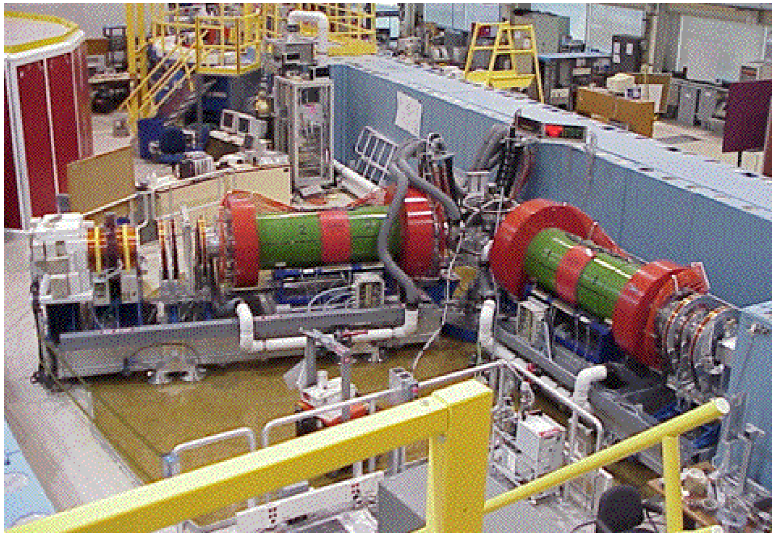
Neutron Scattering Summer School
Neutron Spin Echo



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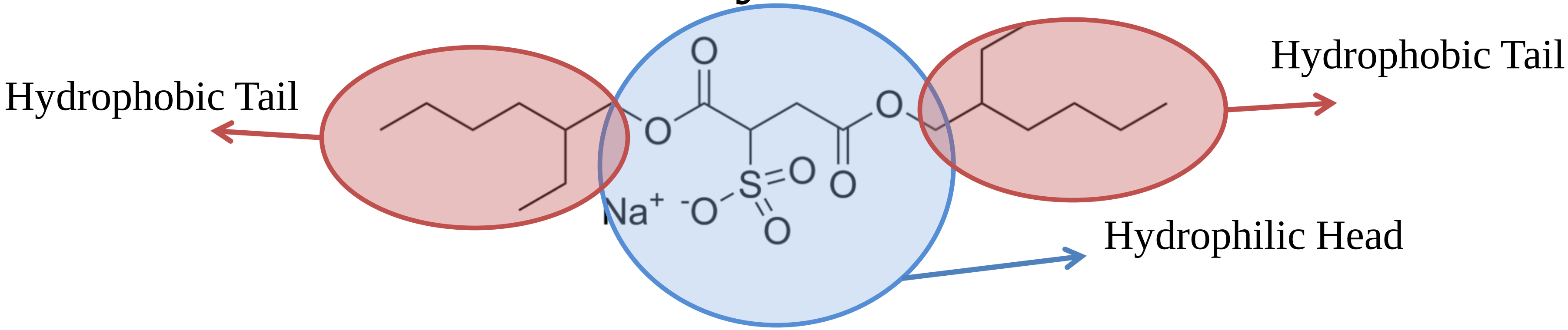
Introduction - AOT Microemulsions

