FACULTÉ DES SCIENCES ET TECHNOLOGIES

Université de Lille

PMM
Physics of Molecules and Materials

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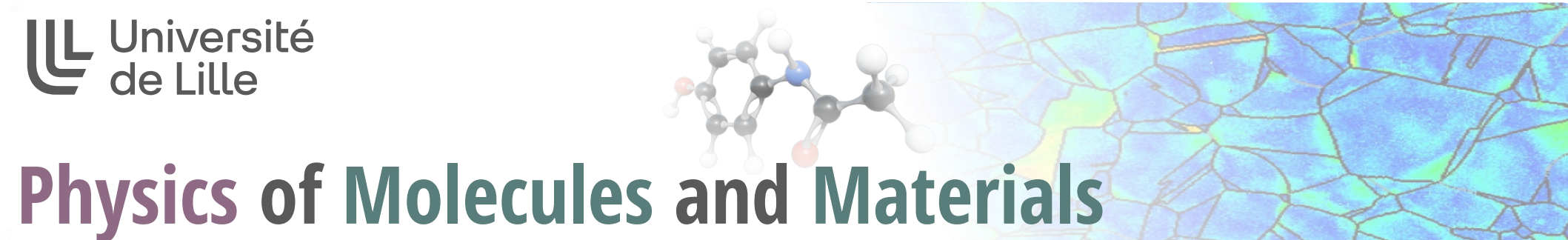
Presentation January 2026



Introduction for PMM

Generalities

- PMM = “Physics of Materials and Molecules”
- 2-years track, part of the “Applied and Fundamental Physics” master’s program
- Some classes shared with
  - “Quantum and Photonic Technologies” master track
  - “Advanced Physics of Pharmaceutical Materials” master track
- Number of students: up to 15 for “Physics of Materials and Molecules”

Entry requirement

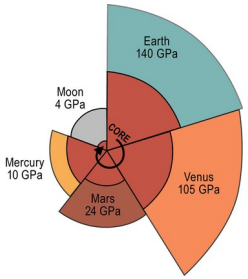
- In first year
  - Bachelor or 3rd year university degree in physics or physical chemistry
- In second year
  - Master or 4th year university degree in physics or physical chemistry

Jobs and careers

- Research in academia
- Public or private research laboratories
- Industry

Training objectives

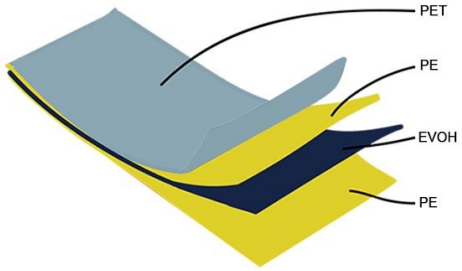
Science for discovery ⟺ *Science for solutions*



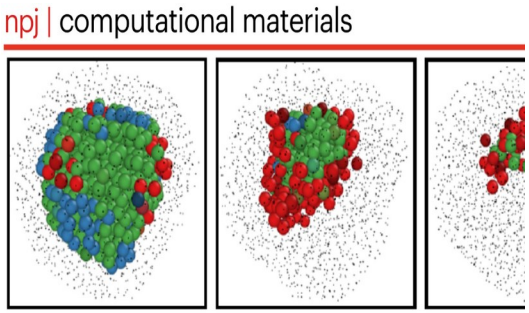
Planetary building blocs
Molecules in the solar system

Metals, applications,
and limitations

Design advanced
experiments

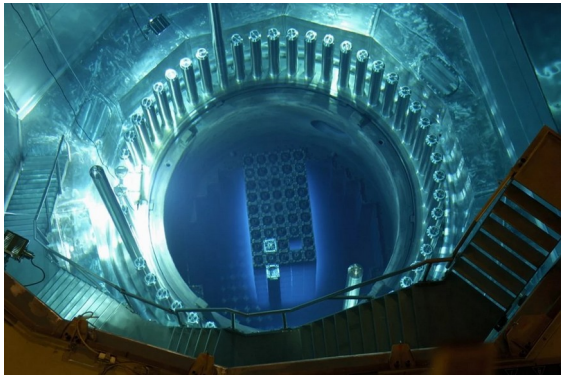


Advanced polymers
for new packaging



Advanced
atomistic
calculations

Materials for novel
energy sources



Training objectives

Physicists and chemical-physicists capable of tackling the major scientific questions of the 21st century

