

SANS BASICS

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Center for Neutron Research

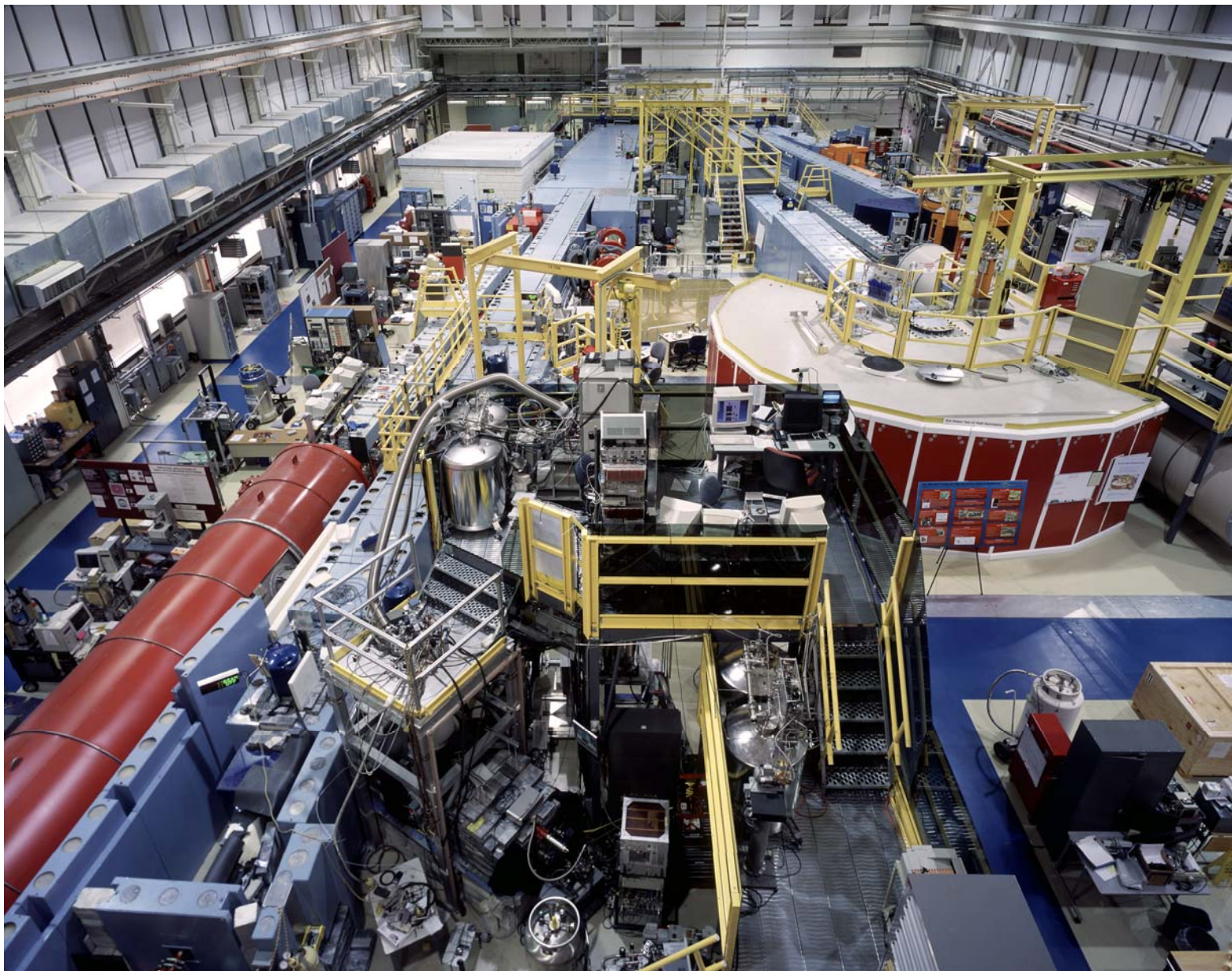
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OUTLINE

- 1. NIST Guide Hall and SANS Instruments
- 2. The SANS Technique
- 3. SANS Data Analysis
 - Standard Plots
 - Porod Exponents
 - Guinier Plots
 - SANS Models
 - The Random Phase Approximation
 - The Ornstein-Zernike Equation
- 4. SANS Research Topics
 - A - Copolymers
 - B – Pluronic Micelles
 - C - Protein Complex
- 5. Gallery of SANS Data Images
- 6. Final Words

