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Inverse Laplace Transform Approaches to βNMR Relaxation

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Spin lattice relaxation is the simplest type of βNMR measurement. The usual approach is to implant a pulse of hyperpolarized nuclei and monitor the time-resolved β-decay asymmetry, yielding the ensemble average spin-lattice relaxation. In the simplest case, the asymmetry decays exponentially with a characteristic time constant T_1, but this ideal is rarely obtained in practice. In most data, the relaxation is more complicated. This can be the result of multiple crystallographic sites for the implanted probe each having a distinct T_1. The sample may also be inhomogeneous due to: impurities or defects (including interfaces important for thin films); intrinsic phase separation; or, if it is a glass. There may also be a background signal from probe ions that stop outside the sample. The general approach to this problem has been the *ad hoc* development of an appropriate relaxation model that avoids overparametrization.

Given the prevalence of more complicated relaxation, it is crucial to develop a *systematic* approach to relaxation modelling. The decomposition of a relaxing signal into exponentials is, however, a mathematically ill-posed problem[1]. This feature is intrinsic and unavoidable, but there are a number of methods to accommodate it for noisy real-world data, including nuclear spin relaxation[2]

Here we demonstrate regularization methods for the inverse Laplace transform adapted to the particularities of βNMR relaxation data, most importantly the strong time dependence of the statistical uncertainty stemming from the radioactive lifetime of the probe.

[1] see Istratrov et al, Rev. Sci. Instr.70, 1233 (1999)

[2] Spencer et al, NMR in Biomedicine 33, e4315 (2020); Singer et al, PRB 101, 174508 (2020).

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