Fundamental Solid-State Physics

Context and aims of our research

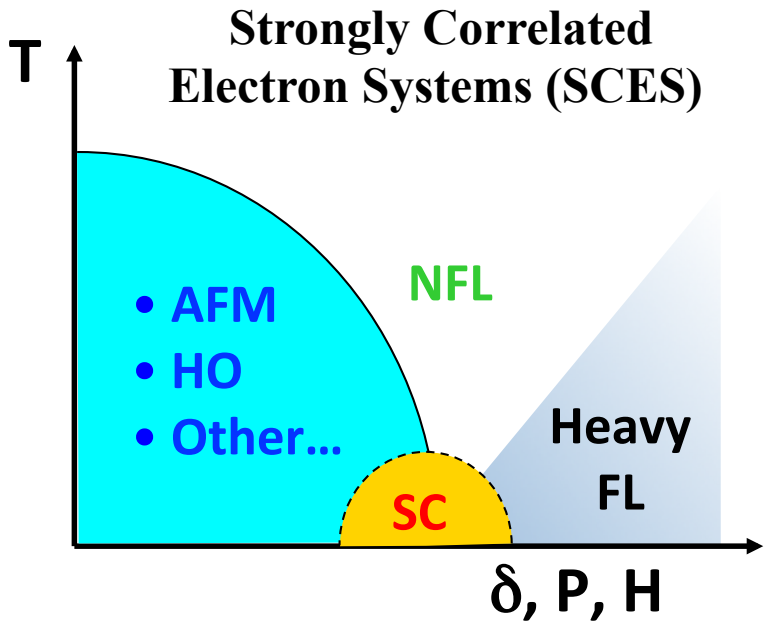
Many fermions + Strong interactions + Low dimensionality

- Nuclear physics
- Particle physics
- Cosmology
- Cold atomic gases

Competing ground states / Collective excitations

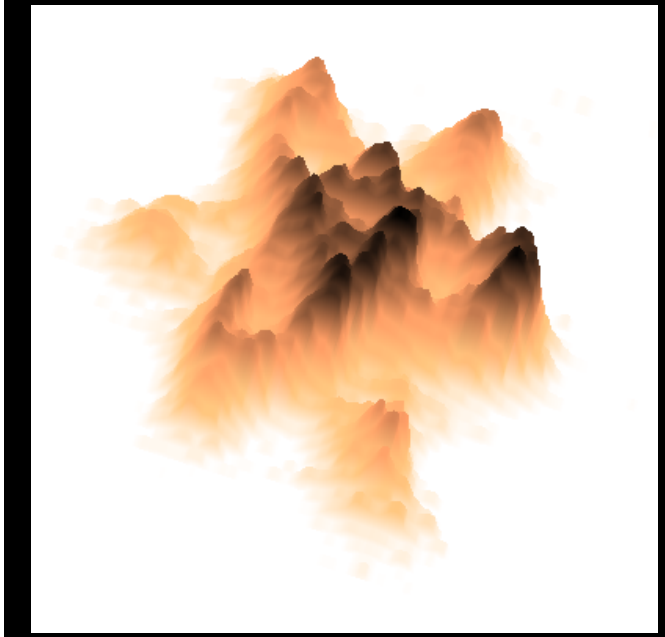
AND

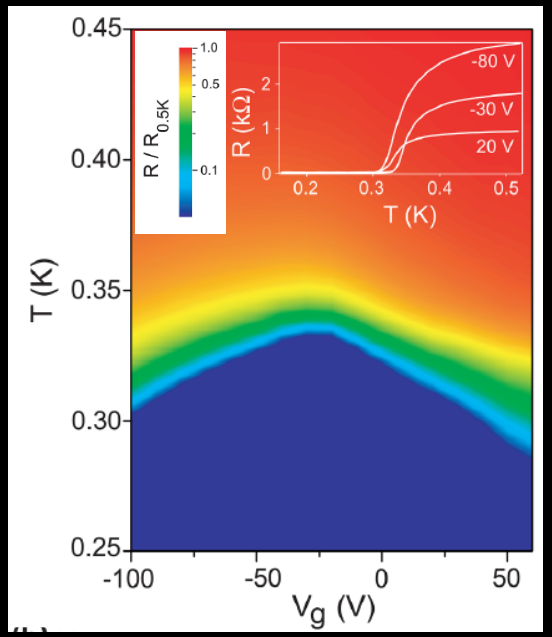
→ **Phase transitions**
→ **New states of matter**
→ **Exotic order parameters**

