Exploratory Workshop on
Condensed Matter Physics
Bariloche, Argentina
November 28th - December 1st 2017

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ACKNOWLEDGEMENTS

We welcome all participants to this first “Exploratory Workshop on Condensed Matter Physics”, which we are holding at the premises of the Centro Atómico Bariloche and Instituto Balseiro in the city of Bariloche, Argentine Patagonia.

This international symposium is a follow up of a series initiated in 2012, aimed at stimulating and forging ties and collaborations between scientists of the Max Planck Institutes in Germany and scientists in Argentina. In this opportunity the activities will be focused on theoretical and experimental approaches to condensed matter physics, including a variety of common interest topics such as quantum properties of correlated materials, functional oxides and liquids, ion transporting materials, thermodynamic properties of intermetallic compounds, narrow band, non-conventional superconductors, confined photonic and phononic properties, heterostructures and thin films, driven quantum systems and topological materials, magnetic, electronic and surface properties, domain walls, sensors, applications to biomedicine, clean energy and also projected facilities such as the new Argentine Neutron Beams Laboratory.

This meeting is organised in such a way as to foster discussions and the identification of common interest research lines and possible collaborations. It will begin with general introductory talks with plenty of time for discussions using the Frauenfelder rule, followed by poster presentations in a relaxed atmosphere and finalising with topical discussions aimed at identifying concrete collaborations.

This workshop was possible thanks to the generous contribution of the Max Planck Society (MPG), the Argentine Atomic Energy Commission (CNEA), the Argentine Ministry for Science, Technology and Innovation (MINCyT) and the Balseiro Foundation. In particular we want to thank the MPG Liaison Office in Latin America and its authorities, Dr. Andreas Trepte and Dr. Barbara Spielmann, the Physics Department of the Bariloche Atomic Center and its Manager, Dr. Alex Fainstein, the Department of Research and Non-Nuclear Applications of the Argentine Atomic Energy Commission and its Manager, Dr. Ingo Allekotte, the Instituto Balseiro and its Director, Dr. Carlos Balseiro.

Above all we want to thank the invaluable work and excellent predisposition of Sebastián Pertossi who is behind every detail of this meeting, the constant support from Buenos Aires of Florencia Labiano, the commitment of our driver, Omar Bustos, and the commitment of Marisa Velazco Aldao and Christina Martinez of the Leo Falicov Library.

We hope the workshop fulfills our highest expectations and that we will meet several times in the future to discuss the progress of our joint research.

Karen Hallberg
Andy Mackenzie
Julian Sereni
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<td><strong>Opening</strong></td>
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<td><strong>Nanostructured materials and devices - Chair Alejandro Butera</strong> Armando Aligia Electronic structure of strongly correlated oxides Surface-physic group: Methods and research lines. <strong>Hugo Ascolani</strong> Surface-physic group: Methods and research lines. <strong>Sebastián Bustingorry</strong> Domain wall motion in thin ferromagnetic films with perpendicular anisotropy <strong>Nestor Haberkorn</strong> Thin film growth capabilities at CAB <strong>Mariano Gómez</strong> B. Low Temperature Sensor Group <strong>Martin Sirena</strong> Nanostructures using functional oxides <strong>Roberto Zysler</strong> Magnetic nanoparticles: from basic research to applications in bio-medicine</td>
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<td><strong>Andrew Mackenzie</strong> MPI for Chemical Physics of Solids, Dresden, Germany</td>
<td><strong>Yaninina Fasano</strong> Centro Atómico Bariloche, Bariloche, Argentina</td>
<td><strong>Carlos Balseiro</strong> Centro Atómico Bariloche, Bariloche, Argentina</td>
<td><strong>Bulk materials – Chair Gladys Nieva</strong> Rodolfo A. Borzi Experiments and Numerical Simulations on Geometrically Frustrated Magnetic Materials. <strong>Gladys Nieva</strong> Superconducting and magnetic single crystals grown at LBT-CAB <strong>Rodolfo Sánchez</strong> Simple and double perovskites are a rich scenario to find itinerant electrons and multiferroic materials <strong>Adriana Serquis</strong> Materials characterization for clean energies applications <strong>David Tew</strong> Accurate and efficient ab initio electronic structure methods <strong>Verónica Vildosola</strong> Spin-orbit and anisotropic strain effects on the electronic correlations of Sr2Ru04</td>
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<td><strong>Julian Sereni</strong> Centro Atómico Bariloche, Bariloche, Argentina</td>
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<td><strong>Driven quantum systems</strong></td>
<td><strong>Colloquium</strong> <strong>Andrew Mackenzie</strong> Water, honey and electrons - evidence for MPI for Chemical Physics of Solids, electronic hydrodynamics in naturally occurring materials.</td>
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<td><strong>Hao Tjeng</strong> MPI for Chemical Physics of Solids, Dresden, Germany</td>
<td><strong>Chair Javier Curiale</strong></td>
<td><strong>Alejandro Butera</strong> Centro Atómico Bariloche, Bariloche, Argentina</td>
<td><strong>Lunch</strong> <strong>Verónica Vildosola</strong> Spin-orbit and anisotropic strain effects on the electronic correlations of Sr2Ru04</td>
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<td><strong>Alex Fainstein</strong> Centro Atómico Bariloche, Bariloche, Argentina</td>
<td><strong>Stuart Parkin</strong> MPI of Microstructure Physics, Germany</td>
<td><strong>Overview of the main research activities of the Magnetic Resonance Laboratory</strong></td>
<td><strong>Coffee break</strong> <strong>Bustingorry</strong> Frustrated Magnetic Materials. <strong>Nestor Haberkorn</strong> Thin film growth capabilities at CAB <strong>Mariano Gómez</strong> B. Low Temperature Sensor Group <strong>Martin Sirena</strong> Nanostructures using functional oxides <strong>Roberto Zysler</strong> Magnetic nanoparticles: from basic research to applications in bio-medicine</td>
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<td>12:30-14:00</td>
<td><strong>Ali Alavi</strong> MPI for Chemical Physics of Solids, Dresden, Germany</td>
<td><strong>Santiago Grigera</strong> Instituto de Física de Líquidos y Sistemas Biológicos, La Plata, Argentina</td>
<td><strong>Is the ground-state of spin-ice like ice?</strong></td>
<td><strong>informal discussions</strong> <strong>Bustingorry</strong> Frustrated Magnetic Materials. <strong>Nestor Haberkorn</strong> Thin film growth capabilities at CAB <strong>Mariano Gómez</strong> B. Low Temperature Sensor Group <strong>Martin Sirena</strong> Nanostructures using functional oxides <strong>Roberto Zysler</strong> Magnetic nanoparticles: from basic research to applications in bio-medicine</td>
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CONDENSED MATTER RELATED DIVISIONS AT CAB

Low temperature Physics
The main lines of research are focused on the following topics. *Superconductivity:* statics and dynamics of vortices, superconductors with high critical temperature, coexistence with magnetism, turbulence in He superfluid. *Strongly correlated electrons:* thermal, magnetic and transport properties of heavy fermion Ce and Yb based intermetallics at low and very low temperatures which exhibit Kondo effect, magnetic frustration, magnetic instabilities and quantum critical fluctuations. *Mesoscopic systems:* manufacture of nanostructured materials, growth of single crystals, thin films of multifunctional metals and oxides and superconductors containing multifunctional materials of multiferroic type. *Devices:* design, manufacture and characterization of micro and nanoelectromechnical systems.

Magnetic Resonance Group
Characterization and measurement of magnetic, thermodynamic, elastic and transport properties of new magnetic materials, both in bulk and in nanostructured systems (nanoparticles, nanowires, nanotubes, thin films and multilayers).

The specific topics are: Structural and magnetic characterization of FePt films and multilayers, stripe magnetic domains in single layers and coupled bilayers, generation and control of spin currents in heterostructures, magnetoelastic coupling in magnetostrictive thin films: Control of magnetism, magnetic interaction in Fe/MnAs thin films: Control of magnetism with temperature, magnetoresistance of FeGa films, study of electronic transitions in multiferroic compounds of the type (RE)CrMnO5, magneto-optical studies of thin films: Domain-wall motion and Kerr measurements, manufacture and physical characterization of multiferroic oxide systems at nanoscale, morphological control and magnetic and magneto-transport properties of bi-magnetic core-shell nanoparticles, applications of nanoparticle in nano-medicine and nano-biology: Functionalization with biological molecules, hyperthermia, toxicity, uses in ophthalomological chirurgic protocol (retinal detachment), active participation in the LAHN project (Argentine Laboratory of Neutron Beams).

Physics of Metals
This Division’s lines of research focus on the study of bulk and nanostructured metallic systems, spanning fundamental and applied research and the development of materials for specific applications. Specific areas of research include: i) Martensitic phase transformations in Cu, Ni-Ti and Fe based Shape Memory Alloys and their applications as dampening and orthopaedic devices; ii) Fretting damage in alloys for components of nuclear reactors, mechanical and microstructural characterization of nuclear alloys and the development of radiation resistant high temperature steels; iii) Microstructural and mechanical characterization of age hardenable Aluminium alloys, Aluminium based Metal Matrix Composites and Titatium alloys; iv) Synthesis and characterization of noble metal nanoparticle systems. The main experimental techniques are transmission electron microscopy and mechanical testing, complemented with optical microscopy, dilatometry, calorimetry, resistivity and internal friction.

