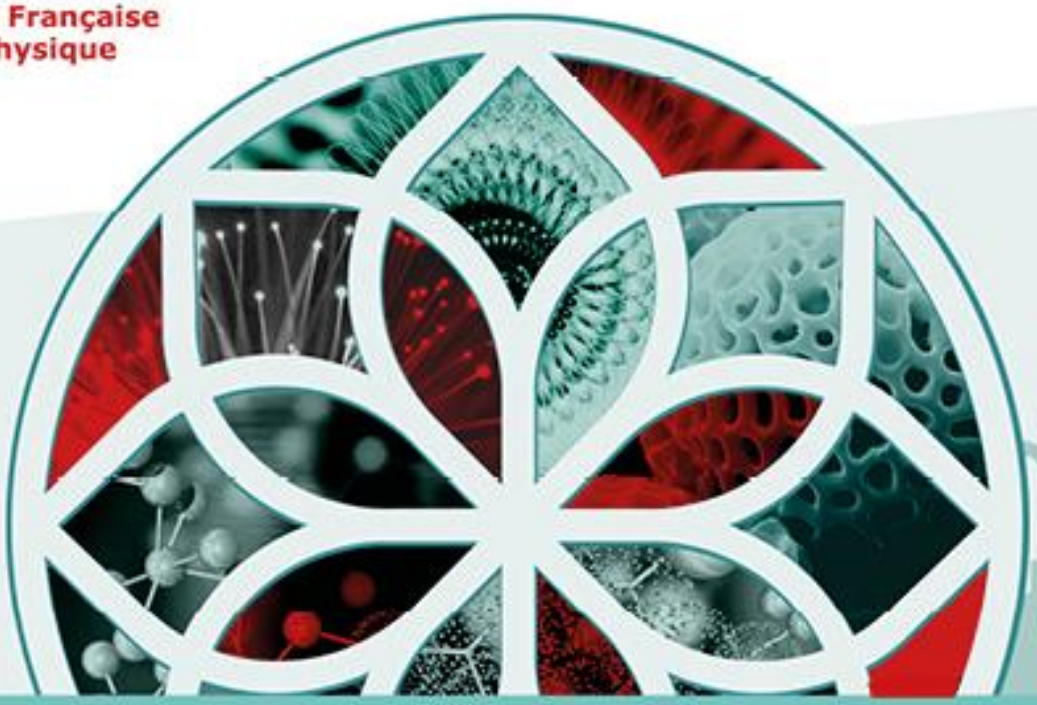
Société Française de Physique



Congrès Général de la Société Française de Physique

Université de Technologie de Troyes

du 30 juin au 4 juillet 2025

www.sfp2025.fr

Un congrès exceptionnel avec la venue de trois Prix Nobel :

Alain Aspect

- Conférences plénières
- Colloques thématiques

Moungi Bawendi

- Sessions Science et Société
- Sessions Posters

Anne L'Huillier

- Expositions industrielle, de culture scientifique et Arts et Science

heure	DIMANCHE 29 juin	LUNDI 30 juin	MARDI 01 juillet	MERCREDI 02 juillet	JEUDI 03 juillet	VENDREDI 04 juillet
			Transfert gare vers site UTT	Transfert gare vers site UTT	Transfert gare vers site UTT	Transfert gare vers site UTT
			Accueil / inscriptions	*Accueil / inscriptions*	*Accueil / inscriptions*	*Accueil / inscriptions*
8:30		**Transfert gare vers UTT**	*Mini-colloques en parallèle :* **MC01, MC02, MC04, MC07, MC09, MC11, MC12, MC16, MC18, MC21, MC24, MC27, MC28, REDP2 (salles spécfiques)**	*Mini-colloques en parallèle :* **MC01, MC04, MC05, MC10, MC11, MC12, MC15, MC17, MC18-MC20, MC28, REDP3 (salles spécifiques)**	*Mini-colloques en parallèle :* **MC04, MC06, MC07, MC09, MC11, MC15, MC18-MC20, MC19, MC28 (salles spécifiques)**	*Mini-colloques en parallèle :* **MC06, MC08, MC10, MC18-MC20, MC19, MC23, MC24, MC27 (salles spécifiques)**
9:00		*Accueil et Inscriptions*				
9:30						
10:00		***Ouverture du Congrès***				
10:30			*Pause-café*	*Pause-café*	*Pause-café*	*Pause-café*
11:00		**Moungi Bawendi-Prix Nobel Chimie 2023** *Colloidal nanocristals* **(M500)**	**International Year of Quantum (M500)**	**Nathalie Palanque-Delabrouille** *Objectif énergie noire* **(M500)**	*Table ronde :* **T2: Evolution science et contexte international (M500)**	**Anne L'Huillier (Prix Nobel Physique 2023)** Attosecond *Physics* **(M500)**
11:30			**Alain Aspect-Prix Nobel Physique 2022** 2nd quantum revolution **(M500)**			
12:00		**Marina Lévy** *Dynamique des fluides : moteur de la vie dans l'Océan* **(M500)**		**Noël Dimarcq** *Redéfinir la seconde : quand, pourquoi, comment ?* **(M500)**		**Alessandro Morbidelli** *Formation planétaire: laboratoire de physique à grande échelle* **(M500)**
12:30			**Aleksandra Walczak** Prediction in immune repertoires **(M500)**			
13:00		*Déjeuner inclus (CROUS)* *Atelier contre le harcèlement (C102)*	*Déjeuner inclus (CROUS)*	*Déjeuner inclus (CROUS)*	***Remise prix posters*** *Déjeuner inclus (CROUS)* *Temps déjeuner Commissions Femmes & Physique (CROUS)*	***Cérémonie de clôture***
13:30	*Inscriptions*					Transfert vers centre ville
14:00	***Journée Effervesciences (Médiathèque Troyes)***	*Table ronde :* **T1: Recyclage matériaux, développement durable (M500)**	**Prix Jean Ricard: Marc BARTHELEMY, Prix Emilie Du Chatelet: Laurette TUCKERMAN, Prix Gentner–Kastler: Regine VON KLITZING (M500)**	*Mini-colloques en parallèle :* **MC02,MC05, MC06, MC08, MC14, MC19, MC21, MC23, MC27, REDP4 (salles spécifiques)**	*Sessions sociétales en parallèles:* **S5: De l'impact de l'IA (M500)** **S6: En quoi les chercheurs sont-ils indispensables pour diffuser la culture scientifique? (N101)**	**Visites culturelles et scientifiques*:*** *-Cité du Vitrail* *-Musée d'Art Moderne* *-Trésors scientifiques des bibliothèques de Troyes - Manufacture Vincent-Petit* *-Musée de l'Outil* *-Visite de la Ville* *-Visite de la CIME* ***-Visite de caves de champagne***
14:30						
15:00						
15:30		**Lyderic Bocquet** *La mécanique moléculaire des fluides* **(M500)**	*Pause-café*	*Pause-café*		
16:00						
16:30		*Pause-café*	Sessions sociétales parallèles: **S1: Parité et égalité des chances (N101)** **S2: Science ouverte, évaluation et IA (M500)**	*Sessions sociétales parallèles:* **S3: Quel avenir pour l'enseignement de la physique? (M500)** **S4: Impact des technologies sur la société (N101)**	*Pause-café*	
17:00		*Mini-colloques en parallèle :* **MC01, MC02, MC04, MC05, MC07, MC08, MC10, MC13, MC16, MC19, MC24, REDP1 (salles spécifiques)**			Transfert vers centre ville	
17:30					***Visites culturelles et scientifiques:*** *-Cité du Vitrail* *-Trésors scientifiques des bibliothèques de Troyes* *-Manufacture Vincent-Petit* *-Musée de l'Outil* *-Visite de la Ville* *-Visite de la CIME*	
18:00			***Session Posters (tous MCs en M104) et Expositions industrie, culture scientifique, arts et science (Hall N & La Rue)***	***Session Posters (tous MCs en M104) et Expositions industrie, culture scientifique, arts et science (Hall N & La Rue)***		
18:30						
19:00	**Evénement grand public:** spectacle equiQuanto, physique quantique et spectacle équestre dessiné **(Cité du Vitrail, Troyes)**	***Cocktail d'inauguration (UTT en M104)***			**Dîner de gala (Espace Argence, Troyes)**	
19:30						
20:00			Transfert vers centre ville	Transfert vers centre ville		
20:30			***Soirée Jeunes Physicien.nes (UTT Bât. A,B,C)***			
21:00				**Evénement grand public Gérard Liger-Belair** l'Odyssée d'une bulle de champagne **(Centre des Congrès de l'Aube, Troyes)**		
21:30						
22:00		Transfert vers centre ville				

