LIV Winter Meeting on Statistical Physics 2026

Book of Abstracts

January 7–9, 2026

Instituto Tecnológico de Monterrey
Monterrey, Nuevo León

Tecnológico de Monterrey

Casa abierta al tiempo
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Welcome

It is our pleasure to welcome you to the **LIV edition of the Winter Meeting on Statistical Physics**, an annual conference held in Mexico and organized by the Mexican Physical Society (SMF). This meeting brings together students and researchers working in statistical physics, complex systems, soft matter, and related areas, and features invited talks, contributed talks, and poster presentations.

Following previous editions held at BUAP Puebla in 2024 and UAM Iztapalapa in 2025, we are delighted to host this edition at the Tecnológico de Monterrey. We sincerely thank the Tecnológico de Monterrey for their warm hospitality, as well as the Mexican Physical Society for their continuous support.

We wish you a stimulating and enjoyable conference.

The Organizers

Aimee Torres Rojas, Department of Mathematics, Faculty of Chemistry, National Autonomous University of Mexico (UNAM), Mexico City

Antonio Ortiz-Ambriz, Department of Sciences, School of Engineering and Sciences, Tecnológico de Monterrey, Monterrey Campus, Monterrey

Claudia Elena Ferreiro-Córdova, Department of Sciences, School of Engineering and Sciences, Tecnológico de Monterrey, Querétaro Campus, Querétaro

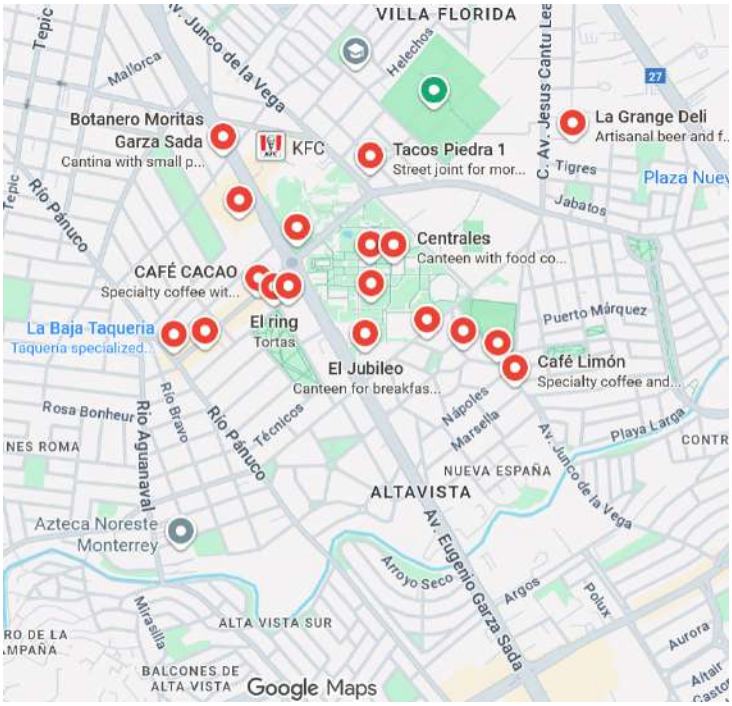
Guillermo Chacón-Acosta, Applied Mathematics and Systems Department, Metropolitan Autonomous University (UAM) Cuajimalpa, Mexico City

Julien M. J. Lombard, Department of Mathematics, Faculty of Chemistry, National Autonomous University of Mexico (UNAM), Mexico City

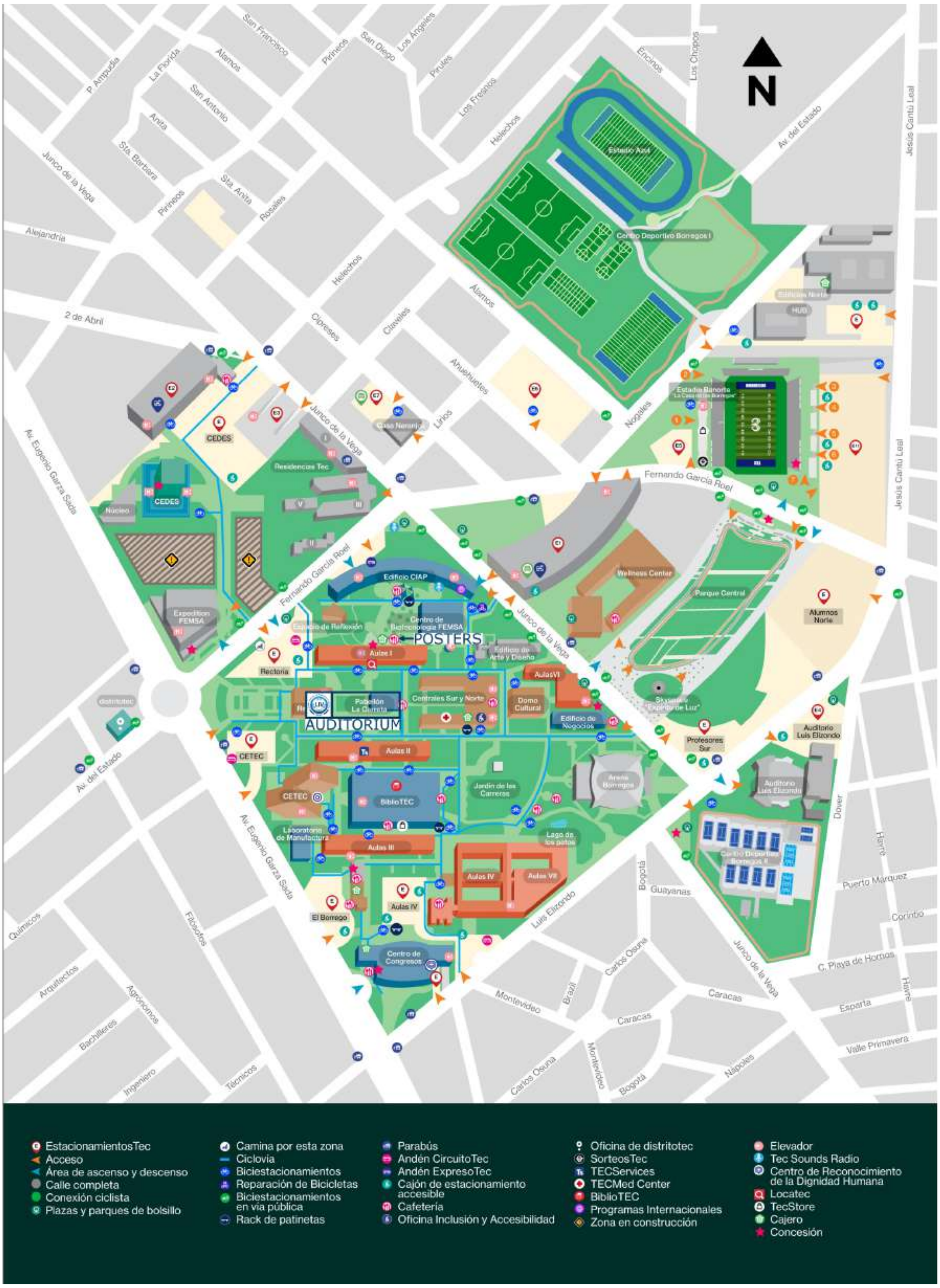
Ruth Hernández-Pérez, Center for Research in Biotechnology and Nanotechnology, Faculty of Chemical Sciences, Autonomous University of Nuevo León (UANL), Monterrey, Mexico

Recommended Places for Food in and around Campus Monterrey

- **El Ring**: Restaurant ($100-200). Sandwiches (Tortas).
- **Tacos Piedra 1**: Tacos ($100-200). Morning tacos.
- **BreAd Expedition**: Bakery ($200-300). Specialty coffee and artisanal bakery.
- **Café Limón**: Café ($100-200). Specialty coffee and roasters.
- **Regular COFFEE AND BOOKS II**: Café ($100-200). Specialty coffee with imported roasts.
- **CAFÉ CACAO**: Café ($100-200). Specialty coffee with bakery items.
- **Catrinas Chilaquiles Tec**: Mexican ($100-200). Breakfast and "comida corrida" (set menu), famous for chilaquiles.
- **La Baja Taqueria**: Taqueria ($100-200). Birria tacos.
- **Centrales**: Food Court ($100-200). Variety of food options in a canteen-style setting.
- **Pholicioso**: Vietnamese ($200-300). Pho and Vietnamese dishes.
- **Comidas Pronto**: Restaurant ($100-200). Box lunches to go, large portions, milanesas (breaded cutlets).
- **El Jubileo**: Café ($100-200). Breakfast and lunch canteen.
- **Panem Bakery & Bistro (ITESM)**: Café/Bakery ($100-200). Coffee and bakery items.
- **Tim Hortons TEC**: Café ($100-200). Coffee and donuts (Canadian chain).
- **MANGIOZ**: Pizzeria ($100-200). Small pizzeria with outdoor seating.
- **La Taberna - House of Brews**: Pub ($200-400). Artisanal beer and pub food.
- **Botanero Moritas Garza Sada**: Grill ($$ moderate). Cantina with small plates for sharing (botana).
- **La Grange Taproom**: Craft Brewery ($300-400). Artisanal beer and fusion sandwiches on a terrace.