Photonics and Optoelectronics
The research focuses on the study of the interaction of light with matter at the nanoscale using Raman spectroscopy and ultrafast optical techniques. Characterization of materials by optical techniques, study of light and ultra-fast vibrations at the nanoscale, and ultra-sensitive detection of molecules and contaminants. In particular, we investigate materials in which quantum confinement effects determine their electronic, vibrational, and optical properties. The work includes the design of new methods, artificially structured materials, the study of novel fundamental phenomena and their technological applications. This group is active in the fields of nanophotonics, optomechanics, cavity quantum electrodynamics, plasmonics, and quantum memories, among others.

Condensed Matter Theory

This group is involved in theoretical research in condensed matter physics, mainly of mesoscopic and nanostructured systems and correlated electronic systems exhibiting magnetism and superconductivity including the following working lines. Nanostructured electronic systems: Superconducting qubits, graphene and similar 2D materials, charge and spin transport properties, molecular transistors, driven quantum systems, topological matter, entanglement and correlations. Statistical physics and condensed matter: Physics of domain walls, superconducting vortices, stochastic thermodynamics, earthquakes and friction, glassy systems, critical phenomena. Devices and applications: Non volatile resistive memories, semiconducting devices. Realistic modeling of materials: Computational material science using ab-initio methods (DFT), graphics interface calculations (GPGPU), dynamical mean field theory (DMFT), numerical renormalization (NRG, DMRG); electronic and magnetic structure of strongly correlated electron systems, design of exchange and correlation functionals, disorder effects.

Atomic Collisions

Atomic, Molecular and Optical Physics. Ionization of atoms and molecules by impact of ions, electrons, positrons and photons. Material characterization with a 1.7MV Tandem accelerator, including PIXE and RBS dedicated lines. Reaction microscopy with a 300KV accelerator. Theoretical studies of few body atomic and molecular processes.

Surface Physics

Experimental and theoretical studies of solid surfaces. The main research lines: a) Nanoscience with organic molecules on surfaces: self-assembly of chiral molecules, build and design of metal-organic coordination networks, self-assembly of thiols. b) Low-dimensional inorganic materials: growth and characterization of germanene on different substrates, electronic structure of nanoparticles with potential use in cathalysis and of superconductive and magnetic thin films. c) Diffraction of grazing incident fast atoms. d) Energy loss of ions in solids. e) Theoretical Simulation of Materials: ab-initio methods (DFT) including dispersion interaction (vdW), electronic and magnetic structure of metal-organic coordination networks and low dimensional systems, surface dynamics (molecular dynamics (MD) and kinetic Monte Carlo (kMC)), molecular reactions including solvent effects. The experimental studies use ion spectroscopies (TOF-DRS, TOF-ISS, SIMS), electron spectroscopies (LEED, AES, UPS, XPS), scanning probe microscopies (AFM and STM with variable temperature). and synchrotron-based techniques (NEXAFS, ARPES, etc).

Materials Characterization Group
This group developed a large expertise in the study of new superconductors, magneto-resistive and mixed ionic and electronic conductor materials. In all the research lines involving non-stoichiometric oxides, the group studied the influence of the oxygen content on the thermodynamic stability and its correlation with the particular physical properties, i.e. superconductivity. Recently, the research activities were mainly focused in developing nanostructured materials for Intermediate Temperature Fuel Cells (IT-SOFC) with the aim to correlate the microstructure, structure and composition with the electrical and electrochemical properties. On the other hand, some applied research was devoted to the study of MgB2 superconducting cables.

The group developed different experimental set-ups to study high temperature properties under controlled atmosphere to perform in-situ determination of the oxygen content, to obtain detailed information about phase diagram and to propose defect structure models and ranges of phase stability in non stoichiometric oxides. The study of the electrical conductivity either, in simultaneous or under the same conditions where the oxygen non-stoichiometry was determined, allows to obtain information about the pO2 dependence and nature of the electronic charge carriers and their mobilities.

In addition to these techniques, the group has expertise in several characterization techniques such as SEM-FEG, XRD, HT-XRD, NPD, Synchrotron XRD, and spectroscopies (XAS, XANES, etc), TEM, FIB and HR-TEM. The group also developed a sample holder specifically designed to study the electrical resistivity, electrode polarization resistance or I-V response evolution simultaneously with structural properties by XRD under in-situ or in-operando conditions. This device can be coupled to the gas atmosphere control, being able to study degradation process such as phase transitions, phase segregations and chemical reactivity, among others, produced during SOFC cell operation.

**MPI - VISITOR'S PROFILES**

**MPI-Chemical Physics of Solids - Dresden**

**Prof. Andrew Mackenzie**

Superconductivity of Sr2RuO4 - Quantum criticality in Sr3Ru2O7 - The effect on Tc and transport properties of lattice deformation in cuprate superconductors - Ultra-high conductivity in delafossite compounds - Magnetic properties of iridates under controlled lattice strain - The interaction of nematicity and superconductivity

We perform challenging measurements on correlated electron materials. Our goal is to measure as directly and precisely as possible the quantities one wishes to know to answer open scientific questions, developing the necessary tools along the way. Our most important tool at present is controlled lattice distortion, using piezoelectric-based uniaxial pressure cells that were developed in-house. Other techniques under development include controlled-stress techniques, mesoscopic sample preparation, and scanning magnetic susceptometry.

By focusing on scientific goals and possibilities we push ourselves to technical achievements that we did not think possible. There is a strong emphasis in our group on the engineering required to achieve our scientific goals, and I hope that students in my group will develop not only scientific knowledge but also strong applied and organisational skills. The measurements we take on are
challenging; our goal is to make them feel easy through a high degree of teamwork and careful preparation.

Prof. Liu Hao Tjeng

He specializes in synchrotron spectroscopy of effective valence states and the influence of spin-orbit coupling on such things.

Spectroscopy is applied in a wide variety of scientific disciplines to explore matter’s electronic structure. We employ synchrotron-based spectroscopic techniques such as Angle-Resolved PhotoEmission Spectroscopy (ARPES), Hard X-ray PhotoEmission Spectroscopy (HAXPES), Resonant X-ray Scattering (RXS), Non-resonant Inelastic X-ray Scattering (NIXS), and X-ray Absorption Spectroscopy (XAS).

Thin Films: Transition metal and rare-earth oxides, which show metal-insulator transition and interesting magnetic properties are in the focus of our research. Single crystalline oxide thin films are prepared by Molecular Beam Epitaxy (MBE) technique. We are also interested in MBE-grown topological insulator compounds, materials having a full insulating gap in the bulk, but topologically protected conducting surface. Our state-of-art in-house UHV equipment allows for in-situ structural characterization by RHEED and LEED, in-situ spectroscopic characterization and determination of the bulk and surface electronic structure by XPS/ARPES, in-situ temperature dependent resistivity measurements.

Prof. Claudia Felser

New Materials with High Spin Polarization. rational design of new materials for spintronics and energy technologies such as solar cells, thermoelectric materials, topological insulators and superconductors.

"Our tool box: the periodic table". In general the material class under investigations are: Heusler compounds with X$_2$YZ with L2$_1$ and XYZ with C1$_b$ structure type, that show the same broad variety of properties comparable to the perovskites, including topological insulators, Kondo behaviour, non-centrosymmetric superconductivity and conventional, tunable magnetic properties, non-collinear magnetism, semiconductivity, magnetoresistance effects, Li-ion-conductivity and other physical properties. Different to the perovskites only a few groups mainly in Germany and Japan are working on this class of materials. However many companies such as Hitachi, IBM, Toshiba, Toyota etc. have research activities based on this material class.

MPI of Microstructure Physics – Halle/Saale

Dr. Stuart SP Parkin

Magnetism, topology with a view to developing next-generation technology, architectures of neuromorphic computing.

Recent advances in manipulating spin polarized electron currents in atomically engineered magnetic heterostructures make possible entirely new classes of sensor, memory and logic devices a research field generally referred to as spintronics. A magnetic recording read head, initially formed from a spin valve, and more recently by a magnetic tunnel junction, has enabled a 1,000 fold increase in the storage capacity of hard disk drives since 1997. The enormous storage capacity of arrays of hard disk drives in the “cloud” has made possible the digital storage and access to all of humankind’s
knowledge since the beginning of mankind, thereby ushering in the age of “Big Data” and data analytics. The creation of unforeseen data driven businesses and the transformation of entire industries is impacting society in manifold ways. Increasing the performance and reducing the energy consumption of storage and computing technologies will very likely spur yet more innovative applications of such technologies.

Spintronic and ionitronic devices that rely on atomically engineered materials have novel properties that may allow for higher performance, lower energy and more compact computing devices. The Racetrack Memory is a novel 3D technology that stores information as a series of magnetic domain walls in nanowires, manipulated by spin polarized current. Racetrack Memory, a spintronic technology combines the best attributes of magnetic disk drives their very low cost per stored bit with those of solid state memories their high performance and reliability. Ionitronics allows for the reversible, non volatile transformation between insulating and metallic states via the flow of tiny currents of ions. Such devices may allow for “plastic” devices that mimic synaptic switches in the brain, thereby allowing for the possibility of very low power computing devices.

MPI for Solid State Research – Stuttgart

Prof. Ali Alavi

Numerical theorist who combines the techniques of quantum chemistry and Monte Carlo with first principles calculations in an overall methodology that essentially no-one else uses.

Recent calculations on cuprate superconductors. The theory group is broadly concerned with the development of ab initio methods for treating correlated electronic systems, using Quantum Monte Carlo, quantum chemical and many-body methodologies. We will also be interested in applying ab initio methods (including density functional theory) to problems of interest in heterogeneous catalysis, surface chemistry, electrochemistry, and photochemistry. It is our long term aim to develop the highly accurate methodologies of Quantum Monte Carlo and quantum chemistry for application to such systems.

