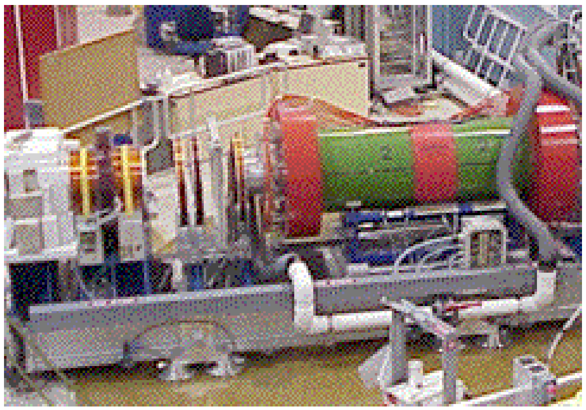
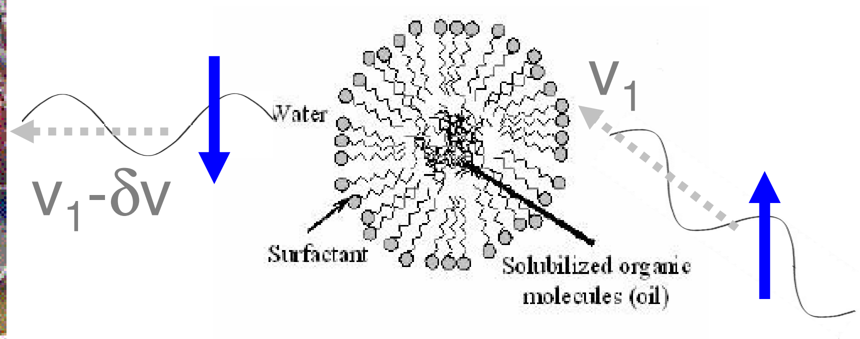
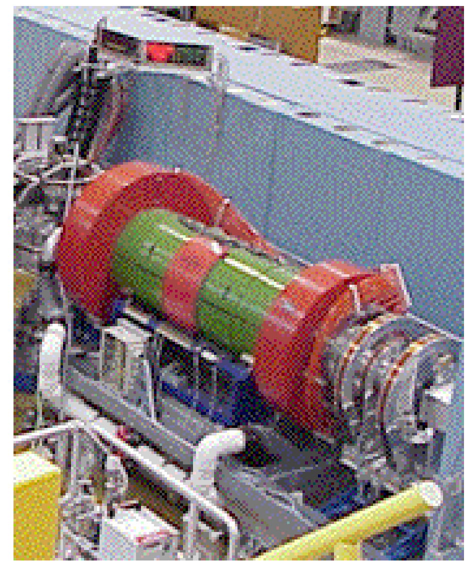






Dynamical Shape Fluctuations
of a
Spherical Surfactant Shell
via
Neutron Spin Echo