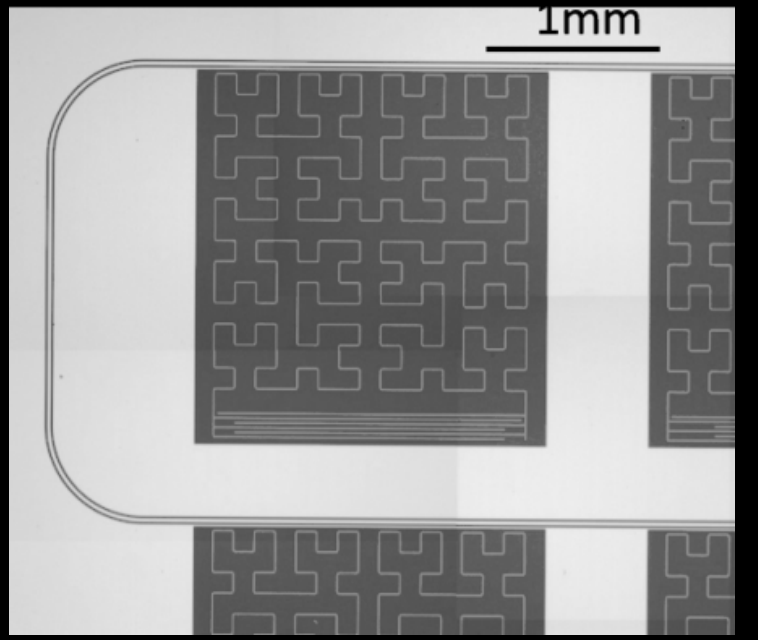


HCERES evaluation of Laboratoires de la vallée d'Orsay

- CSNSM
- IMNC
- IPNO
- LAL
- LPT







Solid-State Physics

Speaker : A. F. Santander-Syro

On behalf of the Solid State Physics group @ CSNSM

14-17 January 2019

Human resources

Permanent members @ 12/2018:

- 3 Maîtres de Conférences UPSud
- 3 CNRS (CR)
- 2 Research Engineers
- 1 Emeritus CNRS (DR)

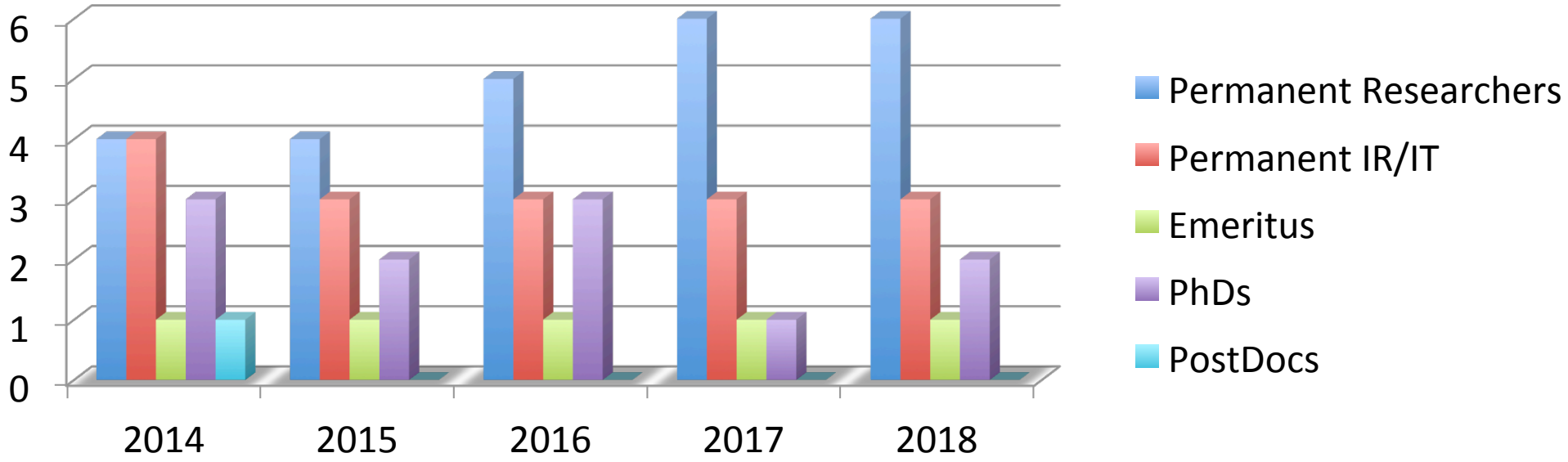
\+ 3 Engineers (Instrumentation Group) involved in our projects

Non-permanent @ 12/2018:

- 2 PhD students

Other members 2014-2018:

- 1 PostDoc
- 3 PhD students
- 5 Internships
- 3 Senior researcher visitors



Finances

(PI = Principal Investigator)

ANR

- 4 ANR Blancs (2 as PI)
- 2 ANR Jeunes (1 as PI)

