International Mini-Conference

FROM WAVES TO MATTER

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17-18 September 2026
Department of Physics, Faculty of Science, University of Zagreb, Zagreb, Croatia

Program and Abstracts

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WELCOME

Dear friends and colleagues,

we warmly welcome you to the mini-conference “From waves to matter” in honour of Professor Antonije Dulčić’s 80th birthday, at the Department of Physics, Faculty of Science in Zagreb, September 17-18, 2026.

The aim of the mini-conference is to celebrate Professor Dulčić’s varied contributions to experimental and theoretical physics with a series of talks by both eminent and early-career scientists. As his collaborators, students, and coworkers, all speakers share a connection to Professor Dulčić, and the talks will cover a wide range of topics that are related to his work. Major themes include electron spin resonance and nuclear magnetic resonance in condensed matter, microwave and optical response of quantum materials, as well as fundamental physics and physics education.

The mini-conference brings together physicists with diverse backgrounds from institutions around the world, and we trust that the relaxed format of the conference and the associated social events will foster a vigorous exchange of ideas and open new possibilities for collaboration. We are delighted that you chose to participate, and hope that you will enjoy both the scientific and the social parts of the programme.

With best regards,

The organizers

Miroslav Požek, Mihael Grbić, Damjan Pelc

ANTONIJE DULČIĆ – SCIENTIST & TEACHER

Antonije Dulčić was born in Zagreb on Oct 9, 1946. After an early childhood in Virovitica and Zagreb, he spent his formative years in Split. He studied physics at the University of Zagreb, where he graduated in 1969 and obtained a PhD in 1973, under the supervision of Professor Janko Herak. His PhD research focused on free radicals in irradiated single crystals of DNA bases using electron spin resonance (ESR).

During his postdoctoral stay at the Ecole Polytechnique in Paris, in the Laboratory for Quantum Optics, from 1976 to 1978, Professor Dulčić made valuable contributions to nonlinear optics. The importance of his pioneering work on nonlinear optical polarizabilities was fully recognized a decade later when nonlinear optics gained strong momentum, and his papers became increasingly cited.

Upon returning to the ESR laboratory in Zagreb, he sought to improve the laboratory's scientific methodology, both by transferring ideas from nonlinear optics and by upgrading the experimental setup. Together with his colleagues, he was engaged in solving a number of problems related to the nonlinear relaxation response in electron spin resonance. In parallel to this experimental work, Professor Dulčić continued to theoretically approach outstanding problems in nonlinear optics. He showed that nonlinear two-photon transitions can be described using rotations with operators of unitary groups, and gave an explanation of multiphoton ionization through modulation of energy levels in a strong laser field.

Soon after the discovery of cuprate high-temperature superconductors in 1986, Professor Dulčić and colleagues uncovered a new effect – a nonresonant modulated zero-field signal. The effect was discovered simultaneously by several ESR groups, and it became a rapid and reliable test of superconductivity in newly synthesized cuprate materials. However, Professor Dulčić and coworkers were the first to offer a sound theoretical explanation of the observed signal.

In 1992 Professor Dulčić established a close collaboration with the group of Professor Michael Mehring at the University of Stuttgart. The two groups jointly studied microwave absorption in cuprate superconductors, not only in polycrystalline samples, but also single crystals and epitaxially grown thin films, using both modulated and unmodulated microwave response. A new experimental setup was developed for precise measurement of the Q-factor and resonance frequency of a microwave cavity. Professor Dulčić significantly contributed to the development of theoretical models for the complex microwave response of thin films, and for extraction of coherence lengths and critical magnetic fields.

As unmodulated microwave response became a well-accepted method to determine critical fields and high-frequency transport properties of various superconductors – from classical niobium, over cuprates, ruthenates, and pnictides, to MgB_2 – the technique was also increasingly used to study the fluctuation conductivity at temperatures above the superconducting transition. In particular, microwave measurements were very successful in establishing the temperature range and nature of superconducting fluctuations in the cuprates. Professor Dulčić's last corresponding-author paper before retirement, in 2011, has been highly influential in this field, and is still regularly cited.

Between 2008 and 2012, Professor Dulčić gave a strong contribution to the founding of the Solid-state NMR laboratory at Department of Physics. Despite numerous commitments at the time, he actively participated in this process, sharing his time and wealth of experience with younger colleagues.

Antonije Dulčić was a remarkable teacher and a favourite professor among undergraduate students. His potential as a lecturer was fully realized when he started teaching introductory physics courses. He completely reorganized the Laboratory exercise courses in the new building of the Department of Physics in 1991. For many years, he gave lectures in Fundamentals of Physics to teaching-oriented physics students and raised several generations of high-school teachers. His hand-written lecture notes were widely copied and distributed among students at the time. In 2009, Professor Dulčić started teaching General Physics for students of research physics. For this purpose, he reorganized and extended the curriculum and wrote new lecture notes that were exceedingly well accepted by the students. The main feature of these notes is that the subject material starts with elementary concepts and gradually reaches a very high level. The students are also guided toward an understanding of every detail.