The A-Team Collaboration

Kenneth Desmond

Jason Haraldsen

Rafael Jaramillo

Xianglin Ke

Jong Keun Park

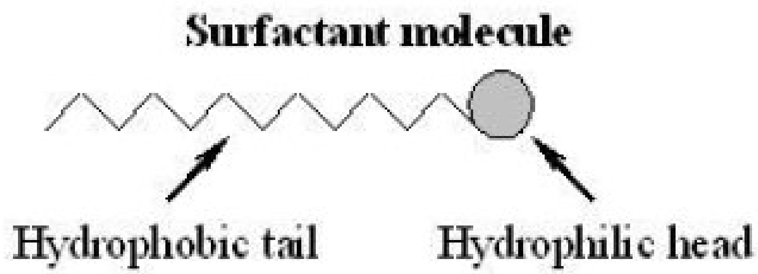
Cuihuan Wang

Shao-Chun Wang

Benjamin White

The A-Team Collaboration

Microemulsions



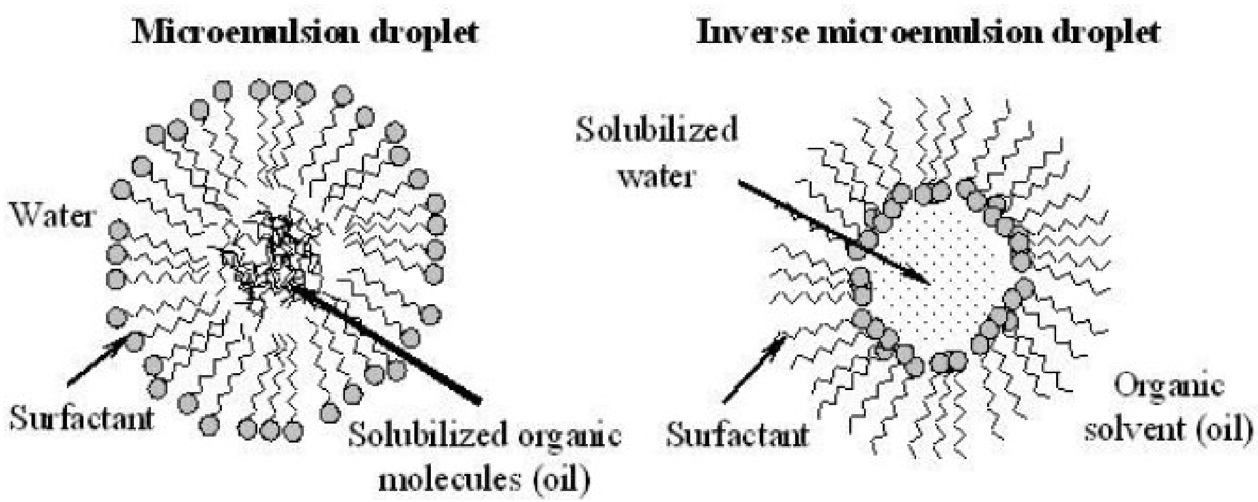
Surfactant:

AOT

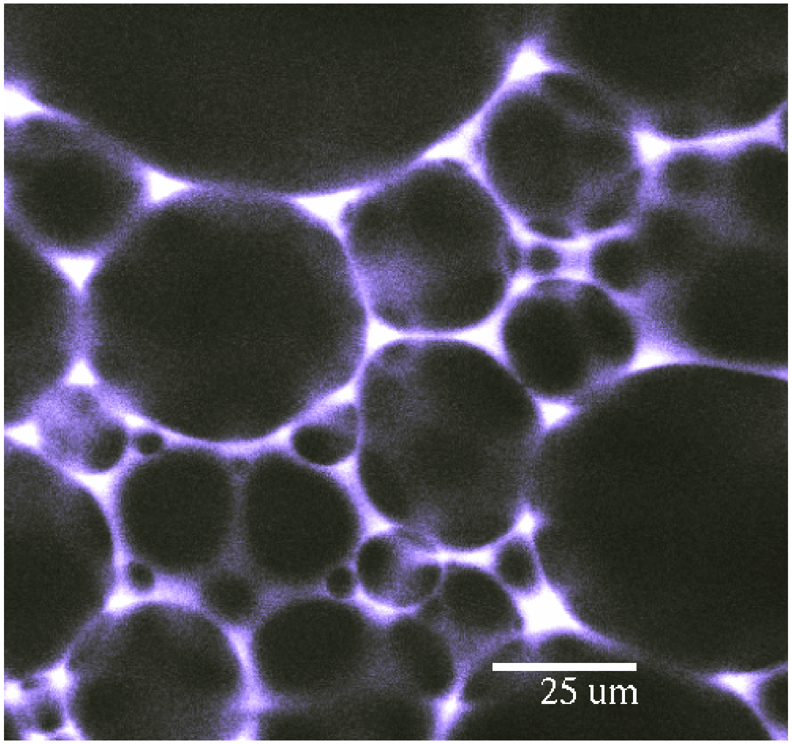
Liquid phase:

Deuterated n-Hexane

Deuterated Water



Experiment

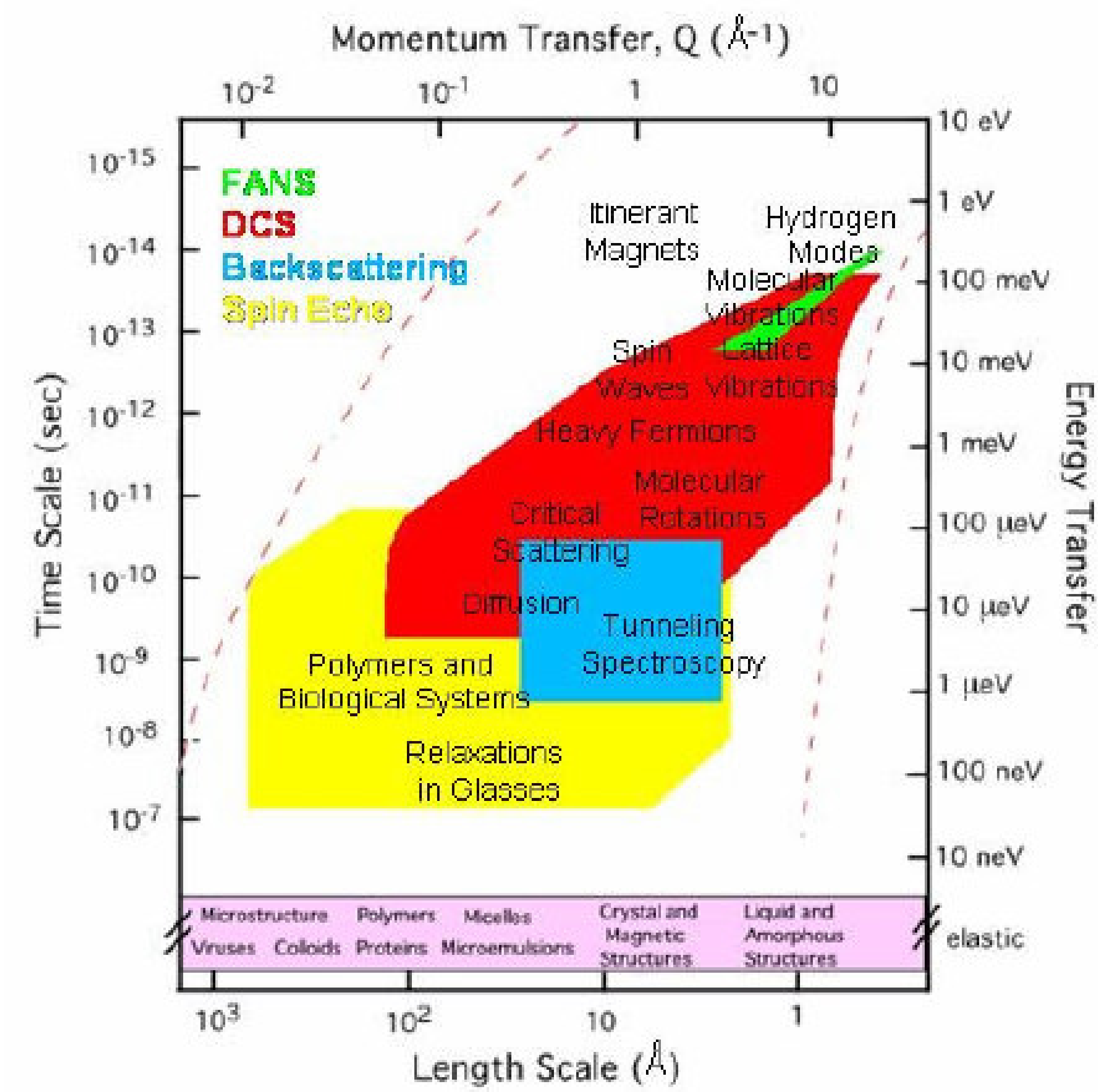


• Structure results from the minimization of the bending elastic energy.

• Surfactant film undergo deformations do to thermal fluctuations.

