Response of dipolar assemblies

P.M. Déjardin

Assemblies of magnetic nanoparticles [1], or dense polar fluids [2, 3], are strongly coupled systems that can be approached by the techniques of the many-body problem [4]. Finding a theoretical route, from the microscopics, to such a macroscopic property as the magnetic or dielectric susceptibility, remains, to this day, an open problem. Approximations able to capture the cooperative mechanisms between orientational degrees of freedom are however not out of reach. Recent progress [5], for a well-known polar fluid (water), was achieved starting from a description of the dynamics in terms of a stochastic partial differential equation for the density of molecules. Figure 1 shows the convincing theory/experiments comparison.

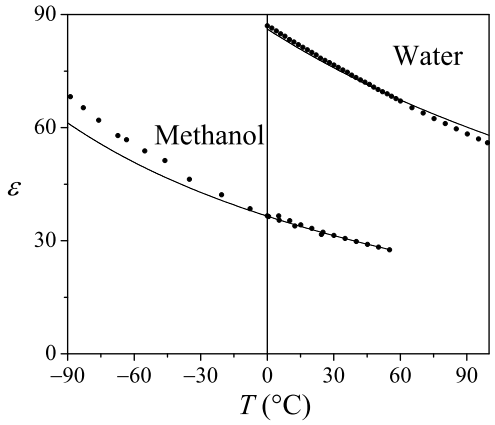

Figure 1: Dielectric constant of water and methanol as a function of temperature. Solid line : Theory. Dots : Experimental data

The goal of the internship is to go beyond this encouraging result. In particular, an understanding of the temperature dependence of the susceptibility of various polar fluids awaits theoretical progress. A central quantity at the core of the problem is the Kirkwood correlation factor [6] which previous works have described too coarsely.

The internship could evolve into a full PhD project with two aspects that

deserve particular attention:

- the analysis and interpretation of a large number of experimental data, in light of the theory, will serve as a guide for physically motivated approximation methods ;
- dynamics-wise, beyond linear response, dense phase of polar fluids display interesting glassy-like properties that are reflected in anomalous nonlinear response functions [3]. Addressing this dynamical regime is an exciting open problem.

Further useful references include:

- [4], for the theory of simple liquids and approximation methods adapted to the description of systems with continuous (positional and orientational) degrees of freedom;
- [7], [8] and [9], for the description of the many-body dynamics in terms of stochastic fields, from which approximations for dynamical correlations and response (including nonlinear response) could be derived.

Starting date: From January 2020.
Location of the intership: Laboratoire de Mathématiques et PhySique (LAMPS), Université de Perpignan Via Domitia
contact: dejardip@univ-perp.fr

References

[1] S. Bedanta and W. Kleeman. *J. Phys. D*, 42:013001, 2009.

[2] P.-M. Déjardin, W. T. Coffey, F. Ladieu, and Yu. P. Kalmykov. *Nonlinear Dielectric Spectroscopy*, chapter Nonlinear Dielectric relaxation in AC and DC electric fields. Springer, Berlin, Germany, 2018.

[3] S. Albert, M. Michl, P. Lunkenheimer, A. Loidl, P.-M. Déjardin, and F. Ladieu. *Nonlinear Dielectric Spectroscopy*, chapter Third and fifth harmonic responses in viscous liquids. Springer, Berlin, Germany, 2018.

[4] J. P. Hansen and I. McDonald. *Theory of Simple Liquids*. Academic Press, 3rd edition, 2006.

[5] P.-M. Déjardin, Y. Cornaton, P. Ghesquière, C. Caliot, and R. Brouzet. *J. Chem. Phys.*, 148:044504, 2018.

[6] C. J. F. Böttcher. *Theory of Electric Polarization*, volume I. Elsevier, Amsterdam, The Netherlands, 2nd edition, 1973.

[7] K. Kawasaki. *Physica A*, 208:35, 1994.

[8] D. S. Dean. *J. Phys. A*, 29:L613, 1996.

[9] L. F. Cugliandolo, P.-M. Déjardin, G. Lozano, and F. van Wijland. *Phys. Rev. E*, 91:032139, 2015.