Professor Dulčić was highly active in the management of science and higher education in Croatia. In 1986, he already became a member of the presidency of Ministry of Science of the Socialist Republic of Croatia (RSIZ). After the Republic of Croatia gained independence, Antonije Dulčić held several key positions related to science policy. He was Head of Department of Physics at the Faculty of Science in two mandates (1995-1997 and 2007-2010), the president of the National Council for Science, Higher Education and Technological Development of Croatia (2004-2005), the president of the Working Group for the State Matriculation at the University of Zagreb (2009-2014), and the vice-president of the Croatian Physical Society (2011-2012).

For his scientific work, Professor Dulčić received the republic award „Ruđer Bošković“ (1986). For his work in the National Council, including the implementation of the Bologna Process in higher education, he was decorated with The Order of Danica Hrvatska with the Effigy of Ruđer Bošković (2007). Professor Dulčić also received the "Andrija Mohorovičić" award of the University of Zagreb (2012) for successful scientific research work, education of young generations of scientists, public activity and promotion of the faculty and University across the country and abroad. He became Professor Emeritus in 2015.

After retirement in 2014, Professor Dulčić devoted himself to family life, especially his three grandchildren. However, he did not forget the unfinished work on his lecture notes. Together with younger colleagues Nikola Poljak, Matko Milin and Miroslav Požek, he completed two General Physics textbooks, published in 2023 and 2024, with a third book in final revision. The books contain many original contributions, and three original papers based on the books have already been published, with more to come.

Miroslav Požek

PROGRAMME

	17.9.	18.9.
	Thursday	**Friday**
9:00	Opening	**Mladen Horvatić** Revisiting magnetization plateaus in $SrCu_2(BO_3)_2$ by high-field NMR
9:10	**Miroslav Požek** Antonije Dulčić – Scientist and teacher	
9:30	**Boris Rakvin** Study of microwave magnetic field saturation of CW-EPR multi-photon transitions in the vicinity of Rabi resonance	**Hans-Joachim Grafe** Sequential magnetic ordering of kagome-plane and interlayer Cu moments in clinoatacamite revealed by site-selective NMR
10:00	**Miroslav Perić** Studies of Ionic Liquids Using Nonlinear EPR Spectral Fitting	**Mihael S. Grbić** Discovery of BKT correlations in the quantum kagome compound $Cs_2Cu_3SnF_{12}$
10:30	Coffee break	Coffee break
11:00	**Vladislav Kataev** Spin dynamics in quasi-2D van der Waals antiferromagnets	**László Forró** Graphite: towards Room-Temperature Spin Devices (The Return of a Forgotten Quantum Material)
11:30	**Steffen Krämer** Studies of MRI contrast agents by resolution-enhanced NMR in resistive high-field magnets	**Neven Barišić** The Cuprate Problem and the Zagreb School of Solid State Physics: Towards a Solution
12:00	**Srećko Valić** Isothermal crystallization of polydimethylsiloxane–zeolite composites: ESR spin–probe and DSC studies	**Nikola Poljak** From the Classroom to Ampère's Law
12:30	Lunch	**Matko Milin** Teaching University Physics from First Principles Closing
14:00	**Damjan Pelc** From kHz to THz: wideband spectroscopy of unconventional metals	
14:30	**Nives Štrkalj** Emergence of Polar Order in WO_3 Thin Films	
15:00	**Veronika Sunko** Magneto–optical detection of time-reversal symmetry breaking in antiferromagnets	
15:30	**Antonio Štrkalj** Many-body localisation escapes to two dimensions	

ORAL SESSIONS

Presentation time: 30 min. (25 min talk + 5 min Q/A)

To save time between talks, please bring your slides on the USB drive and connect it to the conference computer for presentation at least 15 minutes before your session.

Speakers can use their own laptops, but we strongly recommend using the conference computer in the session room, unless a stand-alone presentation file is for some reason impractical. Speakers are welcome to check their presentations well ahead of time.

THURSDAY

Study of microwave magnetic field saturation of CW-EPR multi-photon transitions in the vicinity of Rabi resonance

Boris Rakvin
Ruđer Bošković Institute, Division of Physical Chemistry, Zagreb, Croatia.
rakvin@irb.hr

Recently it was noted that calculated spectra for continuous wave electron paramagnetic resonance (CW-EPR) under the condition of "weak modulation near the Rabi resonance" ($(\omega_2 \ll \omega_1 \approx \omega_{rf})$ where ω_{rf} is modulation frequency with corresponding modulation amplitude ω_2 expressed in frequency units, ω_1=$\gamma\hbar B_1$ is Rabi frequency, γ is the electron gyromagnetic ratio and B_1 is intensity of microwave magnetic field), show spectral features related to modulation sideband (MS) (multi-photon transitions) in power saturation procedure[1]. It was shown that for the first harmonic of phase-sensitive detection spectrum detected 90° out-of-phase with respect of the modulation frequency (out-of-phase spectrum) shows inversion of MS lines while passing Rabi resonance condition ($\omega_1 = \omega_{rf}$) during the saturation process (increasing B_1 (ω_1)).