1 - NIST Guide Hall and SANS Instruments

The NIST Guide Hall



The NG3 SANS Instrument



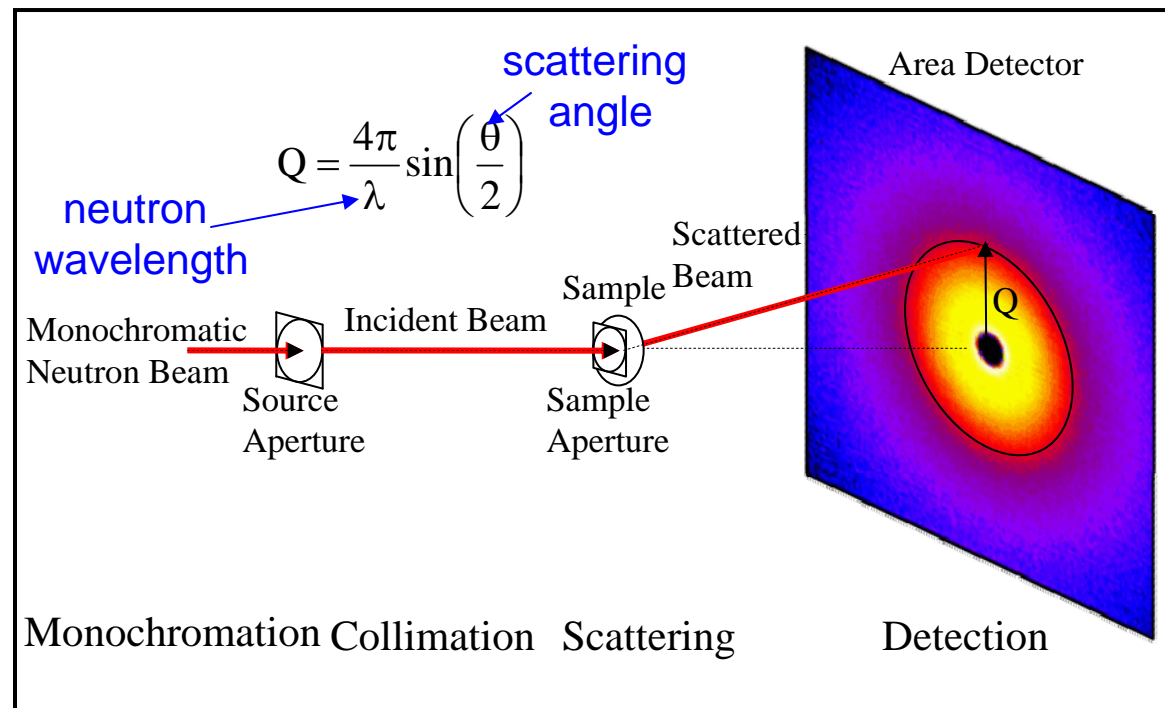
The NG3 SANS Vessel



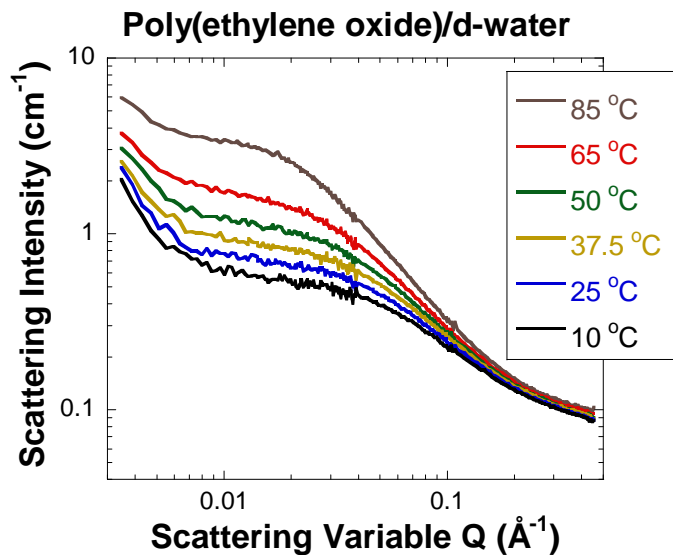
Neutron area detector **Velocity selector**

2 – The SANS Technique

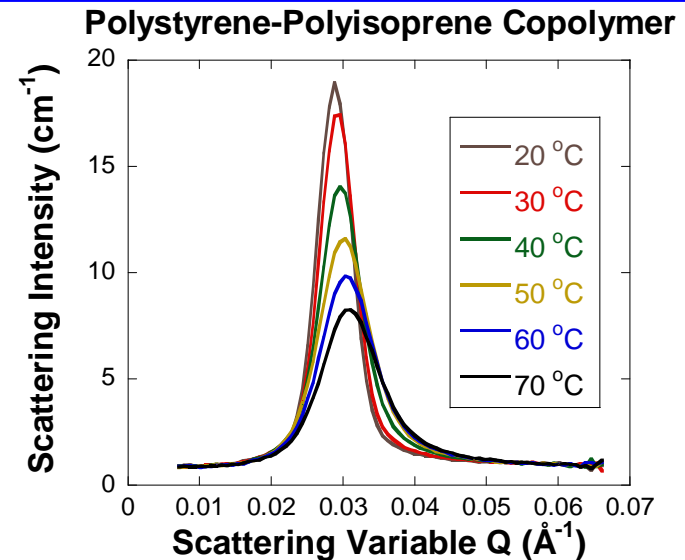
Small-Angle Neutron Scattering



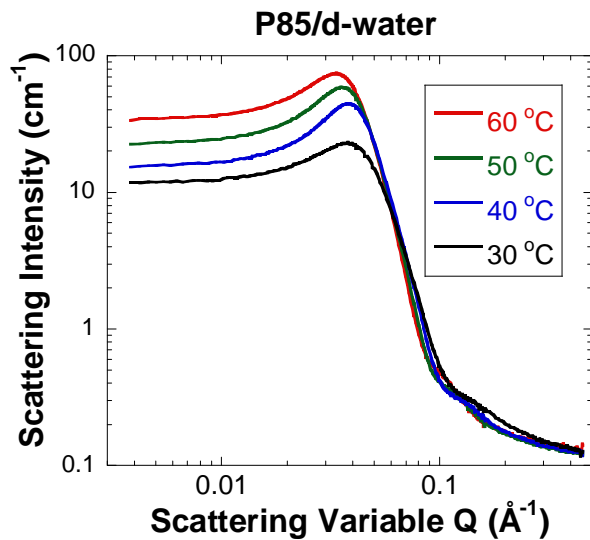
Typical SANS Spectra



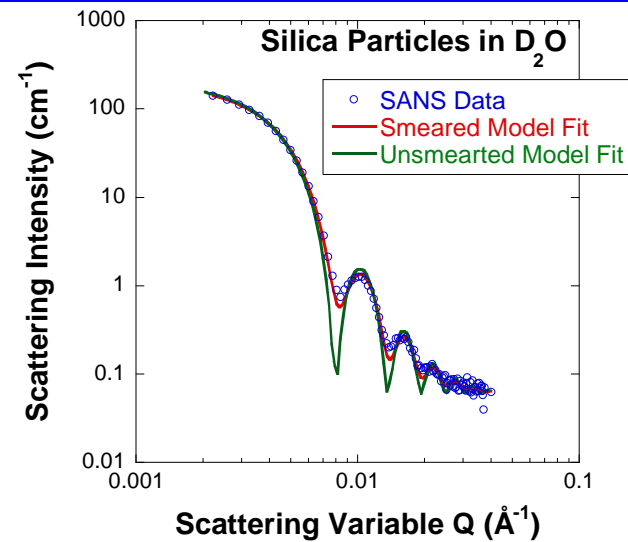
Polymer Solution



Copolymer



Complex Fluid



Silica Particles

SANS Cross Sections

$$I(\mathbf{Q}) = \frac{d\Sigma_{\text{coh}}(\mathbf{Q})}{d\Omega} + \frac{d\Sigma_{\text{incoh}}}{d\Omega}$$