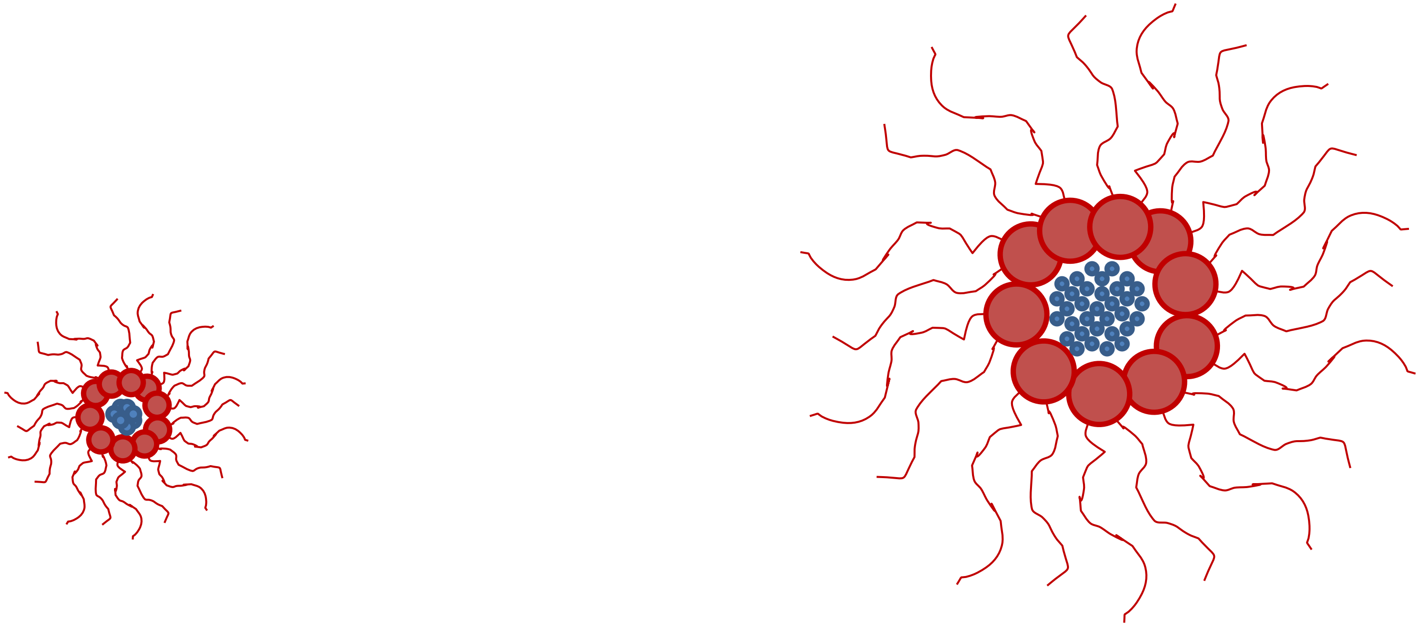
- AOT – Sodium Dioctyl sulfosuccinate



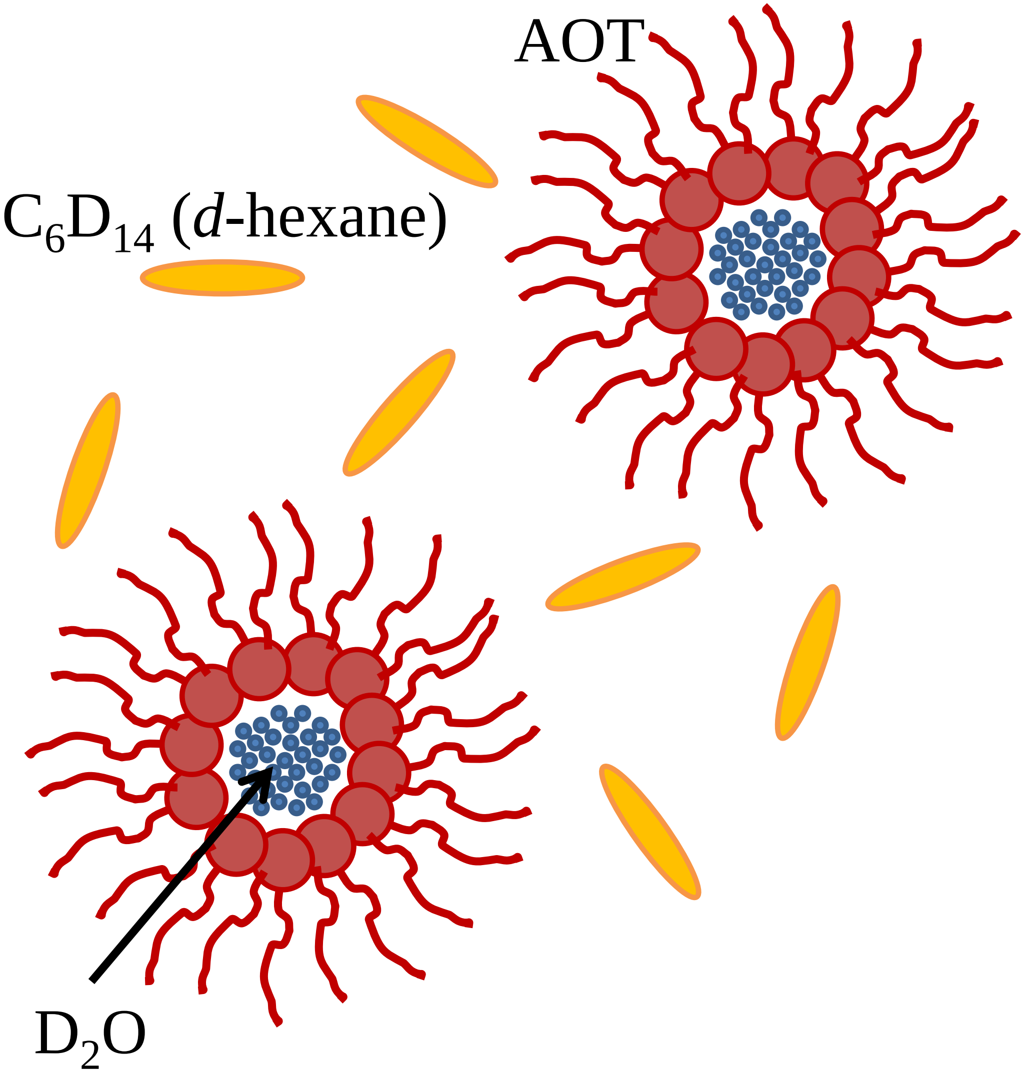
- Forms spherical inverse micelles in apolar solvents
- Micelles swell (radius ~30Å) with added water to form microemulsion

Microemulsion Dynamics

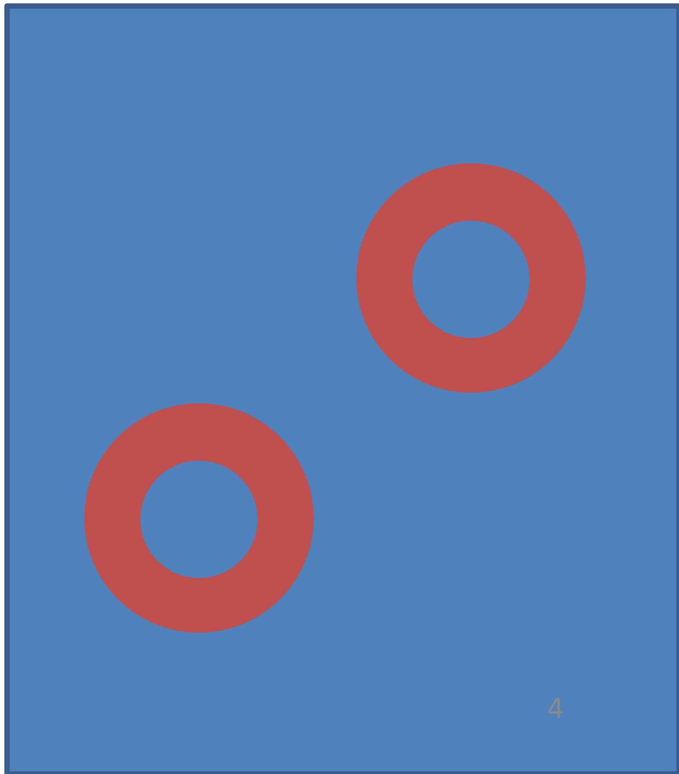
- Micelles diffuse through solvent
- Spherical micelles also exhibit shape fluctuations consistent with bending modulus.