Campus map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POSTERS
AUDITORIUM
EstacionamientosTec
Acceso
Área de ascenso y descenso
Calle completa
Conexión ciclista
Plazas y parques de bolsillo
Camina por esta zona
Ciclovía
Biciestacionamientos
Reparación de Bicicletas
Biciestacionamientos en vía pública
Rack de patinetas
Parabús
Andén CircuitoTec
Andén ExpresoTec
Cajón de estacionamiento accesible
Cafetería
Oficina Inclusión y Accesibilidad
Oficina de distritotec
SorteosTec
TECServices
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Conference Program

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Wednesday, 7 January 2026

Inauguration
(9:00 – 9:25)

Alberto Fernández Nieves *(Invited Speaker)* (9:25 – 10:05)

Hyperuniformity in active nematic defects
Barcelona University, Barcelona, Spain

This talk will discuss recent results pertaining to 2D active nematics in flat space [1]. We will focus on defect number fluctuations and how they relate to the system structure and overall correlations. Contrary to what is often found in active matter, we do not observe giant number fluctuations. Instead, we find that the system of defects exhibits hyperuniformity within the experimentally accessible length scales. However, there are differences depending on whether we separately consider the subpopulations of positive and negative defects, or the total population of defects; the system is thus not multi-hyperuniform. Through a combined experimental and simulation effort, we unravel the physics behind this result.

[1] de la Cotte, Pearce, Nambisan, Levy, Puggioni, Giomi, AFN, pnas (2025).

Aldo Ledesma-Durán (10:05 – 10:30)

Some ideas about the thermodynamics of Turing patterns in irreversible systems
Faculty of Sciences, National Autonomous University of Mexico, Juriquilla Campus, Querétaro, Mexico

Spatial patterns, ubiquitous in nature from zebra stripes to morphogenesis, often emerge from chemical interactions in reaction-diffusion (RD) systems. We explore the connection between pattern formation, RD dynamics, and thermodynamic principles, focusing on energy and entropy. This work reviews the persistence of patterns in nonlinear systems, the stability of steady states in irreversible linear systems, and the role of energy functions in growing domains. We highlight how the Lyapunov function, interpreted as an effective Gibbs energy, guides the evolution toward self-organization, bridging formal pattern equations with non-equilibrium thermodynamics.

Oscar Gallardo (10:30 – 10:55)

Dynamically induced spatial segregation in multispace bacterial bioconvection
Weizmann Institute of Science, Rehovot, Israel

Motile microorganisms found in aquatic environments can exhibit striking collective and coordinated behavior. Despite significant advances in understanding the behavior of single-species systems, little is known about the self-organization and dynamics of multi-species systems, such as complex and diverse bacterial communities. Many bacterial species swim towards air-liquid interfaces by following oxygen gradients. Their accumulation in the upper liquid layer triggers bioconvection — a large-scale, directional flow powered by cell swimming and gravity. By means of different fluorescence imaging techniques and analyses, we report for the first time that multi-species bacterial suspensions undergoing oxytactic-driven bioconvection exhibit dynamic species spatial segregation, despite the enhanced mixing caused by bioconvective flows. Segregation is observed as patterns of spatially interlocked domains, with local dominance of one of the constituent species. Moreover, our analysis of motility characteristics at the cellular level suggests minimization of collisions as a segregation mechanism, rather than biological repulsion among

species. This research offers significant insights of heterogeneity in collective systems, as well as the dynamics of complex microbial communities in the bulk, enhancing our understanding of their spatial organization and collective behavior.

☕ ***Coffee Break*** ☕
(10:55 – 11:25)

Sarah A. M. Loos *(Invited Speaker)* **(11:25 – 12:05) - *Online***

Nonreciprocal matter – irreversibility, heat flows, and persistent currents
Department of Applied Mathematics and Theoretical Physics, University of Cambridge, Cambridge, United Kingdom

While the action-reaction principle rules all fundamental physical interactions and constrains equilibrium physics, the dynamics we effectively observe in complex systems far from equilibrium ubiquitously breaks reciprocity on various scales. I will discuss the impact of such effective, nonreciprocal interactions using two examples. First, we show that vision-cone interactions in a two-dimensional XY model lead to long-range order and directional propagation of defects [2]. For binary fluids, run-and-chase interactions can induce traveling wave solutions. Using fluctuating field theories, we show for a wide class of models that close to transitions to traveling states, fluctuations not only inflate, as in equilibrium criticality, but also develop an asymptotically increasing time-reversal asymmetry and associated surging entropy production [3,4]. The formation of dissipative patterns and the emergence of irreversible fluctuations can both be attributed to a mechanism of mode coupling in the vicinity of critical exception points.

[1] J. Martynec, S. H. L. Klapp, S. M. Loos, *Phys. Rev. Lett.* **130**, 198301 (2023); E. Bandini, D. Venturelli, S. M. Loos, A. Jelić, A. Gambassi, *J. Stat. Mech.* 053205 (2025).

[2] M. Suchanek, K. Kroy, S. M. Loos, *Phys. Rev. Lett.* **131**, 258302 (2023).

[3] M. Suchanek, K. Kroy, S. M. Loos, *Phys. Rev. E* **108**, 064610 (2023); *Phys. Rev. E* **108**, 064123 (2023).

Derek Frydel **(12:05 – 12:30)**

Integral formulation of run-and-tumble particles in simple confinement
Technical University Federico Santa María, Valparaíso, Chile

In this talk, we present an integral equation formulation of run-and-tumble particles (RTPs) under two types of confinement: between parallel walls and within a harmonic potential. This reformulation provides exact analytical results that are not accessible through the standard Fokker–Planck differential equation approach. A second objective is to draw conceptual analogies between the RTP model and other well-known frameworks in statistical mechanics. Finally, we examine why exact solutions can be obtained in certain spatial dimensions but not in others, shedding light on the mathematical structure underlying solvable cases.

Farshad Darabi **(12:30 – 12:55)**

Oscillatory confined Janus colloids
Institute of Physics, National Autonomous University of Mexico, Mexico City, Mexico

We experimentally studied the dynamics of optically confined active colloids composed of silica microspheres partially coated with a thin carbon layer, forming Janus particles that self-propel in water through autothermophoresis. When illuminated by a tightly focused laser beam, the asymmetric absorption of light by the carbon cap generates local temperature gradients that drive directed motion. Within a specific range of laser powers, the particles exhibit quasi-two-dimensional active motion near a solid interface, accompanied by stochastic reorientations

occurring as they move away from the laser intensity maximum, which results in a stable confinement characterized by oscillatory trajectories. The orientational autocorrelation function of this confined motion displays damped oscillations whose frequency increases with propulsion velocity, revealing the coexistence of three dynamical regimes depending on the observation time: thermal diffusion, ballistic motion, and oscillatory confinement. The observed behavior is quantitatively reproduced by a minimal phenomenological model that incorporates a nonlinear optical torque reorienting the particle toward the trap center together with rotational diffusion, demonstrating that the interplay between deterministic torques and stochastic fluctuations governs the non-equilibrium dynamics of active particles under optical confinement.

🍴 *Lunch* 🍴
(12:55 – 14:55)

Rik Wensink *(Invited Speaker)* **(14:55 – 15:35)**

Order, fluidity and symmetry breaking in hybrid liquid crystals
Laboratory of Solid State Physics, CNRS & Université Paris-Saclay, Orsay, France

Intriguing new forms of nanoparticles self-assembly can be explored when thin non-spherical colloidal particles such as rods and discs interact with a thermotropic liquid crystalline solvent. In addition to the intrinsic orientation-dependence of the nanoparticles interactions, the correlations between the immersed colloids are further enriched by so-called surface anchoring and, to a far lesser extent in view of their vanishing internal volume, by nematoelastic forces. At crowded conditions, these forces conspire with orientation-dependent intercolloidal repulsions to form so-called hybrid nematic liquid crystals with point-group symmetries ranging from orthorhombic [1] to monoclinic [2]. Another level of complexity can be achieved by considering chiral molecular host phases with some long-ranged periodicity imposed by their helical mesostructure [3]. In this talk I will give an overview of experiments and modeling studies exploring reconfigurable liquid crystal order, unusual phase behavior and spontaneous biaxial orientational symmetry breaking that naturally occur in these complex liquid crystal materials.

[1] H. Mundoor, S. Park, B. Senyuk, H. H. Wensink, and I. I. Smalyukh, Hybrid molecular-colloidal liquid crystals, Science 360, 768 (2018).

[2] H. Mundoor, J.-S. Wu, H. H. Wensink, and I. I. Smalyukh, Thermally reconfigurable monoclinic nematic colloidal fluids, Nature 590, 268 (2021).

[3] J.-S. Wu, M. Torres Lázaro, H. Mundoor, H. H. Wensink, and I. I. Smalyukh, Emergent biaxiality in chiral hybrid liquid crystals, Nat. Commun. 15, 9941 (2024).

Pavel Castro Villarreal **(15:35 – 16:00)**

Curved graphene: a possible answer to the problem of graphene's diverging magnetic susceptibility
Faculty of Physics and Mathematics Sciences, Autonomous University of Chiapas (UNACH), Tuxtla Gutiérrez, Mexico

A study of curved graphene in the presence and absence of a real magnetic field is conducted to determine the magnetization and magnetic susceptibility. Utilizing a Dirac model, the Landau-level energy corrections are found. These results are compared with those obtained from a tight-binding model analysis, showing good agreement with the Dirac model. The obtained spectra are then used to calculate the free energy, magnetization, and magnetic susceptibility as functions of the external magnetic field and curvature. The resulting de Haas–van Alphen effect exhibits distinctive signatures due to the curvature of graphene, including a resonance effect when the pseudomagnetic and the real magnetic fields are equal. Considering that curvature

induces effective pseudomagnetic fields, a mechanical effect stemming from an electronic contribution is found, resulting in a pseudo de Haas–van Alphen effect without needing an external magnetic field. This effect is associated with oscillating (electronic) forces opposing deformations. These forces, divergent in flat graphene, suggest that graphene (without a substrate) attains mechanical equilibrium through local corrugations. These mechanical deformations prevent the theoretically calculated pristine graphene's diamagnetic divergence at low temperatures, indicating that corrugations produce a finite, experimentally measurable magnetic susceptibility. The divergent susceptibility becomes apparent only when such corrugations are removed using various strategies.