Légende :
- Conférences plénières
- Tables rondes
- Mini-colloques en parallèle
- Sessions sociétales
- Sessions posters
- Moments conviviaux & Grand public
- Visites culturelles & scientifiques

Common program of MC18: Microscopies for biology
and **MC20**: Cellular engineering, tissue engineering and biomaterials

Tuesday	**Room C103**	
Time	**Speaker**	**Title**
8h45 – 9h15	Hervé Rigneault (Invited)	Label free coherent Raman imaging
9h15 – 9h35	Olivier Haeberlé	Reconstruction 3D de cartes d'indice de réfraction améliorée par microscopie diffractive tomographique à double vue
9h35 – 9h55	Anis Aggoun	Quantitative Phase Imaging with a Thin Diffuser: Developments and Applications in Cell Biology
9h55 – 10h15	Tual Monfort	Dynamic Full-Field Optical Coherence Tomography: Recent Advances and Biomedical Applications
10h15 –10h30	Sponsor - Imabio	Presentation of the Imabio Young Scientist Network

Wednesday	**Amphi C002**	
Time	**Speaker**	**Title**
8h30 – 9h00	Laurent Pieuchot (invited)	Bending the rules: Role of Curvature at the cell-material interface
9h00 – 9h20	Sara Faour	Elasto-capillarity of hydrogels: how surface tension drives single cell motility
9h20 – 9h40	Emmanuelle Helfer	MC20: Substrate stiffness alters organization and motility of human induced pluripotent stem cells to modulate their differentiation potential
9h40 – 10h10	Karen Peronnet	Probing Single-Molecule Dynamics in Self-Assembling Viral Nucleocapsids
10h10 – 10h30	Baptiste Bouhet	Monitoring the ribosome dynamics at the single molecule level

Thursday	**Amphi C001**	
Time	**Speaker**	**Title**
8h40 – 9h10	E. Papagiakoumou (Invited)	Wavefront engineering for volume light control in nonlinear neurophotonics
9h10 – 9h30	Julien Nassif	Optimization of speckle-free holography for scanless two-photon voltage imaging.
9h30 – 9h50	Jeremie Nataf	Three-photon Holographic Microscopy For Deep Precise Optogenetics
9h50 – 10h10	Daniel Selma	Minimalistic In Vitro Assay to Study Cell Intercalation in Morphogenesis
10h10 – 10h30	Koloina Randrianavony	Effets mécaniques de la stimulation par ondes de cisaillement sur la peau du visage

Friday	**Amphi C001**	
Time	**Speaker**	**Title**
8h40 – 9h10	Clément Cabriel (Invited)	Eve-SMLM: Enhanced Single-Molecule Localization Microscopy with Event-Based Sensors
9h10 – 9h30	Alexandre Clausolles	Agile two-photon microscope for fast 5D single-particle translation and rotation tracking
9h30 – 10h00	Claire Leclech (Invited)	Influence of substrate topography on vascular endothelial cells
10h00 – 10h30	Olivier Destaing (Invited)	Explorer les systèmes biologiques hors équilibres par manipulation optogénétique

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Label free coherent Raman imaging

Hervé Rigneault * [1]

[1] Institut Fresnel – Aix Marseille Univ, CNRS, Centrale Med – Domaine Univ St Jérôme 13397 Marseille, France

Coherent Raman is a label-free microscopy technique that can image chemical bonds in biological samples. In this talk, I will present our efforts to perform stimulated Raman histology (SRH), a novel real-time histology technique that can produce histology-like images based solely on chemical contrast. I will show how SRH can benefit from AI to diagnose brain cancers and to optimize the explored field of view in complex brain samples.
In the second part, I will present novel developments to perform coherent Raman imaging in wide-field to address large fields of view. Using speckle illuminations, it is possible to achieve wide-field coherent Raman imaging with better resolution and z-sectioning capability.
In the final part, I will review our efforts to develop coherent Raman endoscopes to bring SRH directly into the operating room without tissue removal.