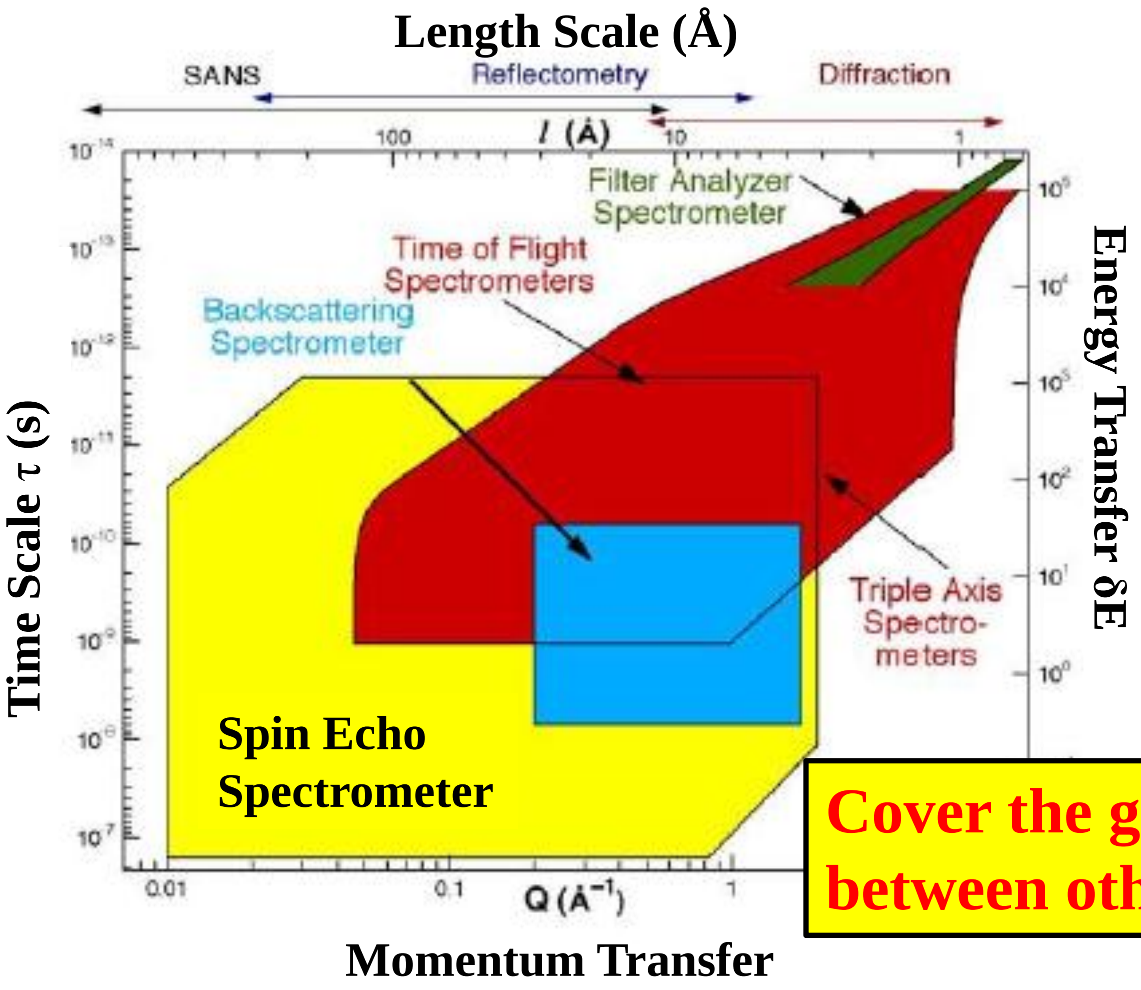
Experimental Design of AOT Micelles



Contrast Matching



Why Neutron Spin Echo (NSE) ?



NSE Spectrometry on Dynamical Studies:

1. Time Scale: 0.01 – 100 ns
2. Length Scale: 1 – 100 Å
3. Works in the time domain
4. Utilizing polarized neutron beam
5. Counting intensive

Cover the gap in the Time Scale between other techniques!!!

Ideal Technique for Dynamical Measurements of:
Polymers, Biological Systems, Glassy Dynamics, Proteins…

Neutron precession in magnetic field

- The neutron experiences a torque from a magnetic field *B* perpendicular to its spin direction.

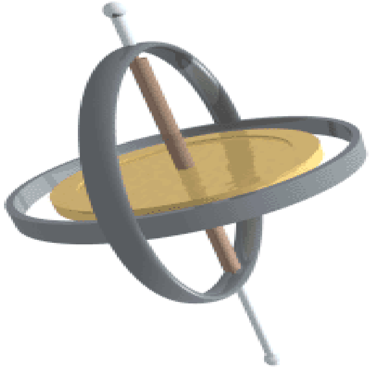
$$\dot{N} = \dot{S} \times \dot{B}$$

Precession with the Larmor frequency:

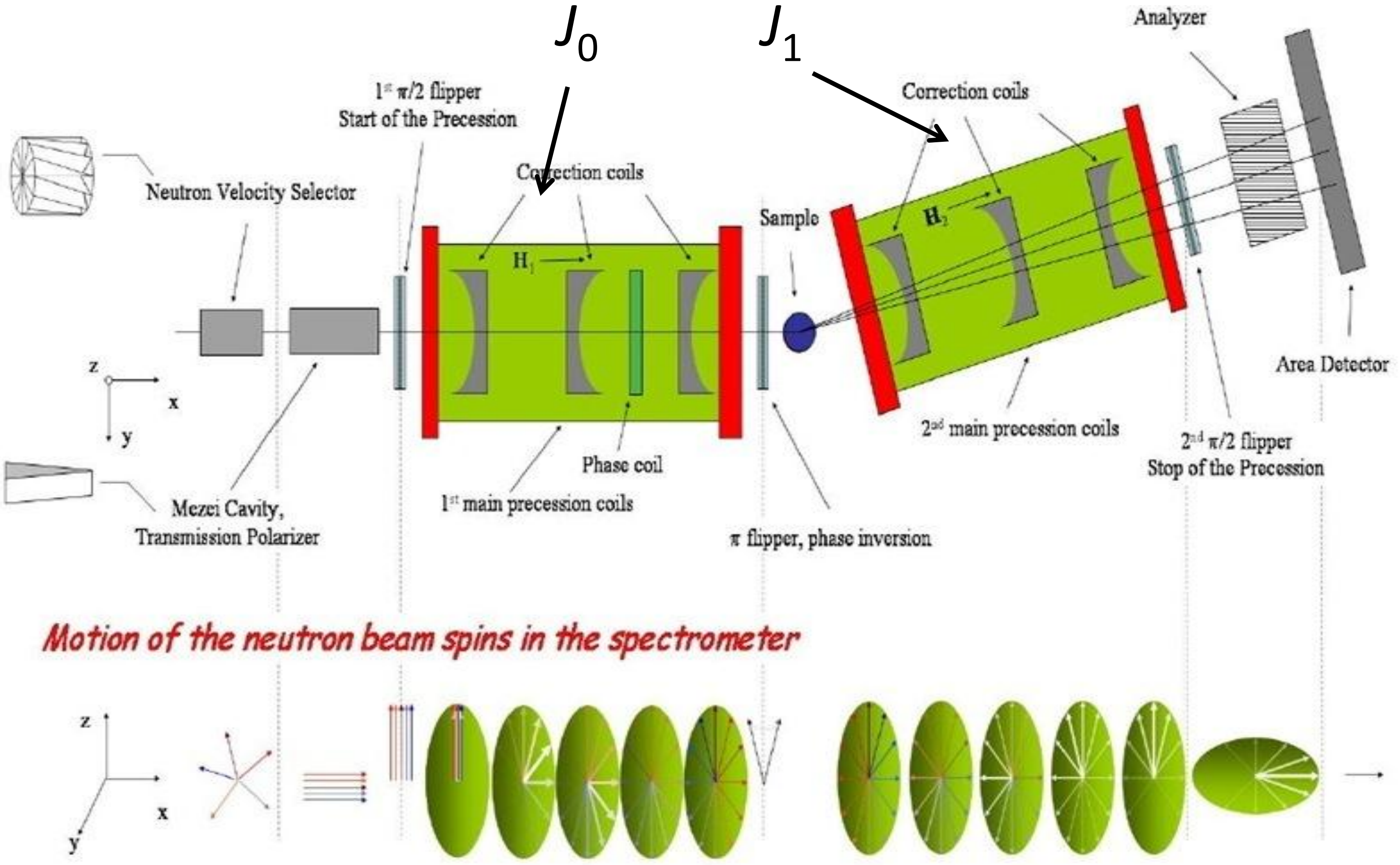
$$\omega = \gamma B$$

NSE encodes dynamic information in the spin of the neutron

Fourier time: $t = \gamma \frac{m^2 \lambda^3}{2\pi h^2} J_0 \longleftarrow$ $\propto$ Magnetic field