Phys. Rev. B 110, 035421 – Published 17 July, 2024, doi.org/10.1103/PhysRevB.110.035421

☕ ***Coffee Break*** ☕
(16:00 – 16:25)

Manuel Ceballos *(Invited Speaker)* **(16:25 – 17:05)**

NanoMOFs: smart architectures for challenges in biomedicine and biotechnology
University of Santiago de Compostela, Santiago de Compostela, Spain

Nanoscale Metal-Organic Frameworks (MOFs) with engineered porosity and controlled architectures are emerging as versatile platforms for biological and biomedical applications [1]. Recent advances in the synthesis of zirconium-based nanoMOFs demonstrate how structural control at multiple length scales can enhance mass transport, enable efficient biomolecule loading, and introduce functionalities relevant to sensing, delivery, and light-mediated processes. Hierarchical Zr-MOFs, such as H-UiO-66-NH2, can be produced through micelle-templated routes that tune particle size (50-150 nm) while incorporating mesopores of 15 nm within the intrinsic microporous framework. This combination of pore domains improves accessibility and provides protective microenvironments capable of stabilizing sensitive biomacromolecules. Encapsulation studies using BSA confirm both efficient loading and enhanced thermal protection, as revealed by structural, thermal, and adsorption analyses. Complementary advances in integrating plasmonic nanoparticles with Zr-based MOFs further expand their functionality. The controlled growth of PCN-224 or NU-1000 shells onto gold nanobipyramids yields photoactive nanocomposites whose shell thickness modulates thermoplasmonic behavior and photodynamic response [2,3]. These hybrid systems enable NIR-triggered intracellular cargo release and efficient activation under Soret band excitation, highlighting their potential as multifunctional theranostic carriers. Together, these developments illustrate how nanoscale MOF engineering through hierarchical porosity and plasmonic-MOF integration provides powerful routes to create stable, stimuli-responsive, and highly customizable platforms for protein stabilization, controlled molecular delivery, and advanced bio-photonic applications.

[1] Cedrún-Morales, M., Ceballos, M., Polo, E., Del Pino, P., and Pelaz, B. Nanosized metal–organic frameworks as unique platforms for bioapplications, Chemical Communications 59(20), 2869–2887 (2023).

[2] Ceballos, M., Funes-Hernando, S., Zampini, G., Cedrún-Morales, M., Vila-Fungueiriño, J. M., Pelaz, B., and del Pino, P. Seeded-Growth of PCN-224 onto Plasmonic Nanoparticles: Photoactive Microporous Nanocarriers, Small Structures 5(5), 2300464 (2024).

[3] Cedrún-Morales, M., Ceballos, M., Soprano, E., Zampini, G., Polo, E., Pelaz, B., and Del Pino, P. Light-Responsive Nanoantennas Integrated into Nanoscale Metal–Organic Frameworks for Photothermal Drug Delivery, Small Science 4(8), 2400088 (2024).

Armando Gama Goicochea **(17:05 – 17:30)**

Shear viscosity of quasi-two-dimensional ionic liquids

Technological University of Studies of Ecatepec (TESE), Ecatepec de Morelos, State of Mexico, Mexico

Ionic liquids are fluids made up of charged particles, which find ample applications, ranging from device engineering to protein stabilizers in drug-delivery systems. In the particular case of quasi two-dimensional ionic liquids, relevant questions arise because the range of the electrostatic interactions becomes strongly modified. There are dynamical and structural implications for quasi-two dimensional ionic liquids under flow that are of current interest for nanotechnology and other applications and that are not yet fully understood. In this contribution, the shear viscosity of quasi-two-dimensional ionic liquids under strong, quasi-two dimensional confinement is investigated using numerical simulations. The study examines how the competition between the electrostatic interaction and thermal energy determines the flow resistance and frictional behaviour of charged fluids at the nanoscale, as the shear rate is increased. It is found that, despite the confinement, the fluid retains a stable structure whose microscopic ordering governs macroscopic rheological properties. Both the shear viscosity and friction coefficient follow universal power-law relations with shear rate whose scaling correspondence—previously observed in neutral polymer brushes—reveals a universal dynamical behaviour emerging from the balance between electrostatic coupling and hydrodynamic dissipation, not previously recognized. These findings elucidate the microscopic physics of flow and friction in confined charged liquids and provide scaling principles relevant to ionic nanofluidics and energy-storage interfaces.

Margarita Sánchez Domínguez **(17:30 – 17:55)**

From Nano to Macro: Microemulsions as Confined Reaction Media for the Synthesis of Metallic, Metal Oxide and MOF Hierarchical Nanoparticles and Superstructures

Advanced Materials Research Center (CIMAV), Monterrey Unit, Mexico

Since first reported in 1982 [1], the microemulsion reaction method has been extensively employed for the synthesis of metallic, metal oxide, and other inorganic nanoparticles with narrow size distributions, high specific surface areas, and good performance in applications such as catalysis. Most of these early investigations were based on water-in-oil (w/o) microemulsions. However, the use of w/o microemulsions requires large amounts of organic solvents, which significantly hinders their applicability at the industrial scale.

From practical, environmental, and economic perspectives, oil-in-water (o/w) microemulsions offer clear advantages, as water constitutes the continuous phase. This approach relies on organometallic precursors dissolved in nanometer-scale oil droplets stabilized by surfactants and dispersed in an aqueous medium. Water-soluble precipitating agents can be added directly as aqueous solutions without compromising microemulsion stability. This strategy was reported for the first time as a proof of concept by our group in 2009 [2], demonstrating that nanoparticles with narrow size distributions, good crystallinity, and high specific surface areas can be successfully obtained.

In recent years, we have also investigated the synthesis of nanomaterials in nonionic bicontinuous microemulsions, resulting in the formation of hierarchical superstructures composed of metals, metal oxides, and hybrid systems [3]. In this contribution, we present an overview of nanomaterials synthesized in both o/w and bicontinuous microemulsions by our research group. Our latest efforts focus on the synthesis of nanostructured metal–organic frameworks (MOFs) in these confined reaction media. In particular, we have succeeded in obtaining nanostructured UiO-66-type MOFs at room temperature.

The obtained results demonstrate the feasibility and versatility of microemulsion-based approaches for the preparation of a wide variety of nanomaterials with potential applications in catalysis, photocatalysis, electrocatalysis, surface-enhanced Raman scattering (SERS) sub-

strates, and environmental remediation.

[1] Boutonnet, M., Kizling, J., and Stenius, P. The preparation of monodisperse colloidal metal particles from microemulsions, Colloids and Surfaces 5, 209–225 (1982).

[2] Sánchez-Domínguez, M., Boutonnet, M., and Solans, C. A novel microemulsion route for the synthesis of nanostructured materials, Journal of Nanoparticle Research 11, 1823–1832 (2009); Sánchez-Domínguez, M., Pemartin, K., and Boutonnet, M. Preparation of inorganic nanoparticles in microemulsions: from fundamentals to applications, Current Opinion in Colloid & Interface Science 17, 297–305 (2012).

[3] Adesuji, E. T., Khalil, L., Videa, M., and Sánchez-Domínguez, M. Hierarchical nanostructures obtained in bicontinuous microemulsions, Electrochimica Acta 360, 136608 (2020); Adesuji, E. T., Guardado-Villegas, E., Fuentes, K. M., Sánchez-Domínguez, M., and Videa, M. Hierarchical metal and metal oxide nanostructures from bicontinuous microemulsions, Catalysts 10, 1311 (2020).

Mónica Olvera de la Cruz *(Invited Speaker)* **(9:00 – 9:40)**

Design and control of responsive soft materials
Northwestern University, Evanston, Illinois, United States

Heterogeneous molecules such as amphiphiles and biopolymers are ubiquitous components of life and physical sciences. In this talk, I will describe how to control the organization and function of heterogeneous molecular assemblies into responsive structures such as catalytic closed shells that undergo self-ionic diffusiophoresis as well as co-assemblies of amphiphiles and polymers into membranes with biomimetic functions.

Francisco Alarcón Oseguera **(9:40 – 10:05)**

Fluctuations, fluids and viruses: a mesoscopic perspective
University of Guanajuato, Guanajuato, Mexico

Most biological systems are immersed in water or other liquid phases, enabling the use of continuum approaches to describe them and to analyze their behavior through the Navier–Stokes–Fourier hydrodynamic equations, elasticity theory, and various other continuum models for complex fluids. However, these equations are often nonlinear, making analytical solutions generally unattainable. Even computational fluid dynamics (CFD) faces challenges in obtaining accurate approximations under such conditions, despite its significant advances and solid mathematical foundation in numerical analysis. Moreover, many of the most relevant phenomena in biological systems occur at micro- or nanoscopic scales, where highly detailed methods such as molecular dynamics become computationally prohibitive. A natural alternative is therefore to employ mesoscopic methods based on fluctuating hydrodynamics and techniques that approximate coarse-grained molecular descriptions. In this work, I present successful case studies demonstrating the application of these methodologies to systems involving viruses and bacteria.