*Speaker

Reconstruction 3D de cartes d'indice de réfraction améliorée par microscopie diffractive tomographique à double vue

Carlos Alberto Chacon Avila [1], Nicolas Verrier [2], Matthieu Debailleul [3], Olivier Haeberlé * [1]

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[2] IRIMAS – Université de Haute Alsace - Mulhouse : EA2332, Université de Haute Alsace - Mulhouse – France
[3] IRIMAS – Université de Haute Alsace - Mulhouse : EA2332, Université de Haute Alsace - Mulhouse – France

La microscopie tomographique diffractive (MTD) est une technique d'imagerie sans marquage, visant à reconstruire la distribution 3D de l'indice optique dans le spécimen observé (1). Cette technique est une basée sur la mesure du champ diffracté par le spécimen, combinée à une synthèse d'ouverture. Celle-ci peut se faire par rotation de l'illumination, par rotation du spécimen, par combinaison de ces deux approches, at aussi par changement de la longueur d'onde d'illumination.
Il faut ensuite résoudre un problème inverse pour retrouver la distribution d'indice produisant le champ mesuré. Son implémentation la plus simple est basée sur l'hypothèse de Born d'un champ diffracté très faible en amplitude par rapport au champ d'illumination, ce qui permet des reconstructions très rapides à l'aide des cartes de calcul GPU modernes, car basées sur des transformées de Fourier (2).

Cependant, plusieurs problèmes apparaissent.

- En MTD en transmission, la présence d'un cône de fréquences manquantes dans les données acquises (missing-cone) limite la résolution axiale, et fait apparaître des artefacts de reconstruction (3).

- L'hypothèse de Born peut rapidement être mise en défaut (spécimen épais et/ou fortement réfractant/diffractant/diffusant).

- La qualité des reconstructions dépend fortement des acquisitions (4).

Une solution pour améliorer la résolution axiale est un montage 4Pi, proposé par Lauer (5). Pour ce faire, il faut réaliser un montage symétrique à 2 objectifs de microscope se faisant face, et permettant d'acquérir 2 images en transmission et 2 images en réflexion.

Dans cette contribution, nous présentons les résultats obtenus sur la double transmission, et

*Speaker

les développements permettant le recalage des données, puis leur fusion, afin d'obtenir une image de qualité améliorée. Les méthodes mises au point devront ensuite être adaptées pour réaliser la fusion des données mesurées en réflexion, afin d'obtenir une image à résolution isotrope.

(1) N. Verrier, M. Debailleul, and O. Haeberlé, Sensors **24**, 5 (2024)

(2) E. Wolf, Opt. Commun. **1**, p. 153(1969)

(3) M. Debailleul, *et al.*, Opt. Lett. **34**, p. 79 (2009)

(4) A. M. Taddese, *et al.*, Appl. Opt. **60**, p. 1694 (2021)
(5) V. Lauer, J. Microsc. **205**, p. 165 (2002)

Quantitative Phase Imaging with a Thin Diffuser: Developments and Applications in Cell Biology

Anis Aggoun * [1], Benoît Rogez [2], Jeremy Brogard [3], Baptiste Blochet [4], Marc Guillon [4], Sacha Reichman [5], Gilles Tessier [6], Pascal Berto [7]

[1] Institut de la Vision – Sorbonne Universite – France
[2] Lumière, nanomatériaux et nanotechnologies – Université de Technologie de Troyes – France
[3] Institut de la Vision – sorbonne université, INSERM – France
[4] Saints-Pères Paris Institute for Neurosciences – Université Paris Cité – France
[5] Institut de la Vision – sorbonne université, INSERM – France
[6] Institut de la Vision – Sorbonne Université – France
[7] Institut de la Vision – Université Paris Cité – France

Quantitative Phase Imaging (QPI) accurately maps amplitude and wavefront distortions caused by the refractive index distribution in microscopy samples. This label-free approach enhances contrast on transparent objects and enables detailed investigation of biophysical features in cells and tissues. Recently, High-definition Wavefront Sensing (HD-WFS) has emerged as a prominent group of QPI techniques. These single-shot methods are_more robust and simpler than traditional reference-based interferometry techniques like Digital Holographic Microscopy, as they operate without a reference arm and can use incoherent light, such as native microscope illumination. This makes WFSs easily integrable with most commercial microscopes.
Here, we introduce an HD-WFS technique called DiPSI (Diffuser Phase Sensing and Imaging). This method is implemented by positioning a thin diffuser near a standard camera, which captures a speckle pattern. The memory effect of the diffuser allows the fine tracking of the speckle grains, enabling a precise quantification of wavefront distortion with high phase sensitivity ($< \lambda/500$) and real-time imaging (> 50Hz). The method is cost-efficient and only uses off-the-shelf components, which should ease the dissemination of QPI. Additionally, we have developed ImageJ and Micro-Manager plugins for phase and intensity image reconstruction from speckle images and for live imaging, respectively, to further facilitate DiPSI adoption, particularly in biology labs.
The potential of the DiPSI method is showcased in cell biology, specifically for identifying retinal cell types derived from organoids. These cells, including retinal ganglion cells and photoreceptors, are derived from human induced pluripotent stem cells (hiPSCs) and are of major interest for vision restoration therapies. As fluorescent tags are not suitable for human use, novel label-free classification methods are required to isolate specific cell types for therapeutic transplantation. Results from our recent efforts that combine DiPSI with Deep Learning tools for the label-free identification of precursor photoreceptor cells will be presented, demonstrating the method's crucial role in advancing vision restoration therapies.