COHERENT

- ~ Contrast factor = $(\rho_A - \rho_B)^2$
- Info. about structure

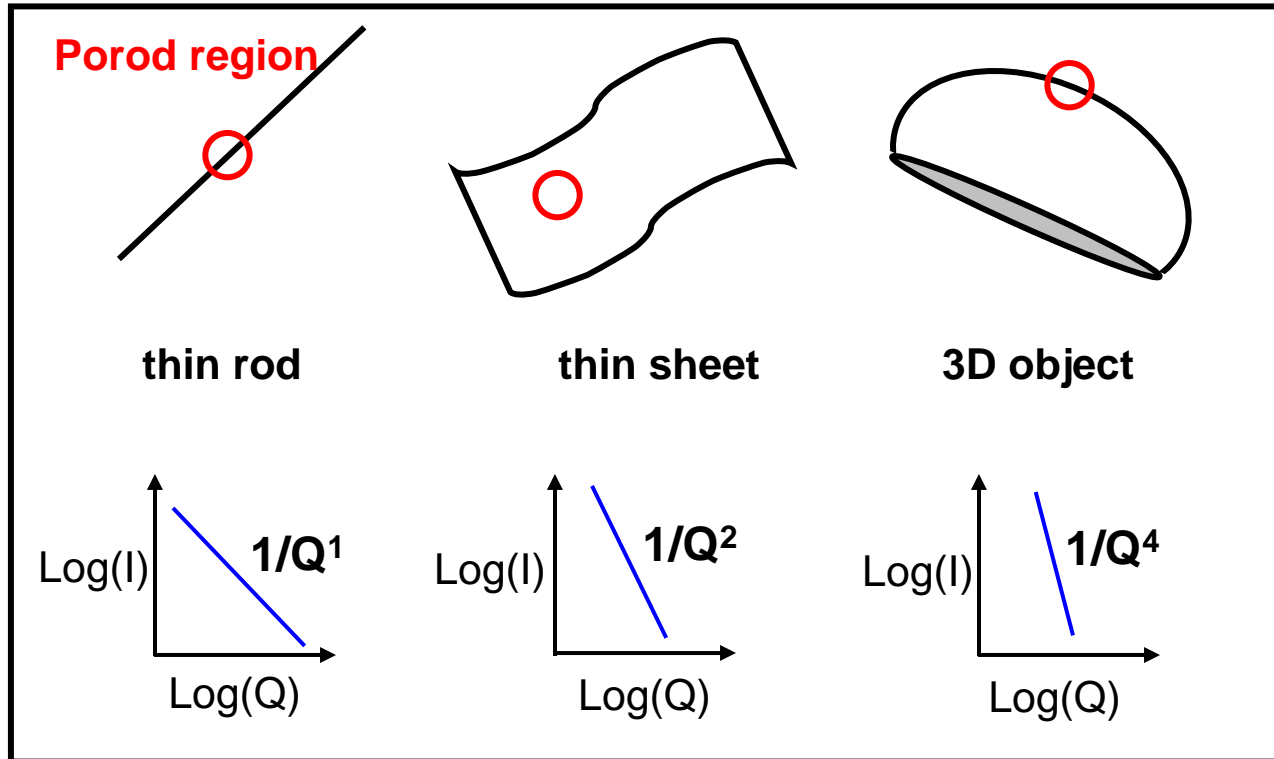
INCOHERENT

- Q-independent
- no info. about structure

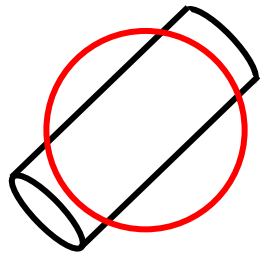
3 –SANS Data Analysis

- Standard Plots (Porod Plot, Guinier Plot)
- SANS Models
- Molecular Simulation

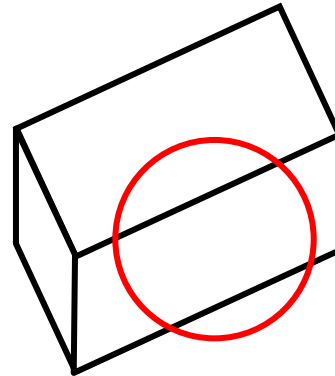
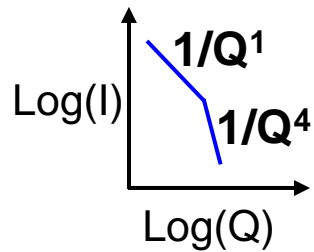
Assortment of Porod Exponents



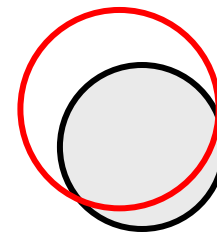
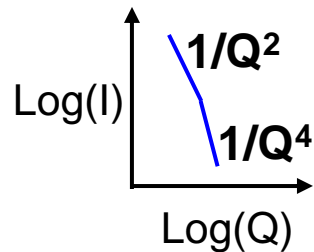
More Porod Exponents



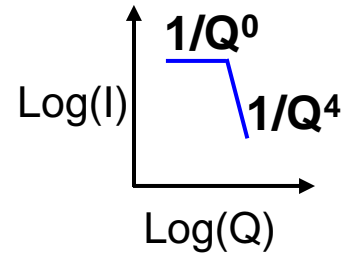
thick cylinder



thick slab

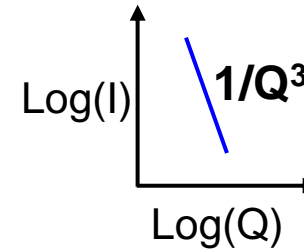
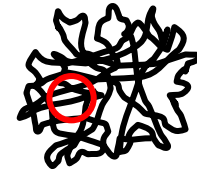
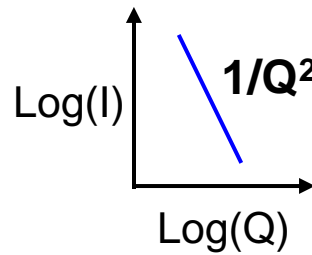
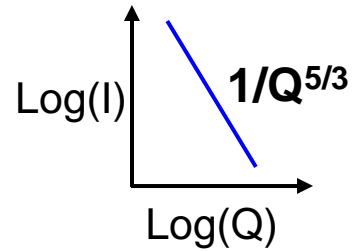
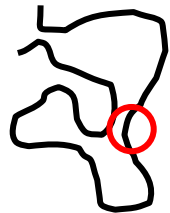


