QLUSTER
Quantum and Classical Ultrasoft Matter

Dear Reader,

The EC Doctoral Network QLUSTER (Quantum and Classical Ultrasoft Matter, HORIZON–MSCA–2021–DN, Project ID 101072964) was launched at 01/01/2023. QLUSTER comprises research groups spanning 7 countries of the EU: CSIC, CNR, FORTH, Universität Tübingen, Forschungszentrum Jülich, HighFinesse Laser and Electronic Systems, Universität Wien, Universität Innsbruck, Universza v Ljubljani and Université Strasbourg., as well as 2 Associate Partners (University of the Basque Country and Università di Roma La Sapienza).

Ultrasoft interactions lead to the observed complexity and analogies in the dynamics, structure, and response to external drives of very different entities such as complex polymers, soft colloids, Rydberg atoms in optical lattices, or vortex matter in superconductors. Despite similarities in phenomena and methods, an effort to bring distinct communities in classical and quantum soft matter together has not been yet undertaken. QLUSTER aims at advancing fundamentals beyond the state of the art, creating permanent ties between such communities. In this newsletter we give you an overview of activities and scientific output of our first year.

Best Regards,

Team QLUSTER

Consortium Activities:

- Of the 10 students the project will host, 9 have now been recruited (picture on the right). For more information see on our students, see the student section on our web page.
- If you're interested or know somebody interested in joining QLUSTER at HighFinesse, please take a look at: https://www.qluster-horizon.eu/student-position-available-at-highfinesse or at https://www.highfinesse.com/
- The first consortium meeting is planned on February 13th to be held at the Mathematics and Physics department of the University of Ljubljana. More information here.
- During the same week, in Ljubljana the students will follow a workshop on Poster Design, for presenting their scientific findings in conferences, as well as a two-day workshop on advanced concepts in soft condensed matter.
- Our summer school on Topology and Materials has been approved! It will take place in Varenna, Italy in July 2024. See the announcement on the next page.
- QLUSTER's first 3 articles are out! See scientific highlights on the next page.

This Project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement No. 101072964.

QLUSTER summer school:

International School of Physics "Enrico Fermi": Topology and Materials 17th-22th July 2024, Villa Monastero, Lake Como, Varenna, Italy

We are happy to announce the International School of Physics "Enrico Fermi": Topology and Materials. The event is co-organized by QLUSTER and the Vienna Doctoral School in Physics and will take place in Varenna from 17th to 22th July 2024.

The interplay between Topology and Physics in the self-organization and the inherent properties of condensed matter and materials is a topic that has attracted vast attention in the recent past. The school will offer its participants an instructive training on both the mathematical fundamentals and the Physics of currently topical issues that bring about the interplay between Topology and Physics for hard and soft matter materials:

- Mathematical fundamentals and topological geometry
- Topological polymers: classification, structure, dynamics and rheology
- Knots and links in Physics and Biology
- DNA topology and function
- Topological defects in liquid crystals
- Topological colloids
- Topological charge and topological quantum number
- Topological insulators
- Topological Quantum Chemistry
- Dirac & Weyl semimetals
- Majorana fermions and topological quantum computing

More information can be found at https://dcafm.univie.ac.at/fermi-school-2024/

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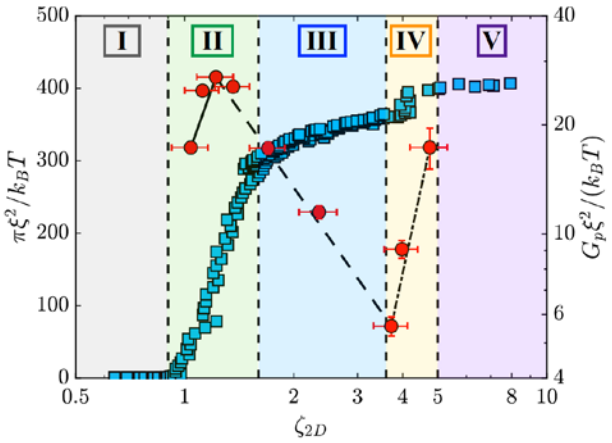
Scientific highlights:

We're happy to announce that the first 3 papers of the project are out and some others are to be published shortly. Here are the abstracts of the published work:

Interfacial Fluid Rheology of Soft Particles,

Maximilian M. Schmidt, José Ruiz-Franco, Steffen Bochenek, Fabrizio Camerin, Emanuela Zaccarelli and Andrea Scotti, Physical Review Letters **131**, 258202 (2023).

In situ interfacial rheology and numerical simulations are used to investigate microgel monolayers in a wide range of packing fractions, ζ_2D. The heterogeneous particle compressibility determines two flow regimes characterized by distinct master curves. To mimic the microgel architecture and reproduce experiments, an interaction potential combining a soft shoulder with the Hertzian model is introduced. In contrast to bulk conditions, the elastic moduli vary nonmonotonically with ζ_2D at the interface, confirming long-sought predictions of reentrant behavior for Hertzian-like systems.



Compression isotherms reporting the surface pressure π (squares) and plateau of the elastic modulus G_p (circles), normalized by k_B T=ξ^2, as a function of generalized packing fraction ζ_2D. Lines are guides to the eye. Different colors identify different regimes of the compression isotherms.

Engineering Ultrasoft Interactions in Stiff All-DNA Dendrimers by Site-Specific Control of Scaffold Flexibility,

Nataša Adžic Clemens Jochum, Christos N. Likos, and Emmanuel Stiakakis, Small **2023,** 2308763.