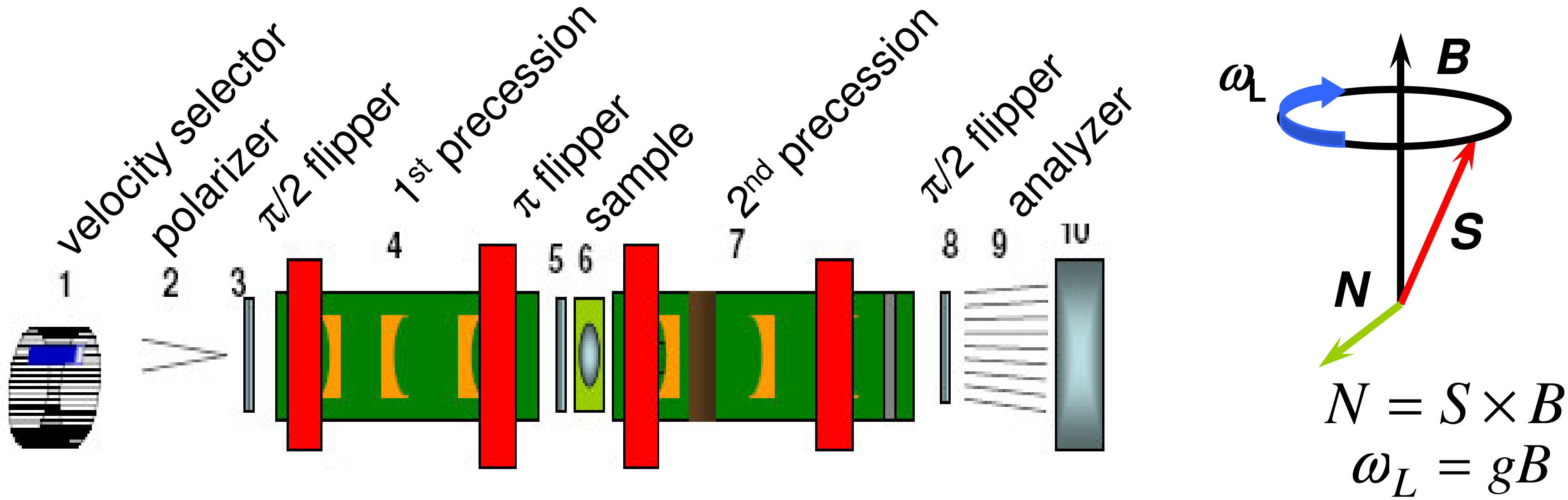
Length Scale of Fluctuations: nanometer scale
Time Scale of Fluctuations: nanosecond scale

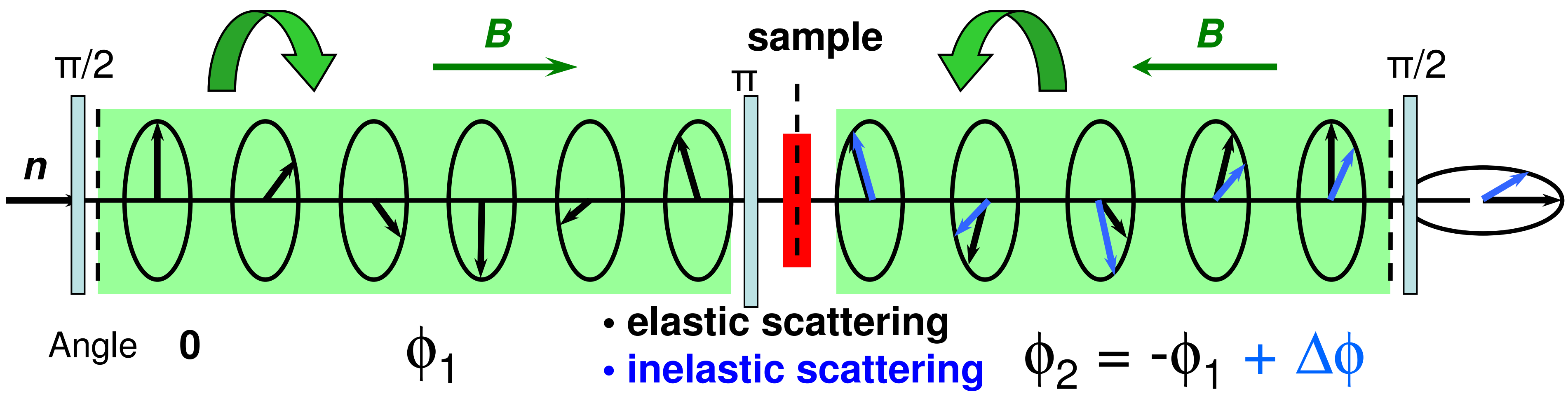
Method



Momentum Transfer, Q (Å-1)
10-2
10-1
1
10
FANS
DCS
Backscattering
Spin Echo
Itinerant Magnets
Hydrogen Modes
Molecular Vibrations
Lattice Vibrations
Spin Waves
Heavy Fermions
Molecular Rotations
Critical Scattering
Diffusion
Tunneling Spectroscopy
Polymers and Biological Systems
Relaxations in Glasses
Time Scale (sec)
10-15
10-14
10-13
10-12
10-11
10-10
10-9
10-8
10-7
Energy Transfer
10 eV
1 eV
100 meV
10 meV
1 meV
100 μeV
10 μeV
1 μeV
100 neV
10 neV
elastic
Microstructure
Polymers
Micelles
Viruses
Colloids
Proteins
Microemulsions
Crystal and Magnetic Structures
Liquid and Amorphous Structures
10
10
10
1
Length Scale (Å)

