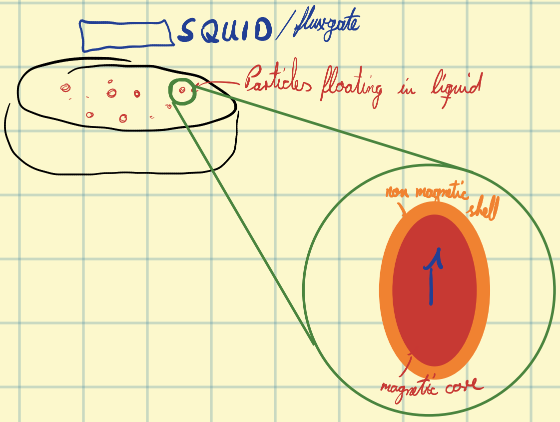
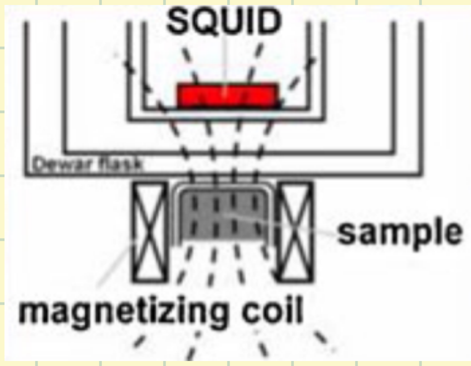
Magnetorelaxometry vs Thermal magnetic noise spectroscopy



Spin flipping by thermal magnetic fluctuations and brown movement $\nu_B = \frac{k_B T}{6\eta V_h}$

V_h: hydrodynamic core volume $V_{c,L} = \frac{\pi D_{c,L}^3}{6}$

η: viscosity



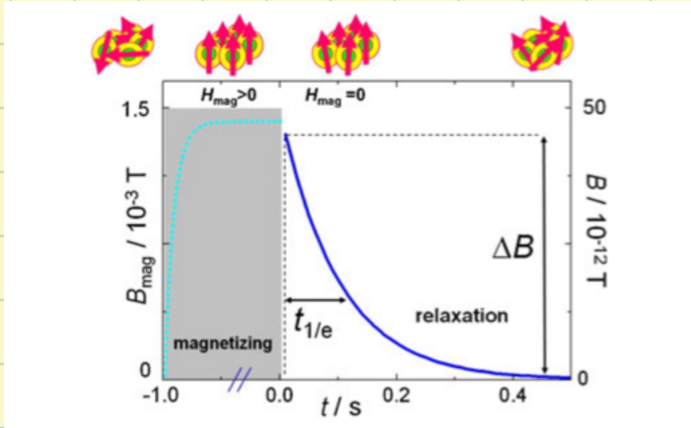


Fig. 3 Magnetorelaxometry principle. The top line (from left to right) portrays a nanoparticle ensemble's behavior: initially in a disordered state without magnetization, partly rotated towards the field direction during magnetizing, and turning back into a randomly oriented distribution of magnetic moments leading to the detected magnetization relaxation. Typically a field of about 1.5 mT is applied for 1 s. After removal of the field and a short interval the SQUID amplifier needs to recover, the relaxation signals are acquired for 0.5 s.

- Particles get magnetized by $\vec{B}_{ext} \sim mT$ for 1 sec

- Relaxing magnetic moment measured for 0,4 s — Néel mechanism $\nu_N = \nu_0 e^{-\frac{KV_c}{k_B T}}$ (K: anisotropy, V_c: magn. core volume)

↳ Superposition:

MRX: $$M(t) = M_0 \int_0^\infty \exp\left(-\frac{t}{\tau}\right) P(D)\, dD$$

$\tau(D)$: relaxation time; $P(D)$: size distribution; D: particle diameter, $D \propto$ log-norm

- subtracted background noise

TMNS: $$S(f) = \int_0^\infty \frac{g(\nu)\, \nu/2}{\nu^2 + (\pi f)^2}\, d\nu$$

$g(\nu) \propto P(\nu(D))$

Lorentzians Superposition

$g(\nu) = \varphi_N P(\nu_N(V_c)) + (1-\varphi_N) P(\nu_B(V_h))$ — φ_N: fitting param

- relaxation signal reduced to 200 logarithmically divided points how? why?

