it provides a valuable platform for communication between the different communities of research in ultrasoft matter.

QLUSTER offers 10 PhD positions. The duration of the PhD contract will be 3 years. The awarded candidates must have an MSc degree (see specific details of each project) at the time of recruitment (before the end of 2023, please contact the supervisors of the PhD projects for details). Fluency in English (written and oral) is required.

IMPORTANT: According to the mobility rules established by the EC, the candidate of a PhD project must not have resided or carried out his/her main activity (work, studies, etc) in the country of the host institution for more than 12 months in the 36 months immediately before the recruitment date. Candidates not fulfilling this rule are not eligible for that project.

The criteria for evaluating the candidates will be:

Curriculum Vitae, including marks of their BSc and MSc (40%)
Background in the concepts and methods of the project (40%)
Declaration of interest and reference letters (10%)
Other merits (10%)

In case of equal qualifications preference will be given to female candidates and to those of underrepresented groups and less favoured countries.

The candidates should send their CV (including marks of their BSc and MSc degrees), declaration of interest and reference letters to the supervisors of the projects (see contact details in the list of projects) BEFORE 28th FEBRUARY 2023. If no suitable candidates have

been found for an individual project its deadline will be extended as long as needed. If this is the case extended calls will be made in other public channels.

List of PhD projects, host institutions, supervisors and gross salaries per year *before all deductions* (see below). **Moreover the contract will include an additional mobility allowance of 7200 euros per year and, if the student has family obligations, a family allowance of 7920 euros per year. Please note that gross salaries and allowances are subject to deductions (which include taxes plus the employer and personal contributions to the Social Security). The total deductions depend on the host country, total gross salary and family status of the student, and are typically 40-50%.** Please contact the supervisors for all financial details.

1) Title: Effective fluid approach for self-healing polymeric dual networks
Host: Consejo Superior de Investigaciones Científicas (CSIC), San Sebastián, Spain
Supervisor: Angel Moreno, angeljose.moreno@ehu.es
Description: The aim of this project is to advance beyond the state of the art the fundamentals of polymer-based self-healing materials with non-covalent and/or dynamically covalent bonds, by exploring the structure and dynamics of dual network-forming systems constructed through the assembly of polymeric single-chain nanoparticles with reversible bonds, through a combination of molecular dynamics simulations and liquid state theory with ultrasoft effective potentials.
Requirements: The candidate should have an MSc in Physics, Chemistry or related areas with preferred background in statistical physics, soft matter and computer simulations. Knowledge on programming is essential. Experience in using simulation packages (GROMACS, LAMMPS, ESPResSo…) will be esteemed.
Gross salary before all deductions and taxes: 37250,20 euros/year.

2) Title: Ultra-low-crosslinked and hollow microgels as candidates for cluster-forming fluids and glasses
Host: Consiglio Nazionale delle Ricerche (CNR), Rome, Italy
Supervisor: Emanuela Zaccarelli, emanuela.zaccarelli@cnr.it
Description: The project will be focused on molecular dynamics simulations of microgel particles at ultra-low-crosslinking at different packing fractions to uncover their phase behavior, dynamics and slowing down close to an arrested (glassy) state. Interpenetration leading to cluster formation will be studied in detail to understand the role of ultrasoft interactions.
Requirements: The candidate should have an MSc in Physics or Chemistry, with preferred background in statistical physics, soft matter and numerical simulations. Some theoretical background in liquid and glass state theory would be preferred. In addition, basic knowledge of programming and analysis tools is required, while previous experience in performing Molecular Dynamics simulations would be preferential, as well as the knowledge of relevant software such as LAMMPS.
Gross salary before all deductions and taxes: 39739,20 euros/year.