Prof. Jochen Mannhart

Specialist in thin films and multilayers and the development of oxide electronics. He is an expert on the superconductivity of the 2d electron layer formed at SrTiO3/LaAlO3 and other all-oxide interfaces.

Focus on the properties of interfaces in complex electronic materials. The efforts of the various teams he was working in resulted in the discovery and development of bicrystal Josephson junctions and SQUIDs, the enhancement of critical currents of high-Tc superconductors by grain alignment, which is the basis for the modern high-Tc superconducting cables, the first imaging of individual atoms with subatomic resolution, and the fabrication of the first all-oxide FETs.
ABSTRACTS

TALKS

Quantum Chemistry and Quantum Monte Carlo approaches to strongly correlated systems

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One of the major challenges of electronic structure theory is the development of computationally tractable methods which can reliably treat strongly correlated electronic systems, by which we mean systems for which mean-field theory (plus perturbative corrections thereof) fail even qualitatively. In my department, we are principally concerned with methodological developments which extend quantum chemistry and Quantum Monte Carlo methods (which are wave function-based methods) to this difficult regime. I will provide a brief overview of the techniques, before moving onto showing on-going applications of current interest, including the spin energetics of cuprates and porphyrin systems. What I will show is that not only can one extract reliable energetics for these systems, but perhaps more importantly, that one can provide **insight** into the key physical attributes which underlie the energetics. Such insight is invaluable to experimentalists, in the context of rational design, and to theoreticians who wish construct minimal models.

Quantum charge and energy transport in mesoscopic systems and topological nanostructures

L. Arrachea
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Boosting the efficiency for the conversion of electrical and thermal energy at finite power is motivating an intense research activity, not only in the areas of material science and applied physics but also in experimental and theoretical areas of statistical mechanics and condensed matter physics. Efforts are concentrated in developing new materials and devices as well as on analyzing different operational conditions. In the latter direction, taking advantage of the quantum effects is one of the most interesting avenues. Nanostructured devices operating at low temperatures are particularly appealing quantum devices, since they offer the conditions for coherent transport, where “parasitic” heat currents by phonons are strongly suppressed.

A two-dimensional electron gas in the quantum Hall regime is one of the most paradigmatic examples of quantum coherent transport. In the first part of the talk, I will present recent results on the thermoelectric response of a quantum dot embedded in a constriction of a quantum Hall bar with fractional filling factors \( \nu = 1/m \) within Laughlin series. The “figure of merit” \( ZT \) for the maximum efficiency at a fixed temperature difference and the thermopower show a significant enhancement in
the fractional filling in relation to the integer-filling case, which is a direct consequence of the fractionalization of the electron in the fractional quantum Hall states. [1]

In the second part of the talk I will present an adiabatic response formalism and a generalization of the thermoelectric theory to describe the exchange of heat, work and charge in electron systems under the effect of adiabatic ac driving, in addition to voltage and temperature biases. Different operational modes will be identified: motors, generators, heat engines and heat pumps, which will be characterized in terms of efficiencies and figures of merit. Some examples will be discussed.[2] Finally, the adiabatic response formalism will be also used to investigate the non-linear dynamics of the charge and energy in a quantum capacitor. [3]

References:

Driven quantum systems

C. Balseiro
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Bariloche (Argentina)
balseiro@cab.cnea.gov.ar

After a brief introduction on historic and current activities of the condensed matter group in Bariloche I will present results on one of our research lines on driven quantum systems. Irradiated graphene and related two-dimensional materials present topological transitions which we show, can be detected either through photoemission experiments or transport measurements. More recently we have been studying multi-terminal Josephson junctions which also present topological structures in the space of the superconducting phase variables.

Overview of the main research activities of the Magnetic Resonance Laboratory

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The Magnetic Resonance Lab. of the Centro Atómico Bariloche has more than 50 years of expertise in the area of Magnetism and Magnetic Materials. I will briefly describe the main research areas that are presently developed in our lab. We have groups working in bulk materials like manganese, cobalt, vanadium and other complex oxides with ferroic and multiferroic properties; single and bimagnetic core shell nanoparticles, with applications in bio-medicine like hyperthermia, drug delivery and ophthalmology; magnetic storage, permanent magnets. Groups working in thin films and multilayers study different aspects of stripe magnetic domains, domain wall dynamics, generation and control of spin currents, spintronic devices, magneto and electro resistance. We
fabricate, measure and characterize single nanostructures such as nanowires and nanotubes with applications in fuel cells and electronic devices. We also collaborate in the solution of problems related to the nuclear industry such as radiation damage in steels, characterization of nuclear fuels, retrospective dosimetry, and magnetic positioning devices.

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**Confined photonics, phononics, and optomechanics**

**A. Fainstein**  
Photonics and Optoelectronics Laboratory - Centro Atómico Bariloche

The interaction of light and sound can be controlled by nanostructure engineering and confinement in resonators leading to novel phenomena and applications. We will briefly describe some of the lines of research at the Photonics and Optoelectronics Laboratory in Centro Atómico Bariloche that exploit these concepts, including motivating questions in domains as diverse as cavity optomechanics and polaritonics, few atomic monolayer membranes, quantum cascade lasers, and the ultrasensitive detection of molecules.

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**Is the ground-state of spin-ice like ice?**

**S. A. Grigera**  
Instituto de Fisica de Liquidos y Sistemas Biologicos,  
Consejo Nacional de Investigaciones Científicas y Técnicas – Universidad Nacional de La Plata  
La Plata (Argentina)

This talk will address the question on the ground state of real spin-ice systems. Spin-ice are magnetic systems, Dy2Ti2O7 to name one example, that are characterised by big magnetic moments sitting on a pyrochlore lattice. At first instance, the interaction between these moments leads to magnetic frustration and the expectation of an extensively degenerate ice-like ground state. Theoretical work and recent experimental evidence put this naive expectation into question. In this talk I will discuss experimental work and numerical simulations on two different spin-ice systems, Dy2Ti2O7 and Ho2Ti2O7, that aim at elucidating the true ground state of spin-ice materials.

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**How Much is a Single Crystals a Single Crystal?**

**Y. Grin**  
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The single crystals attracted attention of humans since hundreds - not to say thousands - of years without any knowledge about their origin and structure. The main reason for that are extreme stability of some natural crystalline minerals and their esthetically appealing shape. Another value of single crystals which is not obvious on the first glance is their informational content, i.e. they carry information about the formation, crystal structure and – most important - intrinsic properties of
substances. Especially the quantum materials are very sensitive in this respect. This part of information can be extracted only from the crystals of an appropriate quality. Developed first for the description of the influence of the point defects on the electronic transport behavior of elemental metals, the residual resistivity ratio (RRR) is currently intensively used as a control parameter for the description of the electronic and phononic transport behavior of single crystals in particular of intermetallic compounds. Beside the point defects as basic reason, also substitution by minority components on selected sites in the crystal structure, planar, most likely stacking defects, inclusions of other coherently grown phases, partial substitutional disorder, and even impurity phases were suggested as the reasons on atomic resolution for the reduction of RRR. The interpretation of these arguments form the chemical point of view is not straight forward task and should contribute to the understanding of chemical and physical behaviors of intermetallic compounds.

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**Clean metals and clean quantum tuning**

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I will first summarize recent research in our department into the properties of so-called delafossite metals, in which triangular lattice layers of Pd or Pt are separated by layers of transition metal octahedra. Remarkably, these have the longest room temperature mean free paths of any known metal, longer even than those of Ag or Cu. At low temperatures, mean free paths of tens of microns are attainable in crystals grown using vapour phase techniques. In the long term, it is highly desirable to take such clean materials and tune their properties using external parameters that introduce no disorder, so I will close by giving an update on our ongoing development of uniaxial pressure techniques.

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**Heterostructures with Integrated Functional Liquids**

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Solid-state heterostructures are the cornerstone of modern electronics. To enhance the functionality and performance of integrated circuits, the material space used in the heterostructures is being expanded by an increasing number of compounds and elements of the periodic table. Here we explore solid-state heterostructures with integrated liquids, thus opening a new phase space of materials. Devices containing tens of microscopic capacitors and field-effect transistors have been realized using patterned and integrated NaCl aqueous solutions. The capacitance-voltage characteristics feature unexpected discontinuities, whereas the capacitances and the transfer characteristics of the devices follow and partly exceed the behavior expected for integrated liquids. Our work paves the way to integrated electronic circuits that include highly integrated liquids, thus
yielding a wide spectrum of novel research and application opportunities based on microscopic solid/liquid systems. This work has been performed together with B. Prasad, G. Pfanzelt, M.J. Zachman, and L.F. Fitting Kourkoutis.

Direct imaging of reversible massive oxygen transport induced by ionic liquid gating and creation of meso-structures

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ionicliquidgateinducedmigrationofoxygenionsatthesurfaceofoxidethinfilmshasbeenproposedrecentlytobeapowerfultoolformanipulatingtheirbulkpropertiesandstructures. Here we directly image these processes, using in-situ IL gating, within a high-resolution transmission electron microscopy, as we induce the reversible transformation between brownmillerite SrCoO$_{2.5}$ and perovskite SrCoO$_3$. A massive quantity of ~0.5 oxygen per formula unit, is observed to be reversibly extracted or injected over several minutes. The film structure is transformed throughout its volume but the phase transformation boundary velocity is highly anisotropic, traveling at speeds ~30 times faster laterally than through the thickness of the film. Furthermore, by taking advantage of ionic liquid gating through lithographically patterned orifices at the surfaces of oxide films with distinctly different anisotropies in oxygen transport, we show that a range of three-dimensional metallic structures such as cylinders and rings can be realized. Our results provide a roadmap to the construction of complex meso-structures in ion-transporting materials from their exterior surfaces.