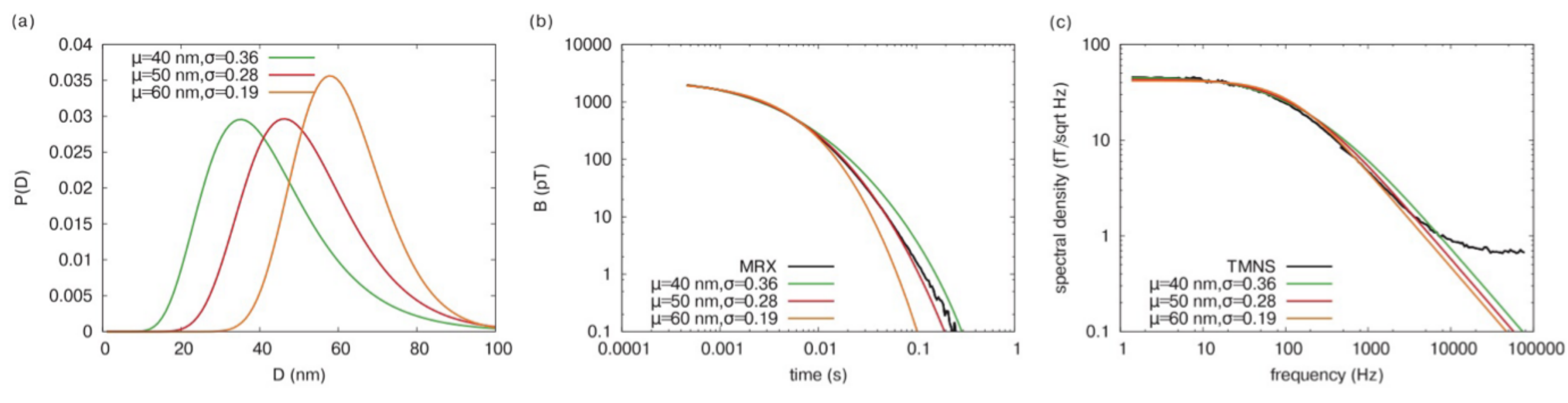
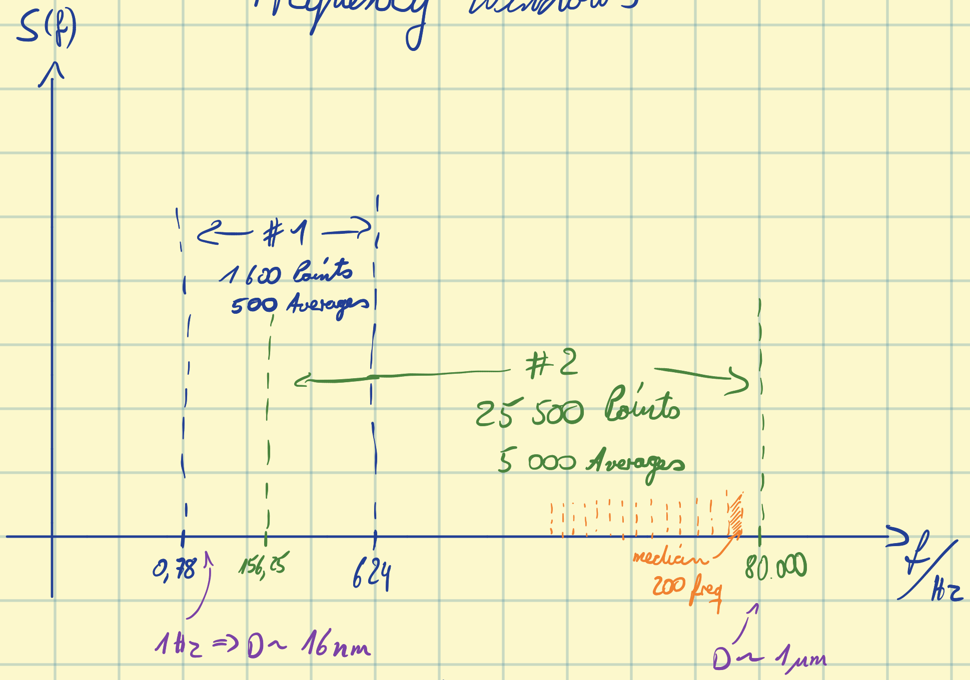
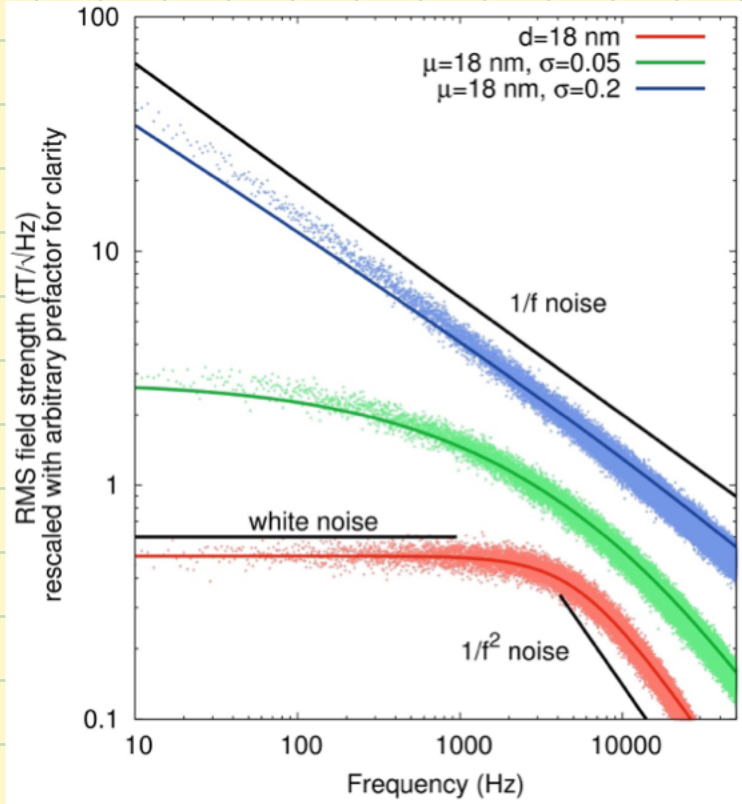