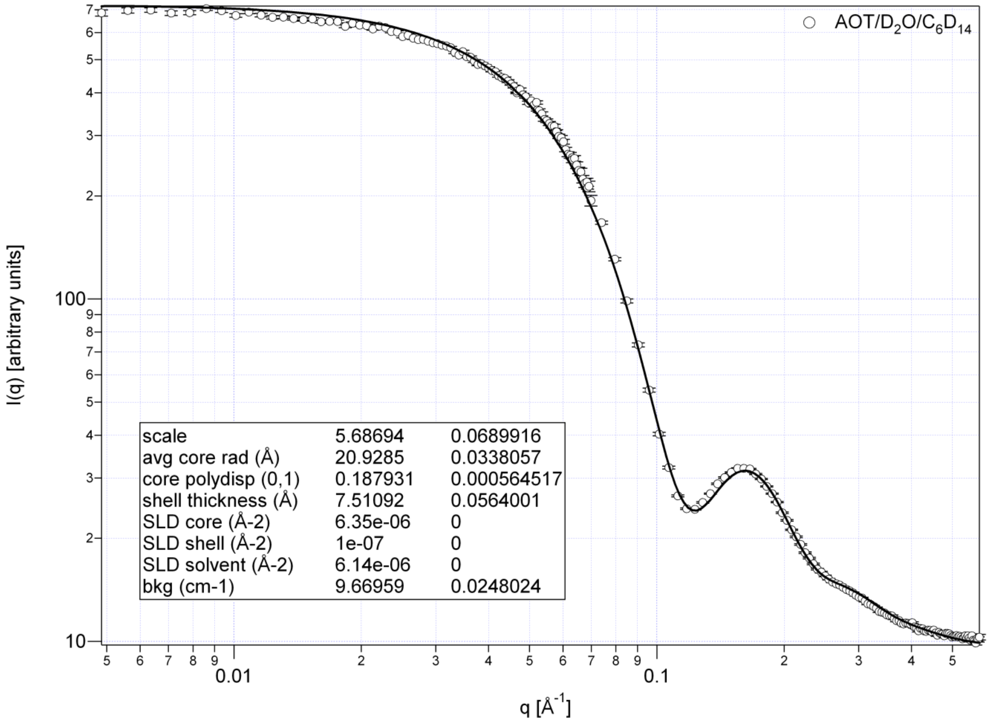


Schematic of NSE spectrometer



Microemulsion Measurements

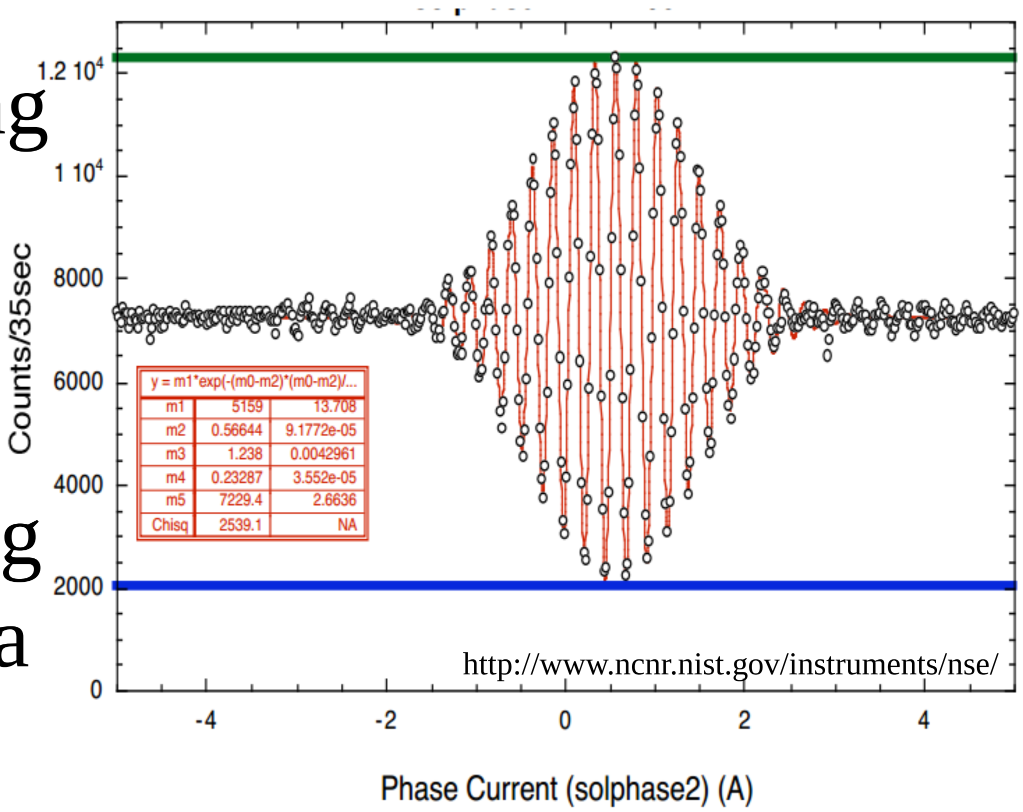
- SANS elucidates size and q ranges of interest through contrast matching of C_6D_{14} and D_2O.
- Need a complimentary technique to measure dynamics.
- NSE is a good option.



scale	5.68694	0.0689916
avg core rad (Å)	20.9285	0.0338057
core polydisp (0,1)	0.187931	0.000564517
shell thickness (Å)	7.51092	0.0564001
SLD core (Å-2)	6.35e-06	0
SLD shell (Å-2)	1e-07	0
SLD solvent (Å-2)	6.14e-06	0
bkg (cm-1)	9.66959	0.0248024

Microemulsion Measurements

- Quasi-elastic scattering determines relaxation properties
- Vary differences between the precessing **B** fields: spin echo at a Fourier time
- Proportional to ISF