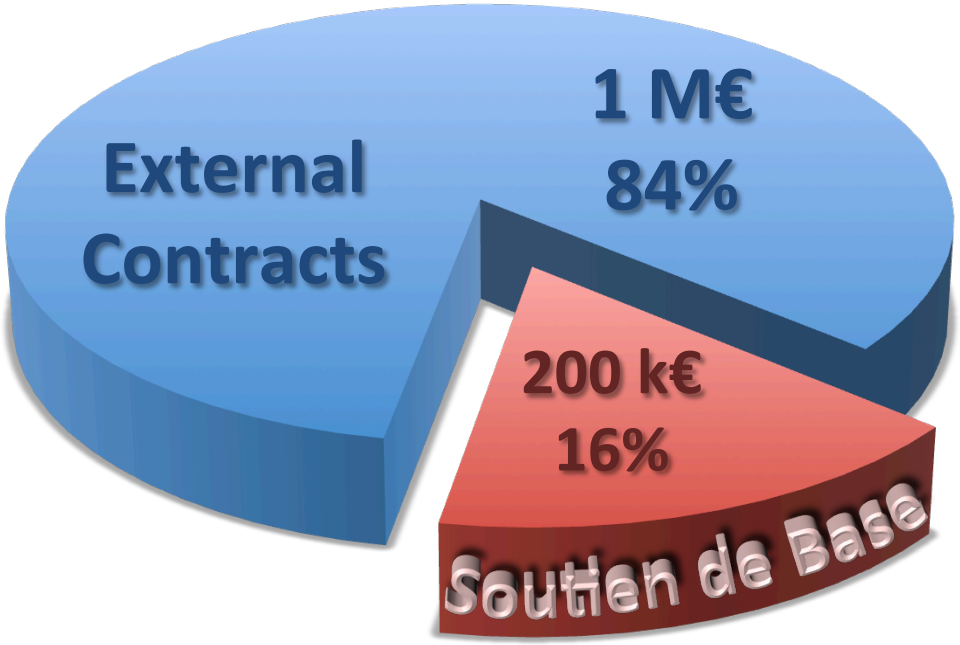
LabEx

- 4 LabEx PALM (3 as PI)
- 1 LabEx Nano-Saclay

Other:

- 2 RTRA (1 as PI)
- 1 DIM OxyMORE (PI)
- 2 PICS-CNRS (2 as PI)

Origin of resources 2014-2018



Teaching

- M2 Fundamental Concepts in Physics (M2-iCFP)
- M2 Grands Instruments
- M2 Outils et Systèmes de l'Astronomie et de l'Espace (M2-OSAE)
- M2 Chimie
- M1 & Magistère de Physique Fondamentale d'Orsay
- M1 Matériaux Paris-Saclay
- M1 Advanced Materials Engineering
- M1 SERP+ Chemistry
- L3 Physique
- L1 Maths-Physique-Informatique (MPI)
- PolyTech – Paris-Sud
- Préparation aux cursus scientifiques d'Orsay
- Formation Permanente Paris-Sud
- Institut Villebon *Georges Charpak*

Teaching Responsibilities:

- Vice-President CSU-28 Université Paris-Sud
- Head of Studies – L3 Magistère de Physique Fondamentale
- Alumni Relations Officer – Magistère de Physique Fondamentale
- Member of the Commission Innovation Pédagogique Paris-Sud
- Web management – Magistère de Physique Fondamentale d'Orsay

Teaching Publications: 1 Am. J. Phys; 1 Papers in Physics

Teaching Prizes: Passion Enseignement et Pédagogie dans le Supérieur

Outreach

- Science Fair CSNSM
- **Jury** – French Physicists Tournament
- **Presentations** – French Physical Society

- **Scientific Boards:** CSU-28 (UPSud), Conference on Low Temperature Detectors, LabEx PALM.
- **Referee work:** Science, Nature, Nat. Commun., Nat. Mater., Nat. Phys., Nat. Quantum Mater., Adv. Mater., PRL, PRB, …
- **Reviews:** ANR (FR), NSERC (CA), FOM (NL), Swiss-NSF (CH), IBS (South Korea), NCN (Poland), MSTS (Israel)

Organization of Schools

Les Houches

School on UV and X-Ray Spectroscopies of Correlated-Electron Systems

- SUCCESS-2014
- SUCCESS-2017

Aussois

Ecole 2018: Détection de Rayonnements à Tres Basse Température

Other

GDR 2016: Quantum Mesoscopic Physics

ÉCOLE DE PHYSIQUE
des HOUCHES

UNIVERSITÉ Grenoble Alpes

SUCCESS-2017
School on UV and X-ray spectroscopies
of correlated electron systems
4-15 September 2017

DRTBT2018

ÉCOLE THÉMATIQUE
DÉTECTION DE RAYONNEMENT
À TRÈS BASSE TEMPÉRATURE
Aussois du 9 au 14 décembre 2018