PMM will teach you how to

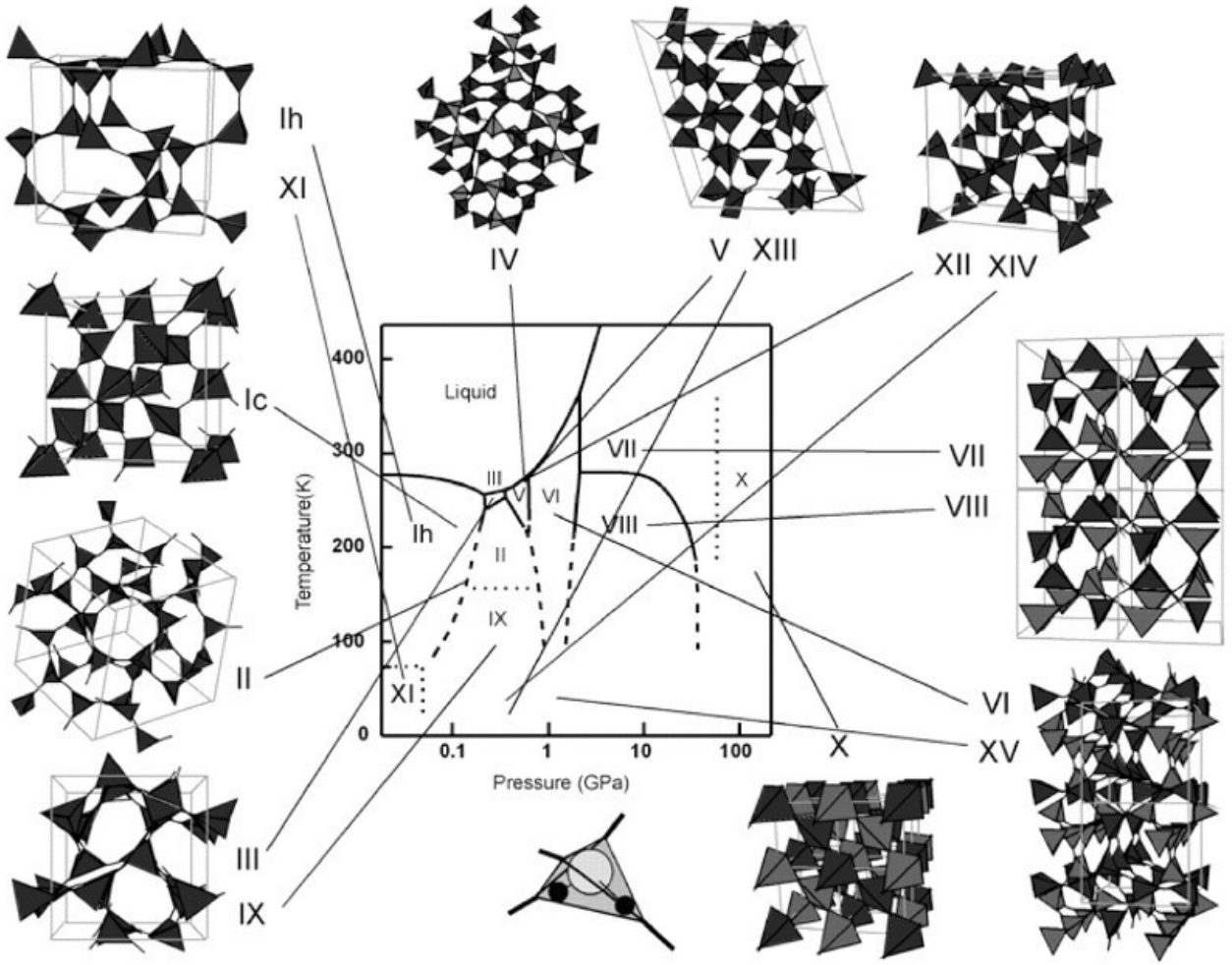
- *Solve concrete problems*
  - Design new materials for tomorrow's industry
  - Improve materials properties in their conditions of use
  - New materials for new energy sources

- *Address fundamental questions*
  - Matter within planets and atmospheres
  - Defects and materials thermodynamics
  - Calculations and theories for the atomic scale
  - Use of major international research instruments

A “simple” material: H_20

H_2O phase diagram

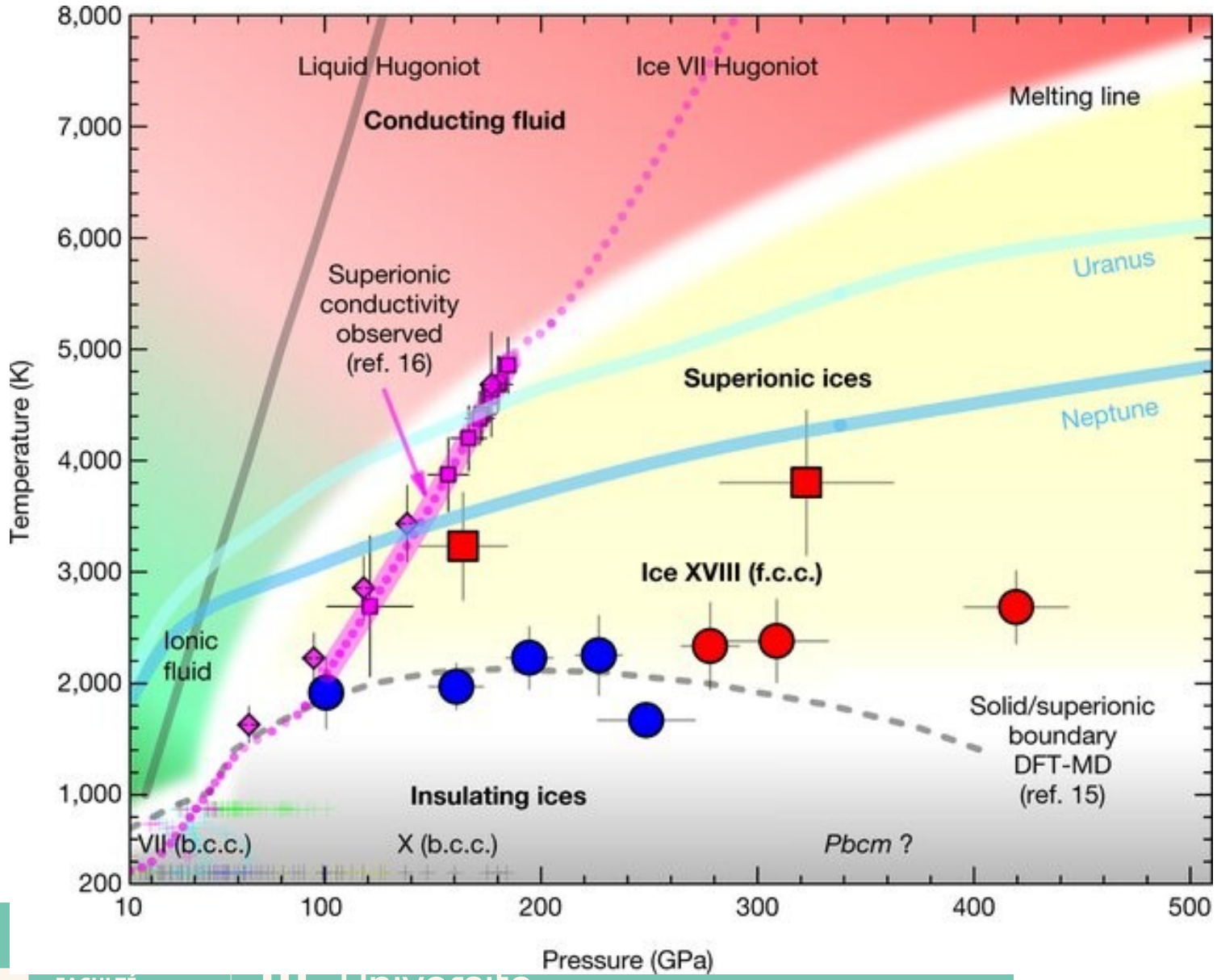
Umemoto Rev. Miner. Geochem. (2015)