Some examples of ab-initio calculations in the Condensed Matter Theory group

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Density Functional Theory (DFT) has become the “standard model” for the ab-initio calculation of system properties in chemistry, atomic, molecular, and solid-state physics. The wide popularity of this calculation tool is grounded in the satisfactory compromise between the relatively low computational cost of the calculations, and the afforded accuracy. The first part of the talk will be devoted to introduce the basic concepts of ground-state DFT, as applied to the case of doped graphene. The fingerprints of the discontinuities of the exchange-correlation energy functional in the measured subband electronic structure of semiconductor quantum wells will be discussed [1]. In the second part of the talk, I will discuss recent developments that shows that the exact-exchange (EE)
formalism provides a natural and rigorous approach for a DFT of the Integer Quantum Hall Effect [2]. Not surprisingly, the EE potential display sharp discontinuities at every integer filling factor \( \nu \).

References:

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### The Argentinean Neutron Beams Laboratory Project

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The RA10 is a 30 MW multi-purpose reactor under construction in Ezeiza, Buenos Aires, designed to satisfy national and regional demand for radioisotopes, nuclear materials testing and neutron beams research. The reactor will start operations on 2021, it will have a liquid deuterium cold source and a large guide hall for instruments. Since 2016 the National Atomic Energy Commission has started a project called “The Argentinean neutron beams laboratory for the RA10 reactor” (LHNN); aimed at implementing state-of-the-art instruments, developing a user community and the laboratory staff. Two instruments are being designed for the first stage of this laboratory: (i) a neutron imaging instrument on a cold beam; and (ii) a multi-purpose diffractometer on a thermal beam, optimized for non-destructive studies on large objects. Both instruments will be placed on the reactor face, in order to exploit very intense, undisturbed, neutron beams. Besides this, an ambitious program has started to popularize neutron techniques in Argentina and create new users. A second phase for the project is being evaluated, taking into consideration the demands of the local and regional scientific community. In this work, the present state of the project is described, providing details of the instruments design and the strategies implemented to develop the Argentinean users community.

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### Thermal trajectories of Entropy in intermetallic compounds suitable for Adiabatic Demagnetization Refrigeration (ADR)

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The search of intermetallic compounds, able to improve classical paramagnetic salts performance for low temperature ADR, was triggered by new application requirements. Their efficiency is intimately related to their thermodynamic properties, notably the specific heat \( C_{4f} \) and entropy trajectories within the sub-Kelvin range, and their magnetic field dependencies. Different thermal behaviors of new Very Heavy Fermions, with \( C_{4f} / (T - T^*) \geq 7 J/mol K^2 \), are recognized and analyzed for alternative ADR applications. These mostly Yb-lattice compounds, remain paramagnetic down to the mK range despite of their robust magnetic moments. Their magnetic field
dependencies reveal distinct nature of the respective ground states, which are dominated by weak magnetic interactions or by magnetic frustration. The constraint imposed by the Nernst postulate drives the change of the Entropy trajectory revealing a sort of Entropy-bottleneck as T-\* 0.

\[ \text{Orbital degrees of freedom in narrow band materials} \]

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The spectacular physical properties often observed in materials containing transition metal and rare-earth elements challenge our comprehension of solid state physics. These properties include superconductivity, unusually large magneto-resistance, metal-insulator transitions, heavy-fermion behavior, multiferroicity, and phenomena involving topologically protected states. We would like to understand how the electrons in such materials interact with each other as to generate those unusual quantum phenomena. From a theoretical viewpoint it turns out that the equations we have to solve are so complicated that we will not be able to obtain exact solutions. To make things worse and more fascinating at the same time, tiny changes in temperature, pressure or in the material composition may cause large changes of the properties, so that it appears that there are many solutions available that are lying very close together in energy.

With exact solutions out of reach, the objective of our ‘Physics of Correlated Matter’ department is to find smart approximations by which we can capture the essential ‘physics’ to describe the ‘correlated’ motion of the electrons in such materials. It may very well be that we need to develop and use different approximations for different materials or properties. In order to probe these materials and properties the research activities of our department are focused on the investigation of the electronic structure of the materials, using both spectroscopic tools as well as material specific many-body calculations. The experimental activities have also a strong material development component: new materials, both in bulk as well as in thin film form, are synthesized in order to tune the relative strength of the relevant interactions.

In this talk, I would like to focus on the topic of ‘orbital degrees of freedom’ and to show that it is an essential aspect for the understanding of metal-insulator transitions in transition metal oxides (e.g. TiO₂) as well as the topological properties of rare-earth compounds (e.g. SmB₆). I also would like to show that with x-ray spectroscopies one has an extremely powerful tool for the identification of the relevant orbitals in the system. In particular, I would like to present the opportunities provided by a new x-ray technique, namely non-resonant x-ray scattering (NIXS). This photon-in-photon-out technique with hard x-rays has become feasible thanks to the high brilliance of modern synchrotrons and advanced instrumentation. The available large momentum transfers allows for the study of excitations that are well beyond the dipole limit, thereby giving a very detailed insight into the ground-state symmetry of the ion of interest. The interpretation of the spectra is straightforward and quantitative, facilitated also by the fact the multipolar excitations are more excitonic than the dipole ones. We now have also the first results from our own Max Planck inelastic scattering beamline at PETRA III in Hamburg.
TOPICAL DISCUSSIONS

NANOSTRUCTURED MATERIALS AND DEVICES

Electronic structure of strongly correlated oxides

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We have derived and used effective Hamiltonians, like the generalized t-J model for the superconducting cuprates, the recently studied T-CuO, the superconductor NaxCoO2, V-doped 1T-CrSe2, which shows an orbital Kondo effect, and the insulator Sr3Cr2O7, which shows simultaneous ordering of spin and orbital with a change of entropy $R \ln(6)$ (see poster). We use perturbation theory and sometimes exact diagonalization of a MO6 cluster, where M is any transition metal including all intra d correlations.

Surface-physics group: Methods and research lines.

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A brief description of the experimental techniques and the theoretical methods used by the surface-physics group, as well as of the current research lines. The main research lines are: a) Nanoscience with organic molecules on surfaces: self-assembly of chiral molecules, build and design of metal-organic coordination networks, self-assembly of thiols. b) Low-dimensional inorganic materials: growth and characterization of germanene on different substrates, electronic structure of nanoparticles with potential use in catalysis, and of superconductive and magnetic thin films. c) Diffraction of grazing incident fast atoms. d) Energy loss of ions in solids. e) Theoretical Simulation of Materials: ab-initio methods (DFT) including dispersion interaction (vdW), electronic and magnetic structure of metal-organic coordination networks and low dimensional systems, surface dynamics (molecular dynamics (MD) and kinetic Monte Carlo (kMC), molecular reactions including solvent effects.

Domain wall motion in thin ferromagnetic films with perpendicular anisotropy.

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Based on a complementary approach between numerical simulations and polar magneto-optical Kerr effect microscopy we investigate domain wall motion in different thin ferromagnetic materials. Our main focus are the glassy dynamic regimes where the the velocity is strongly affected by the intrinsic
disorder of the sample. We then report the main parameters ruling universal and non-universal dynamical properties.

**Thin film growth capabilities at CAB**

N. Haberkorn

We will describe the thin film growth facilities at CAB and briefly enumerate the ongoing research lines, which involve metallic, perovskite, nitride and chalcogenide materials, for superconducting, normal, magnetic, ferroelectric phases.

**Low Temperature Sensor Group**

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The Low Temperature Sensor Group focused on the MEMS devices fabrication, design and fabrication of MEMS and superconductors devices, ASIC electronic, and superconductors, and development of signal processing algorithms for low SNR applications. Our group is actually developing several application related with such research lines: SQUIDs 3 axis magnetometer for geological prospection; muon, neutron, gamma, x-ray tomography for geology and large structures; micro radiography and densitometry; Electrical impedance tomography; and deep brain electrical stimulation for epilepsy mitigation among other topics.

**Nanostructures using functional oxides**

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The group of nanostructures using functionalized oxides has essentially three research lines, micro and nanofabrication of different systems, characterization and manipulation at the nanoscale and the development of technological application using oxides of different nature (e.g. ferromagnetic, ferroelectric, multiferroic and superconducting oxides). In this short presentation will discuss the different techniques and systems that we can fabricate, going from single films and multilayers to tunnel junctions devices and gate operated devices, using lithography tools. We’ll present the different characterization techniques used to study the property of this nanostructures taking advantage of the versatility that offers the atomic force microscopy. Finally we’ll present different developments searching for new applications in the field.

**Magnetic nanoparticles: from basic research to applications in bio-medicine**
Magnetic nanoparticles (MNP) have properties very different from bulk magnetic materials that can be controlled from the composition and morphology of MNP. Mainly, the control of the internal magnetic order and the magnetic anisotropy that determine the superparamagnetic-blocked regime of the magnetization and the saturation, remanence and coercivity of the material are studied. With these same NPM, applications are being studied and developed in the area of medicine.