It can be noted that detection of this effect in the close vicinity of Rabi resonance enables the estimation of $B_1 \approx 3.6$ μT for applied the most usual magnetic field modulation frequency of ($\omega_{rf}/2\pi = 100$ kHz).

In order to experimentally detect this effect of inversion of MS lines in the vicinity of Rabi resonance a synthetic diamond crystal containing low concentration P1 (N_s^0) centers ($[N_s^0]$ <1ppm) was examined by employing an ordinary CW-EPR with magnetic field modulation ($\omega_{rf}/2\pi$=100kHz) [2]. In the detection regime with low modulation field intensity and under the condition that $\omega_2 \ll \omega_{rf}$ detected narrow line components with peak-to-peak linewidth (δ_{pp} ≈6μT) of P1 center shows spectral features related to MS. The saturation of the CW-EPR out-of-phase first harmonic signal reveals the most prominent features on the spectrum in the form of the inversion of sidebands lines while passing Rabi resonance condition ($\omega_1 = \omega_{rf}$). The obtained lineshapes of detected signals can be reproduced with simulated spectra in the close vicinity of Rabi resonance at ($\omega_1 \approx \omega_{rf}$) and the corresponding B_1 assigned. The accuracy of estimated B_1 will be discussed and correlated with other well-known saturation methods for determination of B_1 value.

References:
[1] A. P. Saiko et al., *Journal of Magnetic Resonance* **259**, 47-55 (2015)
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Studies of Ionic Liquids Using Nonlinear EPR Spectral Fitting

Miroslav Perić
Department of Physics and Astronomy, California State University Northridge, Northridge, CA 91330-8268, USA
miroslav.peric@csun.edu

Our laboratory has used nonlinear spectral fitting in EPR spectroscopy for more than three decades because it significantly enhances the precision and sensitivity of spectral analysis. This approach enables highly accurate determination of EPR parameters, including hyperfine coupling constants and intrinsic Lorentzian linewidths, while correcting for inhomogeneous and modulation-induced broadening. As a result, it not only improves measurement sensitivity but also provides access to spectral parameters that are difficult or impossible to obtain using conventional analysis methods. Here, I present two studies that demonstrate the power of nonlinear spectral fitting for investigating ionic liquids.

1) Rotational Dynamics of Nitroxide Probes in Ionic Liquids

EPR measurements of the nitroxide probes Frémy's salt (FS) and di-tert-butyl nitroxide (DTBN) in imidazolium-based ionic liquids show that their rotational dynamics are governed primarily by charge rather than by their similar size and shape [1]. The negatively charged FS resides within the polar ionic network, where its rotational motion becomes increasingly anisotropic as the cation alkyl chain length increases. In contrast, the neutral DTBN preferentially partitions into the nonpolar alkyl domains and undergoes nearly isotropic rotation. Although both probes exhibit the same viscosity-controlled activation energy for rotational motion, their distinct local environments produce markedly different rotational behaviour and hyperfine coupling constants. These results provide direct insight into the nanoscale organization and heterogeneous domain structure of ionic liquids.

2) Phase Behaviour of Paramagnetic Ionic Liquids

EPR spectroscopy was also used to investigate the phase behaviour and magnetic interactions of the paramagnetic ionic liquids [Emim][$FeCl_4$] and [Bmim][$FeCl_4$] [2]. By analysing exchange-narrowed EPR linewidths, nonlinear spectral fitting distinguished crystal polymorphs, phase transitions, and glass formation, and enabled estimation of the superexchange coupling between Fe^{3+} ions. In [Emim][$FeCl_4$], two crystal polymorphs with different superexchange coupling strengths were identified below the solid–solid transition, whereas [Bmim][$FeCl_4$] underwent a glass transition rather than crystallization. These findings demonstrate that EPR spectroscopy, combined with nonlinear spectral fitting, is a highly sensitive tool for probing crystal polymorphism, magnetic exchange interactions, and phase transitions in paramagnetic ionic liquids.

References:

[1] M. H. O'Brien et al., J. Mol. Liq. **404**,124994, (2024)
[2] Y. F. Lencina Wendt et al., J. Chem. Phys. **163**, 174505, (2025)

Spin dynamics in quasi-2D van der Waals antiferromagnets

Vladislav Kataev
Leibniz Institute for Solid State and Materials Research IFW Dresden, 01069 Dresden, Germany
v.kataev@ifw-dresden.de

Layered van der Waals (vdW) magnetic compounds attract currently large attention as they may display an intrinsically low-dimensional magnetic behavior and as such offer an extensive materials base for exploring fundamental magnetic properties of strongly correlated two-dimensional (2D) electron systems [1-4]. Moreover, the structural and compositional variety of these class of materials offers a possibility to realize magnetic ground states with desired types of order and intrinsic anisotropy essential for their application in next-generation spintronic devices [4]. In particular, many of vdW compounds are low-damping antiferromagnetic (AFM) dielectrics, and as such they become promising materials in the new rapidly developing field of AFM spintronics that leverages AFM magnons for transmitting of spin currents instead of electric current to transport and process information [5-7].