Neutron Spin-Echo Spectroscopy





Most boring slide
of 2007 NCNR
Summer School
(official entrant)

Neutron Spin Echo: Polarization ←→ Velocity

Longitudinal polarization at analyzer

Wavelength distribution

ϕ_2-ϕ_1 for mean wavelength

Scattering function

Measure this

$$\langle Pz\rangle = \int f(\lambda)\cos\left[\frac{\Delta\phi(\langle\lambda_1\rangle)\lambda}{\langle\lambda_1\rangle}\right]d\lambda\int S(Q,\omega)\cos\left[\frac{\phi_1(\langle\lambda_1\rangle)m\lambda^3\omega}{2\pi h\langle\lambda_1\rangle}\right]d\omega =$$

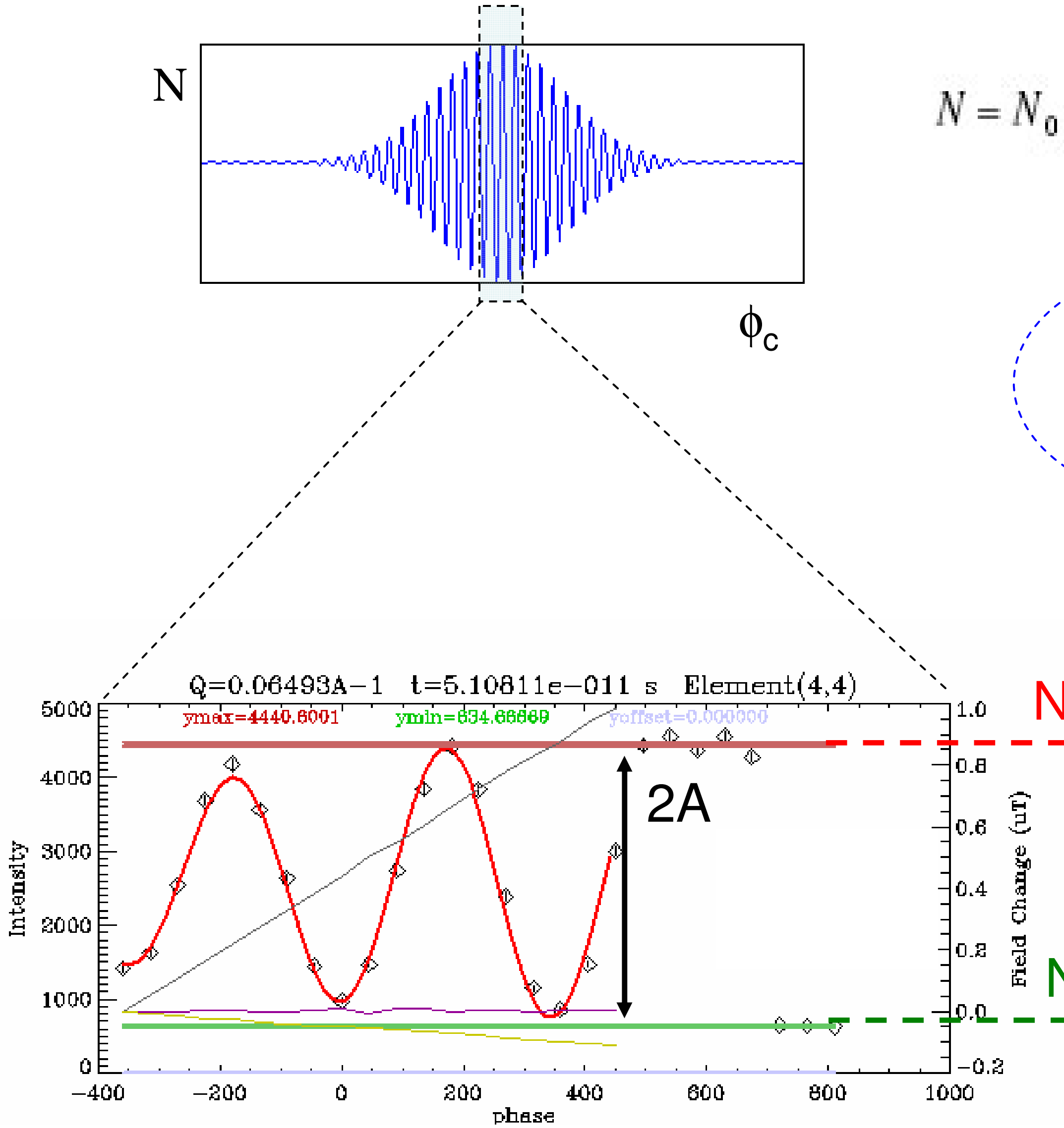
$$\int f(\lambda)\cos\left[\frac{\Delta\phi(\langle\lambda_1\rangle)\lambda}{\langle\lambda_1\rangle}\right]d\lambda\int S(Q,\omega)\cos\omega t_F\, d\omega = \int f(\lambda) I(Q,t_F)\,d\lambda$$

