

INTERNSHIP PROPOSAL

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CNRS identification code: UMR 8552
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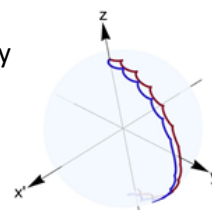
Thesis possibility after internship: YES
Funding: Not secured (Application needed for individual PhD contract, e.g. to EDPIF)

Rf-driven nuclear spin dynamics in low-field NMR and MRI

Context and challenges: Pulses of resonant ac fields are generically used to control the internal states of 2-level systems. In magnetic resonance of (spin-1/2, mostly) nuclei (NMR), elaborate rf pulse sequences have been developed to overcome common experimental imperfections. They provide powerful tools for numerous applications in NMR spectroscopy and imaging, for instance. Accurate control of rf-driven travel on the Bloch sphere is also mandatory for efficient internal state engineering in various 2-level quantum systems, in particular those deemed as promising Qubits in the context of quantum technologies. Such control is also essential for innovative gradient-free imaging (MRI) methods that make use of complex rf sequences applied using specially designed rf coils¹ and may find important applications in low-field MRI.

Travel on the Bloch sphere due to a (near-)resonant pulse of transverse ac field is a standard textbook item. In practice, spin trajectories may be deeply modified by undesirable (but, often unavoidable) additional oscillating field components that contribute to off-resonant or longitudinal spin excitation. Therefore, the actual response to sophisticated trains of rf pulses requires careful quantitative assessment and optimal adjustment.

NMR in low (mT) magnetic fields is a particularly versatile test bench for a variety of behaviours in response to well-controlled pulsed rf excitation, as recently demonstrated in our group.² In particular, the conditions for operation outside the range of validity of the well-known rotating wave approximation are easily met. Very unusual trajectories and departure from canonical expectations are observed.



Internship/PhD project: Combining low-field NMR techniques and optical pumping/probing of ³He polarisation state in gas discharges, the PhD student will perform detailed investigations of Rabi oscillations under resonant pulsed rf excitation. Work will be mostly experimental and supplemented by PC-based numerical simulations. Rf-driven time evolution will be quantitatively investigated for various excitation schemes. The project provides an opportunity for basic research and hands-on experience with generic techniques and strategies for accurate preparation, control, or measurement, of internal atomic/nuclear angular momentum states. Application to design and tests of optimal rf control in gradient-free MRI will also be pursued.

Techniques/methods in use: Pumping and probing with IR lasers; low-field NMR; rf excitation.

Tools: NMR : Commercial console allowing flexible design and application of sophisticated rf pulse sequences. Conventional rf equipment (kHz) and home-made optimised rf coils. Optical measurements: 1083 nm laser sources, basic atomic spectroscopy, and optical polarimetry. Dedicated low-field MRI system equipped for both standard and gradient-free MRI. Hyperpolarised ³He gas or water imaging samples.

¹ Nacher et al., *J. Magn. Reson.* **310** (2020) 106638, <https://hal.archives-ouvertes.fr/hal-02266979>

² Bidinosti et al., *J. Magn. Reson.* **345** (2022) 107306, <https://hal.archives-ouvertes.fr/hal-03765938>

Please, indicate which speciality(ies) seem(s) to be more adapted to the subject:

Condensed Matter Physics:	NO	Soft Matter and Biological Physics:	NO
Quantum Physics:	YES	Theoretical Physics:	NO