Erick Sarmiento-Gómez **(10:05 – 10:30)**

Local area distribution of quasi-two-dimensional colloidal dispersions and its relation to particle diffusion: a Voronoi tessellation approach
University of Guanajuato, Guanajuato, Mexico

The dynamical properties of the local area available per particle and its relationship with the self-diffusion coefficient of colloids in quasi-2D colloidal dispersions are studied using video microscopy, supported by Brownian dynamics simulations. The local area is determined via the well-known Voronoi tessellation technique. Our findings reveal that local areas per particle are highly dispersed, exhibiting slow dynamics over time. Additionally, the evolution of the ensemble-averaged area distribution as a function of concentration shows a long tail at large and small areas for low and high concentrations, respectively, leading to a maximum in information entropy when the distribution becomes symmetric. We introduce and analyze several expressions for local area-weighted diffusion coefficients. Notably, we find that the contribution of the averaged diffusion coefficient can be expressed in terms of local areas, establishing a new framework to determine the weighted influence of each local area on particle dynamics.

Susana Marín-Aguilar **(10:30 – 10:55)**

Unveiling new regimes in ultra-low crosslinked microgels and their crowded conditions

Sapienza University of Rome, Rome, Italy

Microgels are a versatile type of soft particles consisting of crosslinked polymer chains. Their structure and elastic properties are closely related to the amount of crosslinker monomers used in their synthesis [1]. In particular, ultra low-crosslinked microgels (ULCs) represent an extreme case of ultrasoft colloids; their sparse crosslinker network makes them highly deformable and interpenetrable. However, a detailed characterization of their structural changes under crowding remains poorly understood due to experimental limitations. Here, with the use of monomer-resolved molecular simulations, I will show that the structural, mechanical, and dynamical behavior of ULCs differs markedly from that of microgels with higher crosslinker concentrations under crowded conditions. By combining surface-mesh and particle-resolved analyses, we capture the role of dangling chains and quantify shape changes, interparticle overlaps, and bulk moduli with unprecedented detail. Our results reveal a previously uncharacterized regime in which ULCs deform and interpenetrate through their loose outer chains. This strongly impacts their collective dynamics and mechanical response [2]. These findings establish ULCs as a distinct class of ultrasoft colloids and provide a microscopic framework to interpret their collective behavior.

[1] A. Scotti, et al. "Deswelling of microgels in crowded suspensions depends on cross-link density and architecture". Macromolecules, 52,11, (2019).

[2] S. Marín-Aguilar and E. Zaccarelli. "Full Characterization of Ultra-Low Crosslinked Microgels under Crowded Conditions". In Preparation, (2025).

☕ ***Coffee Break*** ☕
(10:55 – 11:25)

Ralf Metzler *(Invited Speaker)* **(11:25 – 12:05)**

Anomalous diffusion, non-Gaussianity and long-range dependent motion

University of Potsdam, Potsdam, Germany

Deviations from the standard laws of Brownian motion, the linear time dependence of the mean squared displacement and the Gaussian probability density function, are quite commonly observed in an abundance of systems [1]. The physical mechanisms for these anomalies are non-universal, prompting the need for different stochastic models along with their identification from measured time series of dynamic motion. The model classification and parameter regression of anomalous diffusion can be successfully achieved by machine-learning tools such as Bayesian Deep Learning [2], which will be introduced along with a brief summary of the two recent AnDi (Anomalous Diffusion) Challenges [3,4].

The talk will focus on long-range dependent stochastic motion, identified in a large range of systems [5]. In particular, it will be discussed how to generalize such models to situations, in which the observed probability density is non-Gaussian, or when the processes display scaling exponents varying in time or space. Diffusion models with stochastically [6,7] and deterministically [8] varying diffusion coefficients and scaling exponents will be introduced. Applications to experimental data will be discussed.

[1] E. Barkai, Y. Garini, and R. Metzler, Strange kinetics of single molecules in living cells, Phys. Today 65(8), 29 (2012); D. Krapf and R. Metzler, Strange interfacial molecular dynamics, Phys. Today 72(9), 48 (2019).

[2] H. Seckler and R. Metzler, Bayesian deep learning for error estimation in the analysis of anomalous diffusion, Nature Commun. 13, 6717 (2022).

[3] G. Muñoz-Gil, Objective comparison of methods to decode anomalous diffusion, Nature Commun. 12, 6253 (2021).

[4] G. Muñoz-Gil et al., Quantitative evaluation of methods to analyze motion changes in single-particle experiments, Nature Commun. 16, 6749 (2025).

[5] O. Vilk, E. Aghion, T. Avgar, C. Beta, O. Nagel, A. Sabri, R. Sarfati, D. K. Schwartz, M. Weiss, D. Krapf, R. Nathan, R. Metzler, and M. Assaf, Unravelling the origins of anomalous diffusion: from molecules to migrating storks, Phys. Rev. Res. 4, 033055 (2022).

[6] M. Balcerek, S. Thapa, K. Burnecki, H. Kantz, R. Metzler, A. Wylmańska, and A. Chechkin, Multifractional Brownian motion with telegraphic, stochastically varying exponent, Phys. Rev. Lett. 134, 197101 (2025).

[7] W. Wang, F. Seno, I. M. Sokolov, A. V. Chechkin, and R. Metzler, Unexpected crossovers in correlated random-diffusivity processes, New J. Phys. 22, 083041 (2020).

[8] W. Wang, M. Balcerek, K. Burnecki, A. V. Chechkin, S. Janušnis, J. Slezak, T. Vojta, A. Wylmańska, and R. Metzler, Memory-multifractional Brownian motion with continuous correlations, *Phys. Rev. Res.* **5**, L032025 (2023).

Sergio Maldonado **(12:05 – 12:30)**

Stochastic mechanics in environmental fluids

University of Southampton, Southampton, United Kingdom

Several processes in environmental fluid mechanics exhibit a stochastic nature, which has important implications for problems of societal relevance. Two examples are discussed here: the erosion of a sediment bed by a water surface flow, and the orientational dynamics of algae cells in fluid flows.

Erosion of a sediment bed is important for many problems in civil and environmental engineering, such as shoreline retreat. The phenomenon can be regarded, at an idealized level, as the movement of spheres resting on top of other spheres by the action of a turbulent boundary layer. By virtue of turbulence, this process is highly stochastic, which leads to significant challenges when it comes to studying this process both experimentally and numerically-theoretically. We will present results from experiments carried out to understand the role of (random) turbulent fluctuations on the dislodgement of such bed spheres.

Algae cultivation is a popular approach to mitigate environmental issues by capturing carbon from the atmosphere. Most cultivation methods involve some fluid flow (e.g. algae raceway ponds), yet, the fundamental interactions between individual algae cells and fluid dynamics stressors (e.g. induced mechanical shear on the cell wall) remain poorly understood. We have experimentally studied the orientational dynamics of algae cells in a von Kármán-Couette flow, and shown, via stochastic numerical simulations, that a full understanding of said dynamics (in particular, the peak value of the preferred orientation) requires the incorporation of stochastic elements. This has potential implications for the natural cycle of algae growth under realistic fluid flow conditions.

Fernando Donado **(12:30 – 12:55)**

Study of the self-assembling process in a granular system as a macroscopic model for the colloidal counterpart

Autonomous University of the State of Hidalgo (UAEH), Pachuca, Hidalgo, Mexico

We study the process of self-assembly in a macroscopic system composed of particles floating on a thermal bath made up of magnetic particles in an alternating magnetic field. The study

spanned various shapes of the particles that are self-assembled. The dynamic properties of the thermal bath particles can be controlled by means of the frequency of the magnetic field. Thus, it allowed us to determine the role of the persistence length of the particles in the thermal bath over the dynamic characteristics of the large species and over their self-assembly mechanism. When a third species is added, the depletion forces can increase in some cases; however, this introduces problems due to the two-dimensional nature of the system. The similarities and differences with colloidal systems are discussed.

Lunch
(12:55 – 14:55)

Organization Winter Meeting 2027
(14:55 – 16:25)

Coffee & Posters (Tec Lounge)
(16:25 – 18:00)

Friday, 9 January 2026

Alfredo Alexander-Katz *(Invited Speaker)* **(9:00 – 9:40)**

Block copolymer self-assembly: universality, transferability and versatility
Massachusetts Institute of Technology (MIT), Cambridge, Massachusetts, United States

Self-assembly emerged as a paradigm of pattern formation in soft-materials many years ago. In this talk I will discuss recent advances in the field, putting emphasis on statistical features of block copolymer self-assembly in relation to different features such as understanding transferability between different models, universal features of the theories, and finally, stimuli dependent self-assembly of confined systems. The latter topic offers insights into the limits of directed self-assembly as well as the creation of versatile platforms that can shift their assemblies due to different stimuli. I will finalize this talk with some thoughts on how one can leverage the statistical features discussed above to enhance machine learning platforms for self-assembling systems.

Maricarmen Ríos Ramírez **(9:40 – 10:05)**

High-speed atomic force microscopy for visualizing dynamic conformations of biomolecules
Weizmann Institute of Science, Rehovot, Israel

A central challenge in biophysics is to connect biomolecular structure with function. Although many high-resolution structures of proteins and nucleic acids are known, far fewer functional mechanisms are fully understood. This limitation arises because most traditional techniques provide static snapshots, while biomolecules are inherently dynamic: they fluctuate, reorganize, interact with partners, and generate mechanical forces. High-Speed Atomic Force Microscopy (HS-AFM) directly addresses this challenge by enabling real-time visualization of individual biomolecules with nanometer spatial resolution at video-rate speeds. HS-AFM allows direct observation of dynamic processes in systems such as membrane proteins on lipid bilayers and DNA minicircles undergoing conformational fluctuations and mechanical stress. When combined with advanced analysis strategies, including localization AFM and deep learning–based approaches for feature detection and state classification, HS-AFM data provide enhanced lateral resolution and quantitative access to structural heterogeneity and dynamic states. Together, these developments establish HS-AFM as a powerful platform to study the nanoscale dynamics of biomolecular systems beyond static structural descriptions.