Publications

Peer-reviewed journals: 46 papers

Including, as **corresponding authors:**

- Nature Materials (1)
- Nature Communications (2)
- Advanced Materials (1)
- Phys. Rev. Materials (2)
- Phys. Rev. B – Rapids (5)
- Phys. Rev. B (2)
- Scientific Reports (2)

Proceedings: 39 papers

Talks

INVITED – Conferences: 21

INVITED – Schools: 5

Contributed: 4

Seminars: 37

Giant spin splitting of the two-dimensional electron gas at the surface of $SrTiO_3$

A. F. Santander-Syro[1]*, F. Fortuna[1], C. Bareille[1], T. C. Rödel[1,2], G. Landolt[3,4], N. C. Plumb[4], J. H. Dil[3,4,5]* and M. Radović[4,5,6]*

Momentum-resolved hidden-order gap reveals symmetry breaking and origin of entropy loss in URu_2Si_2

C. Bareille[1,*], F.L. Boariu[2,*], H. Schwab[2], P. Lejay[3,4], F. Reinert[2,5] & A.F. Santander-Syro[1]

Dissipative phases across the superconductor-to-insulator transition

F. Couëdo, O. Crauste, A. A. Drillien, V. Humbert, L. Bergé, C. A. Marrache-Kikuchi & L. Dumoulin

Prizes/Honors

- Junior Chair – Institut Universitaire de France (2011 – 2016)
- BQR “Emploi” – Université Paris-Sud (2016)

Invited Professorships

- Institute of Solid-State Physics – University of Tokyo (2014, 6 months)
- HiSOR Synchrotron – Hiroshima University (2017, 6 months)

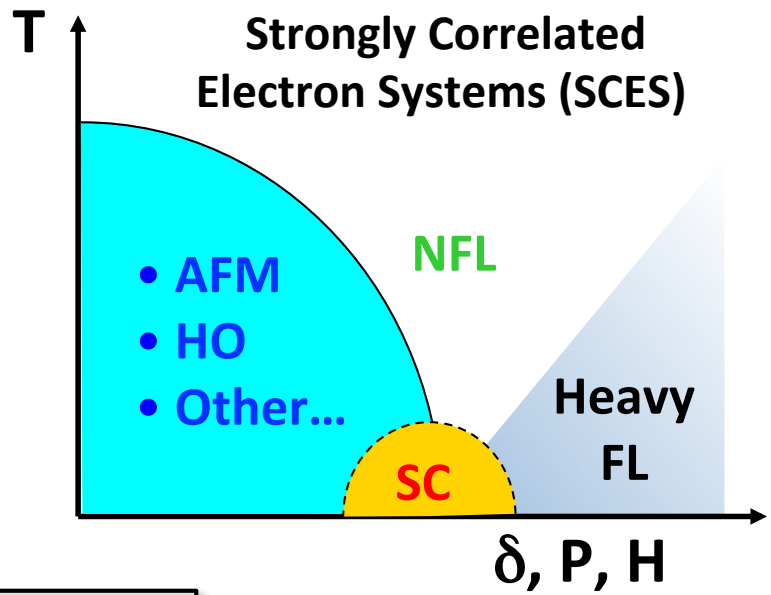
The University of Tokyo
The Institute for
Solid State Physics

Fundamental Solid-State Physics

Context and aims of our research

TOPICS

- **Correlated-electron** systems
- **Low-dimensional** materials
- **Detectors** for astrophysics and HEP



GOALS: Study and Understand…

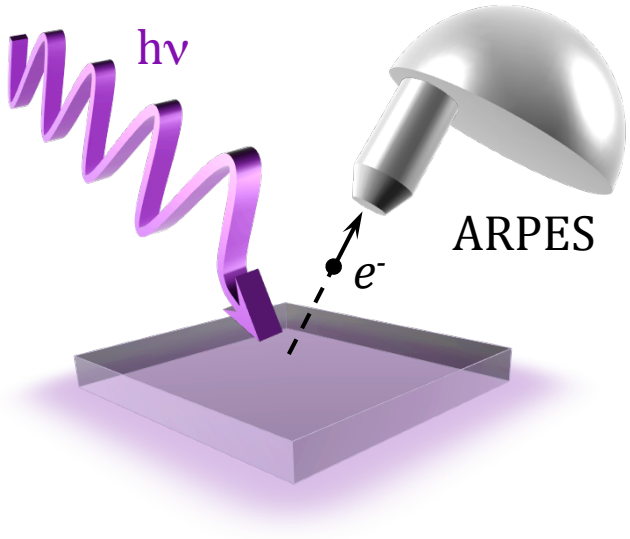
- **Novel electronic states of matter**
- **Interplay disorder – 2D superconductivity**
- **Radiation-matter interaction → Detectors**

Fundamental Solid-State Physics

Techniques and collaboration networks

TECHNIQUES

- Low-T (<1K) transport
- High-frequency (GHz)
- μ-fabrication (clean room)
- ARPES & XPS
- Focused Ion Beam & TEM
- Numerical simulations



