# Tracing molecular propagation in dextran solution by pulsed field gradient NMR

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Molecular self-diffusion in biological systems plays an important role by not only providing a mechanism of matter transport, but also by determining the rates and patterns of bio-chemical reactions in cells [1]. In recent years, fluorescence correlation spectroscopy (FCS) has emerged as a powerful technique for studying transport processes in biological systems on a spatial scale up to hundreds of nanometers [2]. The data obtained by this technique reveal that in most cases diffusion of tracer dye molecules under these conditions shows anomalous behavior, i.e., the mean square displacements grow not linearly with time, but as a power law with the exponent $\alpha < 1$ [3]. This finding, which is typically associated with molecular crowding effect, has far reaching consequences, among which reformulation of the concepts of bio-chemical reactions in life matter is currently under discussion. However, there are much experimental evidences of normal diffusion in highly crowded media. Therefore, experimental exploration of the origins of anomalous diffusion observed in the FCS experiments is of immediate importance for life sciences.
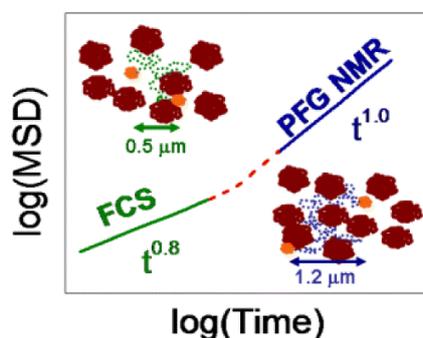


Figure 1: Schematic representation of diffusion patterns of tracer molecules obtained in model crowded media mimicking biological cells using fluorescence correlation spectroscopy and pulsed field gradient NMR.

In the present work, we have used potentials of pulsed field gradient NMR to extend the time- and space scales for the diffusion processes in the same system already probed by the FCS technique [4]. Notably, the latter technique revealed that in the aqueous solutions of dextran mixtures, mimicking crowded media in bio-cells, on the time scale up to 500 nm diffusion has shown subdiffusive behavior with the anomality exponent being a function of the solvent concentration and of the dextran molecular mass and the mixture composition [5, 6]. By choosing an optimal system with still pronounced anomaly, but simultaneously providing reliable NMR signals for diffusion studies, we have traced self-diffusivities of two dextrans of 40 kDa and 640 kDa molecular mass in the mixture in deuterated water. The results obtained have provided clear evidence that for the lighter dextan, being an analogue for the probe molecule in the FCS experiments, there should be a crossover to normal diffusion on the spatial scale between 500 nm and 1200 nm. Bridging the gap between these two values in order to validate the existence of the crossover or to demonstrate that these two types of experimental approaches providing ensemble-averaged quantities (NMR) and operating with finite number of tracers (FCS) may yield differing data is among of our current activities.

## References

[1] A.P. Minton: *The influence of macromolecular crowding and macromolecular confinement on biochemical reactions in physiological media*. J. Biol. Chem. **276**, 10577–10580 (2001)

[2] J. Ries, P Schwille: *Fluorescence correlation spectroscopy*. BioEssays **34**, 361–368 (2012)

[3] M. Hellmann, J. Klafter, D.W. Heermann, M. Weiss: *Challenges in determining anomalous diffusion in crowded fluids*. J. Phys.: Condens. Matter **23**, 234113–234120 (2011)

[4] A. Shakhov, R. Valiullin, J. Kärger: *Tracing molecular propagation in dextran solutions by pulsed field NMR*. J. Phys. Chem. Letters **3**, 1854–1857 (2012)

[5] M. Weiss, M. Elsner, F. Kartberg, T. Nilsson: *Anomalous subdiffusion is a measure for for cytoplasmic crowding in living cells*. Biophys. J. **87**, 3518–3524 (2004)

[6] D.S. Banks, C. Fradin: *Anomalous diffusion of proteins die to molecular crowding*. Biophys. J. **89**, 2960–2971 (2005)