A combined experimental and theoretical study of the structural correlations in moderately concentrated suspensions of all-DNA dendrimers of the second generation (G2) with controlled scaffold rigidity is reported here. Small-angle X-ray scattering experiments in concentrated aqueous saline solutions of stiff all-DNA G2 dendritic constructs reveal a novel anomalous liquid-like phase behavior which is reflected in the calculated structure factors as a two-step increase at low scattering wave vectors. By developing a new design strategy for adjusting the particle's internal flexibility based on site-selective incorporation of single-stranded DNA linkers into the dendritic scaffold, it is shown that this unconventional type of self-organization is strongly contingent on the dendrimer's stiffness. A comprehensive computer simulation study employing dendritic models with different levels of coarse-graining, and two theoretical approaches based on effective, pair-potential interactions, remarkably confirmed the origin of this unusual liquid-like behavior. The results demonstrate that the precise control of the internal structure of the dendritic scaffold conferred by the DNA can be potentially used to engineer a rich palette of novel ultrasoft interaction potentials that could offer a route for directed self-assembly of intriguing soft matter phases and experimental realizations of a host of unusual phenomena theoretically predicted for ultrasoft interacting systems.

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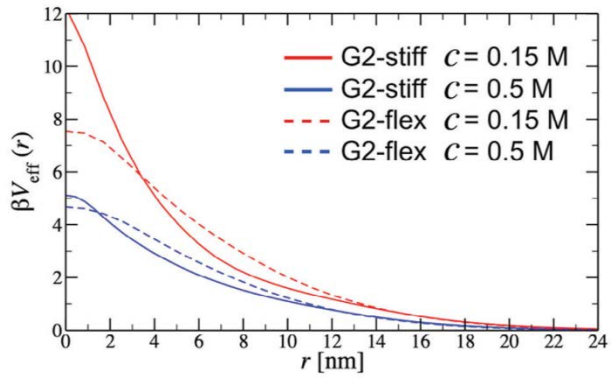
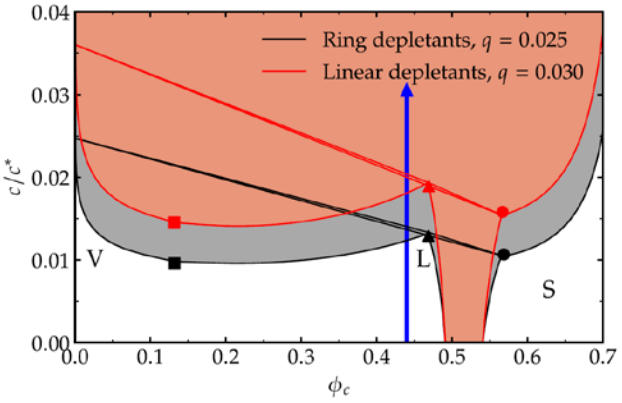


Effective pair interactions between two G2-stiff (solid lines) and between two G2-flex (dashed lines), calculated using Widom insertion method within oxDNA model and shown as a function of center-of-mass-to-center-of-mass separation r, at two different salt concentrations c.

Colloidal gelation induced by ring polymers,

Esmaeel Moghimi, Iurii Chubak,Maria Kaliva, Parvin Kiany, Taihyun Chang, Junyoung Ahn, Nikolaos Patelis, Georgios Sakellariou, Sergei A. Egorov, Dimitris Vlassopoulos, and Christos N. Likos Physical Review Research 6, 013079 (2024).

We provide unambiguous experimental evidence that ring polymers are stronger depleting agents in colloidal suspensions than their linear counterparts. We use an intermediate volume fraction (ϕ_c = 0.44) colloidal gel based on the classic poly(methyl methacrylate) (PMMA) hard spheres, in which the polystyrene depletant is either linear or ring of the same molar mass or the same size. We systematically increase the depletant concentration from zero (no attraction) to well above the gelation point and find that in the presence of rings, gels are formed at smaller concentrations and possess a larger storage modulus in comparison to those induced by the linear chains. Consequently, the yield stress is enhanced; however, the yield strain (gel deformability) remains concomitantly unaffected. Our experimental findings agree with theoretical calculations based on effective interaction potentials. Hence, polymer architecture is a powerful entropic tool to tailor the strength of colloidal gels.



Representative theoretical phase for a colloid-ring mixture (black lines) and a colloid-linear mixture (red lines) of similar size ratio. The gray- (red-)shaded regions denote phase coexistence between the pure phases in the white area below (for the linear depletants, part of that white area appears gray as it is occupied by the phasecoexistence region of the colloid-ring mixtures). The pure phases are the colloidal fcc crystal (S), the colloidal liquid (L), and the colloidal vapor (V). The think black (red) lines denote the three-phase triangle between the V, L, and S at the triple points, and the black (red) square the critical point. The filled triangle and circle denote the location of the L and S phases at triple coexistence with the V phase, for which φ_c ∼= 0. The vertical blue line represents a path of fixed colloid packing fraction φ_c = 0.44, as in the experiments.

All QLUSTER's publications can be found on the website of Digital CSIC dedicated to the project: https://digital.csic.es/cris/project/pj00278

All news on activities can be found on our blog https://www.qluster-horizon.eu/blog

You're always welcome to send us an email at info@qluster-horizon.eu

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