Want this

$$t_F = \frac{\phi_1(\langle\lambda_1\rangle)m\lambda^3}{2\pi h\langle\lambda_1\rangle} = \gamma_L\left(\frac{m}{h}\right)^2\frac{\lambda^3}{2\pi}I_1$$

Fourier time

Data Reduction: Fitting the Spin Echo



$$N = N_0 + A\exp\left[\frac{(\phi_c - \phi_0)^2}{2\sigma^2}\right]\cos\left[\frac{360}{T}(\phi_c - \phi_0)\right]$$

$$\sigma^2 = \frac{1}{4\pi^2\sigma_\lambda^2}$$

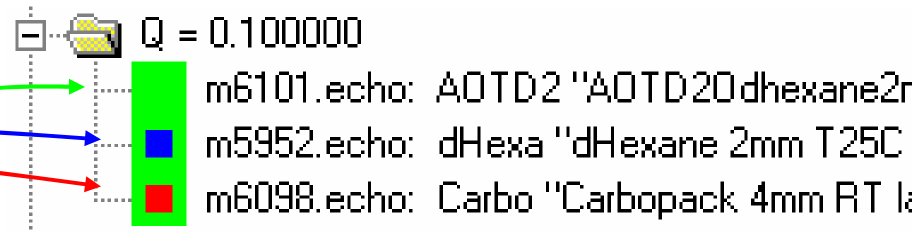
$$T \propto \langle \lambda \rangle$$

N_{up} π/2 flippers off (no precession)
π flipper off

$$\langle P_z \rangle = \frac{2A}{N_{up} - N_{down}}$$

N_{up} π/2 flippers off (no precession)
π flipper on

Data Reduction: Background, etc.



Sample in solution – signal, instrument inhomegeneities, attenuation -- (A, N)

Solvent (background) – instrument inhomegeneities, attenuation -- (A^{bgr}, N^{bgr})

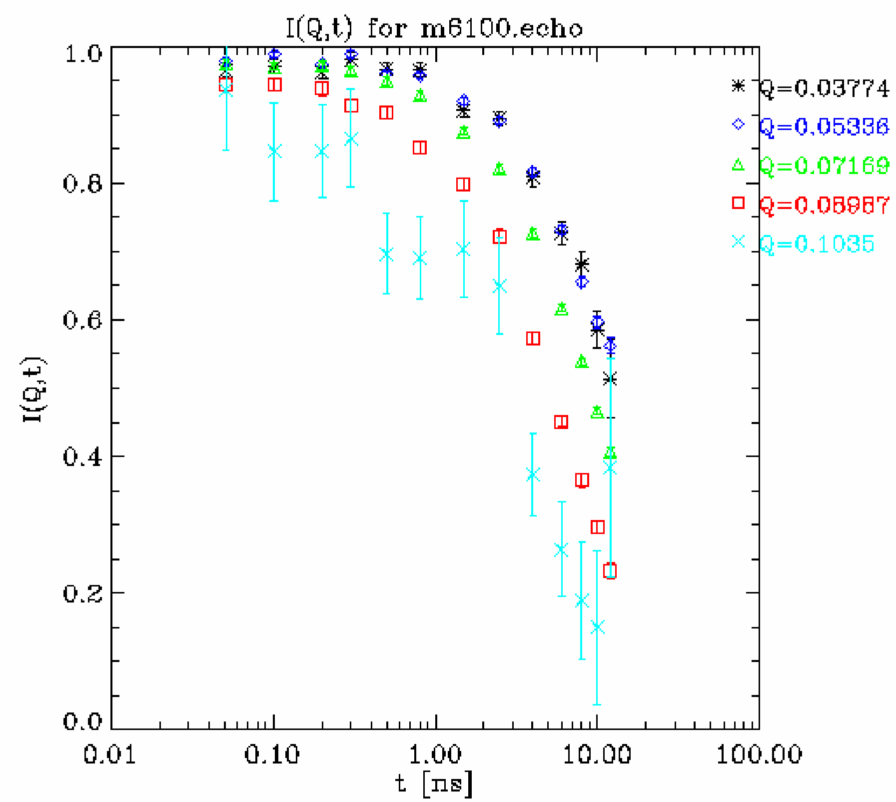
Elastic (dynamics-free) dummy sample -- graphite “carbopack” -- (A^E, N^E)

