Laboratoire Kastler Brossel
Physique quantique et applications

MARGIN

MAgnetic Resonance studies of Gas diffusion In Nanoporous materials

Influence of gas-wall interactions

International Collaborative Research Project, 2020 – 2022

Funded by the French ANR and the Russian Science Foundation.

- **Laboratoire Kastler Brossel** (LKB)
  Paris, France
- **Laboratory of Magnetic Radiospectroscopy & Quantum Electronics** (MRS Lab)
  Kazan Federal University, Russian Federation

Start date: Jan. 1, 2020 – Scientific coordinator: P.-J. Nacher

LKB-MRS Lab links, since 2008: 1 PhD (PHIL project), 1 post-doc (PHeLINet project), MoU.

Teams

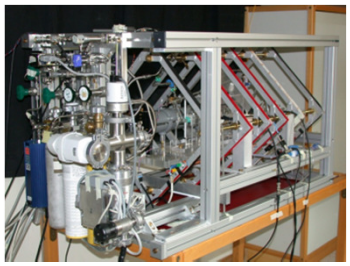
LKB, Paris

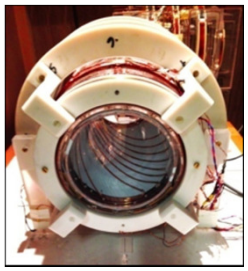
A major research centre for quantum physics and applications. 65 years of history, 3 Nobel Prizes.

[Polarised helium and quantum fluids group]

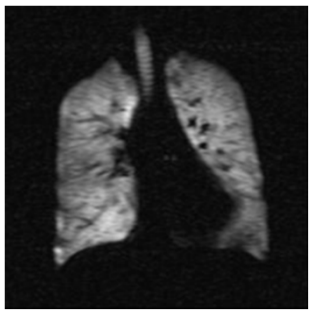
Expertise in **optical pumping** (^{3}He nuclear polarization > 80%) as well as in **NMR and MRI** in hyperpolarized systems (gas and liquid phases, low & high magnetic field).

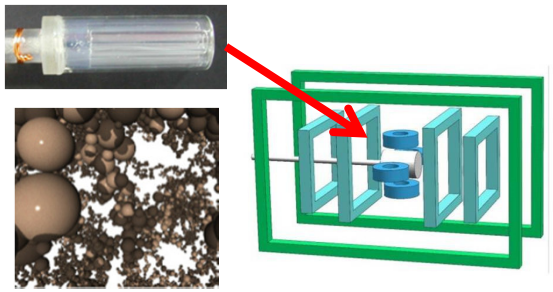
Rev. Mod. Phys. 89 (2017) 045004: "*Optically polarized ^{3}He*"





Porous systems imbibed with ^{3}He gas



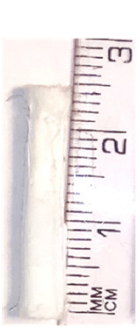


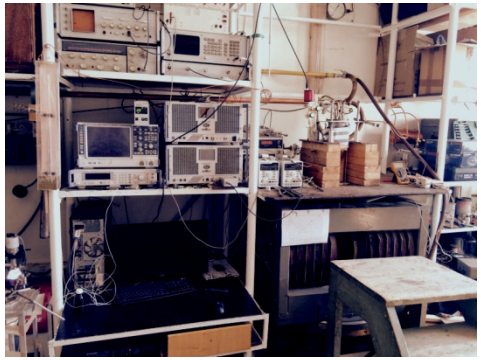
MRS Lab, Kazan

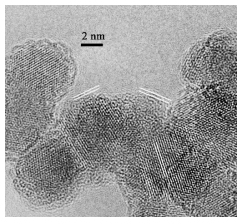
Home of NMR and EPR discovery
(Y.K. Zavoisky, 1941 and 1944)

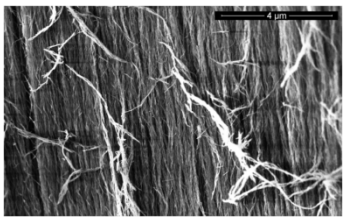
[MRS Lab]

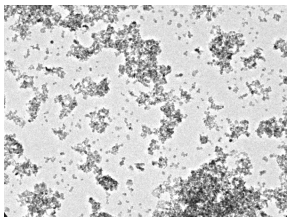
Low-T nuclear relaxation and diffusion of ^{3}He (adsorbed, gas, or liquid phases) in **nanoporous** media (magnetic and non-magnetic. Innovative synthesis of **nano-particles**. Expertise in **cryogenics**, **NMR** hardware + software developments.