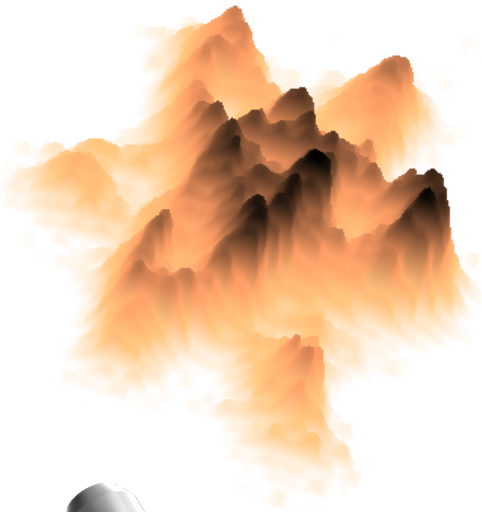
COLLABORATIONS

- **France:** LPS, ICMMO, Thales, C2N, SOLEIL, X, SPEC (CEA), NEEL, CRISMAT, LOMA

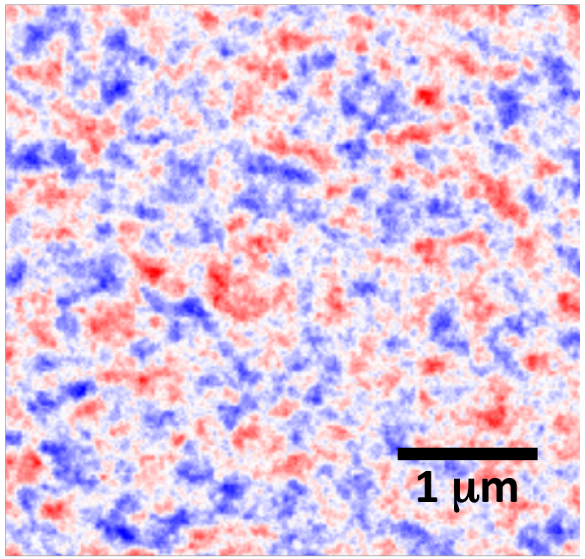
- **International:** UCSD (San Diego), MagLab (Tallahassee), LANL (Los Alamos), Uni-Campinas (BR), CNEA (AR), DIPC (San Sebastián, ES), Uni-Würzburg (DE), Uni-Frankfurt (DE), Uni-Twente (NL), ISSP (JP), HiSOR (JP), Uni-Kyoto (JP), Bar-Ilan University (IL), Weizmann Institute (IL)…