Effect of pressure and temperature on H_20

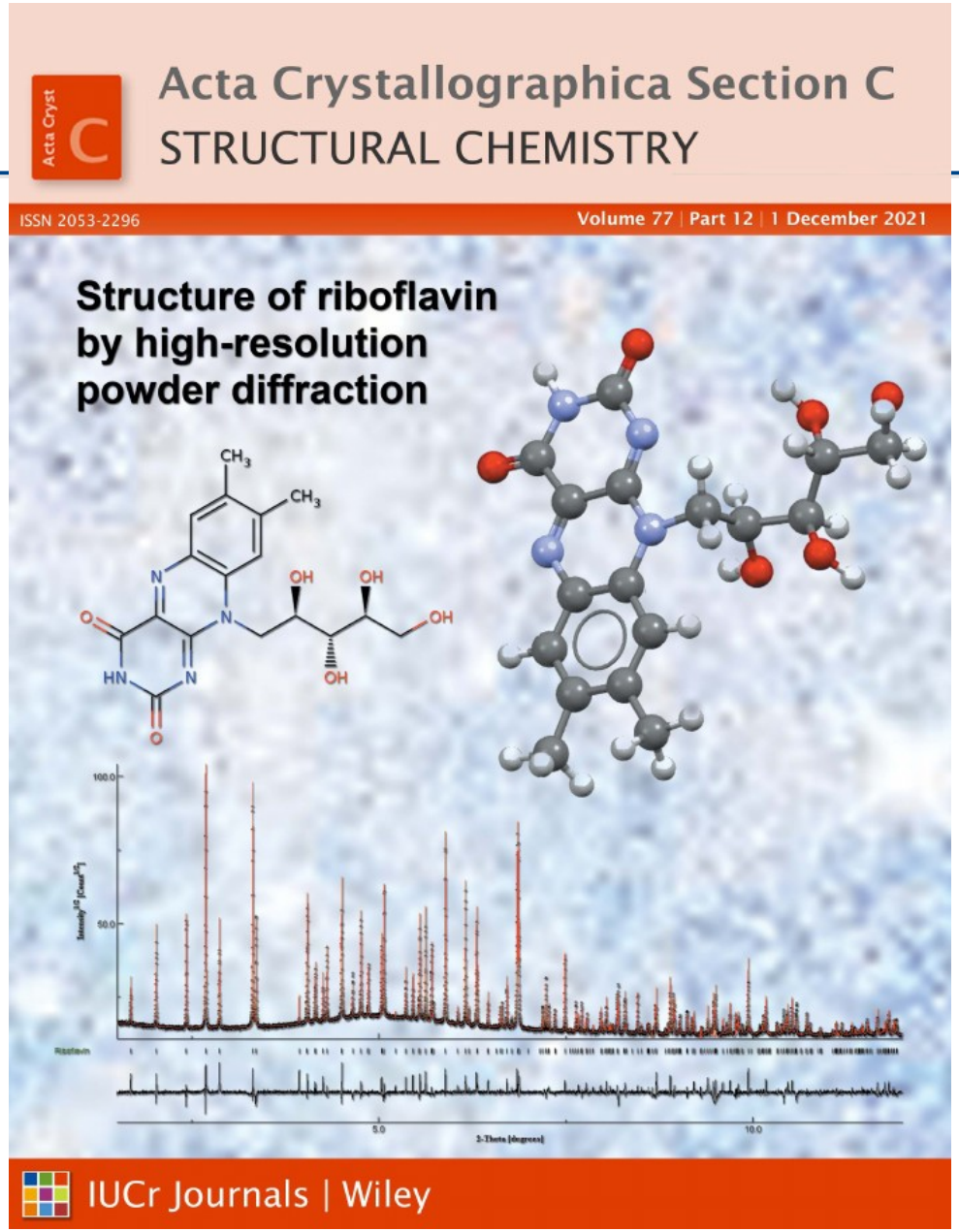
- Over 15 known solid crystal phases
- Requires
  - Thermodynamics
  - Solid state physics
  - Advanced experiments (spectroscopy, diffraction)
  - Quantum calculations
- Applications
  - Extreme environments
  - Planetary interiors

Ice, again!



Millot, Coppari et al, 2019

Vitamins?



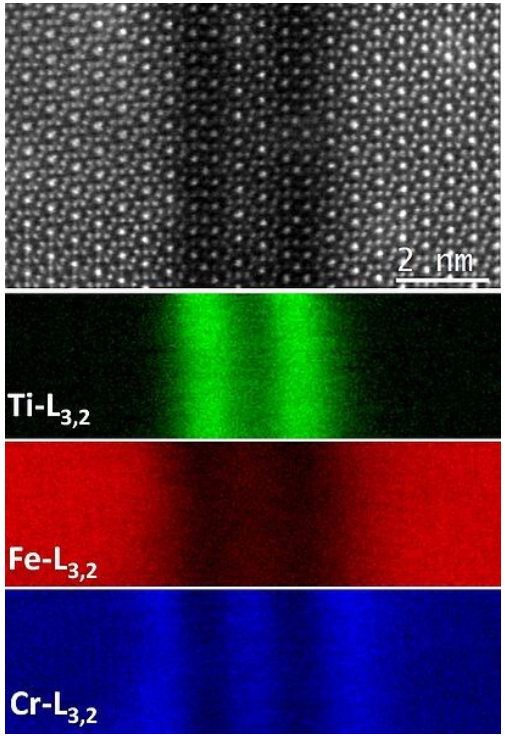
Vitamin B2

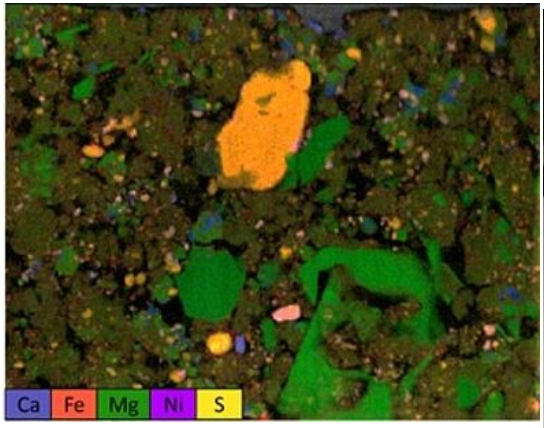
Riboflavine ($C_{17}H_{20}N_4O_6$)

