TTHN2025

Thermal transport in heterogeneous nanosystems

Local versus global regime

International workshop

November 20–21, 2025

Perpignan, France

The workshop will address the general topic of heat generation and diffusion in heterogeneous media, with a particular focus on the emerging trend investigating the fundamental distinction between local and global heating regimes. This theme is highly relevant to diverse applications such as:

- Chemical catalysis (where local heating at active sites drives reactions)
- Magnetic hyperthermia (requiring controlled global heating for therapeutic applications)
- Thermal management in microelectronics (addressing heat dissipation at nanoscale interfaces)
- Magnetocalories

Organizers: R. Bastardis, F. Vernay, H. Kachkachi
PROMES-CNRS UPR8521, Université de Perpignan Via Domitia

Workshop description

The workshop **"Thermal transport in heterogeneous nanosystems"** will take place on November 20–21, 2025, in Perpignan, France.

This event is funded by the French Agence Nationale de la Recherche (ANR) and marks the closing event of our project **NanoHype** (*Magnetic Temperature Profile in Nanomagnet-Based Hyperthermia Devices*).

We aim to bring together researchers from our consortium and the broader research community to exchange ideas and present recent developments.

Funding Acknowledgement

anr agence nationale de la recherche

The organizers acknowledge the support of the French Agence Nationale de la Recherche (ANR) through the project ANR NanoHype under grant number ANR-21-CE09-0043

List of participants

Last Name	First Name	Institution	Laboratory
Barros	Noémi	Université de Perpignan	PROMES
Bastardis	Roland	Université de Perpignan	PROMES
Besbas	Jean	Université de Strasbourg	IPCMS
Chubykalo-Fesenko	Oksana	CSIC Madrid	Instituto de Ciencia de Materiales de Madrid
Déjardin	Jean-Louis	Université de Perpignan	PROMES
Dollet	Alain	CNRS	PROMES
Dupuis	Vincent	UPMC	PHENIX laboratory, UMR 8234
Félix	Gautier	CNRS	Institut Charles Gerhardt Montpellier
Fresnais	Jérôme	Sorbonne Université	PHENIX laboratory, UMR 8234
Goya	Gerardo	Universidad de Zaragoza	MAGNA Magnetism in Nanostructures
Hovorka	Ondrej	University of Southampton	University of Southampton
Iglesias	Oscar	Universitat de Barcelona	Group of Magnetic Nanomaterials
Kachkachi	Hamid	Université de Perpignan	PROMES
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Merabia	Samy	Université Lyon 1	Institut Lumière Matière
Morjane	Abdelhamid	PROMES-CNRS	PROMES
Mystkowski	Arkadiusz	Białystok University of Technology	Automatic Control and Robotics
Russier	Vincent	CNRS	ICMPE, UMR 7182
Serantes	David	Universidade de Santiago de Compostela	Instituto de Materials (iMATUS)
Tournus	Florent	Université Lyon 1	Institut Lumière Matière
Vernay	François	Université de Perpignan	PROMES
Wiedwald	Ulf	Universität Duisburg-Essen	Faculty of Physics
Online participants:			
Chantrell	Roy	University of York	Department of Physics, York University
Ledue	Denis	Université de Rouen-Normandie	Groupe de Physique des Matériaux
Morales	Maria del Puerto	Instituto de Ciencia de Materiales de Madrid	ICMM
Strungaru	Mara	Department of Computer Science	University of Manchester

Preliminary program

Workshop locations

- **Workshop venue:** Laboratoire PROMES, salle de conférences
  https://maps.app.goo.gl/cJSZbY15mA85Y9CV9
- **Accommodation (19/11 + 20/11):** Holiday Inn Perpignan
  https://www.ihg.com/holidayinn/hotels/fr/fr/perpignan/pgfra/hoteldetail

Workshop summary

- **Wednesday evening:** Welcome dinner at La Table du Mas (at the hotel)
- **Thursday:** Morning talks + Lunch + Afternoon talks + Excursion to Collioure + Dinner at Le jardin de Collioure (https://www.lejardindecollioure.com/)
- **Friday morning:** Talks + Lunch at La Cuisine (next to the lab)

Program overview

Thursday, November 20	**Time**	**Friday, November 21**	**Time**
Welcome	8:30–9:00	Maria del Puerto Morales	8:30–9:00
Ulf Wiedwald	9:00–9:30	Oksana Chubykalo-Fesenko	9:00–9:30
Gautier Félix	9:30–10:00	Mara Strungaru	9:30–10:00
David Serantes	10:00–10:30	Vincent Dupuis	10:00–10:30
Coffee break	**10:30–11:00**	**Coffee break**	**10:30–11:00**
Vicent Russier	11:00–11:30	Florent Tournus	11:00–11:30
Oscar Iglesias	11:30–12:00	Gerardo Goya	11:30–12:00
Samy Merabia	12:00–12:30	Denis Ledue	12:00–12:30
		Hamid Kachkachi	12:30–13:00
Lunch	**12:30–13:45**	**Lunch**	**13:00–14:30**
Jean Besbas	14:00–14:30		
Ondrej Hovorka	14:30–15:00		
Departure for Collioure + excursion	15:00–18:45		
Workshop dinner	19:30		