Citlali G. Vidales Hernández **(10:05 – 10:30)**

Dynamic of active flexible superstructures moving through several narrow channels
Benemérita Autonomous University of Puebla (BUAP), Puebla, Mexico

We study the dynamics and shape evolution of a flexible superstructure composed of self-propelled robots confined in a flexible closed chain moving inside rounded regions interconnected by narrow channels, which in some situations, contain a granular medium. This active superstructure can pass through narrow and long channels due to its flexibility and morpho-adaptability. To describe dynamics, we have used the mean square displacement and the effective diffusion coefficient. This dynamic properties of the superstructure are described in terms of the dynamics and configurations of its inner robots. When the channels are partially filled with granular

particles, the superstructure pushes them and unclogs the channels. To describe the effect of the superstructures on the granular medium, we quantify the order by using the sixthfold-bond-orientational order parameter.

Joanna Zielińska **(10:30 – 10:55)**

Stochastic modeling for rotational levitated optomechanics
School of Physics and Astronomy, University of Southampton, Southampton, United Kingdom

☕ ***Coffee Break*** ☕
(10:55 – 11:25)

Rosendo Pérez Isidoro *(Invited Speaker)* **(11:25 – 12:05)**

Biophysical properties of biohybrid materials
Center for Applied Chemistry Research (CIQA-SECIHTI), Monterrey Unit, Monterrey, Nuevo León, Mexico

In the field of Nanomedicine, the investigation of biohybrid materials to improve the controlled release of drugs has gained extensive attention. A central task in this area is to design and characterize new materials with relevant biomedical properties. In this context, our investigation focuses on the study of biophysical properties of biohybrid nanovesicles composed of phospholipids, polymers, and proteins. These biohybrid materials are characterized by combining chemical, physical, and biological techniques. The high biocompatibility, low toxicity, and the ability to encapsulate not only hydrophilic but hydrophobic molecules have positioned lipid nanoplatforms as one of the most effective systems for the transport and controlled release of drugs. However, identifying optimal nanodevices for this purpose entails a great multidisciplinary challenge. Our investigation contributes to a better understanding of the driving forces at the level of lipid membranes that is crucial for the development of new biomedical applications.

Ernesto Hernández Cooper **(12:05 – 12:30)**

Energy densities of encapsulated salts for thermo-solar energy storage
Tecnológico de Monterrey, State of Mexico Campus, Estado de México, Mexico

This work represents an attempt to understand part of the thermodynamics associated with energy storage in confined phase change materials (PCMs). The phase change properties are estimated using thermodynamic trajectories that connect two points along the liquid-solid saturation curve. The analysis results in some conceptual differences between the latent heat obtained by other authors and that estimated in this work. The elastic properties of core-shell systems are coupled with the estimated saturation properties. A set of general equations to obtain volumetric and gravimetric energy densities in compressible media is introduced in this paper. The resulting equations for energy densities incorporate the isothermal compressibility of both the liquid and solid phases. The proposed set of equations provides a more realistic estimate of the storage capacity in confined systems than previous models that do not account for the compressibility of the phases. Therefore, this proposal makes it possible to introduce the **highly compressible limit (HCL)**, which represents an ideal behavior where PCMs have a maximum energy storage capacity.

The thermal performance of confined PCMs can be improved by comparing the energy stored by materials with finite compressibility to their behavior near the HCL. The **energy storage efficiency** of a particular confined PCM configuration is defined as the ratio between the material's energy density and its HCL. Finally, this efficiency is used to evaluate the performance of each combination and to develop a criterion for selecting materials or core-shell combinations. Experimental results are used to validate the HCL introduced in this work.

Raúl Fuentes **(12:30 – 12:55)**

Dielectric constants in confined systems
Universidad Autónoma Metropolitana (UAM), Mexico

The behavior of the solution under nanoconfinement diverges markedly from that observed in bulk conditions, exhibiting distinct structural, dynamic, and dielectric properties. The charging of the graphene nanoslits generates an electric field within the nanopore, which plays a critical role in modulating molecular interactions.

Lunch
(12:55 – 14:55)

Moisés Santillán *(Invited Speaker)* **(14:55 – 15:35)**

Frankenstein, Vitalism and Completely Science
Center for Research and Advanced Studies of the National Polytechnic Institute (Cinvestav), Mexico City, Mexico

Guillermo del Toro's recent cinematic adaptation of *Frankenstein* does more than revisit a Gothic classic; it vividly captures the scientific anxieties of the nineteenth century. The iconic animation of the creature by a lightning strike serves as a powerful metaphor for Vitalism, the belief that life originates from a non-physical vital spark or unique electrical principle. Although modern science has long abandoned Vitalism in favor of mechanistic and biochemical explanations, the fundamental questions raised by the Vitalists remain strikingly relevant.

This talk traces the historical confrontation between mechanistic and vitalist conceptions of life, from the Scientific Revolution to the emergence of modern biology. It examines how early successes in reducing physiological processes to mechanics, chemistry, and electricity coexisted with persistent difficulties in explaining self-regulation, purpose, and the organized wholeness of living systems. While the vital force itself was progressively eliminated by advances in chemistry, electrophysiology, cybernetics, and molecular biology, the vitalist intuition that life is more than the sum of its parts never fully disappeared.

The lecture argues that this intuition finds a rigorous scientific expression today in Complexity Science. Concepts such as emergence, non-linearity, feedback, and self-organization provide contemporary answers to questions once framed in vitalist terms, without invoking any supernatural principle. By following this trajectory from *Frankenstein* to complex systems theory, the talk shows how modern science reconciles mechanistic explanations with a genuinely holistic understanding of living matter.

Daniel Seara **(15:35 – 16:00)**

Sociohydrodynamics: Data-driven modelling of social behavior
University of Illinois Chicago, Chicago, Illinois, United States

Living systems display complex behaviors driven by physical forces as well as decision-making. Hydrodynamic theories hold promise for simplified universal descriptions of socially generated collective behaviors. However, the construction of such theories is often divorced from the data they should describe. Here, we develop and apply a data-driven pipeline that links micromotives to macrobehavior by augmenting hydrodynamics with individual preferences that guide motion. We illustrate this pipeline on a case study of residential dynamics in the United States, for which census and sociological data are available. Guided by Census data, sociological surveys, and neural network analysis, we systematically assess standard hydrodynamic assumptions to construct a sociohydrodynamic model. Solving our minimal hydrodynamic model, calibrated using statistical inference, qualitatively captures key features of residential dynamics at the level of individual US counties. We highlight that a social memory, akin to hysteresis in magnets, emerges in the segregation–integration transition even with memory-less agents. While residential segregation

is a multifactorial phenomenon, this physics analogy suggests a simple mechanistic explanation for the phenomenon of neighborhood tipping, whereby a small change in a neighborhood's population leads to a rapid demographic shift. Beyond residential segregation, our work paves the way for systematic investigations of decision-guided motility in real space, from micro-organisms to humans, as well as fitness-mediated motion in more abstract spaces.

Alán Aguirre-Soto **(16:00 – 16:25)**

On the revisitation of how we teach graduate thermodynamics - Historical perspectives centered around the statistical interpretation of entropy

Tecnológico de Monterrey (Tec de Monterrey)

A graduate-level course in thermodynamics, considering any of its versions, is arguably the only recurring class in the curricula in all of engineering and science. That may not be surprising, considering the fundamental and universal nature of energy conservation and dissipation principles. The teaching of thermodynamics has evolved in many ways. However, it is common to hear from students of both previous and current generations that they understand how to use some of the thermodynamics principles, but struggle to understand the origin and meaning of the functions and potentials that constitute the foundational pillars of the subject. In this talk, the aim is to contrast several approaches to teaching graduate-level thermodynamics to contribute to perspectives that can serve as guidelines to achieve a deeper understanding of the subject by our students. The main discussion considers the approaches in several books, including those by Scott Shell, Juan J. de Pablo and Jay Schieber, Gaskell and Laughlin, McQuarrie, and a few other cases. From their perspectives and insights, our essential recommendation entails using a historical perspective of the development of the thermodynamic potentials and fundamental equations, using entropy as the thread of the story. The benefit of this approach is that gaps in the deep understanding of the thermodynamic functions can be filled, as students transition from the classical to the statistical interpretation of entropy. Another potential effect of such an approach is the possibility of taking the subject to more modern interpretations of entropy in information theory and other contexts that may lead to completely transversal and multidisciplinary coverage of thermodynamics. The latter is well-suited for current academic programs that are receiving an increasingly diverse student population, where the leveling of the students is essential at the beginning of the course, and interests may be significantly diverse as well. Quantitative metrics are used as much as possible, considering that it is not easy to parametrize the depth of the learning process in the students. Ultimately, the general objective is to use this opportunity in such a forum to discuss how we teach thermodynamics at the graduate level, where a deep understanding of statistical mechanics becomes an absolute must.

Closing Remarks **(16:25 – 17:05)**

Conference Dinner **(19:00 – 22:00)**

Poster Session Contributions

Alan Andrei Alvarez Gonzalez — Density-induced phase transition in out-of-equilibrium confined colloids
Colloids are among the most suitable materials for studying and understanding the properties and phenomena that emerge from complex systems driven out of equilibrium. Learning how these systems behave is a crucial step towards the development of industrial applications. Here, we present Brownian dynamics simulations of paramagnetic colloids strongly confined between two parallel plates and subjected to a conical rotating magnetic field. When increasing the packing fraction, the system transitions from a self-organized hexagonal ordered state to an enhanced-diffusion "active" state, where interactions propel particles in random directions and generate an exchange of positions between dimers. This transition appears to break bond orientational order and time reversal symmetry, and it is an example of an out-of-equilibrium phase transition.