Project objectives

MARGIN is designed to probe **gas diffusion by NMR** of ^{3}He and ^{129}Xe:
- high (300 K) and low (... - 1.5 K) temperature
- (hyperpolarized) low-density and (thermally polarized) high-density gas probes
- investigations in a wide range of time and distance scales.

Experimental, numerical, and theoretical studies are planned

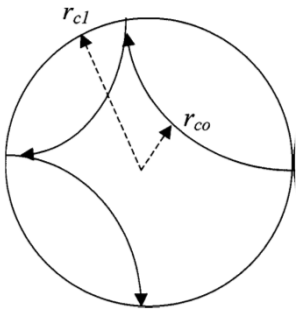
Diffusion measurements are widely used to characterize porous media
(e.g. in petroleum industry)

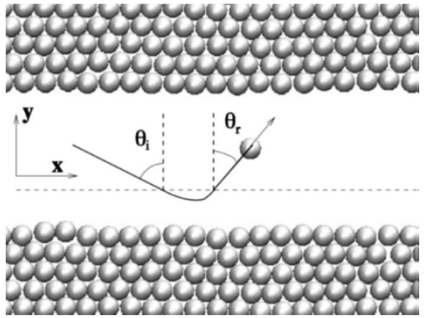
Gas diffusivity correlates with the efficiency of modern nanoporous materials
for gas separation and storage, for catalysis, for random perturbation of superfluid He, etc.

Usual gas transport (Knudsen) model:

ballistic / diffusive transport in pores
+
interactions at the walls.

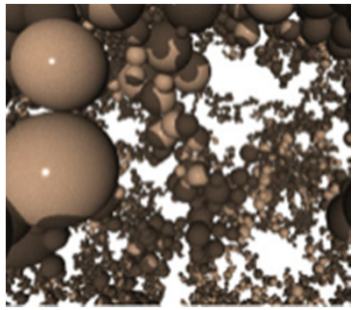
Potential due to distant walls is overlooked

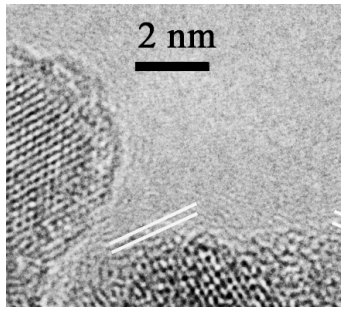


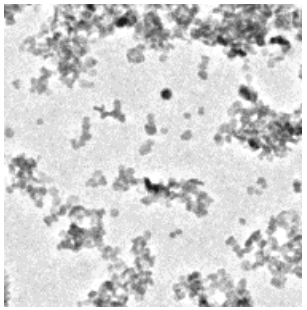


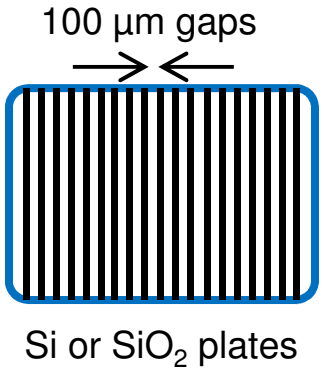
- Deeper understanding of **gas diffusion mechanisms** in complex porous systems
  (Validate NMR as accepted characterization tool for gas diffusion assessment)
- Contribution to advances in **high-precision fundamental physics**?
  (*Search for deviations from the Standard Model at low energy through gas-wall effects)*

Scientific challenges









- ✓ **NMR** of ^{3}He gas at low to moderate field (< 0.8 T) and at low T (< 4 K)
- ✓ **NMR** of ^{129}Xe and ^{3}He gas at 8.5 T and intermediate T (4 K – 200 K)
- ✓ **NMR** of optically polarized ^{3}He gas at 3 mT and high T (100 K – 300 K)
  In case of **short relaxation times** (magnetization lost during measurement time), need for elaborate measurement sequences, or use wall coatings (^{4}He, H_2, Cs,…)

- ✓ **Monte Carlo and Molecular Dynamics simulations** of gas sticking and diffusion.
  Difficulties: quantum effects at low T, reliability of MD simulations over **long times**.

- ✓ **Evaluate relevance of highly restricted ^{3}He diffusion and magnetic relaxation** for searches of EDM, WISPs or short-range spin-dependent forces…
  Sensitivity of experiments could be insufficient for a breakthrough, but the high importance of these fundamental studies makes it worth attempting them.

Dec. 2019 – P.-J. Nacher