Figure 5. (a) Examples of three different lognormal size distributions, each with a combination of μ and σ, corresponding to the black crosses lying on the red lines with minimum error of figure 4. The measured (b) MRX and (c) TMNS data (black lines) are shown together with the simulated signals for the distributions depicted in (a). Although the size distributions themselves are quite different, they give rise to similar MRX and TMNS signals in the ranges we are most sensitive to.

⟹ very difficult to determine right parameters

Frequency Windows





lognormal diameter distribution

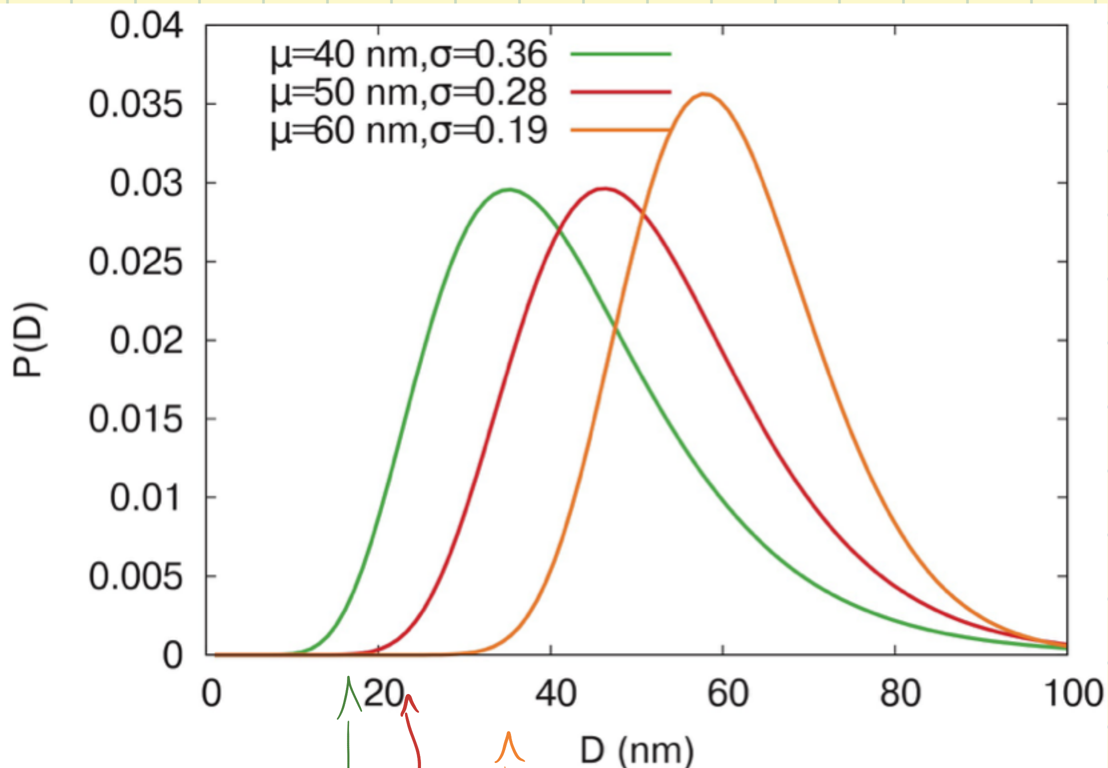
$$P(D\,|\,\mu,\sigma^2) = \frac{1}{\sqrt{2\pi}\,\sigma D}\cdot \exp\left(-\frac{\ln^2(D/\mu)}{2\sigma^2}\right)$$