Each Talk = 20min presentation + 10min discussion

Contact: https://tthn2025.sciencesconf.org/

Advanced Theranostics with (Bio-)engineered Magnetic Nanoparticles

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Magnetic nanoparticles are invaluable for theranostics, integrating multiple diagnostic and therapeutic applications, such as targeted drug delivery, magnetic hyperthermia, and imaging. Mostly prepared ex vivo via wet chemical methods [1], their biocompatibility and solubility under physiological conditions require critical evaluation. A promising alternative is the use of biological nanocompartments for synthesis via biomineralization, enabling nanoparticles tailored for in vitro and in vivo applications while minimizing adverse effects. Naturally occurring nanocompartments like ferritin (diameter 8 nm) and encapsulin (diameter 30 nm) facilitate biomineralization of Fe and other 3d metal ions, forming Fe oxides, hydroxides, and ferrites with tunable properties [2,3]. Their size and anisotropy can be tuned, though some exhibit reduced performance due to polycrystallinity and defects.

We investigated ferritin-based and encapsulin-derived nanoparticles offering innovative strategies for precise magnetic control in biological systems. Ferritin nanoparticles, with a genetically tunable protein cage, enable controlled biomineralization. Doping of 7% Co for Fe enhances their magnetic blocking temperature from 35 K to 137 K and thus, improve inductive heating and enabling rapid, reversible spatial manipulation within cellular environments at high intracellular stability and traceability. Similarly, encapsulin nanocompartments enable fully genetically controlled biomineralization of 30 nm iron oxide cores (Fig. 1), forming quasicrystalline structures with mixed para- and ferrimagnetic behavior. These nanoparticles generate magnetic moments (10^{-15} A·m² per cell), comparable to conventional exogenous labels, facilitating magnetic-activated cell sorting (MACS) and precise cell manipulation. Their ability to enable magnetic control without external agents makes them valuable for advanced biomedical applications.

The presented works are highly interdisciplinary with contributions from Biologists, Chemists, and Physicists. The contributions M.A. Abakumov, I.B. Alieva, I. Beer, S.-V. Bodea, F. Curdt, M.V. Efremova, M. Farle, T. Feggeler, J. Franke, A.S. Garanina, P. Hagemann, N.P. Ivleva, N. Josten, D.A. Kuckla, R. Lavrijsen, R. Meckenstock, A. Neusch, C. Monzel, I.P. Novoselova, H. Ohldag, L.N. Panzl, S. Sadik, A.S. Semkina, F. Sigmund, N. Tetos, G.G. Westmeyer, M. Winklhofer, S. Wintz are highly acknowledged.

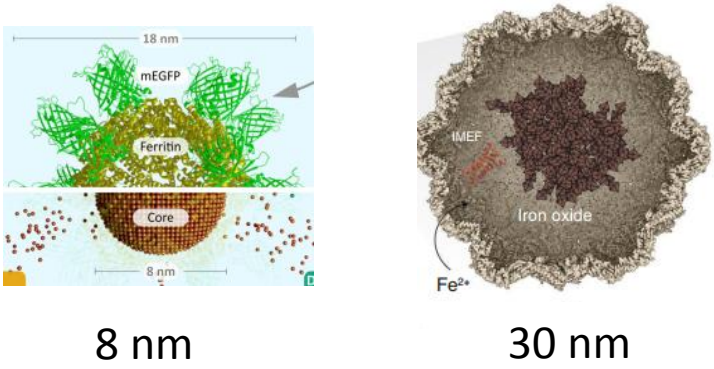

Figure 1: Ferritin (8 nm) and Encapsulin (30 nm) nanocompartments for the mineralization of magnetic nanoparticles.

References

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3. M. V. Efremova et al., Adv. Funct. Mater. **35**, 2418013 (2025).

