NEW EFFECTS INDUCED BY STRONG NUCLEAR MAGNETIZATION

The increase in the NMR performance induces non-linear effects due to interactions between distant spins and between spins and coil.

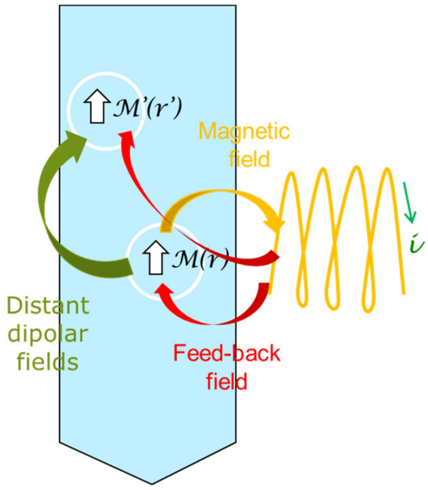
Technological advances succeed in making nuclear magnetic resonance and its most common application, magnetic resonance imaging, always more sensitive. For that purpose, more powerful magnets, optimized radiofrequency coils are developed, or transiently over-polarized (hyperpolarized) systems are used.

However, this ongoing search for ever more intense NMR signal leads to the appearance of non-linear processes which were initially neglected, and which can become predominant. They result from two sources: the direct interactions between remote nuclear magnetic moments (each one creates a magnetic field acting on all other moments), and the individual interactions of these moments with the rf coil which is used for excitation and detection of the NMR signal.

These non-linear processes give rise to unusual behaviors, such as precession instabilities (fast crush of the coherent magnetization) or specific maser emission, but may also lead to technological improvements since new devices or unconventional detection schemes can be proposed and tested.

One question, several converging methods of investigation.

To address these various phenomena, the consortium has benefited from a complementary range of expertise and experimental instruments: hyperpolarized xenon studied in high magnetic fields with potentially custom-made rf coils, helium-3 polarized by pumping optical and used in a low temperature NMR system working at low frequencies, or NMR spectrometry combining very high magnetic fields and detection coils cooled down to cryogenic temperatures. These experimental methods were complemented by theoretical developments and intensive numerical simulations, so as to be able to compare predictions with observations and, hence, to progress in the understanding of non-linear phenomena and propose new solutions and robust applications.



Origin of the two non-linearities in the heart of the IMAGINE project: the dipolar coupling between distant magnetization voxels and the coupling between the magnetization and the coil.

From a fundamental point of view, two axes have led to major results. Relying on a detailed theoretical work, the spin-noise detection scheme has been extended to applications involving the detection of isotopic effects, measurements of Brownian diffusion or the obtaining of two-dimensional spectra. Thanks to the combination of experiments and numerical simulations, the origin of multiple maser emissions has been understood and the difference in behaviors observed in helium-3 and xenon- 129 could be positively related to the influence of Brownian diffusion. This work also led to progresses of technological nature, related to the implementation of new NMR microprobes or to rf preamplifiers and their possible influence on spin dynamics.

All the work carried out has already led to the publication of a dozen of articles in refereed journals, and half a dozen more should follow. A patent application has been filed. Finally around this project two scientific awards were obtained Viacheslav V. Kuzmin, post-doctoral researcher at Laboratoire Kastler Brossel, funded by the project, received the 2013 *Lavrentiev* prize, and N. Müller and H. Desvaux co-organized a workshop in Vienna thank to the *WTZ Amédée* prize.

The IMAGINE project was a basic research project supported by international ANR program and coordinated by CEA-IRAMIS. It associated an Austrian laboratory of J. Kepler University of Linz and the Kastler Brossel Laboratory at ENS, Paris. RS2D, a company located in Alsace, also participated. The project started on March 1st, 2013 for a period of 3 years in France (May 1st in Austria). On the French side, the overall budget was around 900k€ with an ANR grant of 433k€.