Electron Spin Resonance (ESR) spectroscopy and related ferromagnetic (FM) and AFM resonance techniques, FMR and AFMR, play an important role in obtaining valuable insights into the static and dynamic magnetic properties of vdW compounds [8]. In this talk, we will discuss the spin dynamics in the paramagnetic state and the AFM magnon excitations in the magnetically ordered state of two representative vdW antiferromagnets $Mn_2P_2S_6$ and $CuCrP_2S_6$, as revealed by ESR and AFMR spectroscopies [9-11]. It will be shown that in the paramagnetic state both compounds demonstrate an inherent 2D correlated spin dynamics characterized by the diffusive long-time decay of the in-plane spin correlation function evidencing the weakness of the interlayer magnetic coupling in bulk singe crystals. In the AFM ordered state the low-energy magnon excitations probed by AFMR show strikingly different behavior in these compounds due to their distinct magnetic anisotropies. Remarkably, it was found that the properties of these magnon modes can be controlled and selectively tuned by application of an external magnetic field. Based on these interesting findings we discuss the perspectives for the use of $Mn_2P_2S_6$ and $CuCrP_2S_6$ as transmitting medium for spin currents in prototype magnonic devices.

References:
[1] C. Gong *et al*., Nature **546**, 265 (2017).
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[4] S. Yang *et al*., Adv. Sci. **8**, 2002488 (2021).
[5] A V. Chumak *et al*., Nature Phys. **11**, 453 (2011).
[6] B. Flebus *et al*., J. Appl. Phys. **133**, 160401 (2023).
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[8] V. Kataev, B. Büchner and A. Alfonsov, Appl. Magn. Reson. **55**, 923 (2024).
[9] Y. Senyk et al., Phys. Rev. Mater. **7**, 014003 (2023).
[10] J. J. Abraham *et al.*, Phys. Rev. B **107**, 165141 (2023).
[11] J. J. Abraham *et al*., Adv. Funct. Mater., e11057 (2025).

Studies of MRI contrast agents by resolution-enhanced NMR in resistive high-field magnets

Steffen Krämer
Laboratoire National des Champs Magnétiques Intenses (LNCMI), CNRS, EMFL, Univ. Grenoble Alpes, Univ. de Toulouse, INSA Toulouse, 38000 Grenoble, France
steffen.kramer@lncmi.cnrs.fr

Strong magnetic fields are an extremely powerful tool for investigating, modifying and controlling different states of matter on microscopic and macroscopic length scales. Whereas commercial superconducting magnets reach magnetic fields up to 30.6 T, stronger fields are currently only available at specialized large-scale facilities. There, resistive magnets made of copper alloys and their combination with superconducting magnets (hybrid magnets) generate continuous magnetic fields up to 45 T. Due to very high acquisition and operating costs, such facilities currently only exist in a few places in the world (Europe, USA, China and Japan).

Among the numerous experimental techniques used in such strong magnetic fields, nuclear magnetic resonance (NMR) is a preferred microscopic investigation method that is particularly well-suited for research in solid-state physics, which very often also requires extremely low temperatures. Areas of application include the study of high-temperature superconductors, heavy-fermion systems, quantum magnetism, and other systems with correlated electrons.

Recently, the scope of NMR applications using resistive magnets at the LNCMI in Grenoble has been expanded to include areas of chemistry and materials science that require enhanced resolution. In this presentation, we show the potential of this technique in such magnets for the nuclear magnetic relaxation dispersion (NMRD) studies of protons (^{1}H) in water with dissolved paramagnetic compounds up to 33 T, i.e., 1.4 GHz ^{1}H Larmor frequency. In addition to basic research issues, the latter activity serves the development of future contrast agents for magnetic resonance imaging in high magnetic fields [1,2].

However, due to limitations regarding the field homogeneity and stability of resistive magnets, their use in resolution-enhanced NMR requires tailored methods to overcome these drawbacks, which are discussed. These include broadband NMR probes operating at frequencies above 1 GHz, sample volumes in the microliter range to overcome field inhomogeneities, multi-pulse NMR sequences to eliminate the effects of magnetic field fluctuations, and reference deconvolution analyses to improve the signal-to-noise ratio [3].