Photothermal Heating and Real-Time In-situ Luminescent Thermometry with Iron Oxide Core-Silica Shell Nano-objects

Gautier Félix,[a] Farah Abdel Sater,[a] Saad Sene,[a] Udara Bimendra Gunatilake,[a] Basile Bouvet,[a] Tristan Pelluau,[a] Erwan Oliviero,[a] Albano N. Carneiro Neto,[b] Luis D. Carlos,[b] Belén Albela,[c] Laurent Bonneviot,[c] Yannick Guari[a] and Joulia Larionova[a]

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Achieving reliable thermal feedback at the nanoscale remains a major challenge in nanoparticle-assisted heating, especially when precise control over particle morphology and spatial arrangement is required. Building on our previous work, where we developed stellate silica nanoparticles incorporating the luminescent coordination complex $[(Tb/Eu)_9(acac)_{16}(\mu_3\text{-}OH)_8(\mu_4\text{-}O)(\mu_4\text{-}OH)]$ for ratiometric thermometry,[1] we now present an upgraded system featuring a magnetic iron oxide nanoparticle (IONP) core. These new multifunctional nano-objects combine photothermal heating and real-time temperature sensing within a single platform. Under 808 nm irradiation, they enable real-time temperature monitoring in water between 20 and 65 °C, with excellent cyclability, a maximum relative thermal sensitivity of 0.75 ± 0.02 % $°C^{-1}$ at 65 °C, and a thermal uncertainty of 1 °C. In this presentation, I will highlight how the Tb^{3+}/Eu^{3+} luminescence intensity ratio provides reproducible and reliable thermal feedback, paving the way for advanced temperature-controlled nanoscale systems.[2]

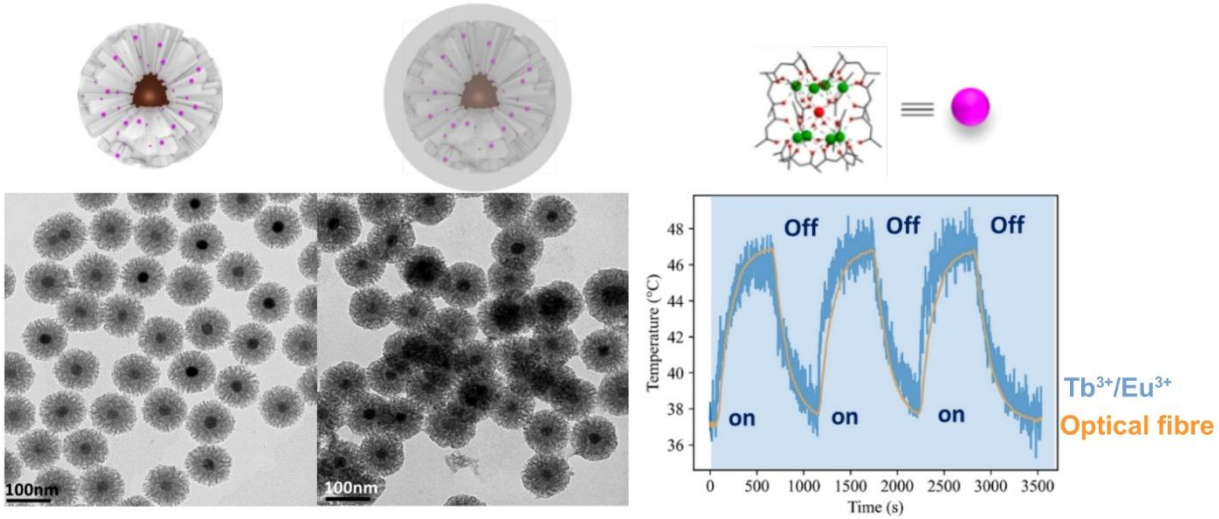

Figure 1: From left to right: TEM image of an open stellate IONP@SiO_2/Ln^{3+} with its corresponding schematic, TEM image of a clogged stellate IONP@SiO_2/Ln^{3+} with its schematic, and thermal kinetics under laser irradiation (λ = 808 nm, P = 2.6 W·cm^{-2}) at both the nanoscale and macroscale, using Ln^{3+} luminescence and an optical fibre, respectively.

References

1. T. Pelluau, S. Sene, L. M. A. Ali, G. Félix, F. Manhes, A. N. C. Neto, L. D. Carlos, B. Albela, L. Bonneviot, E. Oliviero, M. Gary-Bobo, Y. Guari and J. Larionova, *Nanoscale* **15** (35), 14409–14422 (2023)
2. F. Abdel Sater, G. Félix, S. Sene, B. Bouvet, T. Pelluau, A. N. C. Neto, L. D. Carlos, B. Albela, L. Bonneviot, E. Oliviero, Y. Guari and J. Larionova, *Small* accepted (2025), DOI: 10.1002/smll.202508497

Beyond the Frozen Ferrofluid Model: Magnetic Nanoparticles in Viscous Media under AC Excitation

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Remote manipulation of magnetic nanoparticles (MNPs) in viscous media using alternating current (AC) fields underpins key biomedical applications, including hyperthermia cancer therapy, magnetogenetics, and magnetic particle imaging. These systems involve particles embedded in viscous environments where mobility matters. Yet, most interpretations focus solely on magnetization, neglecting colloidal dynamics—a simplification that, while valid in some cases (e.g., intracellular particles), overlooks evidence of their critical role, especially in magnetic fluid hyperthermia (MFH). AC fields can drive structural evolution, such as chain formation, altering heating efficiency over time. Here, we examine how colloidal evolution interacts with magnetization dynamics under AC fields, addressing: (i) anisotropy-driven chain formation before and after field application; (ii) particle size/shape effects and links to DC measurements; and (iii) reversible chains forming only during AC exposure, a metastable phenomenon with potential biological implications despite leaving no observable traces. We conclude with computational strategies and future research directions.