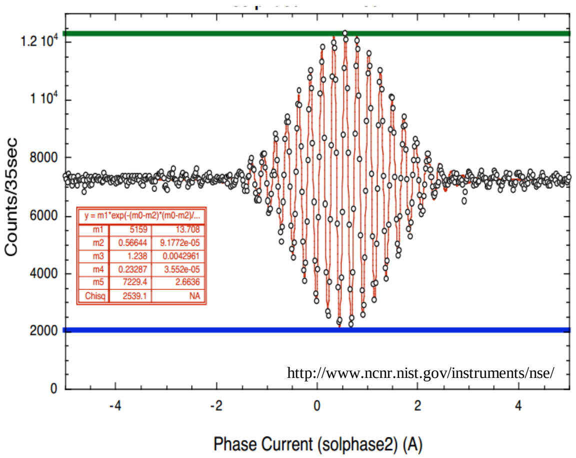


y = m1*exp(-(m0-m2)*(m0-m2)/...		
m1	5159	13.708
m2	0.56644	9.1772e-05
m3	1.238	0.0042961
m4	0.23287	3.552e-05
m5	7229.4	2.6636
Chisq	2539.1	NA

http://www.ncnr.nist.gov/instruments/nse/

$$\varphi \approx \gamma \frac{m}{h} J_o \delta\lambda + \gamma \frac{m}{h} (J_o - J_1)\lambda$$

Data Extraction



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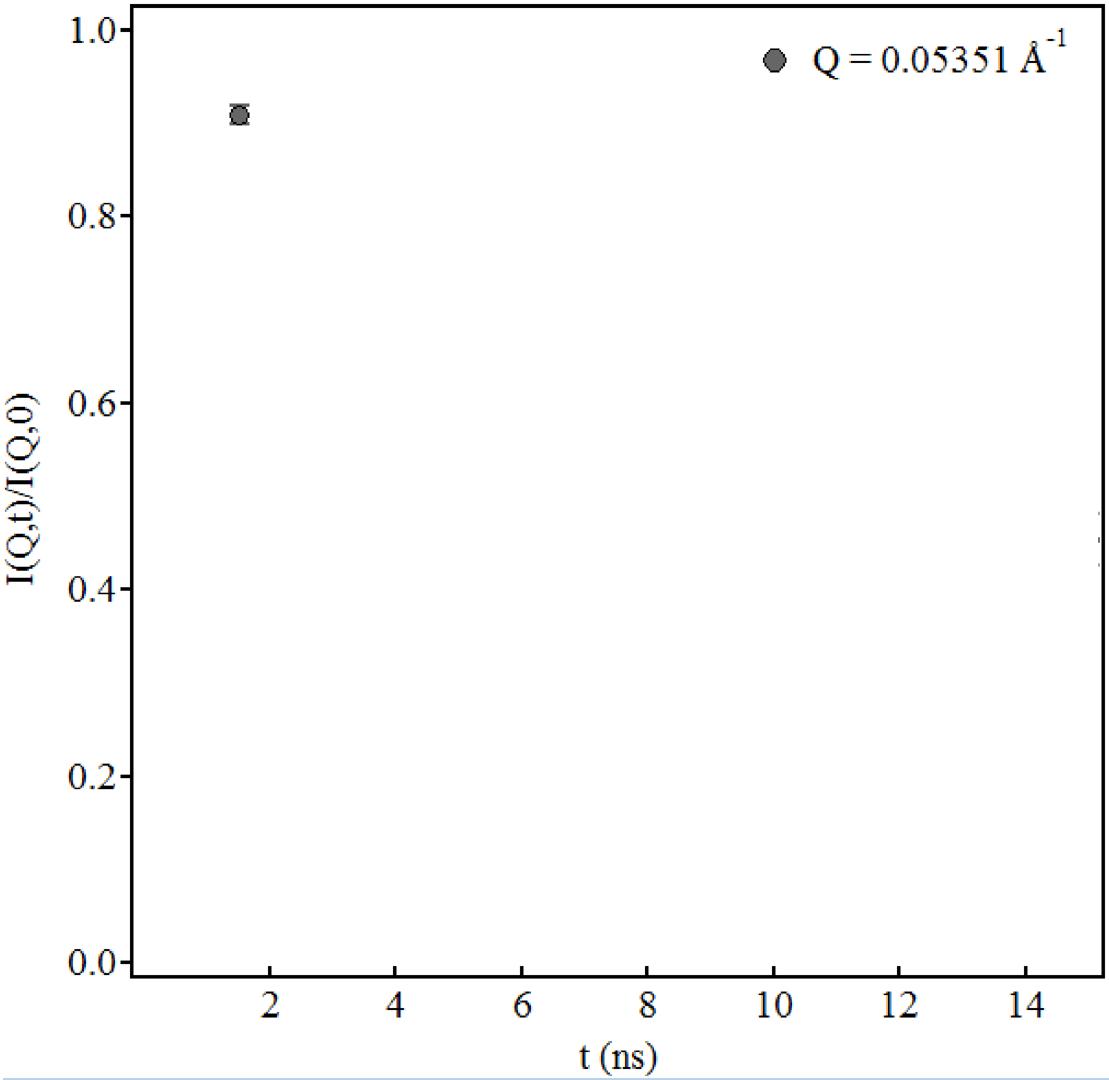
- Echo amplitude corresponds to single I(q,t) point