References:

[1] G. Guthausen et al., *Dalton Trans.* **44**, 5032 (2015)
[2] M. Ibrahim et al., *Dalton Trans.* **48**, 15597 (2019)
[3] R. Nasser Din et al., *Molecules* **29**, 4956 (2024)

Isothermal crystallization of polydimethylsiloxane–zeolite composites: ESR spin–probe and DSC studies

Srećko Valić
Ruđer Bošković Institute, Physical Chemistry Division, Zagreb, Croatia
Faculty of Medicine, University of Rijeka, Department of Medical Chemistry, Biochemistry and Clinical Chemistry, Rijeka Croatia
Centre for Micro- and Nanosciences, University of Rijeka, Rijeka, Croatia
valic@irb.hr; svalic@uniri.hr

The local segmental mobility of polymer chains plays an important role in determining the behaviour of polymeric materials. The presence of zeolite particles can modify the local dynamics, thereby affecting the overall performance of polymer composites with potential for various industrial applications. The aim of this study was to investigate the influence of zeolite addition on the local dynamic behaviour of polydimethylsiloxane (PDMS) chain segments during isothermal crystallization of PDMS–zeolite composites. The effect of PDMS molecular weight was also examined. Molecular dynamics was investigated using the electron spin resonance (ESR) spin-probe method, while thermal behaviour was analysed by differential scanning calorimetry (DSC).

ESR results show that zeolite addition accelerates isothermal crystallization, affecting segmental mobility in the amorphous phase at 188 K and suggesting that not only zeolite loading but also zeolite type plays an important role. At 203 K, three-component ESR spectra are observed, consistent with the presence of three dynamically distinct spin-probe environments. DSC measurements reveal no significant change in the glass transition temperature upon zeolite addition. However, shifts in cold crystallization and melting behaviour are observed, suggesting changes in crystal structure and crystal perfection. These findings demonstrate that zeolites act as heterogeneous nucleation agents and significantly influence the crystallization behaviour and local molecular dynamics of PDMS.

References:
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[3] M.I. Aranguren, *Polymer* **39**, 4897 (1998)

From kHz to THz: wideband spectroscopy of unconventional metals

Damjan Pelc
University of Zagreb Faculty of Science, Department of Physics, Zagreb, Croatia
dpelc@phy.hr

The response to electromagnetic radiation can provide key information on the physics of metals and superconductors, from electronic lifetimes to superconducting gaps and collective modes. Spectroscopic measurements at low photon energies are of particular importance for metals with small densities of charge carriers, as well as unconventional superconductors and systems with charge-density wave order. In this talk, I will discuss our efforts to perform electromagnetic absorption spectroscopy in a wide range of energies, from audio frequencies (kHz) into the millimetre-wave region close to 1 THz, that have yielded interesting insights in a number of unusual metallic systems. First, I will show how ultra-low frequency experiments provide detailed information on slow relaxation processes related to intertwined superconducting and charge-stripe order in the high-T_c cuprate $(La,Ba)_2CuO_4$. Furthermore, a recently developed setup for microwave and millimetre-wave spectroscopy [1] has enabled us to perform measurements with circularly polarized radiation and uncover a new spin-chiral electron-phonon coupling mechanism in the low-density metal $SrTiO_3$ [2]. Finally, millimetre-wave absorption spectroscopy shows evidence of superconducting collective excitations in TaS_2-based materials, suggesting a highly unconventional pairing symmetry.

References:

[1] L. Rogić et al., Rev. Sci. Instrum. 96, 083101 (2025)
[2] N. Somun et al, arXiv:2606.03908 (2026)

Emergence of Polar Order in WO_3 Thin Films

Nives Štrkalj
Institute of Physics, Zagreb, Croatia
nstrkalj@ifs.hr

Ferroelectricity is the spontaneous ordering of electric dipoles that can be reversed by an electric field. This switchable order makes ferroelectric films natural candidates for energy-efficient electronics and motivates their exploration at the nanoscale. At reduced dimensions, elastic and electrostatic boundary conditions at interfaces play an increasingly important role in setting the polarization. In classical perovskite ferroelectrics, polarization is commonly suppressed as thickness is reduced. In contrast, binary oxide fluorite ferroelectrics are non-polar in bulk, but become polar at the nanoscale. This comparison highlights that size effects are not merely a limitation, but can also become a design opportunity.

I will focus on tungsten trioxide, which brings together aspects of both material classes. As a perovskite binary oxide, WO_3 offers a system in which polar order can be promoted through epitaxial strain. We report the deposition of epitaxial WO_3 films at temperatures below 400 °C using atmospheric-pressure spatial chemical vapour deposition. In these films, strain imposed by the substrate promotes the formation of the bulk low-temperature polar phase at room temperature. Evidence comes from x-ray diffraction, scanning transmission electron microscopy, piezoresponse force microscopy, and Raman spectroscopy. Exploring ferroelectricity in ultrathin WO_3 films could provide a new platform for polarization-controlled electronic and optical applications at the nanoscale.