Optimization of the hyperthermia efficiency in magnetic nanoparticles aggregates from the structural dependence of the dipolar interactions.

V. Russier [a)], A. Morjane [a, b)], and F. Vernay [b)].

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Our aim is to study the dipole-dipole interactions (DDI) effect on the specific absorption rate (SAR) of hyperthermia on magnetic nanoparticles assemblies from Monte Carlo simulations *via* a time quantified (TQMC) scheme. Specifically we consider large aggregates of single domain magnetic nanoparticles frozen in position (free of Brownian relaxation in the hysteresis curve). We show that while on spherical shaped aggregates the DDI reduce the SAR a significant increase can be obtained on linear anisotropic ones. Moreover we show that the local structure plays an important role both through the texturation of the easy axes distribution and the ansisotropic structure. The local structure of the aggregate is obtained from the equilibrium structure of a dipolar hard sphere fluid, seen as the ferrofluid model before freezing, in presence of a DC external magnetic field.

Optimizing magnetic hyperthermia performance under safety limits: role of anisotropy, shape and interactions

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A careful assessment of the heating performance of magnetic nanoparticles (MNPs) under alternating magnetic fields is critical for advancing magnetic hyperthermia as a viable clinical treatment, potentially replacing more invasive cancer therapies such as chemo and radiotherapy [1]. Despite numerous experimental studies, a consensus on standards regarding material properties, dosage, and field parameters remains elusive [2]. Moreover, many interpretations of experimental results rely on theoretical models that fail to capture the essentials of realistic NP ensembles or are based on oversimplified assumptions.

In this talk, we review recent progress in understanding the some of the key factors influencing magnetic hyperthermia performance, from a modeling and simulation perspective. We begin by highlighting the pivotal role of magnetic anisotropy and its relation to nanoparticle shape, in the understanding of the heating properties of MNPs. Our results show that even slight deviations from spherical shape can significantly influence the heating efficiency of MNPs (see Fig. 1a) [3]. We identify specific NP size ranges and aspect ratios that optimize heat delivery, constrained by the field amplitude and frequency safety limits required for clinical application. Finally, we address the impact of dipolar interactions in clustered NP ensembles. While such interactions are often considered detrimental, we demonstrate that proper control over spatial distribution and geometric arrangement can mitigate these effects, and that dipolar coupling can even be harnessed to enhance the heating efficiency for certain configurations (see Fig. 1b).

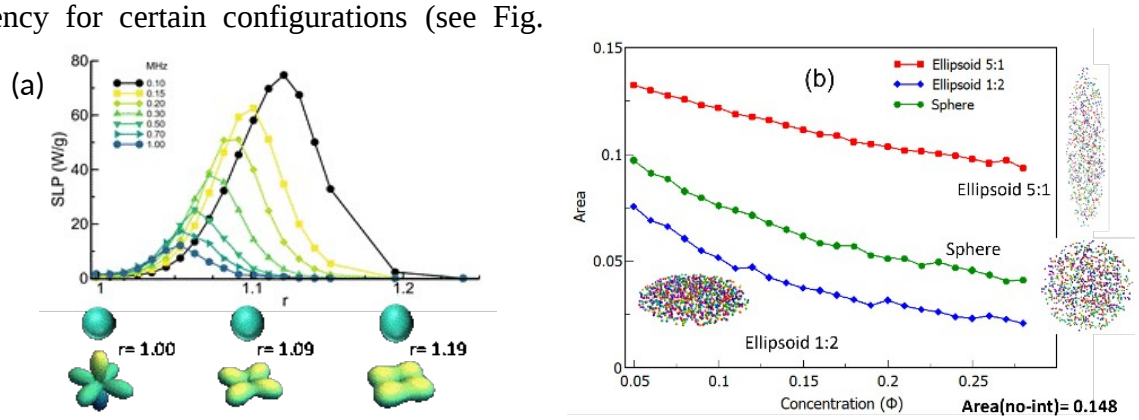

Figure 1: (a) SLP dependence on the aspect ratio (r) of magnetite NP of size D= 25 nm at different frequencies and ac field values complying with the Brezovich criterion. (b) Hysteresis loop area dependence on concentration for disordered NP clusters with different geometries.