*Speaker

Dynamic Full-Field Optical Coherence Tomography: Recent Advances and Biomedical Applications

Tual Monfort * [1], Nate Norberg [2], Sacha Reichman [2], Olivier Thouvenin [3], Kate Grieve [4]

[1] Institut de la Vision – Sorbonne Université, INSERM, CNRS, Institut de la Vision – France
[2] Institut de la Vision – Sorbonne Université, INSERM, CNRS, Institut de la Vision – France
[3] Institut Langevin – CNRS, UPMC, ESPCI – France
[4] Institut de la Vision – Sorbonne Université, INSERM, CNRS, Institut de la Vision – France

Introduction

Optical Coherence Tomography (OCT) has revolutionized biomedical imaging since its inception, offering non-invasive visualization of tissue microstructures. Among its variants, Full-Field Optical Coherence Tomography (FF-OCT) has emerged as a powerful technique for capturing en face images with subcellular resolution. FF-OCT represents a specific configuration of time-domain OCT particularly adapted to high-resolution imaging, capable of capturing the 3D distribution of backscattering structures in complex biological samples.

Dynamic FF-OCT

More recently, Dynamic Full-Field OCT (D-FFOCT) has extended these capabilities by exploiting temporal fluctuations in the interferometric signal, offering unprecedented insights into cellular dynamics and metabolic activity without the need for exogenous contrast agents. This innovative approach reveals active structures in dense environments through the temporal quantification of signal fluctuations.

Mechanisms and Significance

D-FFOCT can identify single living cells within complex biological structures by detecting phase fluctuations associated with the active transport of cell organelles. This dynamic contrast directly relates to metabolic cell activity and is cell-specific, as organelle transport represents a deeply regulated and controlled mechanism at the core of cell physiology. Consequently, these dynamic signatures serve as valuable biomarkers for various diseases that impact local cellular activity.

Scope of Presentation

This presentation will provide a comprehensive overview of recent advances in D-FFOCT technology and its expanding applications across various biomedical fields. We will discuss technical innovations that have improved imaging speed, resolution, and penetration depth, along with

*Speaker

novel computational approaches for signal processing and image reconstruction. Furthermore, we will explore diverse applications in disease modelling, pathophysiology, and tissue engineering, highlighting how D-FFOCT is transforming our understanding of biological processes and disease mechanisms.

Presentation of the Imabio Young Scientist Network

Clément Cabriel * [1]

[1] Institut Langevin - Ondes et Images (UMR7587) – CNRS ESPCI PSL – France

Imabio YSN is a professional network that aims at establishing connections between early career scientists in the bioimaging community. It was created by the GDR imabio in 2018, and it has since grown to connect scientists (PhD students, postdocs, interns, early career research engineers and researchers, etc.) all around France and abroad in the fields of microscopy, chemistry, biology, data analysis and bioinformatics, etc.
We strive to create scientific interaction between our members, promote their visibility, bring down the barriers between yound and more senior scientists, share news and provide information about professional perspectives for our members. To achieve this, we organize various types of actions, including conferences, round tables about career development, imaging platforms visits and more.
We also share useful information via our website and social networks accounts, and we are present at some events organized by the GDR Imabio. As a collaborative network, we are happy to consider propositions of our members to organize new events. Finally, we are always happy to welcome new members, particularly to expand our organization committee, which is a valuable professional experience.

*Speaker

2-2 juil. 2025

Bending the rules: Role of Curvature at the cell-material interface

Laurent Pieuchot * [1]

[1] Institut de Science des Matériaux de Mulhouse (IS2M) – Université de Haute Alsace, CNRS : UMR7391 – 15 rue jean starcky, BP2488, 68057 Mulhouse Cedex, France, France

In this talk, I will give an overview of our research and discuss examples that highlight the central role of curvature in our model systems. I will explore how individual adherent cells sense and migrate in response to static and dynamic variations in curvature, and how this influences their phenotype and collective migration. In addition, I will present recent research on biomimetic and bioengineered systems where curvature is essential. First, I will describe an original device we are developing for the treatment of irradiated colon tissue that unrolls upon water uptake and releases bioactive compounds. Then I will present our work on virus-derived spherical self-assemblies that can mimic extracellular matrix proteins and control cell behavior. Finally, I will present a case where a change in curvature within a micron-scale protein-based weapon, the R-body, induces a shape change that leads to the death of a unicellular organism. Finally, I will outline our future research goals and the potential applications of our findings.

*Speaker

Elasto-capillarity of hydrogels: how surface tension drives single cell motility

Sara Faour * [1,2], Cyrille Vézy [3], Régis Déturche [3], Jérôme Sohier [4], Stéphane Dedieu [5], Rodolphe Jaffiol [6]

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[2] Matrice extracellulaire et dynamique cellulaire - UMR 7369 – Université de Reims Champagne-Ardenne, SFR CAP Santé (Champagne-Ardenne Picardie Santé), Centre National de la Recherche Scientifique – France
[3] Lumière, nanomatériaux et nanotechnologies, UMR 7076 – Université de Technologie de Troyes – France
[4] Laboratoire de Biologie Tissulaire et d'ingénierie Thérapeutique UMR 5305 – Université Claude Bernard Lyon 1, Centre National de la Recherche Scientifique, Centre National de la Recherche Scientifique : UMR5305 – 7 Passage du Vercors 69367 Lyon cedex 07, France
[5] Matrice extracellulaire et dynamique cellulaire - UMR 7369 (MEDyC) – Université de Reims Champagne-Ardenne – Faculté de Médecine 51 Rue Cognacq-Jay 51095 REIMS CEDEX, France
[6] Lumière, nanomatériaux et nanotechnologies, UMR 7076 – Université de Technologie de Troyes – France

Soft polymer-based hydrogel are very promising biomaterials for various applications in tissue engineering and regenerative medicine. Compared to materials made with natural constituents, synthetic hydrogels provide a fine control of composition and functionalization with adhesive ligands, along with tuneable mechanical properties, as it's crucial for most investigations in mechanotransduction. While numerous studies have explored how substrate stiffness influences cell behaviour, the role of surface tension in guiding fibroblast motility remains mostly unexplored. Additionally, the elasto-capillarity of such soft solids is often neglected, especially in regimes where surface tension dominates over bulk elasticity at the water/solid interface (1–5). Here, we present a parametric study using fibronectin-coated PEG/DGL hydrogels with well-controlled stiffness E and surface tension σ to assess their influence on 2D fibroblast migration. Mechanical characterization was performed using optical tweezers via active bulk microrheology and surface micro-indentation. Two fibroblast subtypes, WPMY-1 and CAF-2, were studied across hydrogels of varying DGL concentration. Single-cell trajectories were tracked using epi-fluorescence and phase contrast microscopy, and direction and speed autocorrelations were computed and analyzed using the "stick-slip" model proposed by H. Flyvbjerg (4,5). Finally, we clearly demonstrated that fibroblasts adopt a directional persistence motion when the surface tension increases, highlighted by an increase of the time associated to the direction of motion changes.