Magneto – optical detection of time-reversal symmetry breaking in antiferromagnets

Veronika Sunko
Institute of Science and Technology Austria, Klosterneuburg, Austria
vsunko@ista.ac.at

Optical probes are naturally well suited to detecting broken symmetries, including time-reversal symmetry ($\mathcal{T}$), and are frequently used in this way, for example, to map ferromagnetic domains. But the conditions under which optics can detect $\mathcal{T}$ - breaking in antiferromagnets with no net magnetization are far more subtle. The key distinction is whether the effect of $\mathcal{T}$ can be undone by a simple translation ($\mathcal{S}_{1/2}$); if it can, the product $\mathcal{T}\mathcal{S}_{1/2}$ is a symmetry of the system and $\mathcal{T}$ - breaking is usually invisible to bulk probes. In contrast, antiferromagnets that do not preserve $\mathcal{T}\mathcal{S}_{1/2}$ display a range of bulk $\mathcal{T}$- breaking phenomena, such as the magnetoelectric and piezomagnetic effect.

But what exactly does "bulk" mean? And more specifically, are optical probes "bulk": can they detect $\mathcal{T}$-breaking in $\mathcal{T}\mathcal{S}_{1/2}$ - invariant antiferromagnets? We address these questions by comparing three antiferromagnets: non-collinear $EuIn_2As_2$ and altermagnetic MnTe that break $\mathcal{T}\mathcal{S}_{1/2}$ and $MnBi_2Te_4$ that does not. In $EuIn_2As_2$ we show how an unconventional optical probe, linear magneto-birefringence, can reveal symmetry breaking invisible to more standard measurements [1-3]. In MnTe, simultaneous measurements of linear and circular dichroism reveal microscopic orientation of the $\mathcal{T}$ - breaking order parameter [4]. In $MnBi_2Te_4$, we demonstrate how perhaps the most standard optical probe of magnetism, reflection circular dichroism, can in fact detect antiferromagnetism even when $\mathcal{T}\mathcal{S}_{1/2}$ is preserved in the bulk [5].

Together, these experiments demonstrate both the power and the versatility of optics as a probe of symmetry breaking in quantum materials.

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Many-body localisation escapes to two dimensions

Antonio Štrkalj
University of Zagreb Faculty of Science, Department of Physics, Zagreb, Croatia
astrkalj@phy.hr

Many-body localisation (MBL) provides a mechanism to avoid thermalisation in interacting systems. It is well understood that the MBL phase can exist in closed one-dimensional systems subjected to random disorder, quasiperiodic modulations, or homogeneous electric fields. However, the fate of MBL in higher dimensions remains unclear. Although some older experiments on randomly disordered two-dimensional (2D) systems have observed an alleged MBL phase on intermediate time scales, recent theoretical works show that the phenomenon cannot persist indefinitely or in the thermodynamic limit due to rare regions of weak potential and avalanche instability.

On the other hand, quasiperiodic systems do not host rare regions, and the avalanche instability is avoided; yet, the existence of an MBL phase in these systems remains largely unexplored to date. Here, we investigate the localisation properties of the many-body 2D Aubry-André quasiperiodic model by studying its out-of-equilibrium dynamics [1]. We show that a stable MBL phase exists at long timescales, and potentially even in the thermodynamic limit, in contrast to the random-disorder case. Surprisingly, we find that a sub-dimensional network of deterministic lines of weak potential – naturally appearing in these systems – supports transport while keeping localised regions untouched.

Our theoretical proposal was recently tested in experiments with ultracold atoms, which confirmed the stability of quasiperiodic many-body localisation [2].

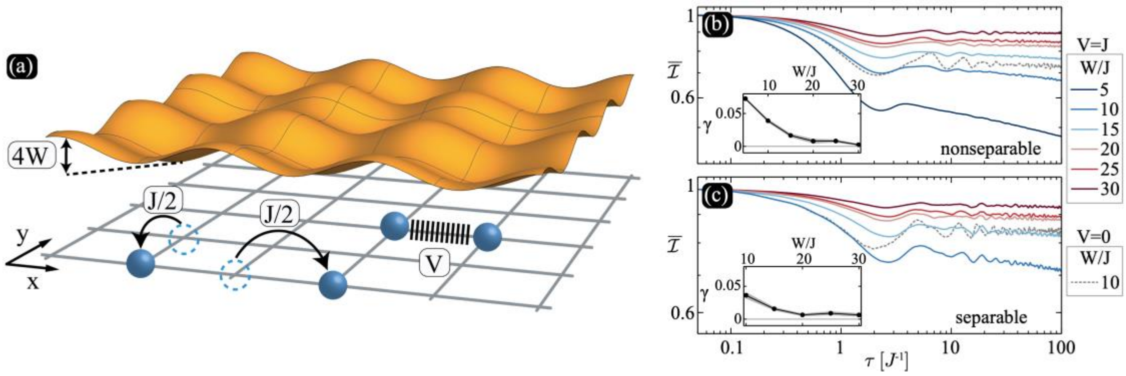

***Figure**: (a) Sketch of the system studied in this work. The kinetic energy of the particles is determined by a uniform hopping parameter J. The particles are subjected to an external incommensurate potential of strength W and interact via nearest-neighbour coupling V. (b), (c) Dynamics of the particle imbalance for different potential strengths, shown for two different realisations of the model in (a). Insets show the fitted power-law decay exponent for each coloured curve, which tends to zero for large W, indicating the localised nature of the system.*