References

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“Modelling heat transfer around metallic nanoparticles under pulse illumination: metal core-silica shell nanoparticles and nanobubble assisted photoporation”

Authors: J. El Hajj, M. Fawaz, J. Lombard, A. Alkurdi, O. Gutiérrez, D. Amans, T. Biben, G. Ledoux and S. Merabia

In this contribution, we shall discuss two issues related to photothermal heating of metallic colloidal nanoparticles from a modelling point of view. The first issue concerns the photothermal response of metallic core-silica shell nanoparticles in water. While it has been early recognized that the presence of a thin silica shell may favor heat transfer to the environment, the microscopic mechanisms at play are still poorly understood. Building on a combination of an extended Mie theory, the two-temperature model and molecular dynamics simulations, we will show that under pulse illumination, electron-phonon processes at the metal-silica interface lead to enhanced heat transfer [1,2]. We will also discuss the effect of the porosity of the silica shell [2].
The second issue to be discussed concerns bubble generation around optically heated gold colloidal nanoparticles and their potential applications for cell membrane poration. We will first discuss the conditions of generation of these plasmonic bubbles and what controls their dynamics [3,4] based on the development of an hydrodynamics code that we have developed at ILM [3]. Our simulations also unveil that at the onset of explosive boiling, strong pressure waves are generated and propagate without loss over microns distances. We will illustrate how this strong pressure response may be exploited to perforate biological cell membranes [5,6].

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Thermal all-optical magnetic toggling of magnetization in the compensated ferrimagnet Mn_2RuGa

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Keywords: Ultrafast optics, all-optical switching, magnetisation dynamics, ferrimagnetism.

Irradiating a metallic ferromagnet with an intense sub-picosecond laser pulse (fs-pulse) raises its spin temperature within a few hundred femtoseconds. When the magnetic ordering temperature is reached, the magnetic system loses the memory of its initial magnetization direction. Upon cooling, remagnetization leads to a random distribution of magnetic domains within the irradiated region. Remarkably, such ultrafast heating can deterministically toggle the magnetization of the compensated, ferrimagnetic, and amorphous alloy Gd(FeCo). This occurs because the FeCo subsystem loses its magnetic order about 1 ps before that of Gd, thereby preserving the memory of the former magnetic state.

In this talk, I will introduce the compensated ferrimagnetic inverse Heusler alloy Mn_2RuGa [1]. Unlike Gd(FeCo), Mn_2RuGa possesses two crystallographically inequivalent manganese sublattices with comparable demagnetization times. Yet, ultrafast heating induced by fs-pulse irradiation can toggle its magnetization, similarly to Gd(FeCo) [2]. I will discuss how ultrafast energy exchange between the electronic, spin, and lattice thermal baths governs this toggling dynamics [3]. Finally I will show that the minimum latency time between toggling events is about 10 ps, demonstrating that optical writing of magnetic bits at frequencies up to 100 GHz is conceptually achievable [4]. These results provide valuable insight into ultrafast energy flow at the nanoscale and may guide future studies of thermal processes in complex magnetic nanomaterials.

ACKNOWLEDGEMENTS

This work was supported by Science Foundation Ireland under contract 16/IA/4534 ZEMS and the European Union Horizon 2020 research and innovation grant agreement 737038‘TRANSPIRE’The Trifolium Dubium deposition/characterisation platform was funded by Science Foundation Ireland under grant15/RI/3218. The work was carried out in the CRANN Photonics Laboratory.

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Learning Markov state models from spin dynamics simulations

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Kinetic Monte-Carlo (KMC) methods are essential for exploring the long-time dynamics and hysteresis in structured magnetic systems, such as assemblies of magnetic particles, hard disk granular media, or permanent magnet materials. The reason is that direct simulations based on the stochastic Landau-Lifshitz-Gilbert (sLLG) equation become prohibitively expensive when energy landscapes grow complex. KMC methods are related to sLLG via asymptotic techniques [1], or by coarse-graining in time [2], and provide a realistic description of the dynamics at a fraction of the computational cost while offering a detailed microscopic insight into the system behavior.

KMC methods effectively sample from the time-dependent probability distribution associated with Markov process driven by thermally activated transitions between system states. Such processes are described by a Master equation whose transition matrix connects thermally activated transition paths with underlying energy barriers. However, determining the transition matrix is challenging due to the lack of a priori knowledge about energy barrier distributions. This has limited the applicability of KMC methods primarily to weakly interacting systems dominated by single-flip transitions [3]. Consequently, modelling multi-spin correlations, which are often crucial in real systems, remains an open problem.