3D object

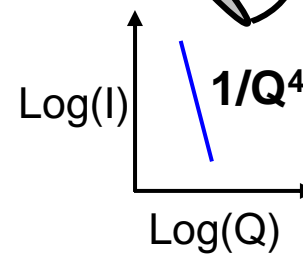
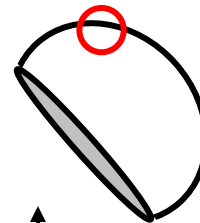
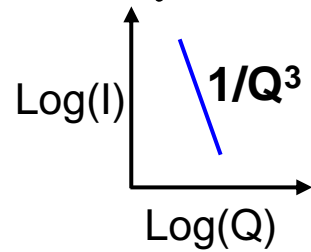
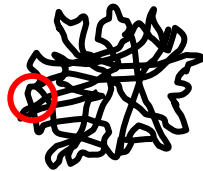


More Porod Exponents

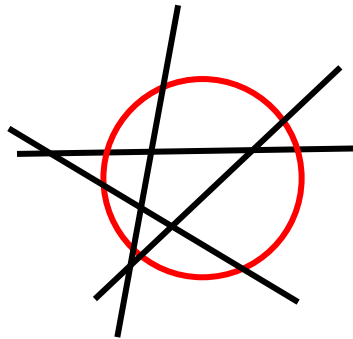
MASS
FRACTALS



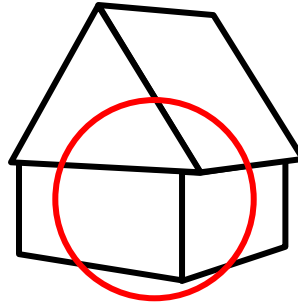
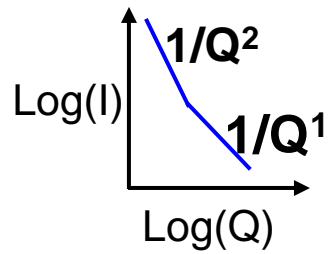
SURFACE
FRACTALS