References:

(1). D. Missirlis, JP Spatz. Biomacromolecules 15, 195-205 (2014). (2). M. Dietrich, H.

*Speaker

Le Roy, D. B Brückner, H. Engelke, R. Zantl, J. O. Rädler, C. P Broedersz. (2018). Soft Matter 14, 2816-2816 (2014). (3). R. Style, A. Jagota, C-Y. Hui and E. Dufresne, Ann. Rev. Condens. Matter phys. 8, 99-118 (2017). (4). R. Gorelik, A. Gautreau. Nat Protoc. 9, 1931-1943 (2014). (5). D. Selmeczi *et al.* Eur. Phys. J. Spec. Top. 157, 1-15 (2008).

Substrate stiffness alters organization and motlity of human induced pluripotent stem cells to modulate their differentiation potential

Jack Llewellyn [1,2], Anne Charrier [3], Rossana Cuciniello [1], Rosanna Dono [1], Emmanuèle Helfer * [4]

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[2] Turing Centre for Living Systems [Marseille] – Aix-Marseille Université - AMU – France
[3] Aix Marseille Univ, CNRS, CINAM, Turing Centre for Living Systems, Marseille, France – Aix Marseille Université, Centre National de la Recherche Scientifique – France
[4] Aix Marseille Univ, CNRS, CINAM, Turing Centre for Living Systems, Marseille, France – Aix Marseille Université, Centre National de la Recherche Scientifique – France

Lineage-specific differentiation of human induced pluripotent stem cells (hiPSCs) relies on complex
interactions between biochemical and physical cues. Here, we assessed how substrate stiffness impacts hiPSC response to differentiation inductive signals. We show that hiPSC differentiation into mesendoderm and endoderm is enhanced on gel-based substrates softer than glass. This correlates with changes in tight junction formation and extensive cytoskeletal remodeling. Live imaging suggests changes in cell motility and interfacial contacts underlie hiPSC layer reshaping on soft substrates. Our results provide mechanistic insight into how epithelial mechanics dictate the hiPSC response to chemical signals and provide a tool for their efficient differentiation in emerging stem cell therapies.

*Speaker

Probing Single-Molecule Dynamics in Self-Assembling Viral Nucleocapsids

Thomas Bugea [1,2], Romeo Suss [1,2], Guillaume Tresset [3], Karen Perronet *
1

[1] Laboratoire Lumière, Matière et Interfaces – CentraleSupélec, Université Paris-Saclay, Centre National de la Recherche Scientifique, Ecole Normale Supérieure Paris-Saclay, Centre National de la Recherche Scientifique : UMR9024 / FRE2036, Centre National de la Recherche Scientifique : FRE2036 – France
[2] Laboratoire de Physique des Solides – Laboratoire de Physique des Solides – France
[3] Laboratoire de Physique des Solides – Laboratoire de Physique des Solides – France

The diversity of viruses we are facing dictated us to learn how to live with them. To facilitate this coexistence and, above all, combat their proliferation, it has been necessary to understand how they work. This need has led to numerous studies on viruses of various sizes and compositions. Up to now, the results obtained through ensemble measurements contribute to improving our knowledge upon assembly pathways of viral capsids and their dependence on salt and pH. Indeed, most of the techniques used give average results for an entire population, without being able to access to the inherent heterogeneity of the assembly mechanism. Total internal reflection fluorescence microscopy (TIRFM) allows us to work not only at the level of the individual capsid, but also at the level of the individual subunit. This experimental setup has been used on the Cowpea Chlorotic Mottle Virus (CCMV), whose dimers and single-stranded RNA were fluorescently labelled.
We probed the binding and unbinding dynamics of fluorescently labeled capsid subunits on hundreds of immobilized viral RNA molecules simultaneously at each time point. A step-detection algorithm combined with statistical analysis allowed us to estimate microscopic quantities such as the equilibrium binding rate and mean residence time, which are otherwise inaccessible through traditional ensemble-averaging techniques. Additionally, we could estimate a set of rate constants modeling the growth kinetics from nonequilibrium measurements, and we observed an acceleration in growth caused by the electrostatic screening effect of monovalent salts (1). Single-molecule fluorescence imaging will be crucial for elucidating virus self-assembly at the molecular level, particularly in crowded, cell-like environments.
(1) Bugea T., Suss R. Gargowitsch L., Perronet K. and Tresset G. Probing Single-Molecule Dynamics in Self-Assembling Viral Nucleocapsids. Nano Letters, 24, 14821 (2024)

*Speaker

Monitoring the ribosome dynamics at the single molecule level

Baptiste Bouhet * [1], Karen Perronet [1], Sandra Blanchet [2], Olivier Namy [2], Charles Truong [3]

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Protein synthesis is a complex multi-step process involving many factors that need to interact in a coordinated manner to properly translate the messenger RNA. As translating ribosomes cannot be synchronized over many elongation cycles, single molecule studies, mainly using total-internal-reflexion fluorescence microscopy, have been introduced to bring a deeper understanding of translation dynamics. In order to perturb as little as possible the translation machinery and to use cell extracts, we decided to monitor the passage of individual, unmodified mammalian ribosomes at specific fluorescent primers hybridized along a mRNA. Because of the ribosome helicase activity, the double strand formed by the oligonucleotide and the mRNA is opened while the ribosome translates this region of the mRNA. Two different oligonucleotides are hybridized at two different places on the mRNA. Thus, the consecutive loss of the fluorescence signal of both oligonucleotides allows us to measure the translation speed distribution of single ribosomes. We use this system to study IRES- and cap-dependent initiation and measure both the initiation and the elongation rate. We are currently developing a magnetic tweezers assay to get complementary information on the elongation kinetics during frameshifting. Thanks to its versatility, this method is a valuable tool to investigate the role of translation machinery modifications in human diseases.