Error Norm: $\underset{y_i}{\operatorname{argmin}} \sqrt{\frac{\sum_i (x_i - y_i)^2}{\sum_i x_i^2}}$

measured Data

Simulation for different μ, σ^2

↳ calculating $M(t)$ (MRX) / $S(f)$ (TMNS)



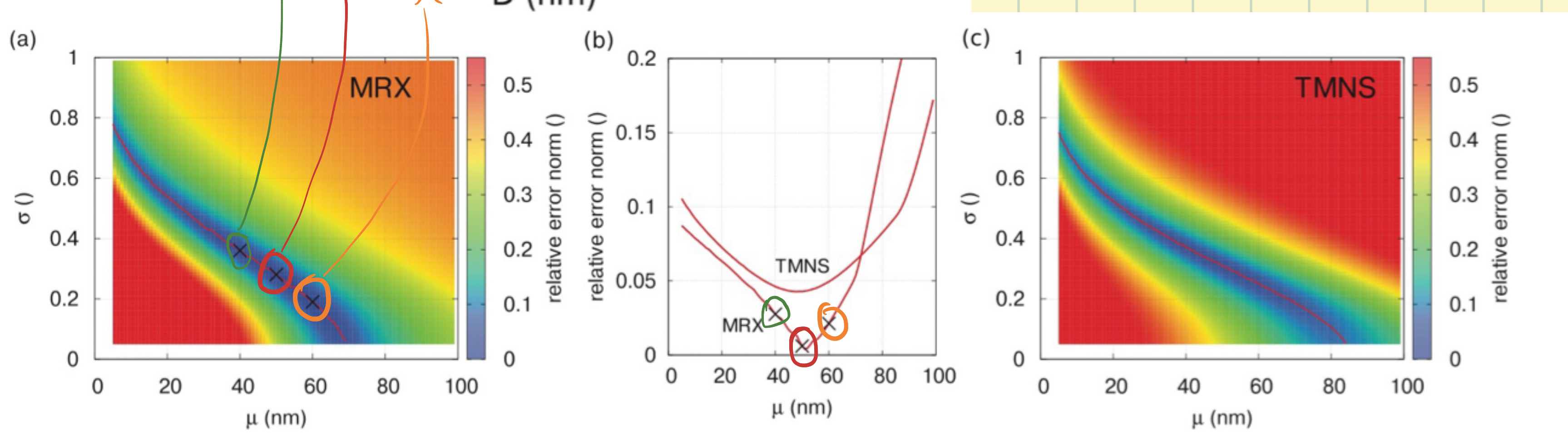


Figure 4. The relative error norm as a function of the fit parameters μ and σ of the lognormal size distribution for (a) the [CFHS] sample with $\eta = 32$ mPa s, measured by MRX and (c) the [CFHS] sample with $\eta = 12.2$ mPa s, measured by TMNS. (b) The relative error norm as a function of μ (for the optimal value of σ) along the red lines in the blue areas in (a) and (c). Both minima lie at the same place but the minimum is better defined in MRX than TMNS data.