In this talk, we present a framework for estimating the Markov state models directly from sLLG simulations of many spin systems by adapting methodologies developed in the molecular dynamics community [4]. This approach involves three key steps: 1) dimensional reduction of many-spin simulations to a latent space containing only the most relevant collective variables, 2) discretization of these collective variables, and 3) enumeration of the thermally activated transitions between discrete states to estimate the transition matrix. We demonstrate that these 'hand-crafted' steps can be optimally reproduced by a neural network (Figure 1), which generates superior Markov state models without requiring manual parameter selection. We validate the framework by evaluating hysteresis in strongly interacting spin systems, beyond the limit of single-flip transitions.

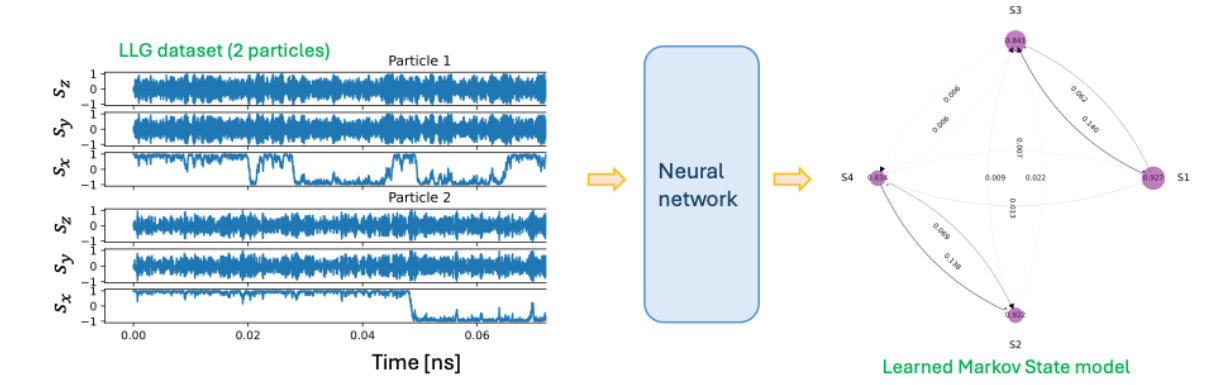

Figure 1: Neural network with autoencoder-like architecture developed to estimate Markov state models from sLLG simulations of interacting particles (macrospins). The network is trained on spin trajectories at time points t and $t + \tau$. The training procedure maximizes the 'variational approach for Markov processes' (VAMP) score, enabling identification of optimal Markov state models directly from simulation data [4].

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Experimental measurements of local heating in magnetic hyperthermia

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Magnetic hyperthermia is a promising technique in different areas that exploits the heat generated by magnetic nanoparticles (MNPs) under an alternating magnetic field (AMF). However, accurately quantifying temperature at the nanoscale remains challenging, as conventional thermometric techniques typically measure only the average or macroscopic temperature of the medium and fails to capture spatial temperature gradients near nanoparticles. In this work, we present a systematic study of local temperature measurements during magnetic hyperthermia using fluorescence proteins as nanothermometers. The experiments were performed on well-characterized iron oxide nanoparticle suspensions under controlled AMF conditions. We analyze the influence of particle concentration, field amplitude and frequency, and medium thermal properties. The results reveal significant local temperature variations within nanometer distances from the nanoparticles, higher than the bulk medium temperature, highlighting the non-uniform nature of heat dissipation in realistic systems.

Modeling of magneto-thermo dynamics

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Magnetization and temperature dynamics are two coupled reciprocal phenomena. In principle, any magnetization change is accompanied by temperature changes, and the fundamental question of practical interest is how to minimize/maximize the effect, depending on the desired application. For example, for magnetic heating applications such as magnetic hyperthermia cancer treatment, the temperature release should be maximized. Here we present the self-consistent micromagnetic model which allows to calculate dynamics of the heat release during the magnetization dynamics. The model shows that the heat release occurs at the same timescale as the magnetization dynamics and can be large in the case of ultrafast magnetization dynamics. As a first example, we will present the possibility to disentangle the dynamics local temperature increase in the case of interacting magnetic nanoparticles [1].

Furthermore, the possibility to move magnetic textures by thermal gradient is well known as a spin-Seebeck effect for domain walls. Less known is the opposite effect- i.e. domain wall motion produces heat in the system. We will show that the ultrafast domain wall motion could be accompanied by a temperature release, known as the spin-Peltier effect for domain wall [2]. In this case the released temperature is proportional to the ratio of domain wall velocity/width. Here we consider the antiferromagnetic Mn2Au material, where ultra-high velocities (up to 40 km/s) are predicted when the domain wall is moved under current by spin-orbit torque. Importantly, when the domain wall velocities are high, its width decreases due to relativistic effects. We estimate that the domain wall motion in this material can be accompanied by a localized ultrafast heat pulse as strong as 0.1K, much higher than for coherent magnetization switching of magnetic nanoparticles. The energy release is especially efficient under inelastic collision of domain walls with the opposite topological charge [3].