**BULK MATERIALS**

*Experiments and Numerical Simulations on Geometrically Frustrated Magnetic Materials.*

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Though a tendency to antiferromagnetism or ferromagnetism is always present in a real spin system, embodied by the nearest neighbours exchange constant J, the realisation of order at low temperatures can be hindered by competition with further neighbour interactions or (depending on the geometry of the lattice) even with itself. What results most interesting is that, even when the most conspicuous manifestation of these interactions --the arousal of an order parameter-- can be suppressed, correlations are sill very strong, favouring the appearance of peculiar excitations, dynamics, and phases.

Our group in La Plata is dedicated to the study of this class of materials and systems where geometry prevents the onset of the usual forms of magnetism. In this presentation I'll briefly review some recent studies performed by our group in La Plata, involving experiments and numerical studies. They comprehend crystal phases of magnetic charges in spin ice-like systems, the possibility of observing magnetic charge order as a consequence of thermal fluctuations (classical order by disorder), and the refinement of the Hamiltonian regularly used to describe canonical spin ice materials.

*Superconducting and magnetic single crystals grown at LBT-CAB*

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We will present the highly oriented materials growing facilities at the Low Temperature Laboratory-Centro Atómico Bariloche. We will briefly describe investigations on the single crystals produced of
high and low critical temperature superconductors including Iron based chalcogenides, magnetic oxides, semimetallic chalcogenides and intermetallic compound single crystals.

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**Simple and double perovskites are a rich scenario to find itinerant electrons and multiferroic materials**

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Complex bulk oxides, including perovskites and double perovskites structures, conform a rich scenario to study different physics properties and also to design new materials as multiferroic composites. In particular, we focus our attention in to study double perovskites with Sr/Ba-Fe-Mo-O compositions that present coexistence of itinerant and localized electrons. On the other hand, other studied system, as double perovskites with Sr/Ba-Mn-Mo-O, shows insulators and ferrimagnetism behaviors. While, R-Fe-Cr/Co-O (where R is rare earth) perovskites present complex magnetic behaviors as magnetic frustration, spin reorientation mechanisms and clues of multiferroic behavior. We will show a brief conclusions about the advance of our studies in the bulk magnetic and in the design of new multiferroic materials.

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**Materials characterization for clean energies applications**

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Materials play a key role in the search for solutions to energy problems. One attractive solution for the transition period between fossil fuels and hydrogen is the development of materials for electrochemical devices such as Solid Oxide Cells (SOC). SOC are highly efficient electrochemical devices which can convert a wide range of fuels (i.e. hydrogen, methane, carbon monoxide) into electrical energy and heat in fuel mode (SOFC) or can generate hydrogen in electroliser mode (SOEC). In this talk I will present some of the latest results obtained in our group involving several ceramic materials that are intended for SOC devices. The focus will be placed on the correlation between the microstructural aspects (determined by the composition and processing parameters) and their physical properties that determine the materials efficiency. The structural stability and chemical compatibility between the electrode and electrolyte materials studied were evaluated through the combination of several characterization techniques, such as electron microscopies (SEM, TEM), X-ray diffraction (XRD), chemical analysis by EDS and synchrotron radiation methods (XANES y EXAFS), including some in-situ and in-operando techniques.

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**Accurate and efficient ab initio electronic structure methods**
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A short overview of recent advances in many-body wavefunction theory will be presented, focusing on methods that are systematically improvable and applicable to extended systems.

Spin-orbit and anisotropic strain effects on the electronic correlations of Sr2RuO4

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Since the discovery of the superconductivity below Tc =1.5 K, Sr2RuO4 has become a key material in the field of strongly correlated systems because, at variance with the Mott insulator character of the isostructural La2CuO4, it exhibits very exotic metallic properties in the normal phase. The possibility of controlling its electronic properties by applying external strain has been recently addressed experimentally. It has been shown that the evolution of the superconducting Tc with uniaxial strain presents a peak that seems to be correlated with a Lifshitz transition of the xy-Ru band [1]. This transition associated to the shift of a Van Hove singularity, has also been observed in systems under biaxial strain [2]. An interesting open question is to what extent this Lifshitz transition affects the electronic correlations in the normal phase of Sr2RuO4 . In this presentation we will show theoretical results of the role of the spin-orbit coupling and anisotropic strain on the electronic correlations of Sr2RuO4 . The implemented calculation technique is a DFT+DMFT[3] approach using a rotationally invariant slave boson technique[4] as impurity solver of DMFT. Our approach provides explicit relations between quantities in the local correlated subspace treated within DMFT and the Bloch basis used to solve the DFT equations. In particular, we present an expression for the mass enhancement of the quasiparticle states in the reciprocal space. We find that the spin-orbit coupling plays a crucial role in the mass enhancement differentiation between the quasi one-dimensional α and β bands, and in its momentum dependence over the Fermi surface. The mass enhancement, however, is only weakly affected by either uniaxial or biaxial strain, even across the Lifshitz transition induced by the strain.

References:
**Water, honey and electrons - evidence for electronic hydrodynamics in naturally occurring materials.**

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Electrical transport in solids is almost always analysed using an approximation in which all scattering is assumed to relax the momentum of the electrons. Although this can be justified in the vast majority of cases, because the electrons are moving in a lattice to which momentum is efficiently transferred, recent measurements by several groups give evidence that it is not always true. In ultra-pure systems with extremely long mean free paths, the momentum-conserving collisions that are ignored in standard theory can become more rapid than the momentum-relaxing ones. In this limit, the electronic flow moves into a hydrodynamic regime in which the electron fluid’s viscosity dominates the resistance measured in flow through constrained channels. Although not very well known by people working on bulk materials, the study of such effects goes back over fifty years in the theoretical literature and over twenty years in experiments on high purity two-dimensional electron gases. I will try to review the history of the field, then describe new experiments on PdCoO₂ and graphene, and finally make some comments about extending the investigation to other systems.
**Field-driven magnetic domain wall dynamics in thin films with perpendicular anisotropy**


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We study the dynamic properties of domain walls (DWs) in magnetic thin films with perpendicular anisotropy using a polar magneto-optical Kerr effect (PMOKE) microscope. The studied samples are ferromagnetic Pt/[Co/Ni]3/Ta multilayers and ferrimagnetic Pt/GdFeCo/Ta thin films, both presenting perpendicular magnetic anisotropy. In our experiments, we simultaneously apply out-of-plane and in-plane magnetic fields and measure the DW velocity as a function of the out-of-plane applied field, and observe changes in the DW roughness due to both applied fields. These observations give us insight into the characteristics of the creep regime of DW motion for these samples. We analyze the effects of in-plane fields, which can be related to variations of the DW energy due to the Dzyaloshinskii-Moriya interaction, thus inducing changes in DW velocities and roughness.

**Optical cavity mode dynamics and coherent phonon generation in high-Q micropillar resonators**

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We study the laser induced temporal dynamics of the optical cavity mode of DBR based semiconductor micropillars, and its relation with the generated mechanical eigenmodes, by means of pump & probe microscopy. Furthermore, we analyze the dependence of the amplitude of the measured mechanical modes with laser-cavity detuning. We show that in order to correctly explain the observed features, the transient photo-carrier dynamics must be considered.
Direct visualization of the order-disorder transition in vortex matter in Bi$_2$Sr$_2$CaCu$_2$O$_{8+\delta}$

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We studied the structural transformations in the surface of the vortex matter nucleated in pristine and electron irradiated Bi$_2$Sr$_2$CaCu$_2$O$_{8+\delta}$, along the second peak transition by direct observation of individual vortices. The effects of point-like disorder, introduced by irradiation with 2.3 MeV electrons, on the phase diagrams were measured with local Hall probe magnetometry. We observed a significant depression of: the critical temperature $T_c$, the first order phase transition (FOT) and the second peak field $B_{sp}$. In order to visualize the vortex structure with single-vortex resolution we used the magnetic decoration technique. This technique makes possible the analysis of structural transformations induced at the surface in the real space, for images with thousands of vortices in a range of applied fields significantly broader than other techniques. We analyzed the defect density, Fourier Transform and the structure factor of the nucleated vortex matter for fields near to $B_{sp}$. Structural features related to an amorphous or polycrystalline state are not observed at fields above $B_{sp}$. This result is in agreement and complements small angle neutron scattering measurements for this material [1].

References:

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Strain tuning of superconductivity and normal state properties of Sr2RuO4

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Sr2RuO4 is an unconventional superconductor with a well characterised Fermi liquid normal state. It is known that one of its three conduction bands lies in close proximity to a Van Hove singularity and we show that by the application of uniaxial pressure the Fermi level can be made to traverse the Van Hove singularity. For the first time we can tune through this topological Lifshitz transition using a clean and continuous tuning parameter. We observe more than a factor of 2.3 enhancement of $T_c$. The low-temperature resistivity is also found to pass through a pronounced peak, at which its temperature dependence deviates strongly from the Fermi liquid $T^2$ dependence.
**Simple model to study magnetic domain walls dynamics**

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We model the magnetization dynamics of quasi-two dimensional systems with perpendicular easy axis of magnetization by using a simple model, based on a classical model of Statistical Mechanics. The model is a simplification of the Landau-Lifshitz-Gilbert equation and allows a systematic study of the motion of domain walls driven by magnetic fields, following typical experimental protocols of polar magneto-optic Kerr effect microscopy. The model considers the magnetization component parallel to the easy axis of magnetization and may include magnetic exchange, dipolar interactions, structural disorder, temperature and an external magnetic field. With the model we obtained domain walls velocity-field curves with usual features of experimental curves.