Structure solved with

- Crystallography
- X-ray diffraction
- Advanced quantum calculations

Advanced modeling and characterization techniques





Left: phase transformation in a Martian meteorite

Top: chemical mapping of a chondrite

Electron microscopy

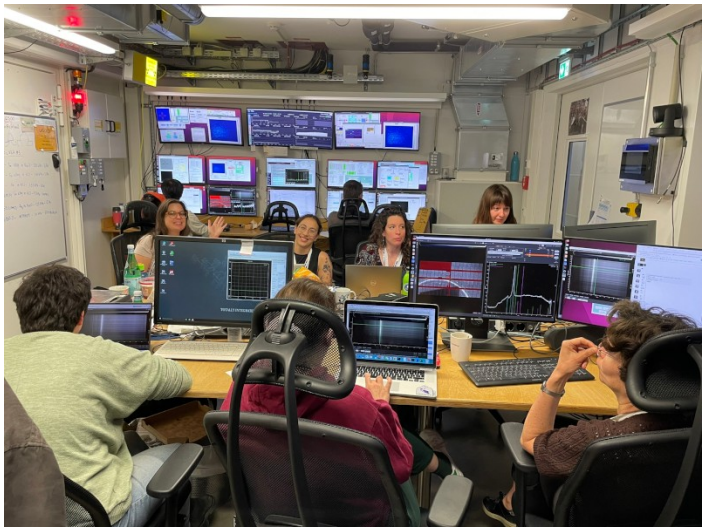
TEM at the Chevreul Institute (on campus)

Spectroscopy

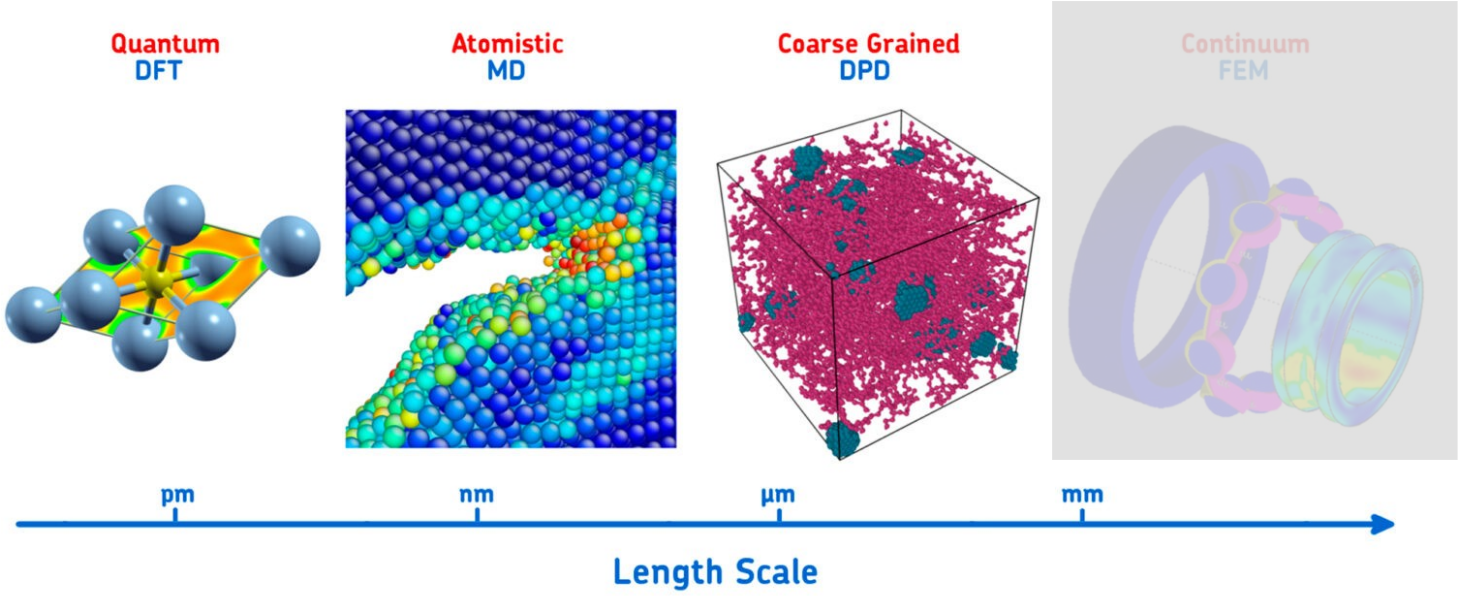
Supercam on Perserverance (artist rendering)

Raman spectroscopy, time-resolved fluorescence (TRF) spectroscopy, and Visible and InfraRed (VISIR) reflectance spectroscopy

Advanced modeling and characterization techniques



European X-ray laser in Hambourg



Atomic scale modeling

Research laboratories support

Attached laboratories in Lille

- UMET: Unité Matériaux et Transformations
  - Materials science, interface between physics and chemistry
  - Applications to polymers, metals, pharmaceutical materials, Earth and planetary science, etc
- PhLAM: Physique des Lasers, Atomes et Molécules
  - Molecular physics
  - Spectroscopy and applications
  - Theoretical Molecular Physico-Chemistry
- IEMN: Institut d'Electronique, Microélectronique et Nanotechnologie
  - Physics of nanomaterials
  - Wave propagation in structured materials
- LOA: Laboratoire d'Optique Atmosphérique
  - Physics and spectoscropy for the observation of atmosphere

Internships can be made outside Lille. It is not required to stay on site, nor in France. First year internships can be outside of academia.