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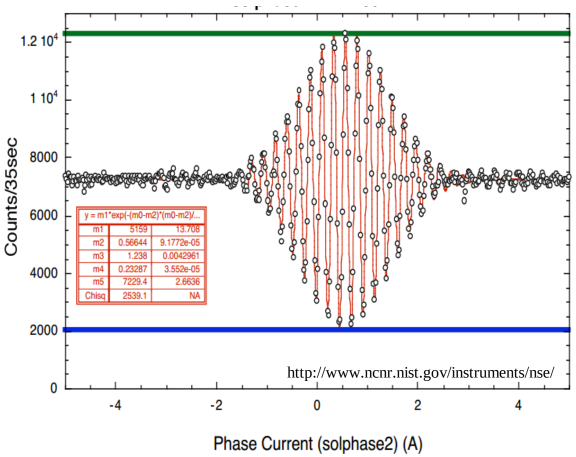
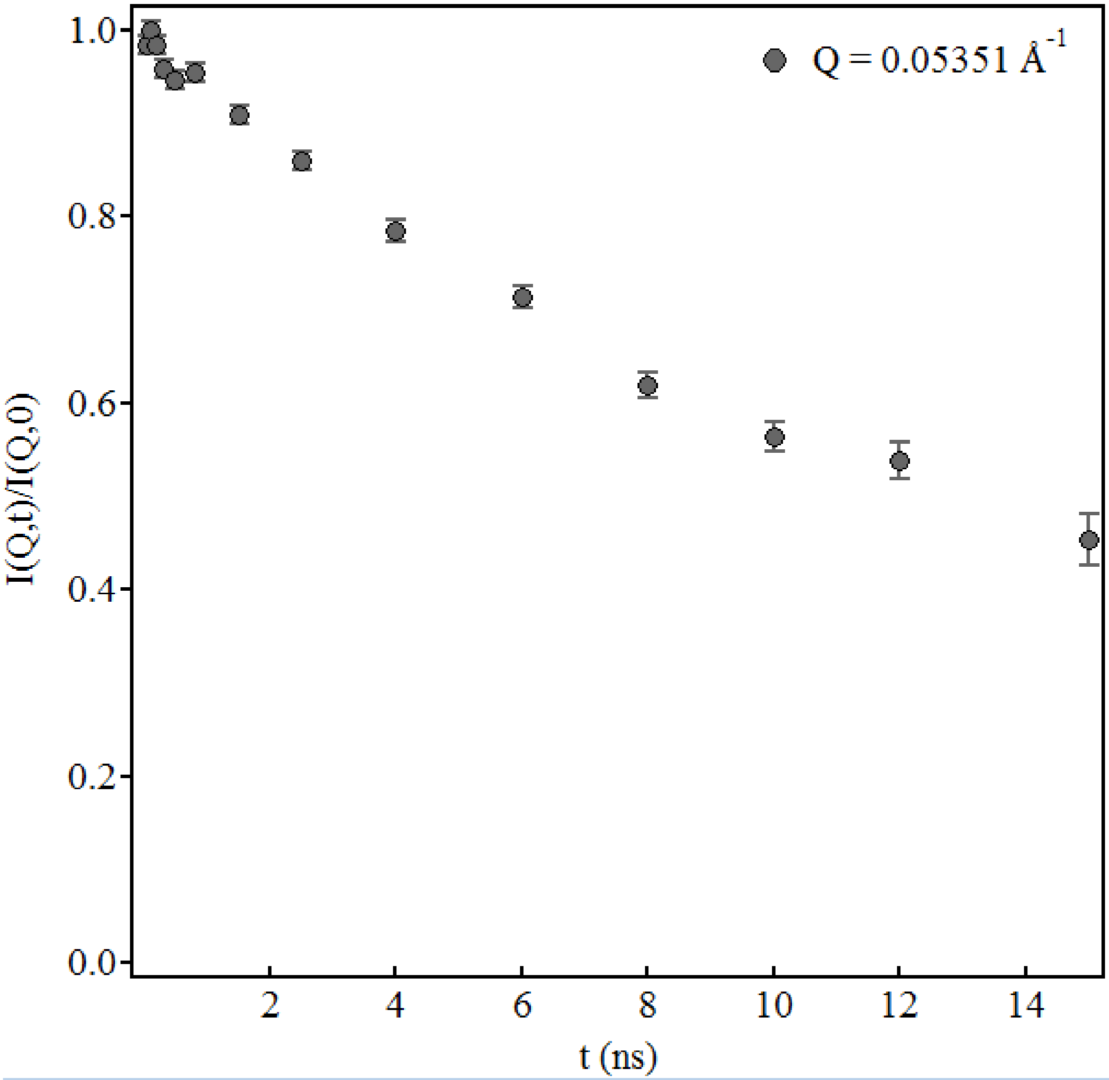


http://www.ncnr.nist.gov/instruments/nse/

- Echo amplitude corresponds to single I(q,t) point
- Field strength varied to access t_F



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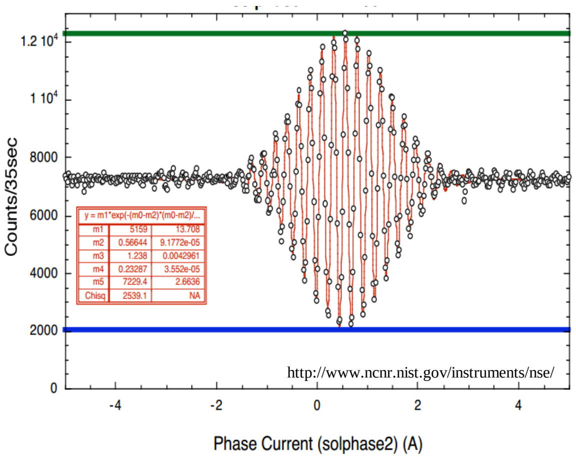