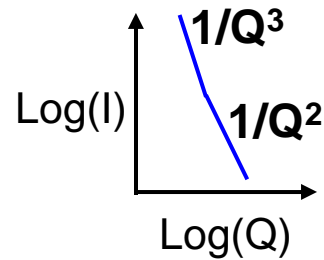
More Porod Exponents



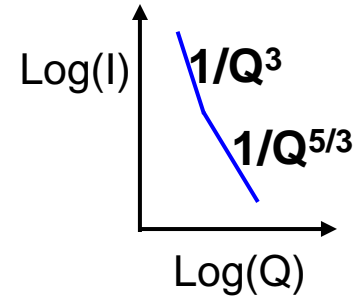
Rod network



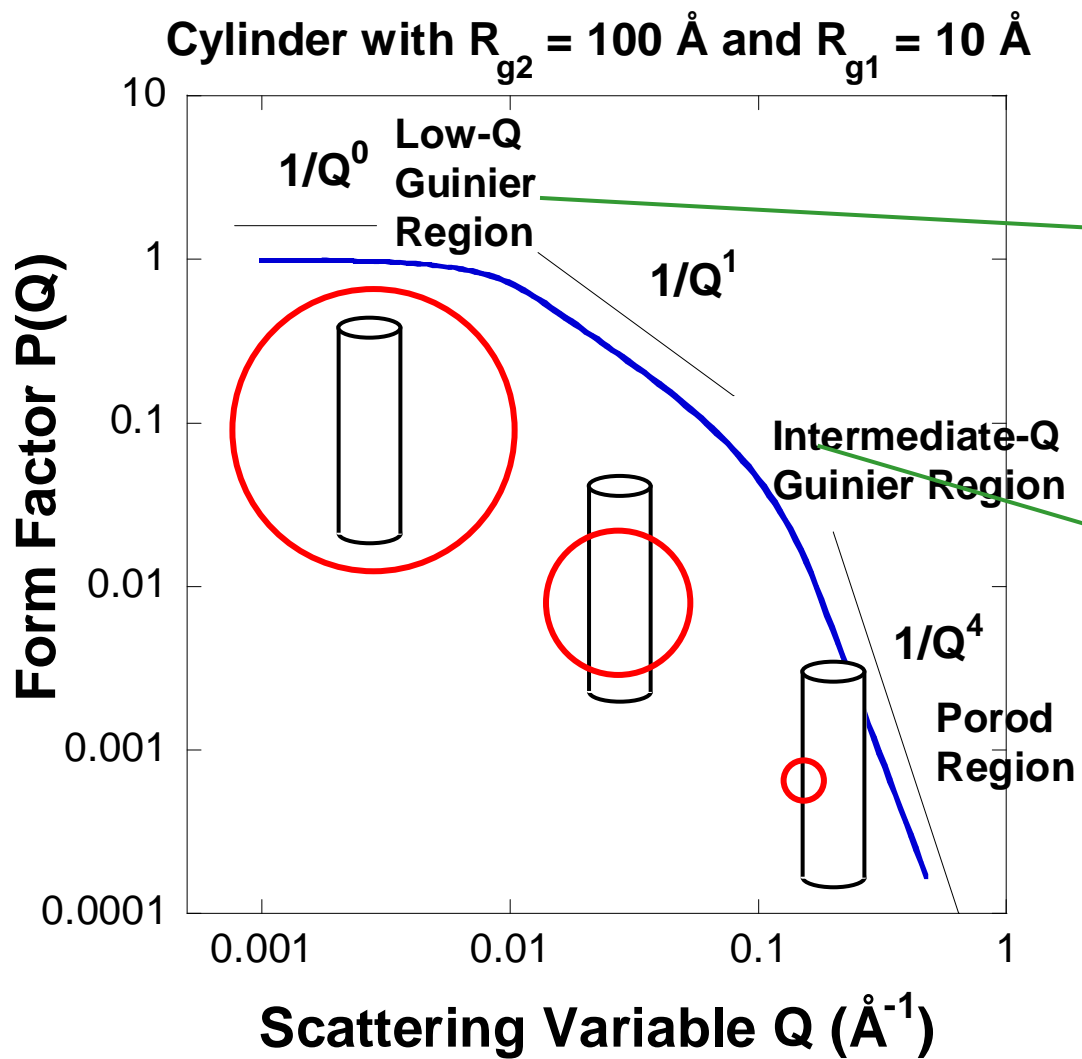
Sheet network



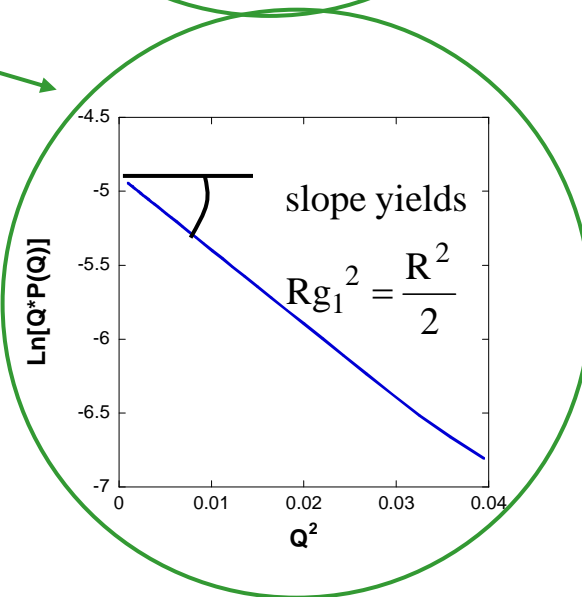
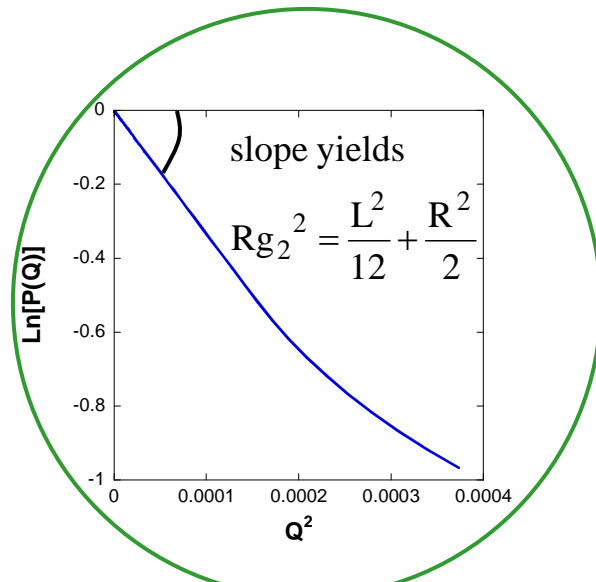
Mystery structure