Luis Angel Aparicio Lino — Dissipative Non-reciprocal Solitons in Active Solids
Nonreciprocal wave propagation has recently emerged as a key component in the design of active metamaterials, enabling directed energy transport and new dynamical regimes that transcend the scope of classical reciprocal systems. In this work, we extend the nonreciprocal mKdV (modified Korteweg–de Vries) framework by incorporating linear dissipation, capturing the competition between directional energy injection and damping. Using classical field theory methods parametrically modifying the equation of motion and a time-dependent soliton ansatz, we derive exact analytical solutions describing dynamically evolving solitary waves, whose amplitude, width, and position are governed by coupled modulation equations. Our analysis reveals three distinct regimes: exponential growth driven by nonreciprocal forcing, exponential decay dominated by dissipation, and a nontrivial equilibrated regime. These results provide a tractable theoretical model for understanding wave dynamics in active non-reciprocal metamaterials under realistic dissipative conditions and pave the way for controlled manipulation of soliton behavior.

Maria Fernanda Barranco Medrano — Self-assembly of magnetic particles in unsteady triaxial magnetic fields
We study a dispersion of millimeter magnetic particles in water under an unsteady magnetic field. The particles self-assemble, forming complex elongated structures that try to keep the magnetic field direction as it changes direction in space according to different unsteady configurations. In particular, we focus our attention on the precession field, rotating field, and random cases. We determine some structural characteristics of the aggregates, such as length, shape, and packing fraction.

Gabriel Caballero-Robledo — Bistability in microfluidic bubble production
Bubbles were produced using a microfluidic flow-focusing device. We study the coalescence of the bubbles when adding a drug to the lipidic membrane. Doxorubicin (DOX), a first-line drug for chemotherapy, is used to evaluate its effect on coalescence probability. We obtained the size distribution of bubbles to estimate the number of coalescence events for each drug concentration. The drug was found not to affect the production or coalescence of bubbles for high lipid concentrations. Instead, at low lipid concentrations, the coalescence probability increases

with drug concentration. Surprisingly, a bistable production of bubbles is detected indirectly through bubble size distributions. To our knowledge, this is the first time that bistability is observed in microfluidic bubble production.

Gabriel Alfonso Carranco-Sapiéns — Giant density fluctuations in an active particle system

An *active particle* is capable of cyclic and systematic dissipation of local energy into persistent movement. Because of this, matter composed of active particles (*active matter*) exhibits stationary states that are inherently out of thermodynamic equilibrium. Such states present emergent properties like the appearance of *giant number* or *giant density fluctuations*.

In general, the number of particles in an open subsystem of a simple system experiences fluctuations, even in thermodynamic equilibrium. Such fluctuations may be quantified for that subsystem by observing that its mean particle number $\langle N \rangle$ and its standard deviation ΔN generally satisfy a power law of the form $\Delta N \propto \langle N \rangle^{\varepsilon}$, where $\varepsilon > 0$. In the case that such a subsystem also has a constant volume, the behavior of the number and density fluctuations is the same. We say that a system experiences *giant fluctuations* when the exponent from the power law is greater than the value usually found in equilibrium, $\varepsilon = \frac{1}{2}$.

In this work, we present a computational analysis of the number fluctuations of a one-dimensional system of *run-and-tumble* active particles in the stationary regime. Such particles are pointlike and impenetrable, subject to a thermal bath of constant temperature, confined within a box of fixed length, and noninteracting in any other manner.

We found that the number fluctuations exponent is well defined and is a continuous function of two parameters: the system density and the ratio defined by the diffusion coefficient of the particles in the fluid and the equivalent active diffusion coefficient. The global minimum and maximum obtained for a system of 2000 particles were 0.447(4) and 0.849(2), respectively. This means that some regions of the parameter space display giant number or density fluctuations, comparable to other active matter systems and equilibrium critical point fluctuations despite the spatial dimension of the system and the lack of velocity-alignment interactions.

We confirmed that the systems with the highest fluctuations at a fixed density are those that lack thermal effects, and that the exponent increases with density. Additionally, we found a second maximum of the exponent for dense systems when thermal effects are present. The exponent of the second maximum also increases with the density, although it requires higher activities according to a power law.

Deisy Casas — Casimir Energy in chiral materials

Casimir interactions are forces that develop between electrically neutral objects and arise from the thermal and quantum fluctuations of the electromagnetic field in the vacuum between them. These forces are dependent on the optical properties of the interacting materials. When these materials exhibit chiral properties, time-reversal symmetry is broken, giving rise to various interesting effects.

In this work, we study the effect of chirality on the Casimir energy between plates composed of an arbitrary number of unit cells. Each cell consists of various layers of birefringent material with a rotation of the optical axis between one layer and the next. This design confers an artificial chirality to the materials. For the calculation of the reflection coefficients, a finite temperature is considered. We use the Cayley-Hamilton theorem, in addition to Tetranacci polynomials, to reduce matrix multiplication and analyze the effect on the Casimir energy of various parameters such as the pitch, the number of cells, among others.

Joaly Delgado Alvarez — Comparative morphological analysis of melanoma and skin

cell lines with synchronized cell cycle under silver nanocomposite treatments
Silver nanocomposites have attracted growing interest due to their potential applications in cancer therapy and biomedical engineering. Understanding their effects on malignant and non-malignant cells requires reliable approaches to assess morphological changes beyond qualitative inspection. In this work, we present a comparative morphological analysis of melanoma and skin cell lines with synchronized cell cycle. Cell cycle arrest was induced with colchicine to standardize the experimental conditions prior to treatment. Cells were then exposed to four conditions: $AgNO_3$, silver nanoparticles (AgNPs), chitosan-coated AgNPs, and untreated control. Morphological evaluation was carried out through sulforhodamine B staining for structural assessment and trypan blue exclusion for viability. To ensure quantitative and reproducible shape characterization, images were analyzed using Lobe Contribution Elliptic Fourier Analysis (LOCO-EFA). This method allows the extraction of objective shape descriptors, enabling the systematic comparison of morphological alterations between different cell types and treatment conditions. This study highlights the relevance of integrating computational morphology analysis with experimental assays to advance the understanding of cell–nanomaterial interactions and to establish reliable frameworks for nanotoxicology, nanomedicine, and biophysics research.

María de los Ángeles Escobar López — Directed crystallization by seeding in two-dimensional magnetic granular system
This work experimentally investigates the optimization of crystallization through seeding in a two-dimensional system of magnetic particles. The system is fluidized by a time-dependent magnetic field, whose magnitude controls the effective temperature. At high effective temperatures, the system behaves as a fluid, while a gradual decrease in temperature drives its evolution toward a crystalline configuration. It was found that placing seeds at the center of the surface, combined with a stepwise cooling protocol, promotes the formation of larger crystals in a shorter time. The minimum time required for the particles to reach their lowest-energy configuration at each temperature step was also determined.

Reyna Itzel Garcia-Gonzalez — From sea to sustainability: ulvan-based biopolymers for a greener future
My project will develop seaweed-based biomaterials that are enhanced with natural additives to improve their mechanical strength, barrier properties, and biodegradability. The aim is to produce "not plastic" bio-packaging suitable for industrial use. Initial work has tested 10 different alginates (brown seaweed biopolymers) in order to compare their physicochemical behaviour with ulvans (green seaweed biopolymers). We are optimising methods for biopolymer extraction using solvent-based techniques, and extracts are being analysed using CD, FTIR, NMR, and UV-Vis spectroscopy. Starting with alginates, we have established a method to calculate the proportion of glucuronic acid (G) and mannuronic acid (M). The M/G ratio helps to determine the physical behaviour of these biopolymers, which we are investigating through bulk and micro-rheology to confirm purity and assess physical properties (gel formation, G' and G" properties, particle diffusion, viscosity).

Following extraction, we will collaborate with industrial partners to define target mechanical properties. Selected biopolymer fractions will then be recombined into tailored polymer blends with predicted behaviours, which will be evaluated for mechanical performance, barrier properties, and biodegradability. These will be tested in different formats (films, coatings, rigid containers) using techniques like casting, extrusion, and moulding.

Juan Rubén Gómez Solano — Transition path time over a barrier of a colloidal particle in a viscoelastic bath
We experimentally study the statistics of the transition path time taken by a submicron bead to

successfully traverse an energy barrier created by two optical tweezers in two prototypical viscoelastic fluids, namely, aqueous polymer and micellar solutions. We find a very good agreement between our experimental distributions and a theoretical expression derived from the generalized Langevin equation for the particle motion. Our results reveal that the mean transition path times measured in such viscoelastic fluids have a nontrivial dependence on the barrier curvature and they can be significantly reduced when compared with those determined in Newtonian fluids of the same zero-shear viscosity. We verify that the decrease of the mean transition path time can be described in terms of an effective viscosity that quantitatively coincides with that measured by linear microrheology at a frequency determined by the reactive mode that gives rise to the unstable motion over the barrier. Therefore, our results uncover the linear response of the particle during its thermally activated escape from a metastable state even when taking place in a non-Markovian bath.

Omar González Amezcua — Equilibrium states of a polymer ring in the presence of an attractive surface

We investigate the phase diagram of a polymer ring that interacts attractively with a surface and with varying types of solvent. Using molecular dynamics, we calculate several parameters that provide information on the structure and conformation of the polymer ring. From the analysis of these parameters, we find three equilibrium phases of the polymer ring: a phase where the polymer ring is in globular form for high values of interaction with the solvent; a second phase where the polymer ring is adsorbed and extended over the surface, for a constant value of interaction with the solvent; and a third region, which is a transition between these two regions, where the polymer is semi-extended.