*Speaker

3-3 juil. 2025

Wavefront engineering for volume light control in nonlinear neurophotonics

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Light-based approaches offer a sensitive, non-invasive means to probe and control brain activity. Recent advances in neurophotonics now enable the all-optical interrogation of neural circuits, combining activity imaging and optogenetic stimulation. This is achieved by targeting neurons genetically modified to express either fluorescent sensors (for calcium or voltage imaging) or light-sensitive actuators (for optogenetic control).
In this talk, I will present optical techniques developed in our group to optimize the excitation volume for efficient multi-neuron photoactivation and functional imaging. Specifically, we have developed methods for three-dimensional light patterning using spatial light modulators that shape the laser beam wavefront. These methods are compatible with both one-photon and multi-photon excitation. In the nonlinear regime, axial confinement of excitation patterns is further enhanced by combining spatial light modulation with temporal focusing.

Applications of these methods to scanless voltage imaging and targeted optogenetic activation of neuronal populations will be discussed.

*Speaker

Optimization of speckle-free holography for scanless two-photon voltage imaging.

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In recent decades, the combined advances in protein engineering and optics have led to the development of so-called "all-optical" techniques for controlling and imaging neuronal activity (1), providing unprecedented access to the functional organization and dynamics of neural circuits. Among these approaches, two-photon voltage imaging (2) stands out as a particularly promising method, enabling direct measurement of neuronal electrical activity with high temporal resolution.
To fully exploit the spatio-temporal resolution of physiological signals over large fields of view, scanless techniques integrated with two-photon voltage imaging (2) use computer-generated holography (CGH) and Fourier-based iterative algorithms to create precise excitation patterns. However, poorly defined initial conditions can cause speckle artifacts, leading to high-contrast regions in the excitation pattern. Since voltage indicators are restricted to the neuronal membrane- a small fraction of the cell-uniform excitation is essential to prevent photobleaching and low signal-to-noise ratios that compromise data quality.

To address this issue, several phase modulation algorithms (3) have been developed, introducing fewer constraints on the final amplitudes in order to optimizing convergence. Although these methods significantly reduce speckle, they generally result in a loss of diffraction efficiency.

The combination of highly efficient speckle-free illumination patterns with advanced optical strategies, such as temporal focusing (2), enables uniform excitation of fluorescent indicators, paving the way for more accurate recordings of physiological signals and improved insights into the dynamics of neuronal circuits ultimately advancing our understanding of neuronal syntax and logic.

Here, we present an experimentally optimized implementation of these methods, enabling the generation of speckle-free excitation beams with high diffraction efficiency, based on a combination of speckle-suppressing algorithms and experimental aberration correction techniques.

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*Speaker

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Three-photon Holographic Microscopy For Deep Precise Optogenetics

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Optogenetics has revolutionized neuroscience by enabling the precise control of neuronal activity with light1. While single-photon widefield approaches allow reliable activation or inhibition of specific neurons expressing optogenetic tools, they lack spatial precision. Two-photon (2P) optogenetics, combined with 2P imaging, has significantly improved spatial precision and enabled near single-cell resolution in vivo, but remains limited in penetration depth to few hundreds of micrometers, due to scattering. Although endoscopic methods extend the reach of 2P techniques, they are invasive and less suited for small or delicate organisms.
Three-photon (3P) excitation microscopy offers deeper tissue penetration and reduced scattering, making it a promising alternative for functional interrogation of deep brain regions2. Despite its widespread use in structural and functional imaging, 3P optogenetic activation has remained largely unexplored, with only one prior demonstration in cultured cells.

Here, we present the first in-depth validation of 3P optogenetics in organotypic brain slices, targeting three excitatory and one inhibitory opsin. Using Computer-Generated Holography (CGH) and temporal focusing (TF)3, we achieved soma-targeted activation with 1300 nm or 1700 nm illumination, confirming that the induced photocurrents followed a 3P excitation regime and elicited reliable neuronal responses. Notably, we show enhanced spatial confinement and reduced out-of-focus activation compared to 2P stimulation, with near single-cell resolution. This new method, combining the depth penetration of 3P excitation with the spatial precision of holographic techniques, opens new avenues for probing deep neural circuits with unprecedented precision.

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*Speaker

Minimalistic In Vitro Assay to Study Cell Intercalation in Morphogenesis

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Cell intercalation, or T1 transition, is a key process in morphogenesis, enabling cells to exchange neighbors while maintaining tissue integrity. This relies on the dynamic remodeling of cell–cell and cell–substrate junctions, occurring through both active and passive mechanisms. While in vivo and in silico models provide insights, the first presents challenges in studying isolated intercalation events, and the latter requires experimental validation.

To address this, we present a tunable in vitro assay enabling real-time imaging and in situ force measurements during T1 transitions. Practically, we engineer four-cell assemblies-cell quadruplets-to replicate the minimal tissue pavement required for T1s. Using the PRIMO maskless photolithography system, we micropattern extracellular matrix (ECM) architectures onto hard and soft substrates, allowing precise control over boundary conditions.

Then, we seed MDCK cells onto these patterns so they self-organize into quadruplets, facilitating reproducible morphological and mechanical analysis. By varying the aspect ratio of such patterns (1, 1.5, 1.75, 2), we introduce anisotropy and modulate the internal stress, affecting junction lengths and the mechanical polarity. Moreover, T1 transition rate varies with AR, substrate stiffness (glass vs. gels), and imaging plane (apical vs. basal). Initial results suggest that unpolarized cell tractions promote cell intercalation. These findings highlight the influence of geometric and mechanical constraints on T1 transitions. By extending this approach to cytoskeletal perturbations using pharmacological agents, we aim to gain deeper insights into the molecular mechanisms governing this topological rearrangement. In essence, this assay provides a controlled framework to study the biophysics of cell intercalation in vitro.