References:

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FRIDAY

Revisiting magnetization plateaus in $SrCu_2(BO_3)_2$ by high-field NMR

Mladen HORVATIĆ
Laboratoire National des Champs Magnétiques Intenses, LNCMI-CNRS (UPR3228), EMFL, Univ. Grenoble Alpes, Univ. Toulouse, INSA-T, 38042 Grenoble Cedex 9, France
mladen.horvatic@lncmi.cnrs.fr

Investigation of magnetization plateaus in the Shastry-Sutherland compound $SrCu_2(BO_3)_2$ by high-field NMR at LNCMI-Grenoble now spans 25 years, during which these experiments marked some of crucial technical advances of the laboratory. The first ever ultra-high-field NMR measurement carried out in a dilution refrigerator [1] brought the experimental confirmation for the nature of the plateaus: the ^{63,65}Cu NMR spectrum recorded at 27.6 T and 35 mK evidenced the commensurate spin superstructure demonstrating the Wigner crystallization of magnetic excitations, taken to be the extended triplets at that time. As the field of 34 T became available, the first experiment carried out up to this field value was the ^{11}B NMR spectroscopy, establishing the precise sequence of the low-magnetization plateaus, at 1/8, 2/15, 1/6 and 1/4 of the saturation magnetization [2]. In the meantime, using advanced tensor-network numerical methods, theorists proposed that constituting elements of the 1/8, 2/15 and 1/6 plateaus are not the spin-1 extended triplets but the spin-2 bound triplet pairs forming a pinwheel pattern [3]. In 2025, by one of the two first experiments carried out in the new hybrid magnet of LNCMI, providing up to 42 T, we could compare the ^{63,65}Cu NMR spectrum in the 1/3 plateau at 41.9 T to the spectra in 27.6 T and 29.0 T, respectively in the 1/8 and 2/15 plateau. Confronting the spectra to the updated theoretical prediction for the spin superstructures, we proved that, as expected, the 1/3 plateau is based on the extended triplets and the 1/8 and 2/15 plateaus on the pinwheel-shaped spin-2 elements [4]. To our knowledge, this is the first ever real-space imaging of a complex, bound triplet pair excitation, demonstrating remarkable power of the NMR technique. Our results add the formation of Wigner crystals of *bound states* as a new paradigm in the theory of magnetization plateaus.

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Sequential magnetic ordering of kagome-plane and interlayer Cu moments in clinoatacamite revealed by site-selective NMR

Hans-Joachim Grafe
Leibniz Institute for Solid State and Materials Research Dresden, 01069 Dresden, Germany
h.grafe@ifw-dresden.de

Frustrated quantum magnets provide a fertile ground for unconventional magnetic ground states arising from competing exchange interactions and reduced dimensionality. The naturally occurring mineral clinoatacamite, a polymorph of the parent compound of the kagome spin-liquid material herbertsmithite, is an important model system in this context. Its magnetic lattice consists of Cu^{2+} (S=1/2) ions coupled through oxygen-mediated superexchange interactions, giving rise to strong magnetic frustration. Previous μSR and neutron diffraction studies reported two magnetic transitions near 18 K and 6.5 K, but their microscopic origin has remained unresolved [1]. Here, we investigate clinoatacamite by site-selective ^{1}H and ^{35}Cl nuclear magnetic resonance. The NMR spectra reveal magnetic transitions at both temperatures, while the site-dependent spin-lattice relaxation rates provide direct evidence that the Cu2/Cu3 kagome planes develop long-range magnetic order below 18 K, whereas the interlayer Cu1 moments remain dynamically fluctuating until they order below 6 K. These results establish a microscopic picture of sequential magnetic ordering in clinoatacamite and reconcile the previously reported experimental observations.

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Discovery of BKT correlations in the quantum kagome compound $Cs_2Cu_3SnF_{12}$

Mihael S. Grbić
University of Zagreb, Faculty of Science, Department of Physics, Zagreb, Croatia
mgrbic.phy@pmf.hr

Frustrated quantum magnets, such as the spin $S = 1/2$ triangular-lattice and the kagome-lattice Heisenberg antiferromagnets, have been extensively studied because a large degeneracy of their ground state and low-dimensional enhancement of quantum fluctuations allow new phenomena to emerge. However, these same features also hinder the experimental determination of the exact nature of the ground state, particularly when single crystals are unavailable. Despite these difficulties, significant progress has been achieved, and various quantum spin liquids, chiral orders and fractionalized excitations have been reported. Surprisingly, notwithstanding the large body of work on two-dimensional (2D) systems, only a single report to date has identified 2D XY correlations of Berezinskii-Kosterlitz-Thouless (BKT) type in a frustrated lattice.