Student target

Background in fundamental physics or physical chemistry, with students both

in search of solutions, who will be trained in the latest advances in the sciences of matter, and will be able to develop and exploit new materials, the latest analytical methods, and the analytical tools to tackle today's societal issues;

in search of discoveries, who will be able to understand the fate of matter in a variety of environments and conditions, from the core of a nuclear power plant, to polymers, metals, pharmaceutical materials, up to the interior of planets or the atmosphere.

*Physics for **solutions** with **discoveries,** physics for **discoveries** with **solutions.***

What will you learn?

Fundamental physics

- Thermodynamics and statistical physics
- Solid state physics
- Atomic and molecular physics
- Materials science
- Light and matter interactions

Observation and experiments

- Spectroscopy and diffraction
- Electron microscopy
- Large scale facilities (synchrotrons, accelerators, etc)
- Remote sensing, satellites

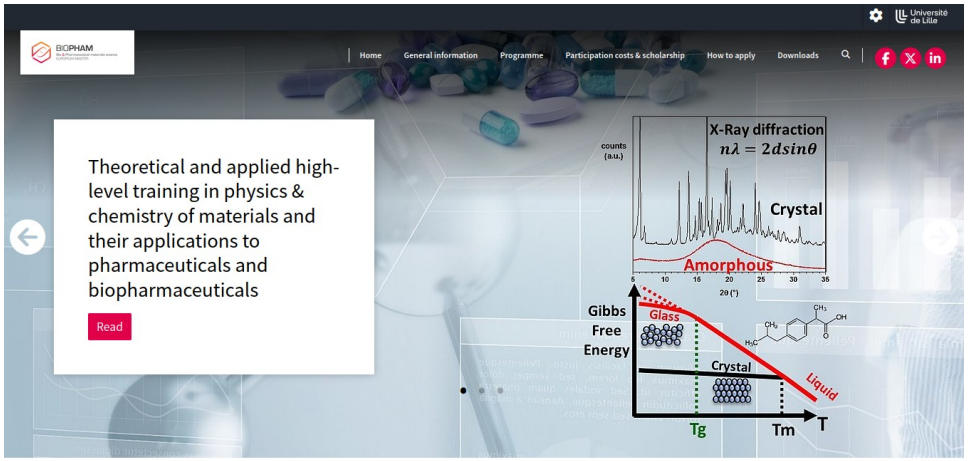
Computation methods

- IA and algorithms
- Molecular dynamics
- Quantum calculations (DFT)

Professional development

- Language courses
- Internships
- Tutored training on advanced topics
- Laboratory projects

BIOPHAM sister's program



~50% of classes in the condensed matter options are shared with BIOPHAM

BIOPHAM

- Erasmus Mundus Joint Master Degree
- Training in materials science and physics & chemistry of materials and their applications to pharmaceutical
- Semester 1 and 3 in Lille

Curriculum

3 teaching blocs, spread over 4 semesters

Bloc 1: Develop specialized skills to produce knowledge in fundamental physics

By implementing advanced and specialized uses of digital tools
By analyzing data for fundamental physics
By practicing an experimental approach adapted to a physics problem
By mobilizing and producing highly specialized knowledge

Bloc 2: Produce and communicate highly specialized knowledge, including in a professional context

By mobilizing and producing highly specialized knowledge
By implementing specialized communication for knowledge transfer
By contributing to transformation in a professional context

Bloc 3: Solving complex problems by applying fundamental physics concepts

By mobilizing and producing highly specialized knowledge
By solving complex problems using fundamental concepts of fundamental physics

Curriculum: Semester 1

Bloc 1
Specialized Skills

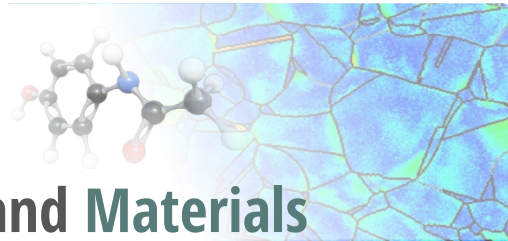
- AI and advanced computational methods in physics
  3 ECTS
- States of Matter and Materials Science Primers
  3 ECTS
- Atomic scale modeling I
  3 ECTS

Bloc 2
Professional Skills

- French or English
  3 ECTS
- Tutored trainings
  3 ECTS
- Materials science graduate program
  3 ECTS

Bloc 3
Fundamental physics

- Continuum mechanics
  3 ECTS
- Statistical physics and critical phenomena
  3 ECTS
- Condensed matter I Electrons
  3 ECTS
- Atomic physics
  3 ECTS



Curriculum: Semester 2

Bloc 1
Spezialized Skills

- Satellites and remote sensing
  3 ECTS
- Radiative transfer and radiation-matter interactions
  3 ECTS
- Large scale research infrastructures
  3 ECTS
- Experimental project
  3 ECTS

Bloc 2
Professional Skills

- Tutored trainings
  3 ECTS
- Internship
  6 ECTS

Bloc 3
Fundamental physics

- Condensed Matter II Phonons
  3 ECTS
- Fundamentals of molecular spectroscopy
  3 ECTS
- Microstructures and defects in materials
  3 ECTS

Curriculum: Semester 3

Bloc 1
Spezialized Skills

Electron microscopy and diffraction
3 ECTS

Advanced Spectroscopy of Molecular Systems
3 ECTS

Atomic scale modeling II
3 ECTS

Bloc 2
Professional Skills

French or English
3 ECTS

Speciality
6 ECTS

3 out of 5
Materials under extreme conditions
Metals and alloys
Polymers
Mathematical crystallography
Instrumentation in spectroscopy