Research Highlights

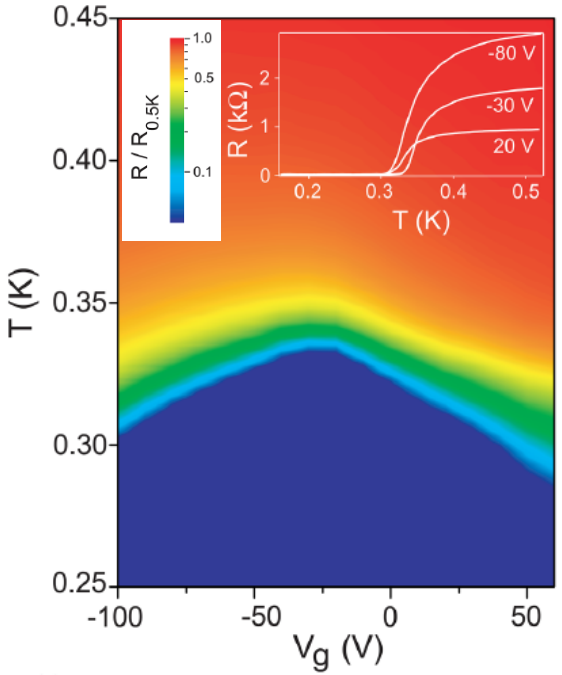
Novel 2DEGs in transparent oxides



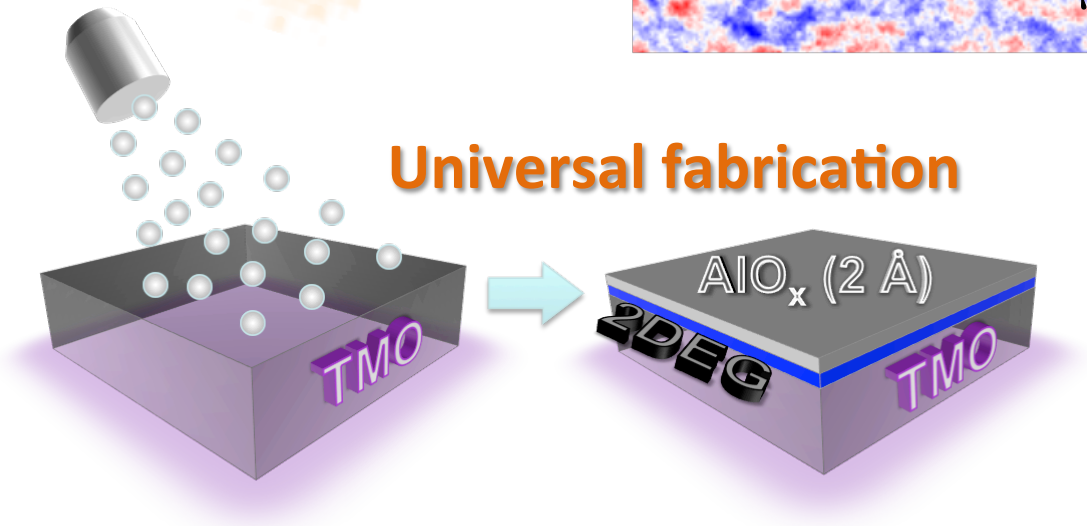
Nano-magnetism



Tunable Superconductivity



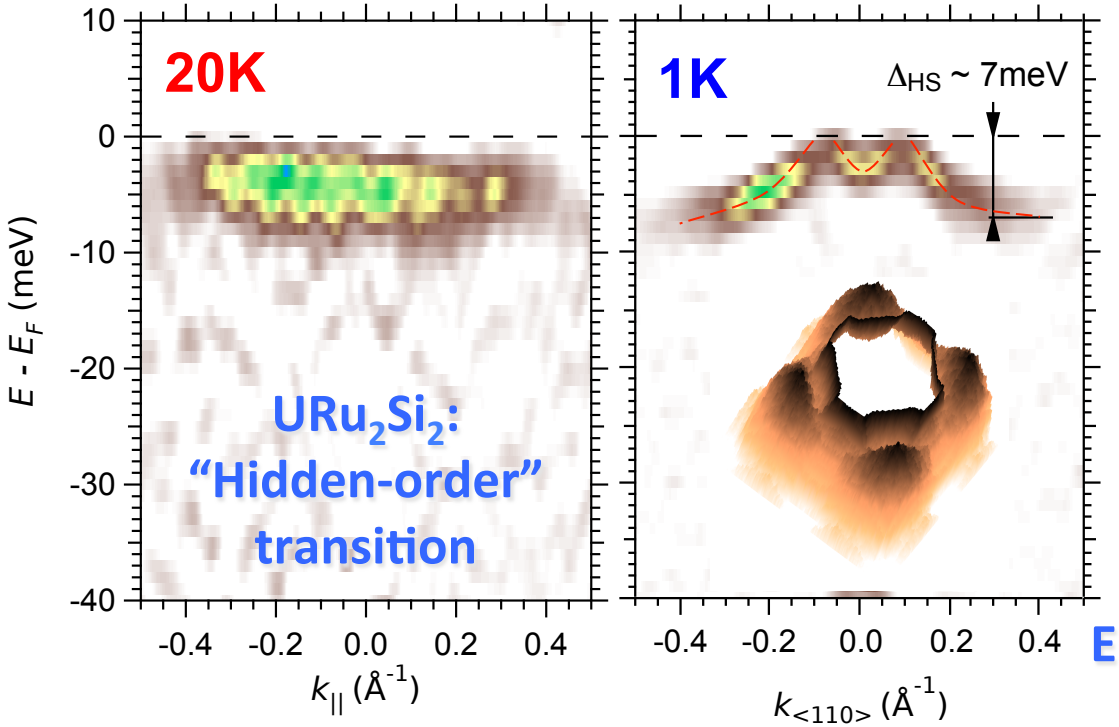
Universal fabrication



- Nature Mater. **13**, 1085 (2014)
- Nature Commun. **7**, 11781 (2016)
- Adv. Mater. **28**, 1976 (2016)
- Phys. Rev. App. **1**, 51002 (2014)
- J. App. Phys. **124**, 213902 (2018)