Our final example will consider ultrafast motion of the Bloch point domain wall in cylindrical magnetic nanowires of high magnetization where the velocities up to 10 km/s can be achieved under applied field [4]. In this case also large local temperature increase is expected.

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Spin-lattice dynamics models: towards nanoscale heating models of magnetic hyperthermia

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Abstract
In magnetic systems, relaxation is governed by the coupling of the magnetic modes (given primarily by the atomic spin/magnons) with the non-magnetic modes (lattice vibrations/phonons and electrons) which can mutually influence one another. A complete picture of a magnetic material would hence involve three degrees of freedom; spins, lattice and electrons, with the transfer of energy and angular momentum between them. Since electrons relax at faster timescales, a unified model of molecular and atomistic spin dynamics, called Spin-Lattice dynamics (SLD), can offer a deeper understanding of magnon-phonon interactions [1,2], relaxation processes, heating and phonon-driven switching mechanism. In this talk, I will present the atomistic spin–lattice dynamics model and show how damping emerges naturally from the coupling between magnons and phonons, allowing us to extract an effective value of the Gilbert-like damping parameter [1]. We further demonstrate that THz phonon excitation can induce magnetization switching [2] and that the resulting heating, which remains on the order of millikelvin, can be quantitatively evaluated within the SLD framework.

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Magnetic hyperthermia at the nanoscale

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Magnetic hyperthermia can be useful for catalysis or for biomedical applications [1]. The local heat exchange around those nanoprobes is however still under study to understand clearly its origin. We have investigated the experimental proof of concept of the detection of heat exchange on photosensitive ligands permanently and covalently bounded to the surface of maghemite nanoparticles. The measurement of rhodamine B lifetime allowed use to evaluate the thermal increase, in very dilute nanoparticle dispersions, at 4 given distances ranging from 5 to 7 nanometres from the surface. This is the first experimental proof of thermal evaluation without chemically cleavable groups at the surface of nanoparticles in solution, contrary to other published results [2,3].

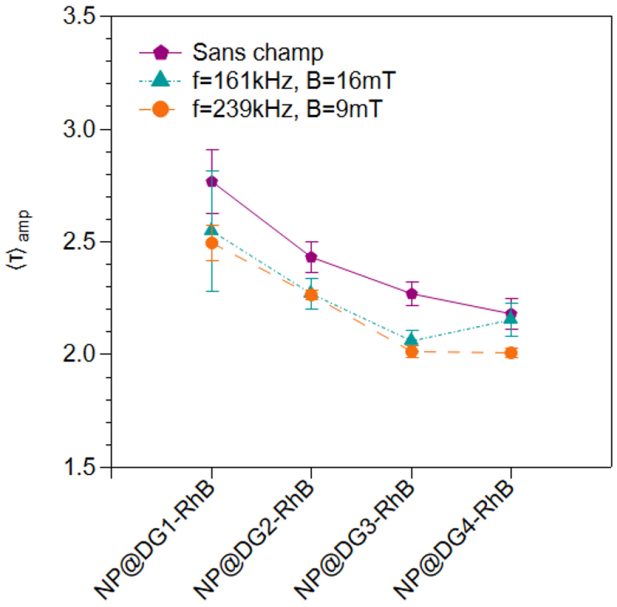

Figure 1: Lifetime of Rhodamine B on maghemite under magnetic hyperthermia.

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Thermal studies with magnetic nano-composites at ILM

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The "Transport, nanomagnetism and materials for energy" team of ILM laboratory (https://ilm.univ-lyon1.fr/index.php) is interested in intrinsic and collective properties of nano-objects, interface effects and couplings, thermoelectric effects, nanostructuring and behavior under extreme conditions. A new line of investigation is devoted to the transport (charge and heat) of nano-composites made of small nanomagnets embedded in a semiconducting matrix, namely Co@Ge thin films prepared by Low Energy Cluster Beam Deposition Technique.

I will thus present preliminary results obtained in the frame of the French ANR project called ENATHER where we want to modify the thermoelectric properties using embedded nanomagnets of adjustable size, concentration and magnetic configuration. We have been able to produce various nano-composite samples with preserved Co nanomagnets in amorphous germanium, displaying the expected blocked-superparamagnetic crossover. We observe that the inclusion of Co particles has a drastic impact on the electronic conductivity while the Seebeck coefficient shows a strong phonon drag peak at low temperature (i.e. when the particles are becoming magnetically blocked). The inclusion of metallic macrospins in a semiconducting material results in a complex system where many physical phenomena are involved (interface effects, charge and phonon scattering, doping & charge transfer, spin polarization, magnetic interactions etc.) and the question of a magnetic signature on the thermal properties in this kind of system is still open.