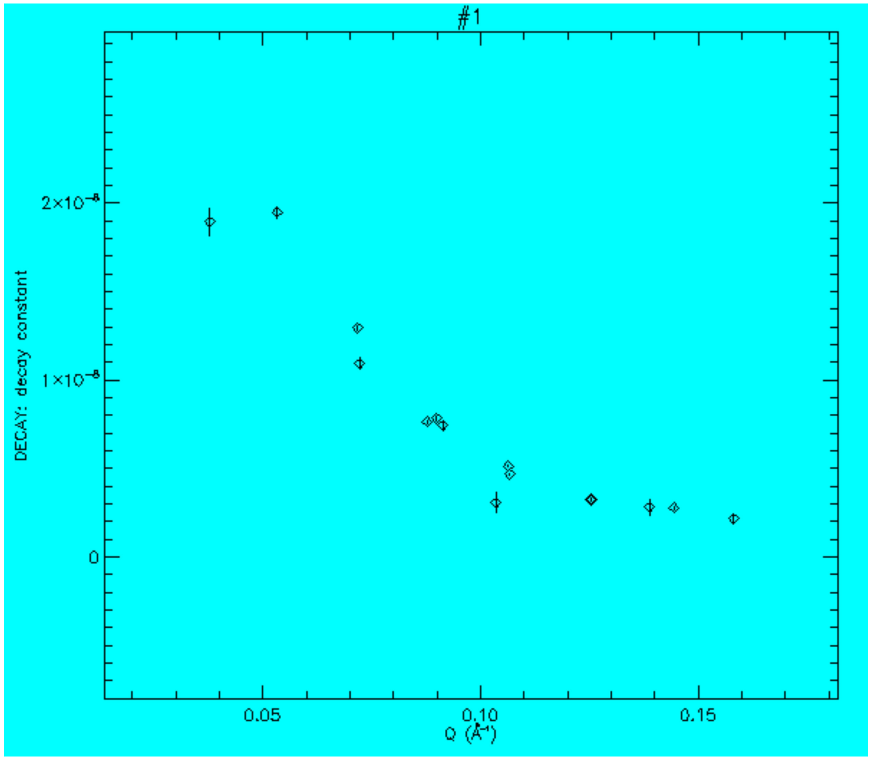
$$\frac{I(Q,t)}{I(Q,0)} = \left[\frac{2\left(A - TA^{bgr}\right)}{\left(N_{up} - N_{down}\right) - T(1-\phi_V)(N^{bgr}_{up} - N^{bgr}_{down})} \right] \Big/ \frac{2A^E}{N^E_{up} - N^E_{down}}$$

T = (sample transmission)/(background transmission) – measures relative contribution to coherent scattering