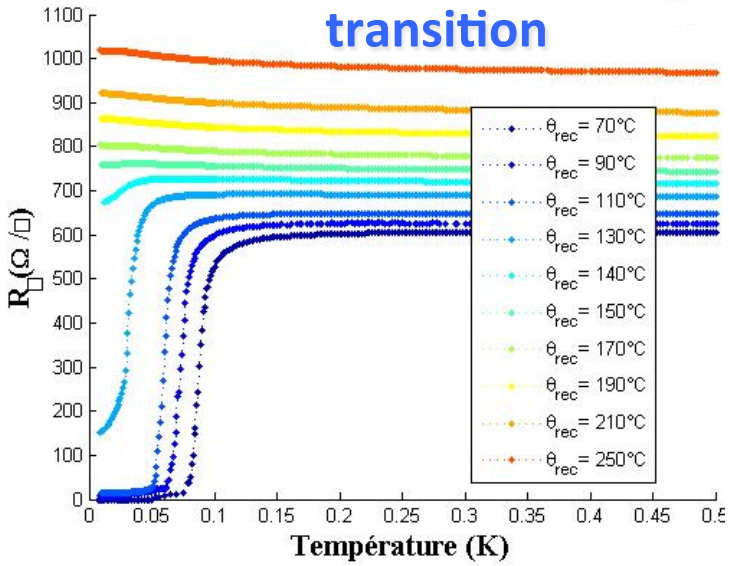
Research Highlights

Exotic classical and quantum phase transitions

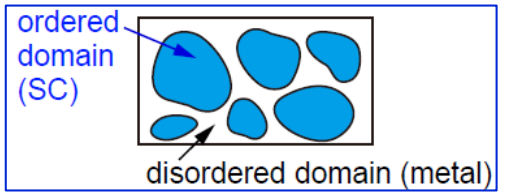


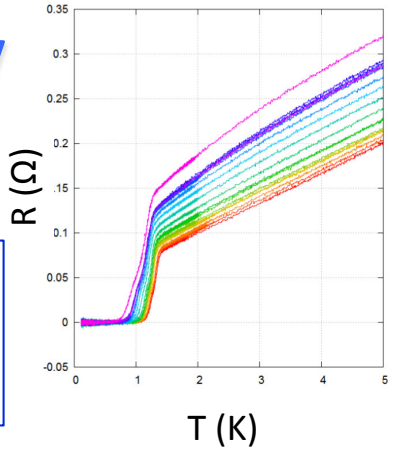
- Nature Commun. **5**, 4326 (2014)
- Sci. Reps. **6**, 35834 (2016)
- PRB **97**, 014521 (2018)

a-NbSi: SC-Insulator transition



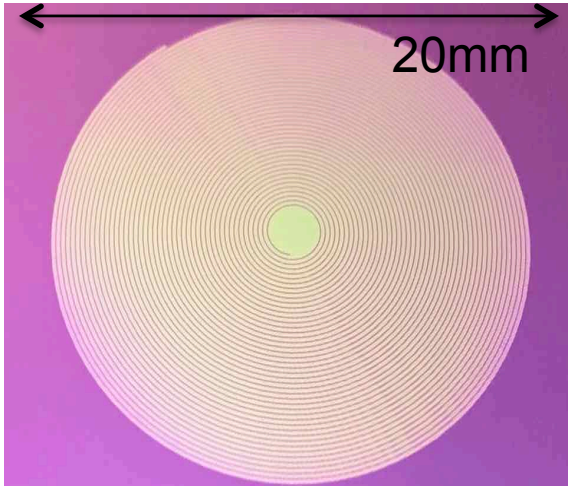
Electronic granularity in organic superconductors

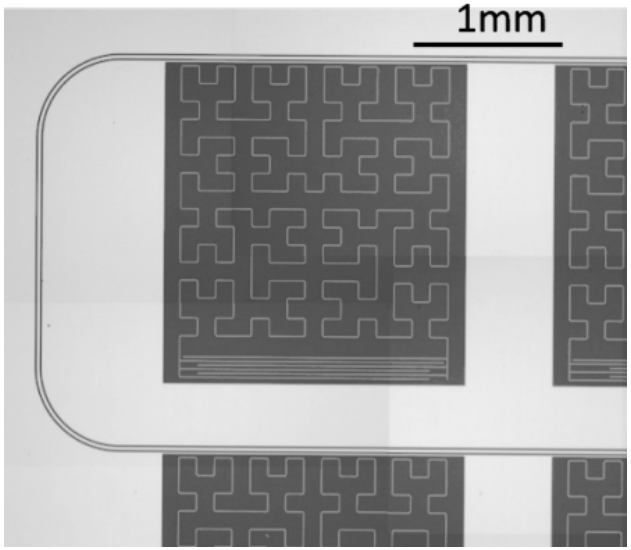




Research Highlights

Application of Condensed-Matter Physics to DETECTORS





- Development of high- and low- impedance **Transition Edge Sensors (TES)**
  - → Cryogenic sub-Kelvin detectors
  - → Edelweiss, QUBIC and LUMINEU
- Understand the electrodynamics of disordered superconductors and proximity effect multilayers:
  - → **Kinetic Inductance Detectors**
  - → High efficiency photon detectors
- **Modeling of radiation-matter interaction**
  - → Very low T bolometers
  - → For Edelweiss experiment

Project 2019-2023

Correlated electron systems & ARPES

2D electron systems in correlated and functional oxides

- **Aim 1:** Realization of **novel types of 2D electron systems in correlated oxides**
- **Aim 2:** Exploration and **tailoring of their electronic structure**
- **Aim 3:** Study the interplay between **2D quantum confinement** and **spin-orbit interaction, correlations, and collective phenomena** (e.g. superconductivity) in the properties of 2D electron systems in functional oxides.