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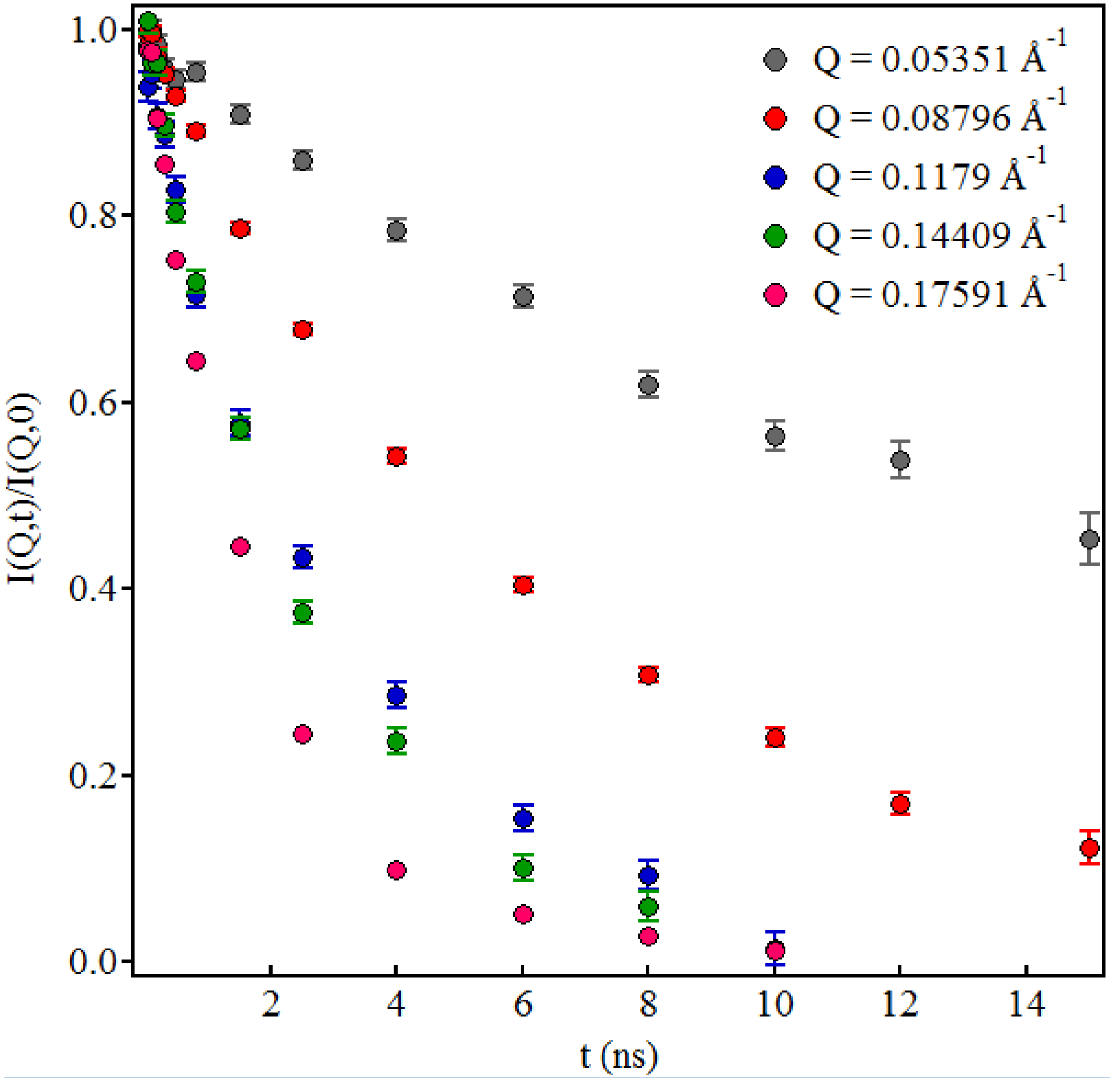
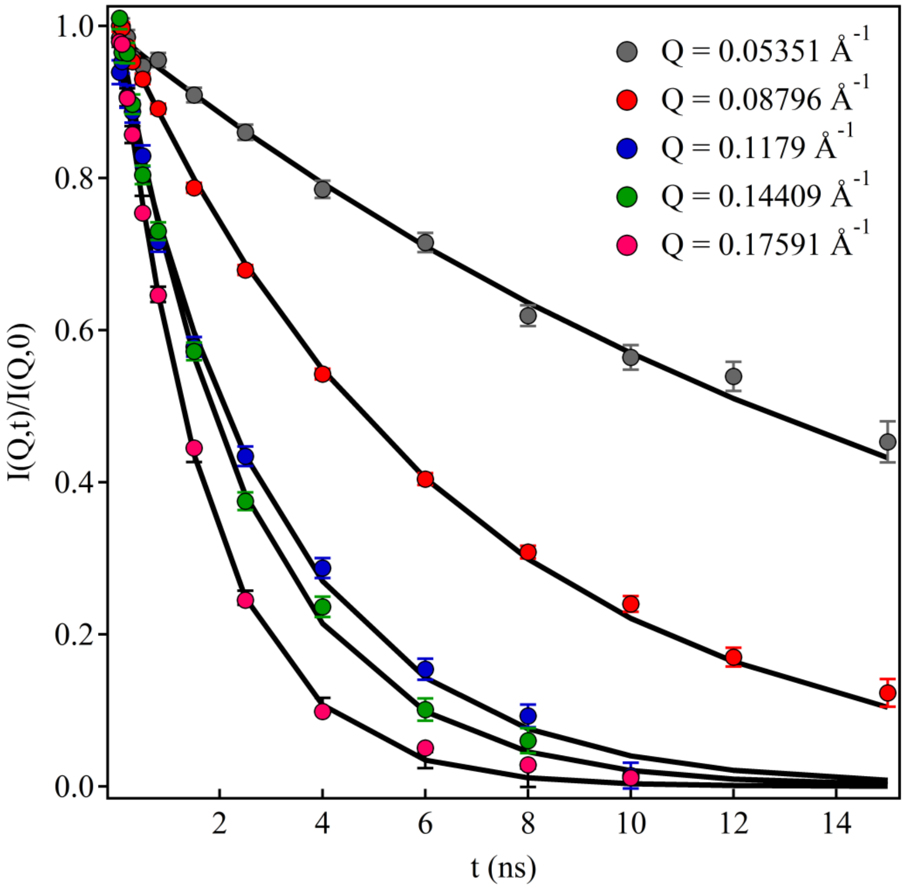
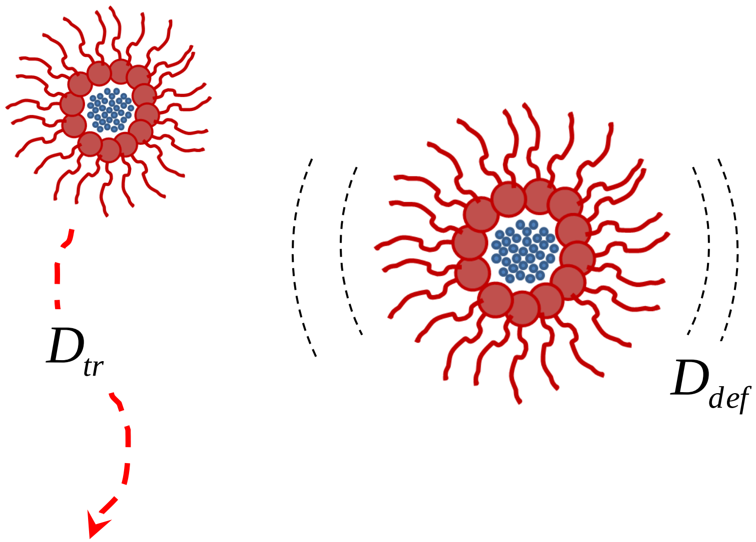


- Echo amplitude corresponds to single I(q,t) point
- Field strength varied to access t_F
- Scan through 2θ