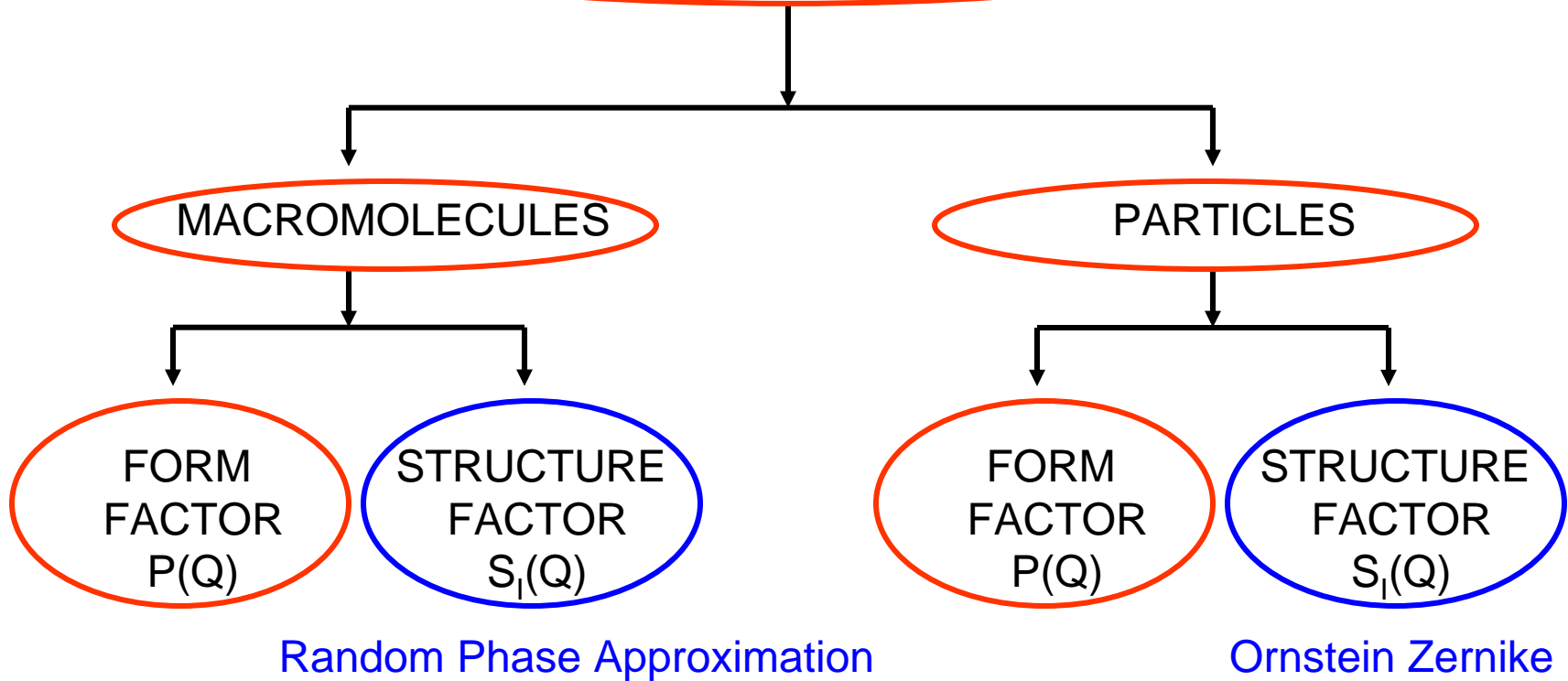
Guinier-Porod Regions



Guinier Plots



SANS Models

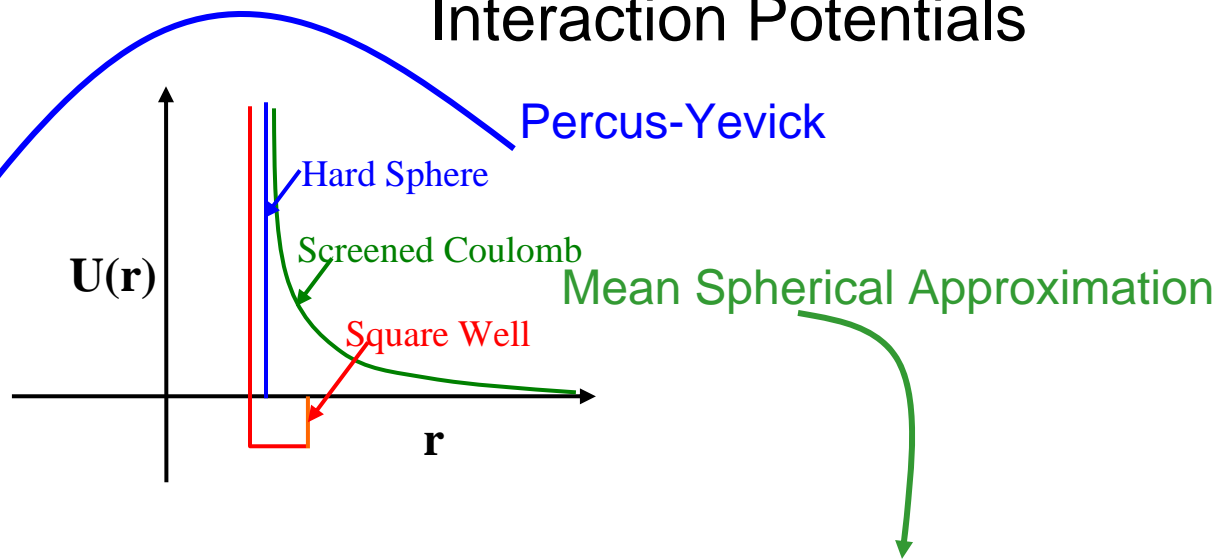


$$\frac{d\Sigma(\mathbf{Q})}{d\Omega} = \left(\frac{N_A}{V} \right) (\rho_A - \rho_B)^2 V_A^2 P(\mathbf{Q}) S_I(\mathbf{Q})$$

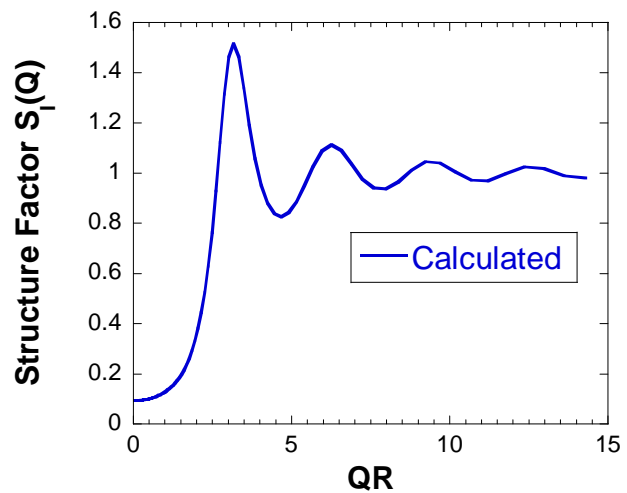
↑ ↑ ↑ ↑ ↑
cross number contrast particle form structure
section density factor volume factor factor