3) Title: Complex systems dynamics in structured atomic gas
Host: Université Strasbourg, Strasbourg, France
Supervisor: Shannon Whitlock, whitlock@unistra.fr
Description: Recent experiments on well controlled systems of ultracold atoms excited to long-range interacting Rydberg states by an off-resonant laser field have shown complex non-equilibrium dynamics and novel phases traditionally found in soft-matter settings, including cluster formation, self-organization, Griffiths effects and glassy dynamics. In this project, the Doctoral Researcher will perform new experiments and theoretical modelling of systems of ultracold atoms in spatially structured environments using a digital micromirror device. By controlling disorder and atomic motion, it will be possible to explore the regime where quantum and classical fluctuations can compete on equal footing. The PhD student will study how characteristic quantities, such as universal critical exponents and decaying correlation functions depend on the mixed coherent-dissipative dynamics, structure and long-range interactions.
Requirements: The candidate should have an MSc in Physics, with a strong background in quantum physics as well as theory and/or experimental research experience in the fields of ultracold atoms or non-equilibrium many-body physics..
Gross salary before all deductions and taxes: 47491,20 euros/year.

4) Title: Effective shoulder-like interactions in the liquid-drop model
Host: University of Ljubljana, Ljubljana, Slovenia
Supervisor: Primoz Ziherl, primoz.ziherl@ijs.si
Description: The project aims at elucidating the role of particle deformability in dense suspensions of micro- and nanocolloids such as microgels. The particles will be described by a generalized liquid-drop model pertaining to particles with a hard core, and one of the objectives of the project will be to compute the phase diagram of the model. This will be used to examine the mapping of the liquid-drop model, which has a consistent micromechanical basis, onto a suitable effective model such as the hard-core/linear-ramp potential. The second objective of the project will be to develop a theory of effective shoulder-like interactions in liquid-drop model based on the transition from partial to complete faceting, which will be used to identify the pairwise-additive and many-body regimes of the drop-drop interaction, thereby providing an insight into the latter. To provide an analysis of the model as complete as possible, we will also study the effects of classical and quantum fluctuations on the structures formed by the particles using a suitable realistic model pair interaction, searching for possible novel effects. The work will be primarily numerical.
Requirements: The candidate is expected to have a good command of thermodynamics, statistical physics, and classical mechanics including the theory of elasticity, and be familiar with numerical methods in physics. Experience with the approaches to be used in the project (as finite element methods) will be esteemed.
Gross salary before all deductions and taxes: 33986,40 euros/year.

5) Title: Collective behaviour of logarithmically interacting particles in two dimensions
Host: Universität Wien, Vienna, Austria
Supervisor: Christos Likos, christos.likos@univie.ac.at
Description: The project will focus on the soft matter aspect of cluster formation of ultrasoft systems while at the same time establishing a strong collaboration with the University of Innsbruck to elucidate connections and analogies with related ultrasoft systems in the quantum regime. An analytical effective model for the steady state of excitations in driven dissipative ensembles of Rydberg atoms will form the basis of our investigations. For Rydberg atoms with van der Waals interactions it can be shown that it is sufficient to include in the formalism only pair interactions that for small distances diverge logarithmically. This is the same effective pair interaction experienced by star polymers, establishing the link between the quantum and classical ultrasoft matter aspects of the project
Requirements: The candidate should have experience in classical simulation techniques, such as Molecular Dynamics and Monte Carlo, a strong background in Statistical Mechanics and a working knowledge of the formalism and tools of Quantum Statistical Mechanics.
Gross salary before all deductions and taxes: 43370,40 euros/year.

6) Title: Self-assembling cluster crystals from DNA-based nano-constructs
Host: Forschungzentrum Jülich, Jülich, Germany
Supervisor: Emmanuel Stiakakis, e.stiakakis@fz-juelich.de
Description: The project aims at the experimental realization and detailed study of equilibrium soft matter cluster crystals. Just as the particles (atoms and/or colloids) in ordinary crystals are arranged in a periodic lattice, cluster crystals are states of matter in which the lattice sites are occupied by clusters consisting of several particles. The interaction between the particles is purely repulsive, leading thereby to the counterintuitive result of clustering in the absence of attractions. The project will focus on the synthesis and study the self-assembly of nanosized DNA-polymer cluster-forming constructs with dendritic and linear architecture.
Requirements: The candidate must hold an MSc degree in Chemistry or related fields with strong hands-on experience in organic synthesis. Experience in analytical methods (such as high-pressure liquid chromatography), scattering methods and molecular biology techniques is welcomed.
Gross salary before all deductions and taxes: 40106,40 euros/year.