Julio Gutiérrez-Vega — Effects of angular momentum on eigenvalue statistics in a two-dimensional quantum system with rotational symmetry

We investigate the effects of angular momentum on the eigenvalue statistics of a two-dimensional quantum system with rotational symmetry that contains concentric Dirac delta barriers within an infinite circular well. Using the transfer matrix method, we computed large ensembles of eigenvalues for various transmission probabilities, numbers of barriers, and angular momentum values. Statistical analyses of the unfolded spectra were performed using level-spacing distributions, number variance, and eigenstate structure. Our results show that as the transmission probability increases, the system undergoes a transition from Poisson to Gaussian-orthogonal-ensemble statistics, with angular momentum modulating the delocalization properties of eigenfunctions and the number variance at higher barrier counts. While the overall statistical transition remains robust against angular momentum, detailed analysis reveals subtle modifications in spectral correlations and wavefunction structure, particularly at low transmission values and large angular indices. These findings highlight the nuanced role of angular momentum in shaping spectral statistics and quantum chaos signatures in rotationally symmetric systems with singular potentials.

Daniel Alejandro Hernández Mendoza — Computational analysis of cell-to-cell transmission of *Trypanosoma cruzi* in mammalian cell culture

Chagas disease, caused by the intracellular parasite *Trypanosoma cruzi*, can progress to chronic infection, leading to chagasic cardiomyopathy or enteropathy, among other complications. However, the mechanisms that prevent complete parasite eradication by the immune system or currently approved drugs once chronic infection is established remain poorly understood. Recent studies in mammalian cell culture have proposed an alternative mechanism of *T. cruzi* propagation based on direct interactions between infected and uninfected cells (cell-to-cell infection). This process may contribute to immune evasion and parasite persistence during the chronic stage.

To evaluate the relevance of this mechanism in cell culture, we developed a cellular automata computational model that incorporates key processes of infection, including cell-to-cell transmission. Parameter fitting by least squares and simulation analyses indicated that this type of infection may be necessary to reproduce experimental infection kinetics, supporting the cell-to-cell infection hypothesis. Future work will focus on the cellular and molecular characterization of this mechanism, with the goal of identifying pharmacological targets that could enable therapies aimed at achieving parasite eradication even in the chronic stage.

Maria Fernanda Hernandez Flores — Dry-active motion induced by resonant dynamics through an alternating magnetic field

We present an experimental and theoretical study of the transport dynamics of the motion of a magnetized ball under the influence of a periodically alternating external magnetic eld. The coupling between the driving eld and the particle magnetic moment creates an energy reservoir that the particle uses to self-propel, while the oscillation frequency of the field, governs the rich variety of the particle patterns of motion. For each maximum amplitude of the external magnetic field considered in this study, the particle's motility dynamics exhibits different transport properties. These range from low-persistent motion at small frequencies, to a highly persistent regime at intermediate frequencies. Through theoretical analysis of the single-particle trajectories, we demonstrate control of the transport properties of the particle by tuning the frequency of the external driving field. We elucidate that for frequencies close to the characteristic frequency defined by the coupling between the ball's magnetic moment and the driving oscillating field, persistent motion emerges as consequence of the resonant dynamics.

Jorge Raul Hernandez Bordier — Self-assembly dynamics in a granular system

In this work, we use a magnetic granular system composed of steel beads with a diameter of 1 mm. Plastic mica tracer particles are incorporated within and on top of a medium consisting of steel beads, water, and soap. We investigate whether tracer particles of different shapes and sizes can self-assemble as a result of collisions within the thermal bath. Additionally, we analyze the influence of the initial position, the number of tracers, and the frequency of the sinusoidal magnetic field signal on the self-assembly process.

Jaime Jaramillo Gutiérrez — Deviations from ideality in solutions of dicarboxylic acid salts modeled within a BiMSA theory for flexible chains

In the framework of the primitive model, where the solvent in a solution is treated as a continuum, the Binding Mean Spherical Approximation (BIMSA) theory for flexible polyelectrolytes is used to describe the thermodynamic properties of aqueous solutions of dicarboxylate salts, such as potassium oxalate, sodium malonate, and sodium succinate. These salts are of the 2:1 type, consisting of two identical cations, K^+ or Na^+, for one molecular dianion of valence -2, specifically $C_2O_4^{2-}$, $C_3H_2O_4^{2-}$, or $C_4H_4O_4^{2-}$.

The model proposed in this work considers molecules composed of charged hard spheres (representing the cations) and charged chains (representing the dianions). The chains consist of two, three, or four spheres, representing the oxalate, malonate, and succinate molecules, respectively. Cations and dianions interact through a Coulomb potential and can form ion pairs (cation-dianion) and trimers (cation-dianion-cation). Solvation effects and variations in permittivity are included in the model.

Good agreement is found between the theoretical framework and experimental data for the osmotic and activity coefficients.

Francisco López-González — Hexatic Order and Translational Correlations Charac-

terized by Anisotropic Radial Distribution Functions
The Kosterlitz–Thouless–Halperin–Nelson–Young (KTHNY) theory predicts that the melting of two-dimensional hexagonal crystals proceeds through two continuous transitions: a loss of translational quasi-long-range order at the solid–hexatic transition, followed by the disappearance of bond-orientational order at the hexatic–liquid transition. However, experimental characterization of the hexatic phase has been particularly hindered in finite systems, where the definition of a unique reciprocal lattice vector $\mathbf{G}$ is ambiguous. The translational correlation function, defined as

$$g_G(|\mathbf{r}_j - \mathbf{r}_i|) = \langle e^{i\mathbf{G}\cdot(\mathbf{r}_j - \mathbf{r}_i)} \rangle,$$

is sensitive to this ambiguity. Previous works have either discarded $g_G(|\mathbf{r}_j - \mathbf{r}_i|)$ due to this issue [**?**] or reported anomalous decays attributed to finite-size effects and imprecise lattice orientation [**?**]. More recent corrections showed that misalignment between the global orientational parameter and the true lattice axis is responsible for spurious exponential decays, and that proper alignment restores the expected algebraic scaling consistent with KTHNY predictions [**?**].

Here we introduce an alternative framework based on anisotropic Radial Distribution Functions (RDFs) defined with non-Euclidean metrics (Chebyshev and hexagonal). These metrics encode lattice symmetry directly in real space, enabling the simultaneous detection of translational and orientational order without the explicit construction of $\mathbf{G}$. Moreover, the positions and orientations of the RDF peaks provide a natural and robust estimator of $\mathbf{G}$, offering a dual contribution: independence from, yet improved recovery of, reciprocal lattice information. Numerical tests on hexagonal lattices with controlled defects demonstrate that this method consistently distinguishes solid, hexatic, and liquid phases, offering a robust real-space probe of the KTHNY scenario in hexagonal systems while being extendable to other symmetries.

[1] J. Schockmel, et al., Phys. Rev. E 87, 062201 (2013).

[2] A. Brodin, et al., Condens. Matter Phys. 13, 33601 (2010).

[3] Y.-W. Li and M. Pica Ciamarra, Phys. Rev. E 100, 062606 (2019).

Hector Medel — Geometry-driven non-equilibrium phase transition in hard-sphere gas on 1-D elliptic curves
In this work we present a qualitative analysis of a non-equilibrium phase transition in hard-sphere gases confined on elliptic curves, where intrinsic geometry curvature drives spontaneous clustering. Using an exact symplectic integration we could reach a good relative energy conservation that allowed us to study the dynamics of clustering. We found a ranges of parameters where cluster follows deterministic and stochastic nucleation without the indication of thermodynamic criticality. Despite of energy conservation the system follows a not thermalized behavior in the domain of time we studied. The phenomenon resembles motility-induced phase separation in active matter but clearly arises from purely geometric conditions.

Rosario Moctezuma Martiñón — Formation of magnetic particle clusters in shear-thinning fluids
We conducted experiments to study the formation of magnetic particle clusters under oscillatory magnetic fields. Particle with shear-thinning viscosity form larger clusters than those formed in Newtonian fluids. Using a theory that considers the single-sphere, generalized Newtonian drag, and numerical simulations, we intend to explain some aspects of the non- Newtonian contribution to the cluster formation.

Elder Morales — Experimental study on the behavior of microbubbles under acoustic fields in microfluidic conditions

Microbubbles (MBs) are biocompatible, gas-filled spheres (1–10 µm) with a perfluorocarbon core and a phospholipid shell, similar in size to red blood cells (RBCs). Stimulation by acoustic radiation force (F_{rad}) is a promising strategy to enhance controlled drug release by promoting MB interactions with the vascular endothelium. However, despite its potential, MB–F_{rad} behavior in the presence of RBCs remains poorly understood. Therefore, this work aims to characterize the F_{rad}-induced displacements of MBs within a microfluidic device and to elucidate their interactions with blood components. A polydisperse MB suspension (DPPC:DSPE-mPEG$_{2000}$ with C_3F_8 gas), predominantly 3 µm in diameter, was used and flowed (flow rate 0.1 µL/min) within a rectangular channel (128 × 16 µm^2) in a microfluidic device, allowing visualization by optical microscopy, video recording at 250 fps, and F_{rad} stimulation at a frequency of 3 MHz with acoustic pressures (peak-negative pressure PNP) ranging from 90 to 152 kPa. To quantify the effect of F_{rad}, changes in MB trajectories were measured, revealing a PNP-dependent decrease in velocity along the flow direction (217 to 157 µm/s) and a corresponding PNP-dependent increase in the transverse component (106 to 368 µm/s). The deviation angles of the MBs also exhibited a clear dependence on PNP, decreasing from 67° at the lowest to 23° at the highest. Finally, the presence of RBCs at a 1:3 MB-to-cell ratio under PNP of 152 kPa further reduced the deviation angle to 34°. In conclusion, these findings demonstrate that MB displacements are strongly influenced by both PNP and the presence of RBCs, indicating that such interactions should be considered to optimize MB performance in diagnostic and therapeutic applications.