$(1-\phi_V)$ = solvent volume fraction

Results

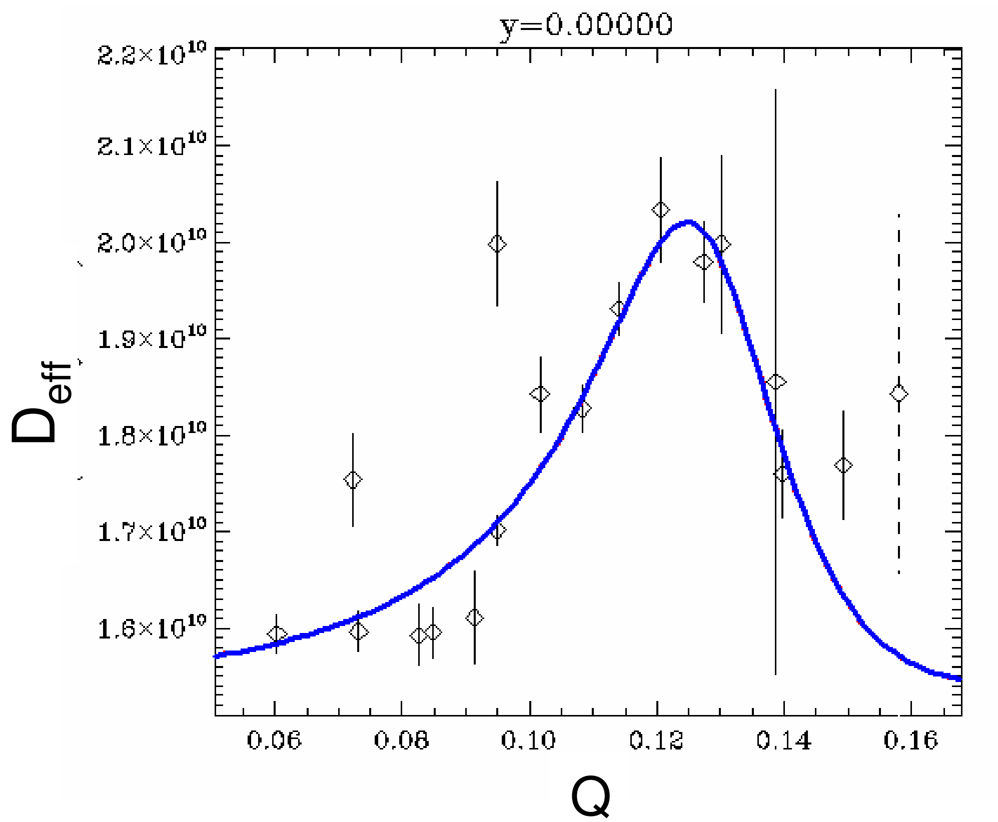




$$\frac{I(Q,t)}{I(Q,0)} = \exp\left[-D_{eff}(Q)Q^2 t\right]$$

Decay Constant = $D_{eff}(Q)Q^2$

Results



D_{eff} can be decomposed into two types of motion

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

If there were only translational motion, then D_{eff} will be invariant

λ = 7.75 x 10^7 1/s

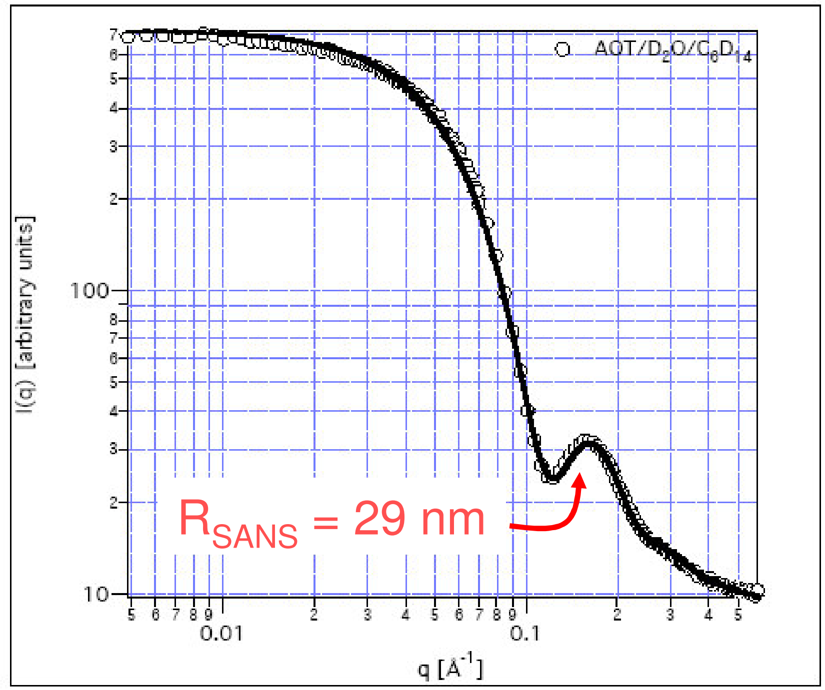
Radius = 24nm

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

Comparison with SANS Data

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

η (d-hexane)	0.31 cp	0.0031 Pa·s
η' (D2O)	1.096 cp	0.001096Pa·s
Polydispersity	0.188	
λ	77470000 1/s	
R_0	$2.46 \cdot 10^{-9}$ m	
k_B	$1.38 \cdot 10^{-23}$ J/K	
T	293 K	



$k = 0.4\ k_B T_{room}$

Conclusion/Acknowledgements

- NSE – unique tool for measuring coherent, high-resoultion dynamics
- Nanometer & nanosecond dynamics in soft matter

- Thanks to
  - NCNR
  - NSF
  - DAVE Collaboration
    (www.ncnr.nist.gov/dave/download.html)