Ultralow-field NMR of liquids confined in ferromagnetic and paramagnetic materials

Michael Tayler[1,2], Jordan Ward-Williams[1], Lynn Gladden[1]

[1] Cambridge University Dept of Chemical Engineering and Biotechnology, Cambridge, UK
[2] ICFO - Institute of Photonic Sciences, Castelldefels (Barcelona), Spain

Nuclear magnetic resonance (NMR) techniques provide unique insight into the physical and chemical behavior of fluids, including composition, dynamics and reactivity. Such insight is permitted even when the fluid is completely enclosed in a structure that is opaque to visible radiation. Historically, however, NMR in metallic or electrically conductive enclosures is a technical challenge, since (i) induced gradients obstruct the spatial and spectroscopic resolution and (ii) the AC signals may be strongly attenuated due to the skin depth effects. These problems can be mitigated by detecting NMR at a sufficiently low nuclear precession frequencies, using spin-exchange relaxation-free (SERF) atomic vapor magnetometers[1,2].

Here we report on ultralow-field ^{1}H NMR of liquids inside sample vessels or nanoscale confinement that are weakly ferromagnetic (i.e. have a magnetic moment even at zero applied field) and/or paramagnetic (i.e. have a magnetic moment proportional to the applied field) detected with a SERF ^{87}Rb magnetometer. Both types of magnetism may contribute to the net field experienced by the nuclear spins and may consequently broaden or shift the center frequency of the NMR spectral line. Ultralow-field NMR is an advantageous method to distinguish each contribution[3]. We demonstrate results for closed containers of an aluminum alloy (showing a remanent magnetic field of around 50 nT) and for nano-disperse cobalt oxide on porous silica.

[1] M.C.D. Tayler, J. Ward-Williams and L.F. Gladden, J. Magn. Reson. **297**, 1 (2018).
[2] S. Xu et al. Proc. Natl. Acad. Sci. USA **103**, 12668 (2008).
[3] M.C.D. Tayler et al. Appl. Phys. Lett., submitted (2019).