Bloc 3
Fundamental physics

Advanced thermodynamics and phase transformations
3 ECTS

Molecular mobility and amorphous state of matter
3 ECTS

From macro to nanophysics
3 ECTS

Materials plasticity
3 ECTS

Curriculum: Semester 4

Bloc 2
Professional Skills

Option
or Graduate Program
3 ECTS

Internship
27 ECTS

Offers for internships 2024-2025

LOA

- Aerosol Measurement Over Oceans

PhLAM

- Characterization of Gas-Phase Atmospheric Organic Compounds and their Weakly Bonded Complexes via Rotational Spectroscopy
- Complexation of trivalent actinides by phosphate species
- Linking core spectra features of actinide complexes to their local environment
- Studying Reactivity of Atmospherically Relevant Radicals using Chirped Pulse Fourier Transform Millimeter wave spectroscopy
- Theoretical Investigation of the Surface Activity of Organosulfates on water droplets

Subjects for internships

- Can be outside Lille
- change from year to year, depending on students, labs, etc.
- Not so many from LOA this year. Could be different next year

UMET

- High PT experiments for modeling the Earth's inner core
- Machine-learning approaches for nanoparticle simulations
- Modeling of dislocations in perovskite oxides ABO3
- Phase-field modelling of radiation induced segregation application to nickel based alloys
- TEM analysis of a possible natural deep Earth sample

IEMN

- Using strong coupling to detect gas traces in the THz range
- Exploring Proteins quantum dynamics by using strong coupling in the Terahertz range
- Developing Novel THz Spectroscopy Techniques for Biological Sample sensing
- THz-Photonics in Biomolecular Research

Offers for internships 2025-2026

LOA

- Global volcanic gas emissions from satellite and ground-based observations
- Megafires : growth, persistence and climate impact of fire particles injected into the stratosphere
- Investigating Arctic Cloud-Aerosol Interactions Using EarthCARE satellite data
- Variability and long-term trends of vertical aerosol profiles at the ATOLL site: influence of extreme events and long-range transport
- Combining ground and space measurements to assess aerosol impacts on cloud microphysical properties
- Intercomparison of Radar Simulators Applied to LES Outputs
- Determination of the infrared spectral emissivity of natural Earth surfaces

UMET

- Microstructure Analysis by Transmission Electron Microscopy of an asteroid sample
- Machine-learning approaches for nanoparticle simulations

Subjects for internships

- Can be outside Lille
- change from year to year, depending on students, labs, etc.

PhLAM

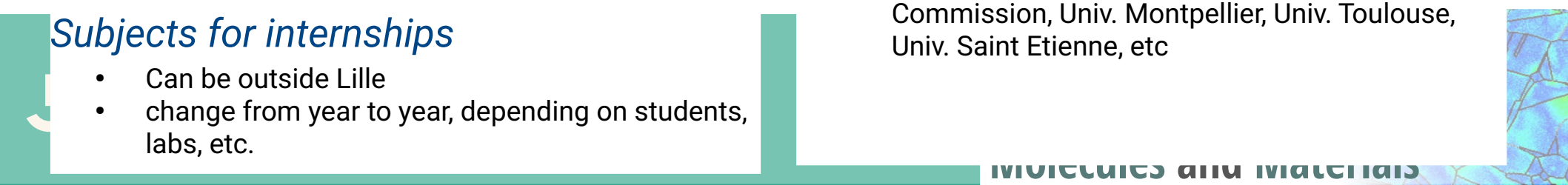
- Direct detection of dark matter by precision molecular spectroscopy
- Probing Actinides properties via quantum chemical approaches
- Time Evolution Millimeter Spectroscopy of Reactive Species: Instrumental Development
- Molecular-Level Characterization of Volatile Organic Compounds and their weakly bounded complexes: A Combined Spectroscopic and Theoretical Approach
- Linking core spectra features of actinide complexes to their local environment
- Molecular insights on the surface propensity of organosulfates

IEMN

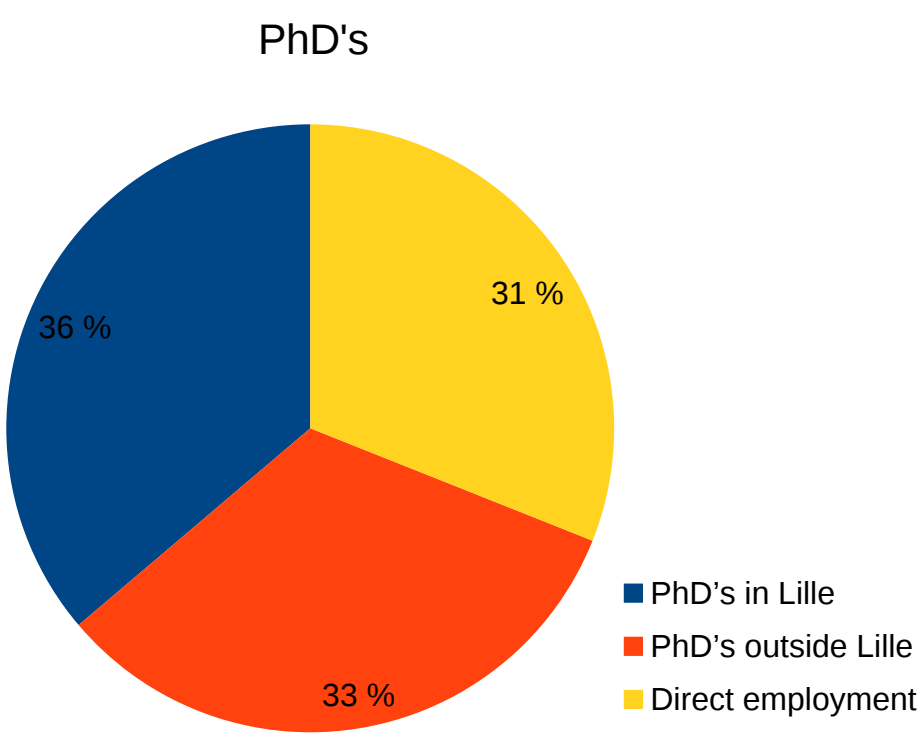
- Plasmonic Modeling and Simulation of Metallic Nanoparticles for Optimizing Electrochemical CO_2 Reduction