Finally, I will also briefly present the experimental facilities available at ILM for thermal measurements on nanosystems.

Energy Generation and Transport in Magnetic Nanoparticles: Desires, Theory, and Experiment.

Gerardo F. Goya

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This talk will examine some of the ideas and claims of nanoscale “hot spots” in magnetic nanoparticles under radiofrequency field. I will summarize some of the parameters such as heat-diffusion bounds and interfacial thermal conductance that, under typical conditions, would yield to steady-state interfacial ΔT sufficient for selective biochemical control compatible with measured power densities and aqueous thermal transport. I will outline those time and length scales where transient gradients can exist, the expected relaxations and what mesoscale confinement or collective effects may yield measurable heating without implying nanoscale spikes. As an alternative to temperature-spike narratives, I will discuss a framework for enzyme stimulation mediated by thermal phonon currents near energized particles, which predicts activity changes as a function of particle Specific Power Loss (SLP) and enzyme-particle separation. The talk proposes discriminating experiments and analysis criteria that separate bulk heating, transient interfacial effects, and phonon-mediated stimulation in heterogeneous media.

Abstract TTHN2025 (20-21/11/2025)

"*Magnetization relaxation of interacting chains of nanomagnets*"

D. Ledue, H. Kachkachi, F. Vernay and R. Patte

This study focuses on the effect of dipolar interactions (DI) on the relaxation rate of nanoparticles and on the magnetization relaxation of chains of nanomagnets. This work was carried out by means of semi-analytical calculations based on the Langer's approach and on numerical simulations using the time quantified Monte Carlo (MC) method. In the longitudinal case, *i.e.* when the applied field is along the chain direction, analytical calculations and MC results are in good agreement and evidence a decrease of the relaxation rate with increasing the intensity of DI. This decrease is confirmed by the calculated and simulated magnetization relaxation of the chain which is significantly slowed down in presence of DI.

Local-to-global heating crossover: a 1D model

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In this work, we perform an analytical study of heat generation and diffusion in a one-dimensional open chain of coupled nanomagnets. We identify the conditions under which the system transitions from a local heating regime, dominated by individual nanomagnets, to a global heating regime, characterized by collective thermal behavior. We analyze the resulting space–time temperature profiles, introduce the concept of a thermal correlation length, and show that the temperature variance serves as a reliable indicator of the crossover.

Finally, we discuss the case of an assembly of magnetic nanoparticles dispersed in a fluid. We present the corresponding space–time temperature elevation profiles and compare our theoretical predictions with experimental measurements on magnetite/maghemite-based ferrofluids.

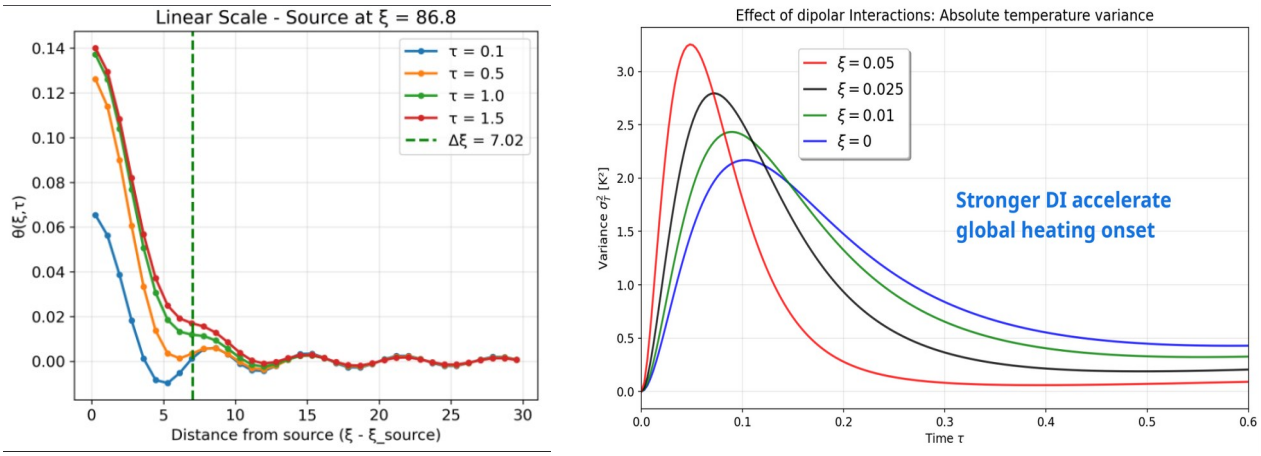

Figure 1: (Left) Space profile of the temperature elevation at a selected source (nanomagnet) and times τ.
(Right) Variance of the temperature elevation as a function of time a selected valeus of the dipolar-interaction intensity.

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