*Speaker

Effets mécaniques de la stimulation par ondes de cisaillement sur la peau du visage

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La peau est un organe multicouche composé de l'épiderme, du derme et de l'hypoderme. Cette structure stratifiée lui confère ses propriétés et lui permet de remplir son rôle de barrière protecteur. Des thérapies mécaniques comme le massage peuvent être utilisées pour stimuler la peau afin de modifier ses propriétés mécaniques. Un dispositif innovant de stimulation par onde de cisaillement (SOC) a été développé pour pouvoir stimuler la peau sans contact. Il utilise la pression des jets d'air pour générer des ondes de cisaillement et de compression à l'intérieur de la peau. Il est intéressant de voir comment réagit la peau du visage, plus précisément la joue, lorsqu'on la stimule avec un tel dispositif. L'étude a été réalisée sur 12 sujets femmes, *in-vivo*. Tous les sujets ont donné leur consentement éclairé. Cette étude a été réalisée conformément à la dernière déclaration d'Helsinki. Chaque joue a été stimulée pendant 5 minutes deux fois par jour pendant quatre jours. Chaque joue a été stimulée avec différents temps d'ouverture pour pouvoir étudier l'impact de ce dernier : 20 ms pour la joue gauche et 50 ms pour la droite. Les paramètres du SOC sont les suivants : le diamètre des aiguilles de sortie est de 1,19 mm ; la distance d'intervalle du mouvement selon l'axe Y est de 5 mm ; et la pression de l'air de chaque sortie a été réglée à 4 bars. Trois dispositifs ont été utilisés pour caractériser les propriétés mécaniques de la peau dans cet ordre : Adhelaskin pour mesurer le module élastique et la fermeté de la peau, UNDERSKIN pour mesurer le module de cisaillement de la peau en fonction de la profondeur et un échographe. Les mesures ont été effectuées avant la première SOC et une heure après la dernière. Les résultats mettent en évidence l'impact des différentes intensités de stimulus sur les propriétés de la peau. Cette étude démontre l'importance d'adapter les paramètres de l'appareil en fonction de la localisation du corps et de l'effet recherché. Les différences observées reflètent certainement une modification des fibres de collagène et d'élastine. Cela suggère l'utilité de cette méthode de SOC dans de différents domaines tel que la cosmétique ou encore pour améliorer la cicatrisation des plaies.

*Speaker

4-4 juil. 2025

Eve-SMLM: Enhanced Single-Molecule Localization Microscopy with Event-Based Sensors

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Although single-molecule localization microscopy (SMLM) gives access to spatial resolutions down to the scale of protein size, a number of applications in live-cell imaging remain challenging due to the trade-off between temporal and spatial samplings. This is particularly problematic whenever the system studied displays heterogeneous protein densities, as scientific cameras (EMCCD/sCMOS) are poorly suited to these purposes. We recently introduced a new approach to SMLM, which we call Eve-SMLM, using event-based sensors (EBS) instead of scientific cameras. EBSs are commercially-available matrices of independent, asynchronous pixels that are sensitive to optical intensity variations rather than to the absolute number of photons integrated over a set exposure time. With this approach, we were able to successfully detect single molecules to perform SMLM bioimaging with a spatial resolution comparable to that achieved with scientific cameras. We furthermore used the intrinsic sparsity of the data to efficiently deal with the challenge of high density SMLM imaging, where the overlap of the Point Spread Functions (PSF) cause traditional strategies to under-perform, allowing the reconstruction of dynamic SMLM images of living samples with a temporal resolution around 1 minute (1).
Building upon Eve-SMLM, we further exploit the EBS' asynchronous detection and improved response with modulated excitation techniques. Since Eve-SMLM provides the temporal profile of the emitted signal at the single-molecule level, it is possible to encode information about the absorption spectrum of each molecule in the retrieved signal frequency by modulating the excitation laser. We used this in the context of multicolor SMLM imaging, allowing identification of different fluorophores in a simultaneous acquisition. This simple approach furthermore can improve the spatial resolution by increasing the number of events generated by each molecule as the modulation frequency increases.

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*Speaker

Agile two-photon microscope for fast 5D single-particle translation and rotation tracking

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We present a two-photon microscopy setup to measure intraneuronal transport parameters in a 3D sample in a super localisation regime thanks to the non-linear optical response from nanoparticles (second harmonic generation (SHG)). We take advantage of a Digital Micromirror Device (DMD) to perform digital holography and change the focus position of the excitation laser. We create a pattern of excitation in the vicinity of the nanoparticle, which allows us to super-localise the particle in real time (millisecond regime), with a localization precision of less than 5 nm by maximum likelihood approach (1). The DMD is fast enough to track the nanoparticle during its motion. We also use the holograms to correct the wavefront and obtain thus a diffraction-limited spot at the laser focus. The tracking method has been tested on nanoparticles (BaTiO3 nanospheres, _˜100 nm diameter) internalized in living cells displaying directional trajectories and typical go and stop phases.
We aim at completing the intraneuronal transport parameters, inferred from the x(t), y(t), z(t) positions, with the measurement of the rotational movement of vesicles. This additional parameter is useful to understand how the molecular motors are driven along the microtubules (2,3). The nanoparticles' SHG signal depends on their crystalline axis and polarization of the excitation laser. By rotating the incident polarization and detecting along two orthogonal polarizations, we are able to track the translation motion as well as the rotation of the nanocrystal (4). Our first measurements display standard deviations around 1∘ for azimuthal and polar angles
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*Speaker

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Influence of substrate topography on vascular endothelial cells

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Vascular endothelial cells (ECs) in blood vessels are subjected to various biophysical cues that arise not only from the apical blood flow but also from the properties of the underlying vascular basement membrane (BM). How ECs integrate and respond to these cues, alone or combined, remains incompletely understood. In vivo, ECs are anchored to a vascular basement membrane (BM) that exhibits a topographical organization at different scales. We have been investigating the influence of surface structuration on ECs *in vitro* by using microgroove substrates as an idealized mimic of anisotropic BM topography. We have shown that microgrooves induce extensive nuclear deformations and control EC shape, alignment, and collective migration.