Reduced NSE Data



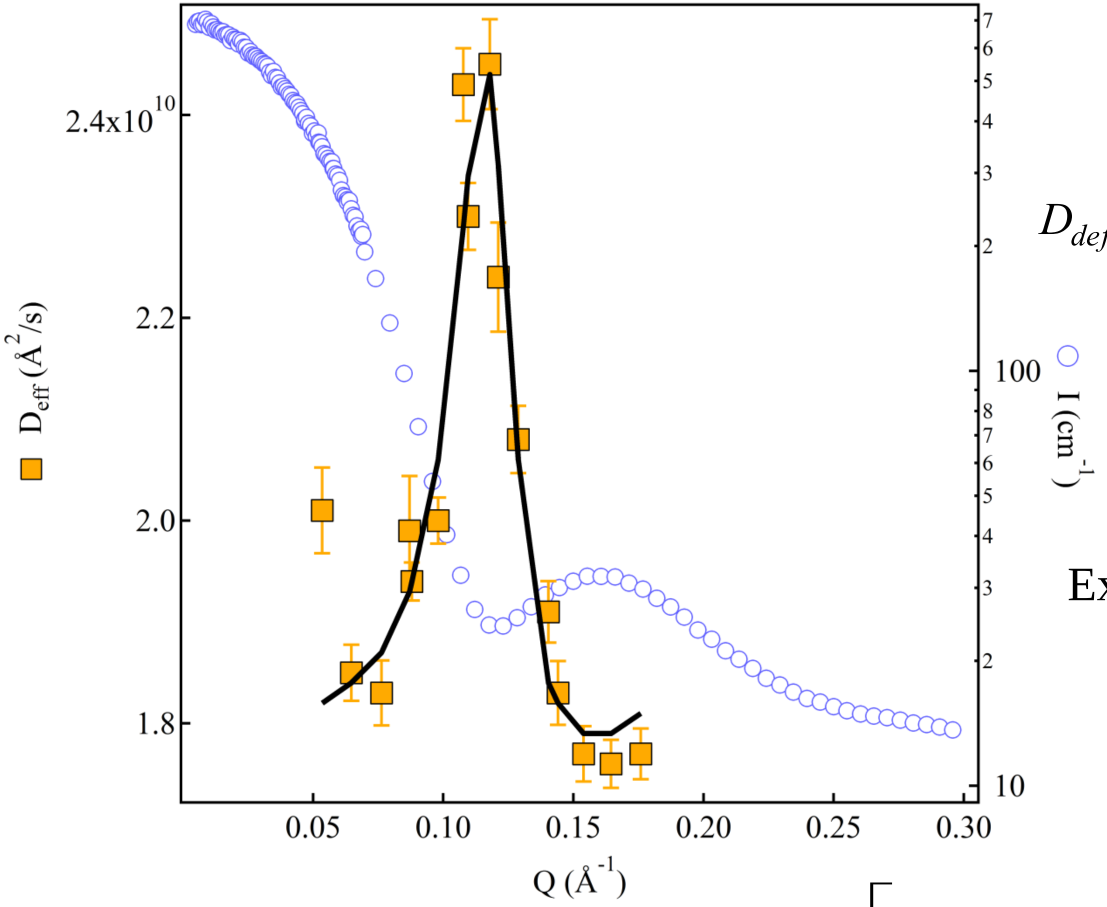
$$\frac{I(Q,t)}{I(Q,0)} = A\exp\left[-D_{eff}(Q)\cdot Q^{2}t\right]$$



$$D_{eff}(Q) = D_{tr} + D_{def}(Q)$$

Intermediate Scattering Function allows us to extract the effective diffusion coefficient as a function of Q

Fitted Effective Diffusion Coefficient



Shape Dynamics

$$D_{def}(Q) = \frac{5\lambda_2 f_2(QR_0)\langle|a_2|^2\rangle}{Q^2\left[4\pi j_0(QR_0)^2 + 5 f_2(QR_0)\langle|a_2|^2\rangle\right]}$$

$$\boxed{f_2(QR_0) = \left[4 j_2(QR_0) - QR_0 j_3(QR_0)\right]^2}$$

Extracted parameters:

$$D_{tr}\ ,\ \lambda_2\ ,\ R_0\ ,\ |a_2|$$

Bending Modulus: $$k = \frac{1}{48}\left[\frac{k_B T}{\pi p^2} + \lambda_2 \eta R_0^3 \frac{23\eta' + 32\eta}{3\eta}\right] = 0.29 k_B T$$

Polydispersity ↗

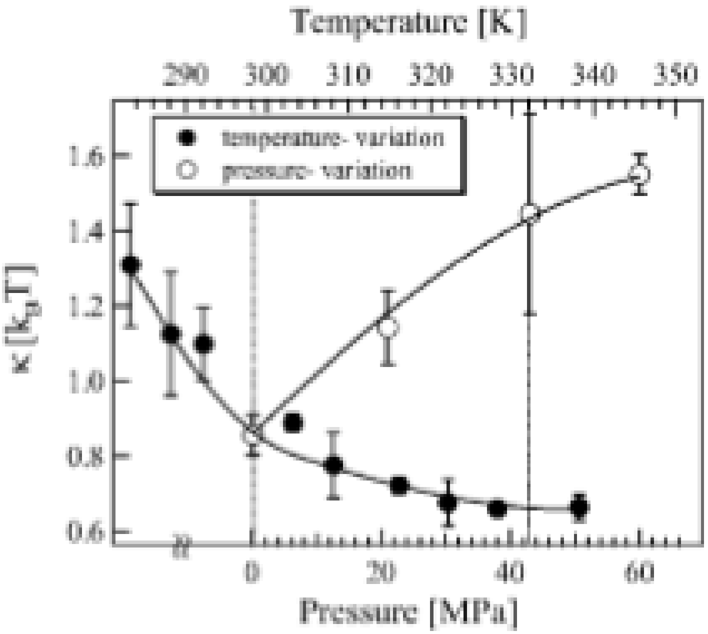
Conclusion

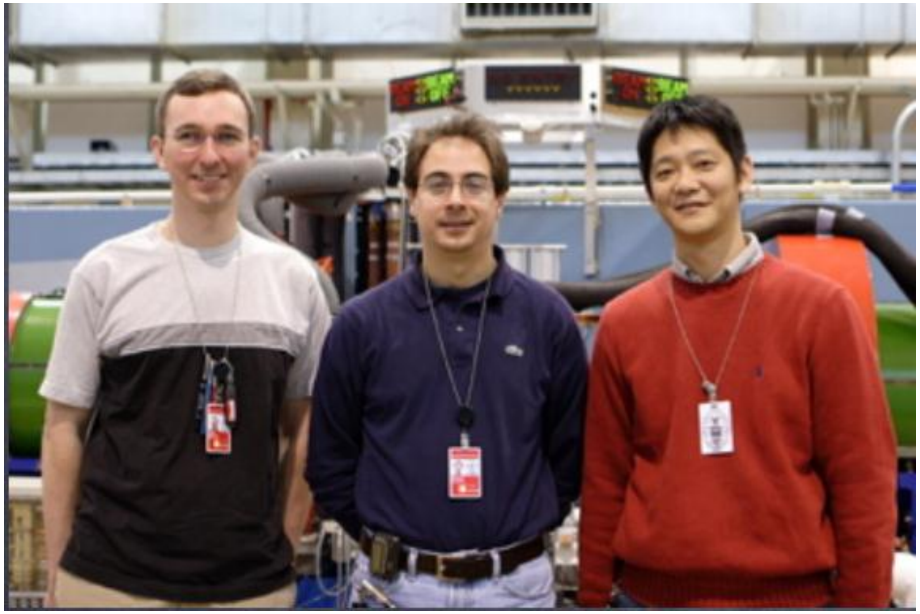
- Using the Neutron Spin Echo technique, the dynamics of the shape fluctuation of AOT microemulsion droplets is revealed.

- The intermediate scattering function $I(Q,t)/I(Q,0)$ is fitted by a single exponential decay function

- The bending modulus of elasticity of the AOT surfactant is 0.29 k_BT

Acknowledgements





Y. Kawabata, Hideki Seto, Michihiro Nagao, T. Takeda J. Chem. Phys. 127, 044705 (2007)