7) Title: Rydberg induced ultrasoft interactions in reconfigurable optical tweezers
Host: Universität Tübingen, Tübingen, Germany
Supervisor: Christian Gross, christian.gross@uni-tuebingen.de
Description: The project aims at realizing coherent softcore interactions induced by Rydberg dressing in a reconfigurable optical tweezer array. Driven many-body quantum systems with applications in quantum computation will be studied. The Doctoral Researcher will work in a team of two fellow PhD students and one postdoc. Together they will work on a state-of-the-art experiment with potassium atoms in optical tweezers.
Requirements: The candidate should have a strong background in quantum physics and experience in experimental work with ultracold atoms or related fields. She/he should be motivated to work with a complex experimental system and should show a strong drive and endurance to solve challenging problems in the lab. Daily challenges include debugging and development of electronical and optical subsystems as well as programming tasks for experiment control and data analysis. The complexity of the experimental system makes careful and thoughtful lab-work and team spirit a central trait to a successful PhD in our group.
Gross salary before all deductions and taxes: 40106,40 euros/year.

8) Title: Quantum Optimization from Ultrasoft Rydberg Interactions
Host: Universität Innsbruck, Innsbruck, Austria
Supervisor: Wolfgang Lechner, wolfgang.lechner@uibk.ac.at
Description: The research project will be interdisciplinary theoretical physics connecting atomic, molecular and condensed matter physics. The work will be numerical and analytical to a similar extent, and will apply concepts of non-equilibrium and equilibrium statistical mechanics to derive novel phase diagrams of quantum soft condensed matter. The candidate will learn to solve numerically quantum master equations with noise, quantum Monte Carlo, and analytically derive effective Hamiltonians from the interaction between lasers and atoms.
Requirements: The candidate should have a strong theoretical background in quantum physics and statistical mechanics.
Gross salary before all deductions and taxes: 43370,40 euros/year.

9) Title: The effects of attraction and polydispersity on the flow properties of frustrated soft colloids
Host: Foundation for Research and Technology Hellas (FORTH), Heraklion, Greece
Supervisor: Dimitris Vlassopoulos, dvlasso@iesl.forth.gr
Description: Colloids of mixed size and shape (eg spheres and rods), and of different softness, will be investigated. A starting point will be grafted particles of varying grafting density. Replace matrix of different nature (molecular or viscoelastic material) will be considered. Focus on nonlinear shear and uniaxial extensional rheology will be made. A 3D mapping diagram of molecular parameters vs rheological state is targeted. Subsequently, important effects such as thixotropy, Payne effect and instabilities will be investigated. A connection to structure will be attempted. Interpretation using simulations (via collaboration) is also planned.
Requirements: The candidate should have an MSc in Physics, Chemistry or related areas. Experience in rheology and scattering techniques will be highly esteemed.
Gross salary before all deductions and taxes: 33292,80 euros/year.

10) Title: Dynamic laser frequency and linewidth control for engineering ultrasoft quantum matter
Host: HighFinesse Laser and Electronic Systems GmbH, Tübingen, Germany
Supervisor: József Fortagh, fortagh@highfinesse.de
Description: The Doctoral Researcher will conduct a project on the application of interferometric optical wavelength measurement technologies in the field of soft-matter ultra-cold atomic Rydberg systems. The DR will be employed in an industrial environment at HighFinesse, an internationally renowned manufacturer of commercial high-precision wavelength measurement instruments. The research will cover the development of novel multi-laser frequency and linewidth stabilization schemes specifically tailored to the needs of soft-matter applications based on, and potentially going beyond, HighFinesse's state-of-the-art measurement technologies
Requirements: The candidate should have an MSc in Physics and, ideally, experimental skills in the field of soft-matter cold atomic systems, knowledge about fast-feedback laser frequency stabilization as well as expertise in computer-based automatization procedures (like signal acquisition, processing and/or analysis).
Gross salary before all deductions and taxes: 40106,40 euros/year.