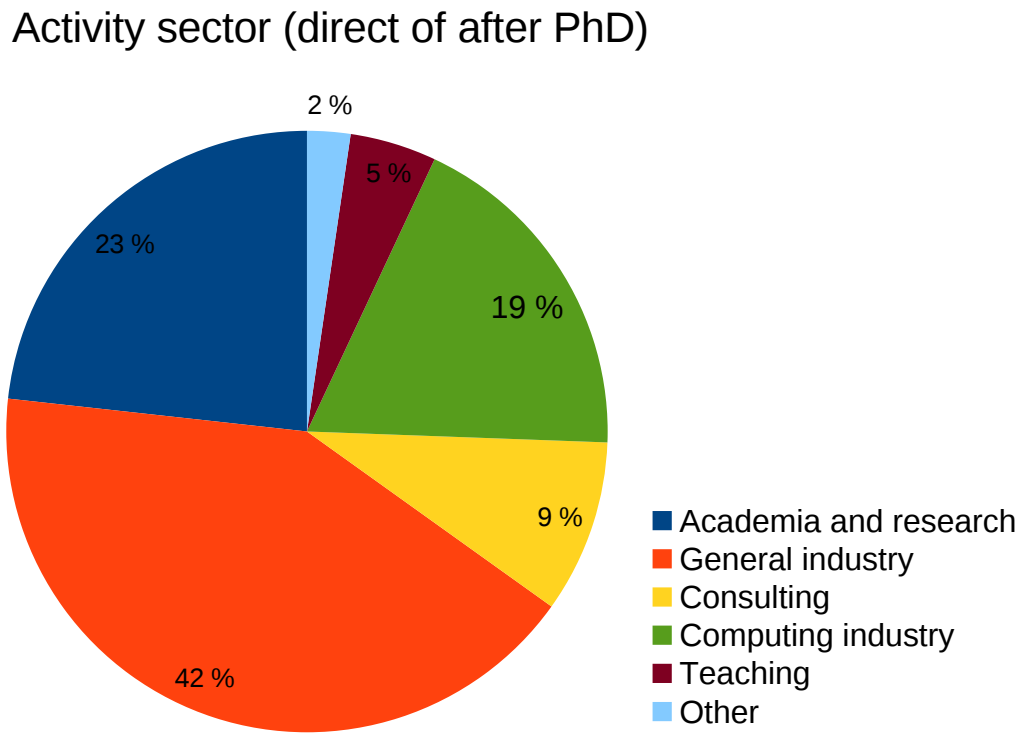
Outside Lille

- Offers at Gustave Eiffel University (Cergy outside Paris), Saint Gobain research labs, Atomic Energy Commission, Univ. Montpellier, Univ. Toulouse, Univ. Saint Etienne, etc



Statistics on ~60 students 2008-2024





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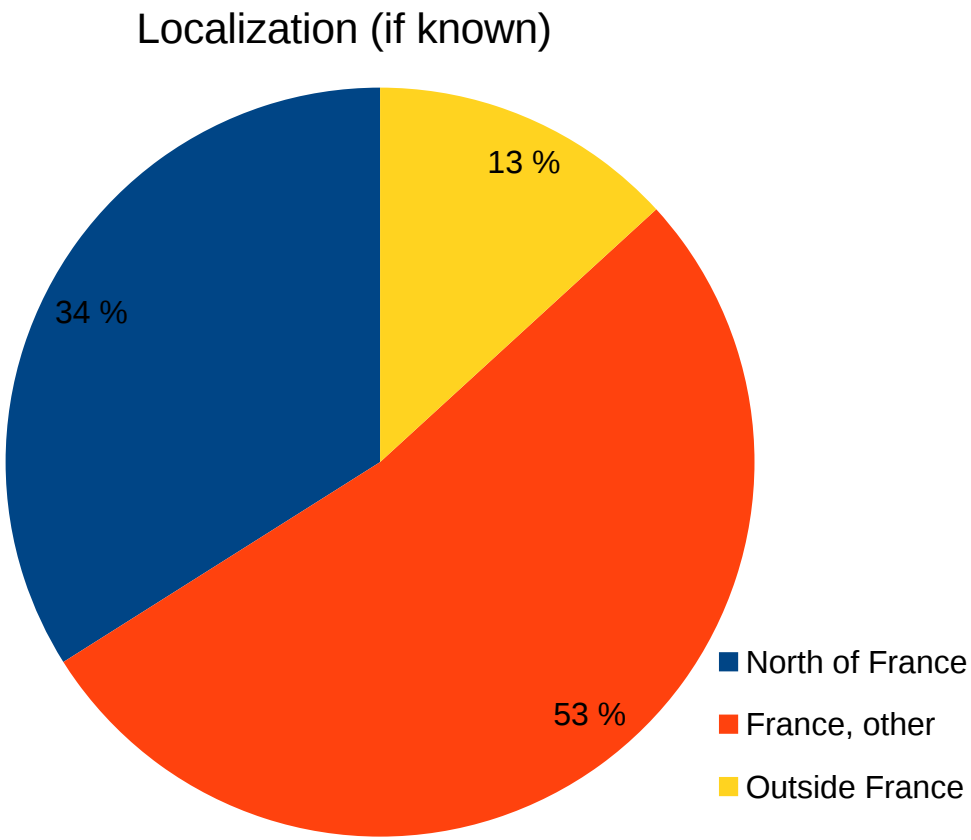


Former students: employers

Academia / Government agencies

- CNRS
- Yale University, US
- Phoenix University, US
- Université Tours
- Univ. Lille
- Universitas 17 Agustus 1945 Surabaya, Indonesia
- Canadian Nuclear Laboratories
- CEA
- Onera
- Grenoble INP
- Université libre de Bruxelles

Private sector (industry)

- Siemens Energy
- Framatome
- EDF
- Decathlon France
- Altsom
- Raclot Industries
- AstraZeneca
- Imerys
- Groupe Institut de Soudure
- ITP Interpipe
- Blue Capsule Technology
- PPG

Consulting / computer industry

- Devoteam G Cloud
- Sopra HR Software
- Sopra Banking Software
- Groupe Luminess
- Axecom
- Calogena
- DEF
- Assystem
- Power Inside Data

How to apply?