We investigate the microscopic properties of the kagome compound $Cs_2Cu_3SnF_{12}$ using ^{63,65}Cu nuclear quadrupolar resonance (NQR) in single crystal samples. Analysis of the local hyperfine fields below the Néel temperature $T_N = 20$ K indicates a spin structure consistent with $P2_1/n$ symmetry of negative vector chirality. Measurements of the spin–lattice relaxation rate T_1^{-1} reveal signatures of a gapless ground state and two-dimensional BKT–type correlations above T_N, extending over a broad temperature range of approximately 130 K in zero magnetic field [1]. Within the same temperature range, the observed increase in the NQR linewidth is consistent with short-range chiral order recently identified by neutron scattering. Our results establish $Cs_2Cu_3SnF_{12}$ as a unique quantum kagome system exhibiting BKT behaviour.

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Graphite: towards Room-Temperature Spin Devices (The Return of a Forgotten Quantum Material)

László Forró
Stavropoulos Center for Complex Quantum Matter, University of Notre Dame, Notre Dame, USA
lforro@nd.edu

The Cuprate Problem and the Zagreb School of Solid State Physics: Towards a Solution

Neven Barišić
Institute of Solid State Physics, TU Wien, Vienna, Austria
University of Zagreb, Faculty of Science, Department of Physics, Zagreb, Croatia
neven.barisic@tuwien.ac.at, nbarisic@phy.hr

From the Classroom to Ampère's Law

Nikola Poljak
University of Zagreb Faculty of Science, Department of Phyics, Zagreb, Croatia
npoljak.phy@pmf.hr

My collaboration with Professor Dulčić began in teaching, during the semester in which I was his assistant during the General Physics course. After that, I took over his lectures, continuing a teaching approach that emphasizes simplicity and clarity of physical models, as well as mathematical precision.

This teaching collaboration gradually developed into joint work on university textbooks. After publishing University textbooks Mechanics [1] and Electromagnetism [2], we are currently continuing work on a third book, with the plan to complete the cycle with a fourth. During the writing of the textbooks, certain problems and ways of presenting them outgrew the initial didactic framework and became topics for separate educational articles. Here, I present several examples of the development of such ideas, with special emphasis on the work in which Ampère's law is derived from the Biot–Savart law for arbitrary geometry as schematically shown in Fig. 1. The basic idea was found by Professor Dulčić, after which we developed it together - first for presentation in the textbook, and then for an educational-scientific article [3]. This example shows how a question that arose when writing a teaching text can lead to a new transparent result and how teaching cooperation with prof. Dulčić naturally developed into a joint author's work.

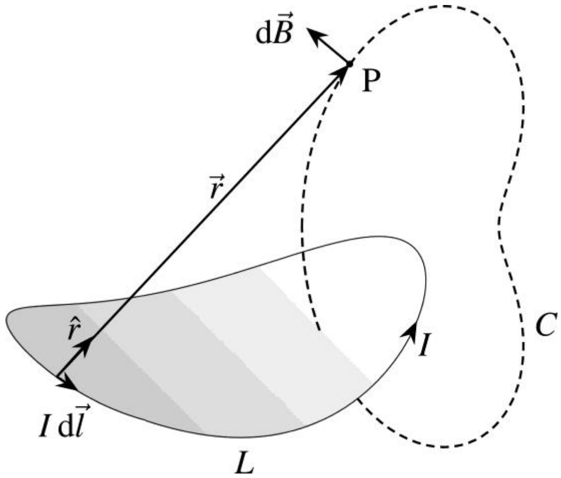

***Figure**: A schematic view of the derivation of Ampère's law from the Biot–Savart law for arbitrary geometry [3].*

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Teaching University Physics from First Principles

Matko Milin
Physics Department, Faculty of Science, University of Zagreb, Croatia
matko.milin@phy.hr

As physicists, we all fondly remember our first encounter with "real physics" during the early years of our university studies. It was at that stage that the use of rigorous mathematical tools first enabled us to progress from fundamental concepts to models capable of providing a remarkably accurate description of a wide range of natural phenomena. Part of the beauty of learning physics at this level lies in the fact that virtually no "why?" question is considered off limits, and that such questions are (almost) never answered dogmatically.

Unfortunately, traditional physics textbooks only partially reflect this spirit. They quickly become overloaded with technical and often secondary details, leaving little room for the careful construction of conceptual foundations. This rush through the fundamentals is, in fact, counterproductive, as the resulting gaps in understanding frequently become apparent when students encounter more advanced topics. Nevertheless, this approach has become the norm and is rarely questioned.

Throughout his teaching career, Prof. Dulčić devoted himself to reversing these priorities by placing complete and fundamental understanding of physical phenomena at the heart of his teaching, without skipping essential steps or leaving important concepts insufficiently explained. In this contribution, I will discuss my experiences collaborating with Prof. Dulčić in developing and implementing this philosophy of teaching [1-3]. Using the examples of elastic forces and friction, I will illustrate how these concepts can be introduced naturally from first principles and Newton's laws, leading students to a deeper and more coherent understanding of the underlying physics.

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