The Ornstein-Zernike Equation

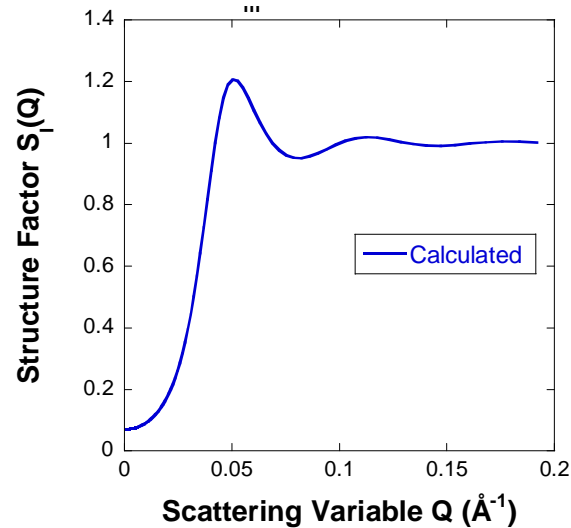
Interaction Potentials



Percus-Yevick



Mean Spherical Approximation



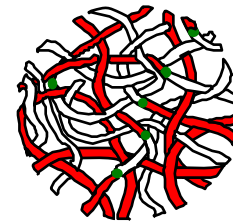
4. SANS Research Topics

A - Copolymers

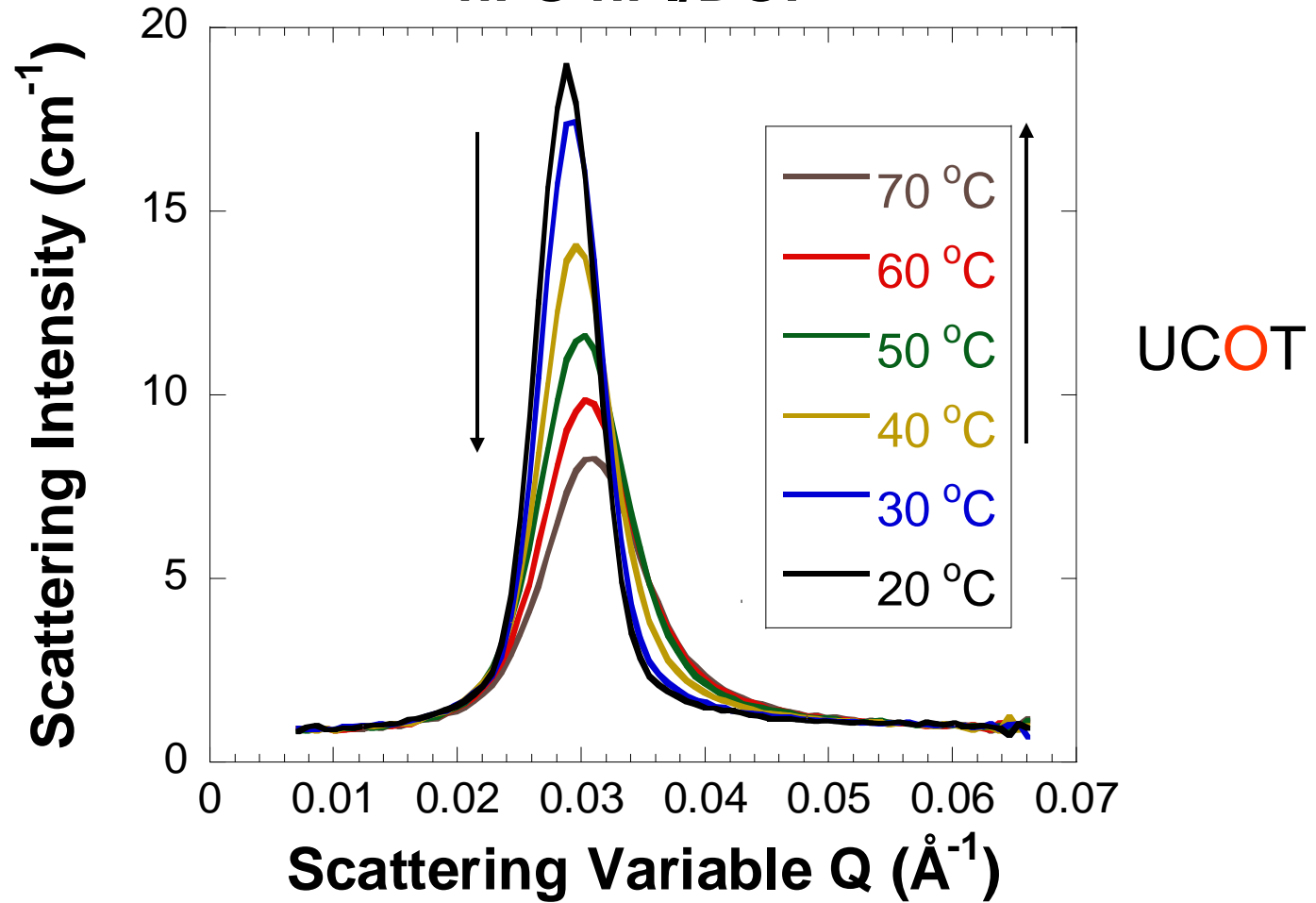
B – Pluronic Micelles

C - Protein Complex

A - Copolymers

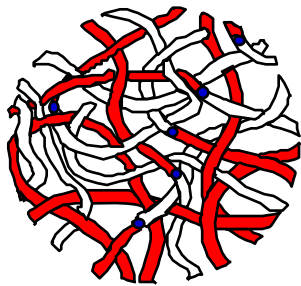


Block Copolymer hPS-hPI/DOP

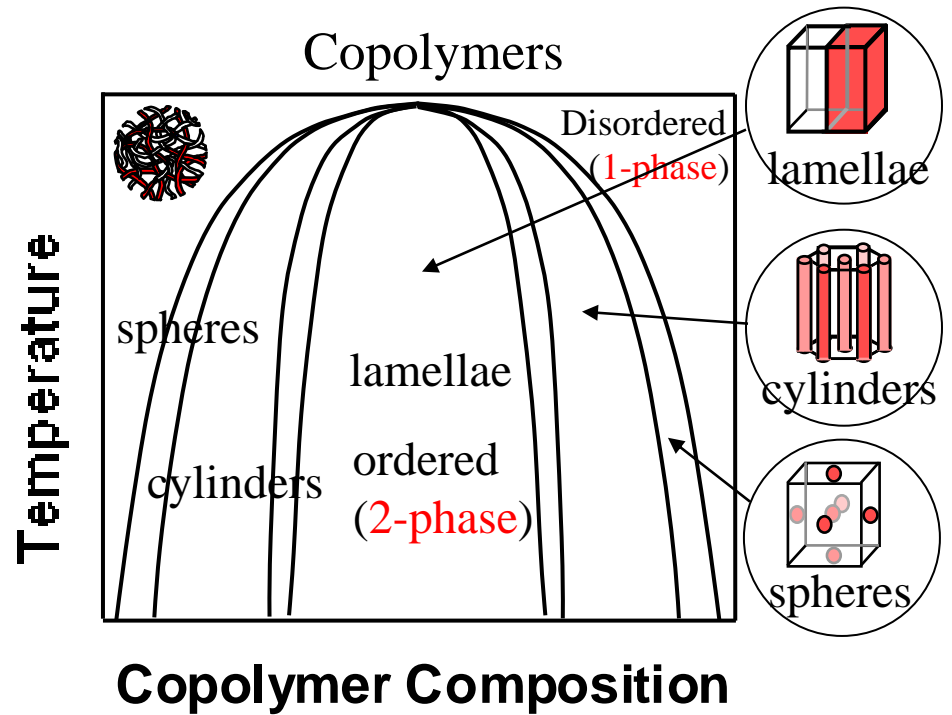
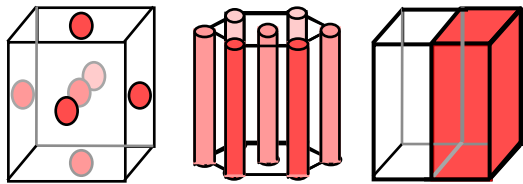