Towards Applications

- Realization of (nano-)devices using 2DEGs in functional oxides.

Low-temperature (1K) & high-resolution (1meV) ARPES setup

- Setup and characterization of a laboratory ARPES machine (2D electron detection)
- He-free sample cooling down to 1K
- In-situ fabrication of samples (MBE)

Project 2019-2023

Exotic classical and quantum phase transitions

Quantum critical transitions in heavy-fermion materials

- **Aim 1 :** understand the relation between **changes in electronic structure** and **symmetry breakings** across a Quantum Phase Transition (QPT)
- **Aim 2:** explore experimentally the analogies between QPTs and problems in Cosmology (e.g., black holes)

Superconductor-to-Insulator transition

- **Aim 1:** settle long-standing controversy on the existence of 2D metallic states by specific heat measurements, tunneling measurements
- **Aim 2:** model systems for high energy physics problems. Universal behavior close to critical points in correlated systems
- a-NbSi, YSi, NbN, $AlO_x/SrTiO_3$

Exotic superconductivity

- Visual proof of granular superconductivity in clean crystalline samples
- Organic Superconductors (coll. LPS, Kyoto Univ., INSP)

Project 2019-2023

Application of Condensed-Matter Physics to DETECTORS

Development of very low energy threshold sensors:

- **Essential for EDELWEISS and RICOCHET**
- Single charge detection in massive Ge crystals
- Thermodynamic temperature fluctuations limited macro-bolometers

R&D on superconducting sensors for temperature and charge read-out :

- Out of equilibrium athermal phonon sensors
- Superconducting Single Photon Detectors technology for charge read-out

Modeling of radiation-matter interaction in cryogenic detectors for EDELWEISS:

- **Aim:** model charge collection with special reference to near-surface interactions, taking into account the phonon-wind-driven expansion of the electron-hole cloud generated by particle interaction (Steranka et al, PRL 53 2181 (1984)).
- Development of a dedicated code & comparison with experimental data

R&D on superconducting sensors for event discrimination (for CROSS) :

- **Aim:** surface event tagging thanks to superconducting thin films

Perspectives:

Teaching – Outreach – Valorization

Teaching :

- Continue our strong implication in the **teaching and administrative activities** of the Physics Department, **from L1 to M2 and Doctoral Studies**.
- Setup of a **platform for lab-practices in photoemission**

Outreach :

- Realization of **MOOCs** on Condensed-Matter Physics and Correlated Electron Systems

Valorization :

- Patents for devices using functional oxides

Perspectives:

Human resources

Researchers & Engineers:

- 1 CNRS/Faculty: Compensate for the departure in 2019 of 1 CNRS researcher at the interface between condensed-matter research and applications to detectors.
- 1 Research Engineer: Evolution of complex state-of-the-art equipment in ARPES and ultra-low temperature measurements.

Technical staff:

- 1 Assistant Engineer/Technician: Maintenance of photoemission, transport and nano-fabrication instruments.

Expectations:

Funding

Local & National Funding :

- LabEx: 3-4 projects for PhDs, post-docs, and equipment (100-200 k€)
- ANR: 2-3 projects as Principal Investigators, 2-3 projects as partners
- PICS: 2-3 projects to continue our successful collaborations (Japan, Argentina) establish new ones (Brazil, Netherlands, Israel,…)

European & International Funding :

- ERC: Postulate to 1 Advanced and 1-2 Consolidator grants

STRENGTHS

- High quality research (papers, invitations).
- Successful in a large field of frontier subjects & techniques.
- Worldwide recognition in our field.
- Strong international collaborations.
- Remarkable capability to attract funds at all levels (regional, national, European).
- Numerous PhDs and undergrad trainees.

WEAKNESSES

- Dilute manpower in the different projects.
- Lack of a permanent young researcher expert in low-T detector technology and related astroparticle physics applications.
- Only partial exploitation of the possible links among the particle-detector and the fundamental-solid-state-physics components of the group.
- Scarce funding from IN2P3 for our basic-research activities (essentially SB only).

OPPORTUNITIES

- Prospects to play a crucial role in major astroparticle and astrophysics projects.
- Exploitation of basic research.
- Strong potential for applications.
- Frequent use of international large scale facilities leads to fruitful transversal collaborations.
- Active participation in international review committees provides a deep view of the state-of-the-art research worldwide

THREATS

- The fusion of the laboratories will dilute the representative power of the Solid-State Physics team.
- Importance of keeping a research in fundamental Solid-State Physics, not subject to development of detectors.
- Some of the fabrication techniques uniquely developed by us strongly rely on the know-how of just one researcher.