Adrian Perez Rodriguez — Effect of curvature on bulk-mediated surface diffusion
In this work, we analyze bulk-mediated surface diffusion (BMSD), which describes how particles diffusing in a bounded or partially bounded volume are transiently adsorbed onto a surface with a specific geometry. The coupling between the bulk and surface dynamics gives rise to an emergent anomalous dynamics in the surface concentration, characterized by the mean squared displacement (MSD). The BMSD model is fundamental for describing biological systems, such as transport in cell membranes, and has applications in nanotechnology, for instance, in the design of porous materials, among many others. The anomalous nature of the transport depends on the difference in diffusivity between the bulk and the surface, as well as on the surface geometry. The objective of this study is to analyze the influence of surface geometry on the anomalous dynamics of particles, with a focus on the evolution of concentration and moments, including MSD and kurtosis, at different time scales. Although previous work on cylinders and flat surfaces has shown that geometry influences dynamics in various scenarios, our approach aims to explore alternative surfaces, such as spheres and deformations, through parameterizations like Monge's.

Rodolfo Reyes Aguilar — Transport in complex channels of magnetic walkers in magnetorological dispersions under the influence of rotating fields
In this work, we experimentally and theoretically study the transport processes that occur in magnetorheological dispersions exposed to rotating magnetic fields. Magnetorheological fluids are dispersions of micrometer-sized magnetic particles in a non-magnetic base fluid. This system exhibits a significant and reversible rheological response to the application of external magnetic fields. When subjected to a static or variable magnetic field, the suspended particles aggregate into clusters whose morphology and complexity directly depend on the characteristics of the applied field, such as its intensity, direction, or frequency. This work presents results from the analysis of self-organization processes in such dispersions under the influence of rotating and precessing magnetic fields. These studies provide insight into how particles dynamically reorganize into hierarchical structures under controlled conditions.

Daniel Rodríguez López — Discharge of liquid and grains from a silo with multiple orifices

Using a multi-orifice cylindrical silo, the average flow rates Q_1 and Q_N through one and N orifices, respectively, were first measured for the discharge of water or dry grains and then for the mixture. As expected, $Q_N = NQ_1$ for monophasic discharges. Nevertheless, for the mixture, $Q_N \ll NQ_1$, and the effect becomes more notorious as N augments and when the grain size is decreased.

A simplified continuum model of a flow through a dynamic porous medium, with hydrodynamic resistance that increases with N, is used to reproduce the experimental results. Additional analysis in a two-dimensional cell reveals interacting parabolic flow profiles of the immersed particles close to the orifices, with a reduction in the average velocities when N is increased, which helps to understand the non-additivity of the total flow rate.

Ivany del Carmen Romero Sánchez — A dynamical equivalence for the cageing-release colloidal problem

A commonly observed dynamic scenario of Brownian particles presenting multiple time regimes is the diffusion-cageing-diffusion dynamics, i.e., a short-time diffusive region, followed by a plateau-like regime, and finally a second diffusive regime at long times. This scenario occurs when a particle interacts with a complex fluid, or during the glass transition, and is typically explained in terms of the cageing-release scenario: after a period of confinement, the particle is released from the confined region, either through a thermally activated process or the motion of neighboring elements. In this contribution, we analyze a dynamic scenario that exhibits the same phenomenology, where the perfectly confining cage undergoes random motion. Thus, the particle is unable to escape from it but moves along with it. We demonstrate that the two scenarios are dynamically equivalent in terms of their mean-squared displacement, presenting the three-regime dynamics explained before. However, we also propose that the non-Gaussian parameter can be used to efficiently differentiate between the two dynamics. A mixed scenario is also analyzed, finding a nontrivial evolution of the non-Gaussian parameter. Possible implications on microrheology and in the glass transition are also discussed.

Jose Guadalupe Santiago Garcia — Metal–insulator transitions in dense one-dimensional crystalline systems

In dense crystalline systems, orbital overlap strongly affects electronic properties and can modify metal–insulator transitions. We introduce a simple correction for nonorthogonal orbitals by incorporating a metric tensor in Hilbert space, which renormalizes energies, couplings, and on-site potentials. This approach circumvents the use of Wannier transforms while providing accurate spectral descriptions for nonorthogonal systems. When applied to representative models such as Harper's model with irrational flux, orbital overlap is found to smooth the transmission transition. In the uncorrelated Anderson model, the transmission remains robust, whereas in the correlated Anderson case, orbital overlap enhances transmission. These results open new possibilities for controlling metal–insulator transitions in strongly coupled electronic, photonic, and elastic structures.

Cecilio Tapia-Ignacio —Confinement-Induced Hyperbolic Traps in Bubble-Driven Flows Probed by Hydrogel Tracers

We investigate the anomalous diffusion of passive hydrogel tracers in a quasi-two-dimensional system where a confined bubble-driven flow generates a bistable potential landscape. Two dynamical regimes are explored: a baseline state, in which tracers remain trapped within isolated wells, and a perturbed configuration with added obstacles that promote inter-well transitions. Particle trajectories are analyzed through Mean Squared Displacement (MSD), Detrended Fluctuation Analysis (DFA), and Fourier spectral methods, revealing strongly superdiffusive and anisotropic motion. The extracted exponents violate standard stochastic scaling relations, point-

ing to non-Markovian dynamics dominated by intermittent bubble-induced perturbations and barrier-crossing events. Our findings establish this system as a minimal physical platform for probing non-equilibrium statistical mechanics, where hydrodynamic fluctuations and geometric constraints conspire to produce persistent motion and long-range temporal correlations.

Emilene Yamilet Ugalde Salas —PFOA detection using SERS substrates based on UiO-66-F_4 MOFs synthesized by bicontinuous microemulsion and decorated with Au–Cu nanostars

Metal-organic frameworks (MOFs) are crystalline hybrid materials composed of metal nodes and organic ligands. They are characterized by their high surface area, tunable porosity, and functional versatility, making them ideal for applications in catalysis, storage, and sensing. In this work, the UiO-66-F_4 MOF was synthesized using a bicontinuous microemulsion route, which allowed obtaining a stable nanometric structure. Subsequently, hybrid surface-enhanced Raman scattering (SERS) substrates were developed by combining UiO-66-F_4 with bimetallic Au–Cu nanostars, designed to generate surface plasmons capable of amplifying the Raman signal of adsorbed molecules. The SERS evaluation was performed using perfluorooctanoic acid (PFOA) as the analyte, an emerging contaminant belonging to the PFAS family, known for its high persistence and toxicity, which poses a significant risk to human health. The results demonstrated that substrates based on UiO-66-F_4 MOFs and Au–Cu nanostars were able to detect PFOA concentrations as low as 0.4 parts per trillion (ppt), reaching an enhancement factor (EF) of up to 1.7×10^{10}, which is below the limits established by the United States Environmental Protection Agency (EPA). These findings highlight the great potential of the developed hybrid substrates as ultrasensitive, selective, and sustainable tools for environmental monitoring and the detection of emerging contaminants at trace levels.

Jose Ignacio Vellojin —Diffusion of core–shell colloids in quasi-2D water and polymeric complex fluids

Core–shell colloidal particles are widely used as probes of microscopic dynamics, yet their true diffusive nature in water and in polymeric complex fluids remains an open question. Depending on confinement, shell viscoelasticity, and medium heterogeneity, their trajectories may deviate from classical Brownian motion. Understanding these deviations is essential for correctly interpreting particle-based microrheology and transport in structured media.

We explore this problem in quasi-two-dimensional sample chambers that confine particles within a narrow axial gap, thereby restricting motion to a plane and minimizing out-of-focus excursions. Using high-resolution optical microscopy, we extract mean-square displacements (MSD) with sub-pixel accuracy and evaluate the diffusion exponent α via MSD log–log slopes. This criterion allows us to differentiate true Brownian diffusion ($\alpha \approx 1$) from hindered, subdiffusive, or non-Markovian dynamics. We complement these measurements with dynamic light scattering (DLS) and diffusing-wave spectroscopy (DWS), comparing ensemble diffusion coefficients with single-particle results.

By contrasting behaviors in pure water with those in polymeric or micellar complex fluids, we identify how hydrodynamic wall effects (Brenner, 1961), localization noise (Michalet, 2010), particle-tracking limitations (Crocker & Grier, 1996), and statistical uncertainties in MSD analysis (Berg-Sørensen & Flyvbjerg, 2004) shape the observed dynamics. This combined methodology enables us to determine under which physical conditions core–shell colloids retain Brownian character and when anomalous diffusion emerges due to medium-induced memory or confinement.

Mario Villada-Balbuena — Configurational temperature and entropy changes in

RNA unfolding from Brownian dynamics simulations

We analyzed a set of three-dimensional RNA structures of varying molecular weights, obtained from the Protein Data Bank (PDB), to determine key chain parameters such as the radius of gyration, contour length, and persistence length. Distribution functions of different degrees of freedom were used to derive effective potentials describing the interactions between the centers of mass of the nucleotides, which were subsequently refined using Iterative Boltzmann Inversion. These optimized potentials enabled the development of a novel coarse-grained force field to investigate the mechanical unfolding of RNA chains.

Brownian dynamics simulations, combined with theoretical analysis, were employed to quantify changes in free energy and entropy, which were then compared with theoretical predictions. Additionally, we monitored the configurational temperature of the simulated molecules throughout the entire unfolding process.