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**Thickness effects on the physical properties of $\beta$-FeSe thin films**

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The exploration of new emergent phenomena and exotic matter states is an active area in condensed matter physics. These studies require samples of very high quality, which involves characterizing and controlling properties at microscopic scales maintaining homogeneity macroscopically. In this work, we studied thickness effects in the properties of $\beta$-FeSe films grown by sputtering.

We report a superconductor-insulator transition by reducing the thickness, for films in different types of substrates (SrTiO$_3$, MgO and Si) in a wide range of growth temperature. In the literature, there are similar reports in epitaxial films of $\beta$-FeSe, which have been interpreted in terms of a possible continuous quantum phase transition induced by disorder [1-2]. In our samples, as the thickness decreases the evolution of the structural and magnetic properties is not trivial, implying that the scheme of induction of disorder is inappropriate.

In the limit of textured thick films, the critical temperature takes values slightly higher than the expected for bulk $\beta$-FeSe, $T_c \sim 12K$, probably owing to a nanoscale intergrowth of $\beta$-FeSe and $\gamma$-Fe$_7$Se$_8$. 

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The electronic structure were explored by performing magnetotransport and Hall experiments, finding features associated to the tetragonal-tetthorhomorphic structural phase transition. The non-superconductive and insulating samples growth by sputtering present an epitaxial nature. The tetragonal structure and the magnetic order present in this samples suggest the possibility that these films are of the \( \beta-\text{Fe}_4\text{Se}_5 \) phase [3], recently proposed as the non-superconductive parent of FeSe.

References:

Enhancement of penetration field due to surface Andreev bound states in vortex nanocrystals of \( \text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_8-\delta \)

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The nucleation of nanocrystalline vortex matter with a large surface-to-volume vortex ratio in micron-sized superconducting samples opens the possibility of studying the influence of surface effects on its magnetic properties. For instance, theoretical studies predict that the penetration and depinning fields for vortices in d-wave superconductors is altered by fermionic Andreev-bound states appearing at the sample surface. [1] These states, that can exist at zero excitation energy depending on the relative orientation of the the sample-surface to the d-wave gap function, generate an anomalous Meissner current running opposite to the supercurrents. The Bean-Livingston surface barrier limiting vortex entry at intermediate temperatures is altered by these surface states and as a consequence the penetration field \( H_p \) depends on the orientation of the surface of the sample to the d-wave superconducting order parameter. [1] An experimental study indeed detected a tiny crystal-orientation dependence of \( H_p \) in relatively macroscopic samples. [2] In this work we study vortex nanocrystals with 10-1 % surface-to-volume vortex ratio nucleated in cuboid \( \text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_8-\delta \) samples of 50 to 20 \( \mu \)m width and roughly 2 \( \mu \)m thickness (see Fig. 1). The engineering method we use [3, 4] allowed us to generate two sets of micro-cuboids, one with the edges aligned along the nodal and another along the anti-nodal d-wave order parameter directions. By means of Hall probe magnetometers with active areas of 16 × 16 \( \mu \)m\(^2\) we measure local dc and ac-magnetization. We detect that the penetration field is enhanced when the edges of the micro-cuboids are parallel to the nodal direction of the d-wave order parameter. This result, in agreement with the theoretical predictions, has only been detected thanks to the combination of low-noise local magnetic techniques and the nucleation of vortex nanocrystals with a significant surface-to-volume vortex ratio.

Figure 1: Nanocrystalline vortex matter nucleated in field-cooling processes in \( \text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_8-\delta \) cuboids with 30 \( \mu \)m sides
and 2 ,im thickness. Magnetic decorations were performed at 4.2 K and at applied fields of 20 (left panel) and 40 Oe (right panel).

References:

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**Efficient Density Matrix Renormalization Algorithmm for correlated impurity models**

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We develop a highly efficient Density Matrix Renormalization algorithm to solve ground-state and excitation spectra of correlated impurity models. It is based on the truncation of the Hilbert space using the highest eigenvalues of the reduced density matrix, as in the DMRG method. We find that the bipartite entanglement is reduced appreciably upon a rotation of the single-particle basis from the real-space to the natural orbital representation, which optimises the occupation number operator.

Thus, we obtain high precision ground state and dynamic correlations by keeping only a small fraction of states, much lower than in the traditional DMRG or even for the Wilson chain using the Numerical Renormalization Group technique. We expect this improvement to be useful to treat more complex impurities and also other correlated models.

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**Study and Development of Magnetic Nanostructures and Oxide Multiferroic Multilayers based on New Materials.**

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A systematic study on fabrication and characterization of multiferroic superlattices that present strongly correlated electrons properties has been made. In this way, the design of structures with four (or more) resistive states that can be reverted either with magnetic or electric fields can be carried out. We present a Metal/Insulator interface multilayers type, composed by La₀.₈Ba₀.₂MnO₃...
(ferromagnetic, FM) and Ba$_{1.1}$Sr$_{1}$TiO$_3$ (ferroelectric, FE) materials grown by magnetron sputtering DC and RF technique. In their Atomic Force Microscopy (AFM) topography characterization we observe a dependency between roughness and the sample ferroelectric thickness. Also X-ray diffraction patterns indicate a strongly-textured growth of the samples. A significant dependence of the transition metal-insulator Temperature (Tp) was observed as function of the FM layer thickness. Additionally, unexpected changes of Tp with different FE thickness were observed and they could be related to some kind of FM-FE interaction mechanism. Finally the coercive and remnant magnetization dependence with the applied field direction was studied for these multilayers.

References:

**Spectral characterization of gold over nanosphere surfaces for molecular detection using SERS spectroscopy**

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For molecular detection using surface enhanced Raman spectroscopy (SERS) in gold over nanosphere surfaces we explore sample parameters as frequency and size. In good agreement with simulations, we find a very strong enhancement of the SERS signal: this makes this approach very attractive for basic plasmonic physics and a broad range of applications.

**Topological properties of monolayer transition metal dichalcogenides irradiated with a laser beam**

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In this work we study the topological properties of a monolayer of Transition Metal Dichalcogenides (TMDC) in the presence of a laser field. First we identify its crystal structure and the atomic orbitals involved by using previous results from DFT. The simplest model has three bands and uses only the orbitals $d_{z^2}$, $d_{xy}$ and $d_{x^2}$ from $W$. We present models with nearest neighbors and up to third neighbors. It is seen that the model with nearest neighbors is a good approximation for the band structure near some symmetry points, whereas with a model with up to third nearest neighbors we can describe the entire First Brillouin Zone.

With these models we investigate the effects of a circularly polarized laser beam acting normally on the monolayer using Floquet theory. The topology of the Floquet band structure is characterized
calculating some topological invariants (winding numbers). To support these results we calculate the Floquet bands in bulk and on the edges of nanoribbons, with zigzag and armchair edges. Finally we calculate the conductance in nanoribbons with different edges and discuss the effects of the Floquet gaps induced by the laser and the formation of topological edge states.

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**Singlet Orbital Ordering in Bilayer Sr3Cr2O7**


We perform an extensive study of Sr3Cr2O7, the n=2 member of the Ruddlesden-Popper Sr_rn+1 Cr_n O_3n+1 system. An antiferromagnetic ordering is clearly visible in the magnetization and the specific heat, which yields a huge transition entropy, R ln6. By neutron diffraction as a function of temperature we have determined the antiferromagnetic structure that coincides with the one obtained from density functional theory calculations. It is accompanied by anomalous asymmetric distortions of the CrO6 octahedra. Strong coupling and Lanczos calculations on a derived Kugel-Khomskii Hamiltonian yield a simultaneous orbital and moment ordering. Our results favor an exotic ordered phase of orbital singlets not originated by frustration.

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**Microstructuring correlated electron materials**

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Even though correlated systems in general are being study extensively, relatively little work has been done to explore such systems in the mesoscopic regime, i.e. on dimensions comparable to characteristic length scales of the system such as the mean free path in metals. We present two examples for studies of microstructured samples: in the delafossite metals PdCoO2 and PtCoO2, strong signatures of non-ohmic transport, including evidence for hydrodynamic electron flow, are observed. And microstructuring of YbRh2Si2 enables electrical transport measurements at temperatures in the millikelvin range which can provide direct insight into phase formation and changes of the Fermi surface. We also discuss novel experimental approaches for the investigation of microscopic samples.

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**Magnetic structure of CaBaCo$_4$O$_7$ determined by single-crystal neutron diffraction**

The novel oxide CaBaCo$_4$O$_7$ (CBCO-114) is a magnetoelectric compound with the largest ferroelectric polarization induced by magnetic order reported so far (17 mC/m$^2$). It belongs to a family of oxides that displays outstanding electronic and magnetic properties, involving magnetic frustration in a three-dimensional framework of Co tetrahedra \cite{1}. CBCO-114 crystallizes in the polar space group $Pbn2_1$ which allows electric polarization along the textit{c} axis. No structural transitions have been observed between 4 K and room temperature and the compound is believed to have charge-order. Despite the Co arrangement in triangular and kagomé cells, which typically generates frustrated states, an important orthorhombic distortion allows for the development of long-range magnetic order. 

The magnetic structure for CBCO-114 was first determined by Caignaert in 2010 \cite{1} using neutron powder diffraction (NPD) measurements. The authors reported a ferrimagnetic ordering at low temperature which involves a non-collinear spin arrangement but this structure had not been confirmed yet by single-crystal diffraction, a much more sensitive technique for these complex magnetic structures.