More recently, we have integrated microgroove substrates into a flow chamber to understand how ECs integrate both basal topography and apical flow. Our results show synergistic effects on EC orientation when grooves and flow are oriented in the same direction. On the other hand, orienting the grooves perpendicular to flow reveals a level of competition between the two biophysical cues, with the effect of the grooves on ECs becoming progressively more dominant as groove depth is increased.

The current results underscore the importance of extracellular environment topography in the vascular system and point to interesting processes of cellular integration of multiple biophysical signals. From a more applied perspective, this work highlights the potential of using substrate topography to control endothelial behavior, with potentially interesting implications for the design of implantable vascular devices.

*Speaker

Investigating biological out-of-equilibrium systems by optogenetics probing.

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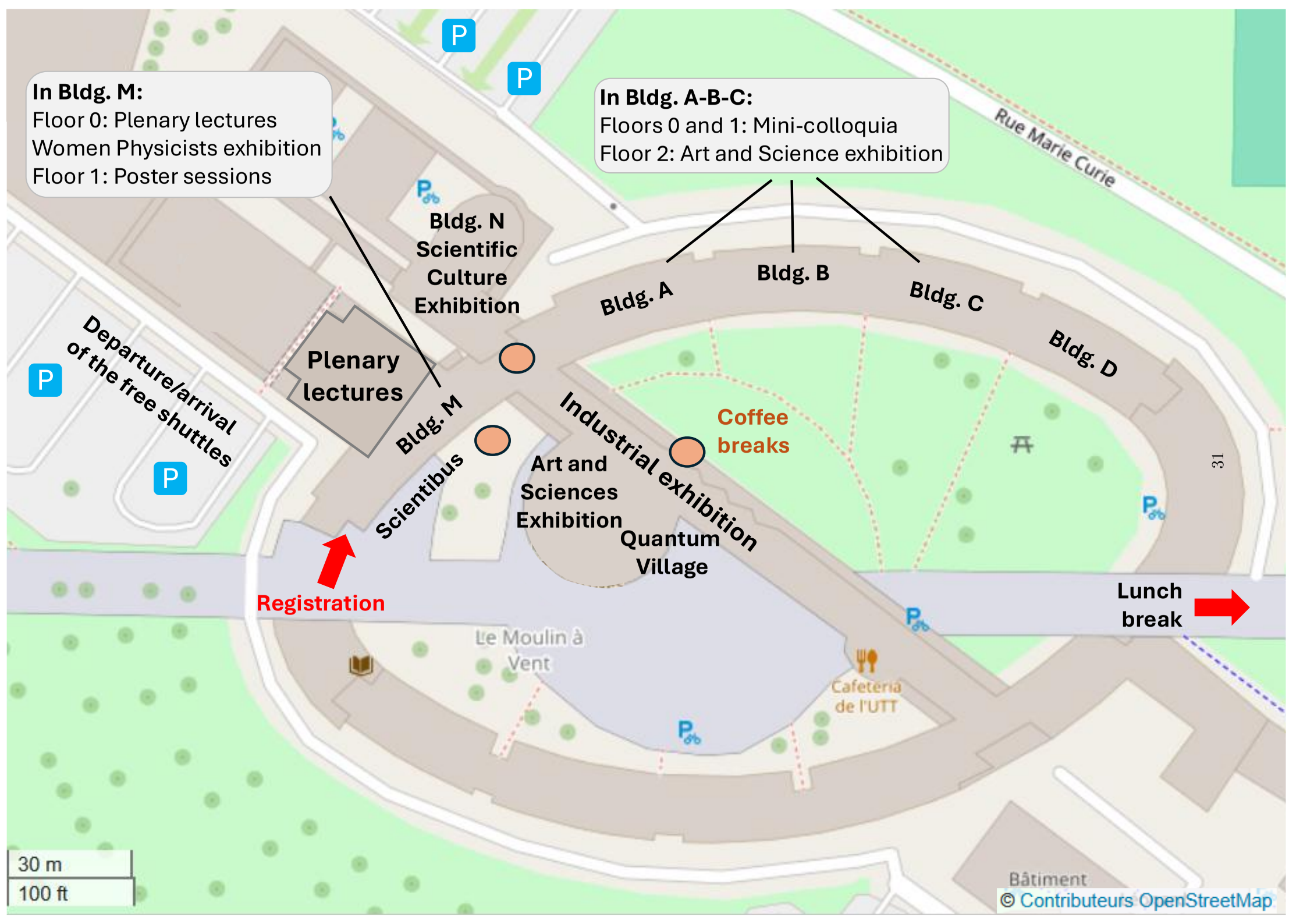
The discovery of the concept of homeostasis has highlighted the dynamic nature of biological systems at all scales, from the cell to the whole organism. Biological systems are characterized by their ability to maintain a dynamic equilibrium in response to changes in their environment. Although classical approaches in biology, such as genetics and pharmacology, can modulate these systems, they act on time and space scales far removed from the equilibria under study.
The introduction of optogenetics has made it possible for the first time to interact with biological systems on scales characteristic of these systems, ranging from seconds to days, and from micrometers to centimeters. This approach has led to a revolution in the understanding of neural networks through the control of neuronal activation.
Our team has focused on developing methods, probes and optical systems to enable a wide range of optogenetic approaches aimed at controlling multiple and diverse biological functions. These causal approaches to biology are perfectly attuned to the characteristic timing of the targeted biological processes. We have recently proposed new molecular bases for basic principles of cell signaling, such as decision making or signal redundancy, and developed multiple probes for optogenetic control of mechanosensitive transcription factors or inflammatory organelles. These synthetic biology approaches have led to new approaches in biotechnology.
Optogenetics is an approach to causal manipulation of multiple levels of biochemical regulation, enabling new conceptual interactions at the physics-biology interface.

*Speaker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