The "Etudes en France" (Studying in France) procedure

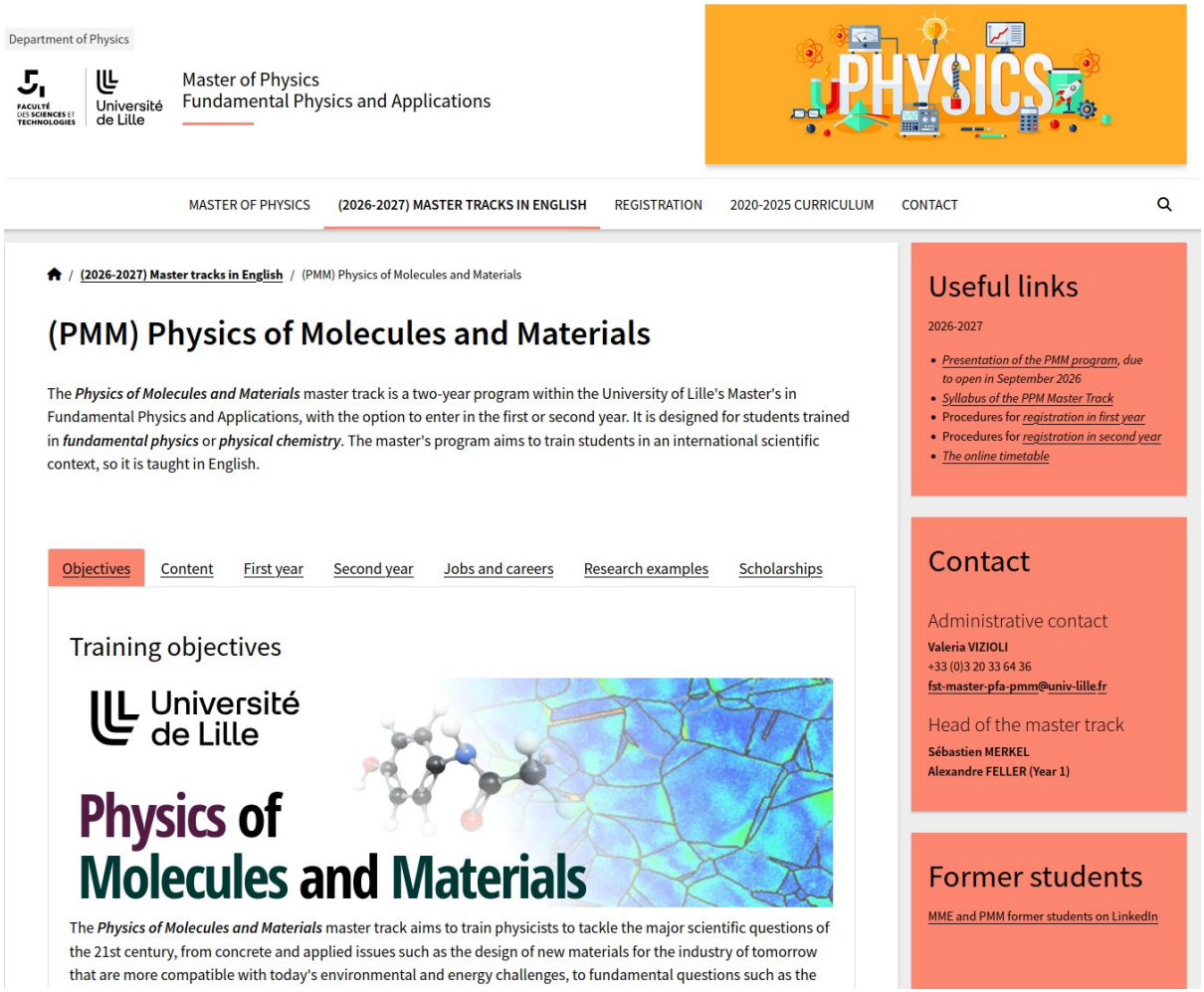
- Applies to ~70 countries
- Create an account on the "***Study in France***" platform and apply
- Deadlines: ***mid-December***, probably
- Will take care of admission procedures and visas

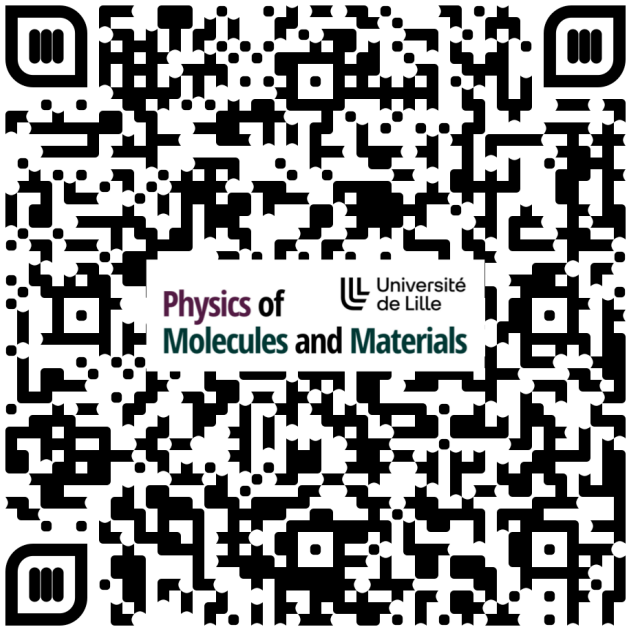
Students with no procedures on "Etudes en France"

- 1st year: use ***monmaster.gouv.fr*** internet platform, the French national platform for information and applications for a national Master's degree. Applies to
  - International students residing in France;
  - Students who are citizens of or reside in a country in the European Economic Area;
  - International students who reside in a country that is not covered by the "Etudes en France" procedure.
- 2nd year: apply directly to the University, on a platform called ***e-candidat*** (same conditions as above)
- Deadline: ***spring 2026***.

"Etudes en France" is mandatory if you do not meet the conditions above. Do not try to apply directly. We can not accept applications that do not follow the procedure.

Updates and additional information





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