In the framework of a collaboration between the Centro Atómico Bariloche (CAB) and the Paul Scherrer Institut (PSI), we synthetized a single-crystal of CBCO-114 with the aim of performing new studies using neutron diffraction. The crystal was grown using the floating zone method. Its purity was checked by X-ray diffraction and neutron experiments were performed at two different temperatures: 10 K and 100 K in the ferrimagnetic and paramagnetic temperature ranges respectively. The magnetic structure derived from these experiments indicates that the easy axis for the magnetization is along the textit{b} axis in agreement with the published results; while the spins do not only lay in the textit{ab} plane as previously reported, but have a component of the magnetic moments along the textit{c} direction. This discrepancy might be due to the fact that the powder method might loose some information for such complex magnetic arrangements, as reflections overlap and the technique is not as sensitive as the single-crystal diffraction.

References:
\cite{1} V. Caignaert et al. Phys. Rev. B – vol. 81, n. 9, 2 (2010).

**Multiferroic properties of RFe$_{0.5}$Co$_{0.5}$O$_3$ with R= Tm, Dy, Er, Tb and Ho.**

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We present magnetic and electric properties results of five members of the RFe$_{0.5}$Co$_{0.5}$O$_3$ family with R= Tm, Dy, Er, Tb and Ho. From x-ray and neutron diffraction techniques, we characterize the samples as orthorhombic ($Pbnm$). For all samples, the magnetization as a function of temperature data have been measured at different magnetic fields, between 5K and 800K and under FCC (Field cool cooling) and ZFC (zero field cooling) protocols. The FCC and ZFC curves show a shift between
them below the characteristics temperatures, which depend of R ($T_N$, from 220 K to 285 K). This shifting evidence a magnetic frustration, although the extrapolation from high temperature of the inverse of magnetic susceptibilities show principally antiferromagnetic correlations between the magnetic ions. The electrical conductivity of the samples can be described with a semiconductors behavior following a VRH model, which is generally observed in systems with disorder. The pyroelectric currents taken increasing temperature were measured after cooling the samples under a high electrical field of 3keV/cm² from $T>T_N$. From these data we obtain the electric polarization, and the sign, of the pyroelectric current and the polarization is the same that the sign of the high electric field cooling. The magnitude of saturation polarization moment is approximately 0.04 μC/cm². Our experiments demonstrate that the $RFe_{0.5}Co_{0.5}O_3$ perovskite is a multiferroic material.

**Exciton-polariton ribbons with spin-orbit coupling**

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Polaritons are quasi-particles that emerge from the coupling between excitons and photons confined in optical microcavities. These cavities can be shaped into micropillars, and their coupling allow the construction of uni-and two-dimensional lattices with arbitrary geometries. These polariton’s lattices constitute a novel and versatile platform with which it is possible to emulate, in the context of photonics, electronic properties of conventional condensed matter systems and in turn to design Hamiltonians with peculiar transport properties. In this work we present a generalized tight-binding model that allows to describe, with a minimal amount of parameters, the band structure and edge states of two-dimensional polariton’s lattices, including the effect of an effective spin-orbit coupling between polarizations. This model based on non-orthogonal photonic orbitals faithfully reproduces experimental results reported for different geometries and contributes to understand properties related to the non-trivial topology of this class of systems. We analyze in particular the influence of the non-orthogonality of the orbitals and the photonic spin-orbit coupling on the polarization and dispersion of the edge states associated with the s and p bands.

**The leading role of surface electrons state in the Kondo effect of Co/Ag(111)**

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Exploratory Workshop on Condensed Matter Physics  
Bariloche, Argentina - November 28th - December 1st 2017

Single atoms with partially filled d- or f-shells on a solid state surface are known to exhibit strong electron correlations leading to physical properties that do not correspond with the isolated-atom picture. The magnetic properties of such impurities on metals are inherently connected with many body interactions between the localized magnetic moment and the supporting surface [1-5]. In this framework, the Kondo effect [1, 6] is the most frequently found. Using scanning-tunneling spectroscopy, we report results on the Kondo temperature $T_{K}$ of Co atoms on the (111) surface of Ag, as the surface density of state $\rho_{S}$ changes. Due to the long Fermi wave vector of the surface states, $\rho_{S}$ at a given surface point is affected by defects lying far away from this point. We have cleaned a large area on the Ag(111) surface and measured the differential conductance at a given surface point with and without a Co atom. From this information we obtain $T_{K}$ and the change in $\rho_{S}$ at the Fermi energy at different points on the surface. We obtained that $T_{K}$ varies approximately linearly with $\rho_{S}$. We analyzed the data on the basis of an SU(4) Anderson model derived from ab initio calculations, obtaining agreement with the experimental data. The results suggest that at least a quarter of the coupling of the Co impurity with extended states is due to surface states.

References:

New technique for manufacturing memristive systems based on multiferroic oxides
Lucas Neñer, Martin Sirena

In this poster we will present the design of a new type of memristor developed using microfabrication techniques on thin films. Its operation is based on exploiting the intrinsically remanent behavior of a ferroelectric when subjected to an electric field, in order to disturb the conduction state of a sensitive film. Due to the interaction between both materials and the geometry used, a remanent response is induced in the resistivity of the sensor, in the same way as one would expect from a memristor. This development was presented to INPI for patenting.

In order to verify the effectiveness of the development, a device using a Barium Titanate film as ferroelectric and a conduction channel of Lanthanum-Barium Oxide as sensor was designed, manufactured and characterized. It will be explained in detail how the interactions give rise to a memristor-like operation, the manufacturing process used will be described and results of the measurements will be shown.

Low-energy quasiparticles in the two-orbital Hubbard model
Núñez-Fernández Y.¹, Kotliar G.² and Hallberg K.¹
We find conspicuous low-energy quasiparticle resonances for the two-orbital Hubbard model with repulsive interaction $U$ in each band in the presence of an inter-orbital Coulomb repulsion $U_{12}$.\cite{1}

These states are charge-neutral spin-singlet orbital-triplet holon-doublon bound states formed between both orbitals when one of the bands is metallic and they are observed as a resonance in the density of states in the other band at an energy $U - U_{12}$, even if this band is insulating, i.e. in an orbital-selective Mott (OSM) phase. As a consequence, when $U = U_{12}$ the quasiparticles are located at the Fermi energy and we do not find an OSM phase for any ratio of bandwidths, as long as they are finite, solving a long-standing controversy. These states should be observed in ARPES and optical conductivity experiments where this model is applicable.

For this study we have implemented an efficient impurity solver for the Dynamical Mean Field Theory (DMFT) based on the Density Matrix Renormalization Group (DMRG) which leads to reliable density of states on the real frequency axis directly, works at $T=0$, does not suffer from fermionic sign problems and can deal large complex impurities. This technique is promising to treat, for example, multi-orbital Hamiltonians or to obtain non-local self energies using the cellular DMFT. \cite{2}

References:
\[1\] arXiv:1710.08792

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**Spin-Lattice coupling on the two dimensional Ising Model**

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The Ising model is, without a doubt, the most studied magnetic model for insulating solids. One of its most salient features is that it has an exact solution for one and two dimensions. Despite this, the richness of behaviours and phases on real materials has lead people to consider more complex models which take into account, for example, dipolar interactions or lattice distortions. The latter has been the subject of extensive work over the last years and several extensions to the Ising model have been proposed that describe the coupling between elastic and magnetic degrees of freedom. In most of this work, the methodology has been to integrate out the elastic degrees of freedom in order to obtain a simpler effective Hamiltonian, written solely in terms of spin degrees of freedom. One drawback from this methodology is that it does not allow one to obtain information about the lattice distortion or to account for magnetic scenarios occurring after a possible structural phase transitions. In this work we consider a simple Ising magnetic model in two dimensions over a square lattice with Einstein-like distortions and do a Monte Carlo simulation that takes into account both degrees of freedom simultaneously. We find that at above a certain degree of coupling between the two degrees of freedom, the system undergoes a simultaneous structural and magnetic transition into a “checkerboard-like” phase. We have studied additional implications of this instability.
Incidence of the growth conditions on the domain wall motion in Pt/Co/Pt films

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The films that exhibit perpendicular magnetic anisotropy (PMA) have gained interest because they are potentially suited for magnetic memory devices. In these materials, much effort is devoted to studying the dynamics of magnetic domain walls (DW) since the DW motion is a key issue to control magnetization reversal [1]. Moreover, in some particular kind of memories, DW motion is in the heart of the working mechanism of the device [2]. Understanding and controlling the effects of fabrication conditions of stacks with PMA on the magnetic properties, and in particular on the DW dynamics, is a mandatory issue to achieve a memory device based on such materials.

Perpendicular anisotropy in films may have its origin in multiple factors but surface effects and preferred crystalline orientation play a key role. In such cases, the competition between in-plane and out-of-plane anisotropies determines the resulting easy axis direction. In order to elucidate the growth conditions incidence on domain wall dynamics, we fabricated and studied Co films with PMA. Pt/Co/Pt trilayers with PMA were deposited by DC sputtering. Since the typical thickness of the magnetic layer (Co) is of 1 nm or less, this was challenging from the technical point of view. Having assured reproducibility, fabrication conditions such as substrate quality, substrate type and Co thickness were varied. The resulting samples were exhaustively characterized, both structurally and magnetically. Magneto-optic Kerr effect magnetometry and microscopy combined with X-ray reflectometry and atomic force microscopy were adopted as experimental techniques. Interestingly, we have found that increasing the thickness of the magnetic layer (from 0.4 to 0.9 nm) the coercive field increases too, while the domain wall velocity, for a given magnetic field, strongly decreases. In this work, we will particularly discuss on the relationship between the DW velocity, the coercive field and growth conditions.

References:

Implementation of an atomic force microscopy for the study of nanostructured systems mechanical properties
Due to the constant miniaturization of the components applied to modern technology it has been necessary to develop new characterization techniques that allow to study the phenomena and physical properties present in a wide variety of nanostructured systems. At present, and in particular in the area of nanotechnology, one of the main problems has been the study of the mechanical properties of this type of systems where the conventional techniques of industrial scale (macroscopic) don’t have application due to the great instrumental sensitivity required for that purpose. To give some solution, the use of different instrumented techniques by Atomic Force Microscopy (AFM) has been intensively promoted as a powerful and precise tool for the study of these properties in different kinds of nanomaterials (biological and engineering materials).

In this work I will discuss the main advantages and disadvantages of using an AFM for the mechanical study of nanostructures, giving a brief introduction to the theoretical framework of the problem. Specifically, I will communicate some advances made in the implementation of the nanoindentation technique, focusing mainly on the experimental aspects to be taken into account before performing mechanical tests and the theoretical aspects to be considered for a correct interpretation of the results. All this focused on the analysis of the detection limits of the technique and the evaluation of the type of materials that are possible to study through it. In particular, the results obtained in the analysis of bulk samples as Al₂O₃: Cr, Ti (sapphire), Si monocrystalline and In polycrystalline, as well as film/substrate systems such as Au/Si and FePt/SiO₂, will be shown.

The experimental results show that cantilever maximum deflections between 0,1 - 4 V allow us to perform indentation tests with maximum loads between 5 and 350 µN, reaching a maximum depth penetration about 400 nm (in the case of a very soft sample like Indium) and with a depth sensibility about 1 nm. Those characteristics makes the AFM an useful tool for testing the mechanical properties at nanometric scale.

**Stages of Se adsorption on Au(111): A combined XPS, LEED, TOF-DRS, and DFT study, RG.**

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We have studied the adsorption of Se on the surface Au(111) using XPS, TOF-DRS and LEED. The use of a doser that operates in vacuum allowed us to investigate all the stages of the adsorption from the clean surface up to the formation of multilayers. In the monolayer regime we have found two ordered phases with distinctive LEED patterns. The LEED pattern of the first phase presents three fractional spots arranged symmetrically around the positions of the spots in a $\sqrt{3} \times \sqrt{3}$ pattern. The analysis of this pattern suggests that in this low-coverage phase the Se adsorption does not remove the $22 \times \sqrt{3}$ reconstruction of the gold surface. This conclusion is supported by DFT calculations which show that the charge transfer to the Se adsorbates would not be enough to destabilize the surface reconstruction. Increasing the coverage, beyond 0.3 ML a new LEED pattern appears with broad spots which upon annealing at 150 °C become well defined indicating a $1 \times 8$ periodicity. At the highest doses we have observed the formation of multilayers with no discernible LEED pattern. The comparison with adsorption experiments carried out in liquid solutions show similarities and also some important differences.

**First order phase transition of vortices in $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_{8+\delta}$ with columnar defects**

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The first order transition in vortex matter in $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_{8+\delta}$ with a moderate dose of columnar defects was studied with Hall probe magnetometry. The presence of the transition is revealed by a paramagnetic peak in ac measurements, while a transition between two glassy or solid-like phases is observed at lower temperatures via the second peak effect. Results obtained for matching fields of 10, 30 and 60 G are presented and compared, the persistence of the transition and the features of the phase diagram are discussed.

**Characterization of long-wavelength density fluctuations in vortex matter**

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Hyperuniformity, i.e. the suppression of long-wavelength density fluctuations, is trivially present in crystals and quasi-crystals, but it can also exist in certain amorphous systems. In the latter case, the

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concept of disordered hyperuniformity has been recently developed and shown to describe unusual and interesting physical properties [1].

Motivated by recent theoretical predictions suggesting that disordered hyperuniformity can arise in vortex lattices in presence of disorder [2] we experimentally study vortex matter nucleated in pristine and irradiated samples of $\text{Bi}_2\text{Sr}_2\text{CaCu}_2\text{O}_{8+\delta}$ by magnetic decorations. From the digitized vortex positions we analyze the long-wavelength density fluctuations, both in real and Fourier space. Our preliminary results suggest that the analyzed amorphous vortex structures, corresponding to the irradiated samples, are not hyperuniform, at variance with the pristine sample.

References:

Effect of the disorder in the pinning centers array over the superconductor vortex lattice

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The design and construction of pinning center arrays in superconductors has allowed for the study of the effects of commensuration between the pinning array and the superconducting vortex lattice [1,2]. It has been found that both static configuration and dynamic response are affected. The signature of these effects is the appearance of maxima in the critical current, or minima in the resistivity, at matching fields whenever the lattice parameter of the vortex lattice is commensurate with that of the pinning center array. Surprisingly, one aspect of the commensuration that has not been studied in detail is that of the role of disorder in the pinning center array [3]. We have grown superconducting Nb films on top of porous alumina membranes. The disorder degree of the pore network was controlled and adjusted during the anodizing process. Magnetic response measurements clearly show matching effects between the pinning center array and the vortex lattice. The characteristics of this matching will be discussed in terms of the disorder in the pore network.

References:

Frustrated Magnetism
We address physical effects of exchange frustration and quantum spin fluctuations in (quasi) two-dimensional (2D) quantum magnets ($S=1/2$) with square, rectangular and triangular structure. Our discussion is based on the $J_1$-$J_2$ type frustrated exchange model and its generalizations. We discuss ground state properties like magnetization, saturation fields and ordered moment in the full phase diagram as obtained from numerical exact diagonalization computations and analytical linear spin wave theory. We also review finite temperature properties like susceptibility using the finite temperature Lanczos method and the reentrant behavior of the field-dependent magnetic ordering temperature. We focus mostly on the observable physical frustration effects in magnetic phases where plenty of quasi-2D material examples exist to identify the influence of quantum fluctuations on magnetism.

Optomechanical coupling in DBR-based hybrid semiconductor nanoresonators

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We present a detailed theoretical study using finite-difference modelling of optomechanical coupling rates in GaAs/AlAs optomechanical micropillar cavities, in order to compare the role of the different optical forces driving confined acoustic phonons in the GHz-THz range. We demonstrate the leading role of resonant photoelastic and optoelectronic related-forces, and discuss their potentiality for the observation of sideband resolved cooling and phonon lasing in these devices.

A new classical collective paramagnet: the monopole liquid

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A monopole liquid is a magnetic charge-disordered spin system defined over an Ising pyrochlore lattice, with one single topological charge or monopole in each tetrahedron. We define a simple model Hamiltonian for this system (which is a spin liquid, as well as a liquid of monopoles) and compare its thermodynamics with that of spin ice, a phase free of these charges. We find that our system of monopoles presents a larger residual entropy, and encompasses two further spin liquids: a polarized monopole liquid, for moderate magnetic fields along [100], and the monopole crystal, a fragmented spin liquid with no analog within spin ice. As previously guessed, a field along [111] leads to a three-dimensional Kasteleyn transition. We find that it is of a new type, with excitations (in the form of loops of reversed spins) existing even below the transition temperature. In other words,
there exist a whole nondegenerate manifold (the loop phase) associated with the zero-string topological sector. We briefly discuss how the different monopole liquid states can be related to previous experiments and models, or stabilized by the combination of magnetic interactions and lattice deformation, and show how other interactions present in real materials may enrich its properties.

**Pump-probe measurements in multi-layered MoSe$_2$**

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We study the dynamics of the acoustic breathing mode in bilayered to multi-layered MoSe$_2$, directly in the time domain, by means of the ultrafast optical spectroscopy picoseconds acoustics technique. The experiments were performed for different flake's conditions, from supported (deposited on SiO$_2$ substrate) to free standing conditions.

**Achieving giant Rashba splitting in transition metal oxide surface states**


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Based on the large majority of existing experimental evidence gathered to date, Rashba-like spin splitting at surfaces and interfaces is usually assumed to have an energy scale that is a relatively small fraction of the bare spin-orbit coupling scale of the atoms involved. By analysing surprising observations on surface states of the delafossite oxides PdCoO$_2$, PtCoO$_2$ and PdRhO$_2$, we have understood that this need not be the case. The key issue is the energy scale of inversion symmetry breaking in the Hamiltonian relevant to the surface or interface states. If this inversion-breaking energy scale is smaller than the spin-orbit coupling energy, it is the limiting factor on the scale of the Rashba splitting. However, for certain structural configurations such as that of the edge sharing transition metal octahedra in delafossites, the inversion breaking scale is both very large and directly related to the conduction electron bandwidth. In these situations the Rashba splitting is determined by essentially the full spin-orbit energy. We show how this results in Rashba splitting of up to 60 meV in Co-derived surface states, and how it can be increased to as much as 150 meV by changing Co to Rh in PdRhO$_2$. Finally, we discuss the relevance of this insight to ‘materials by design’ in which special surfaces of other materials with different structural classes can also be expected to yield this maximally efficient Rashba splitting.
Quantum well photoelastic comb for ultrahigh frequency cavity optomechanics

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In this work we show that it is possible to engineer the interaction between photonic and phononic fields in DBR based GaAs/AlAs semiconductor optomechanical nanoresonators in order to selectively amplify higher orders of the fundamental vibrational mode (20GHz), strategy that we demonstrate by selectively amplifying the 13th order (240GHz).
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