Phase Diagram for Block Copolymers

Disordered Block Copolymer

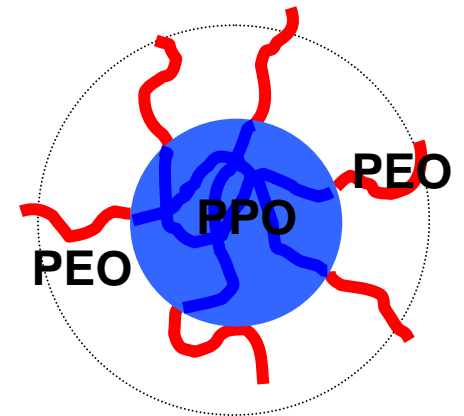


Ordered Block Copolymers



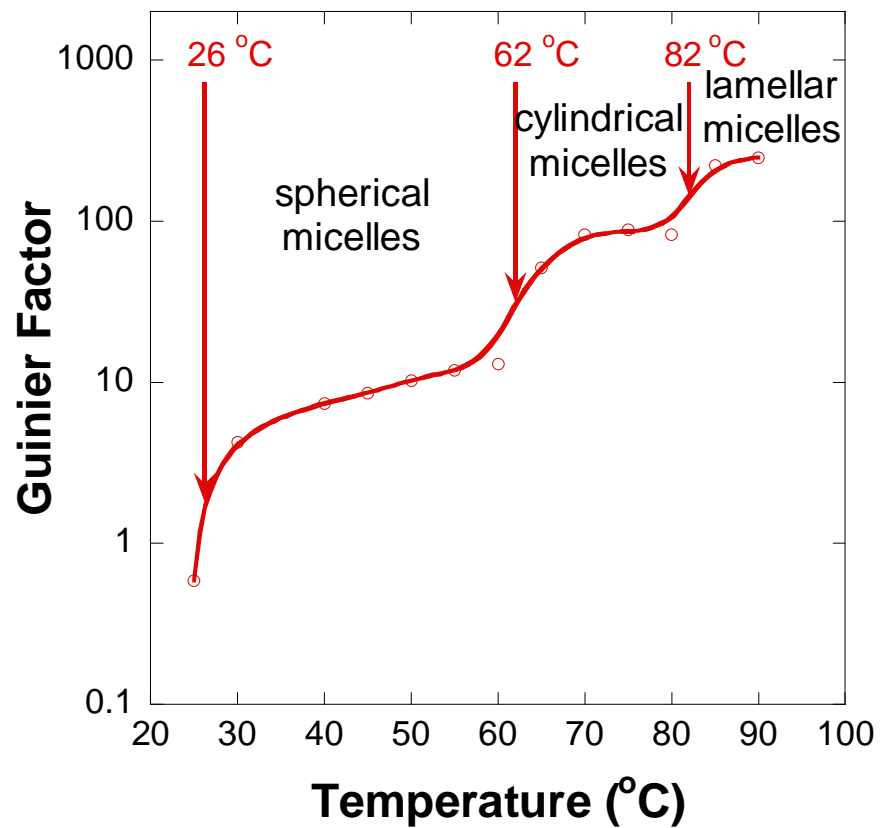
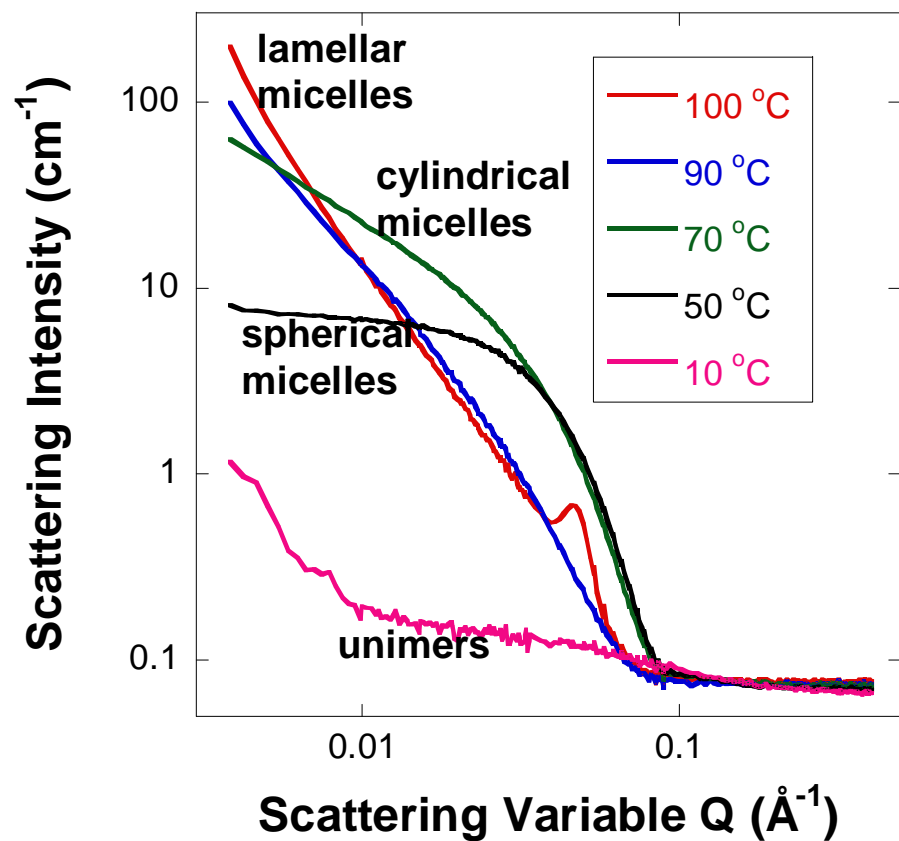
Upper Critical Ordering Temperature

B – Pluronic Micelles



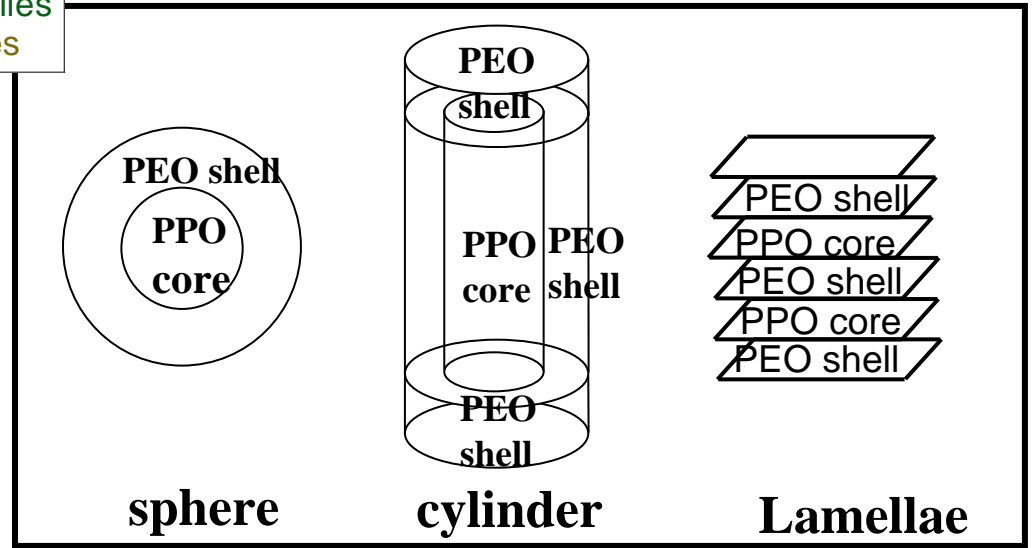
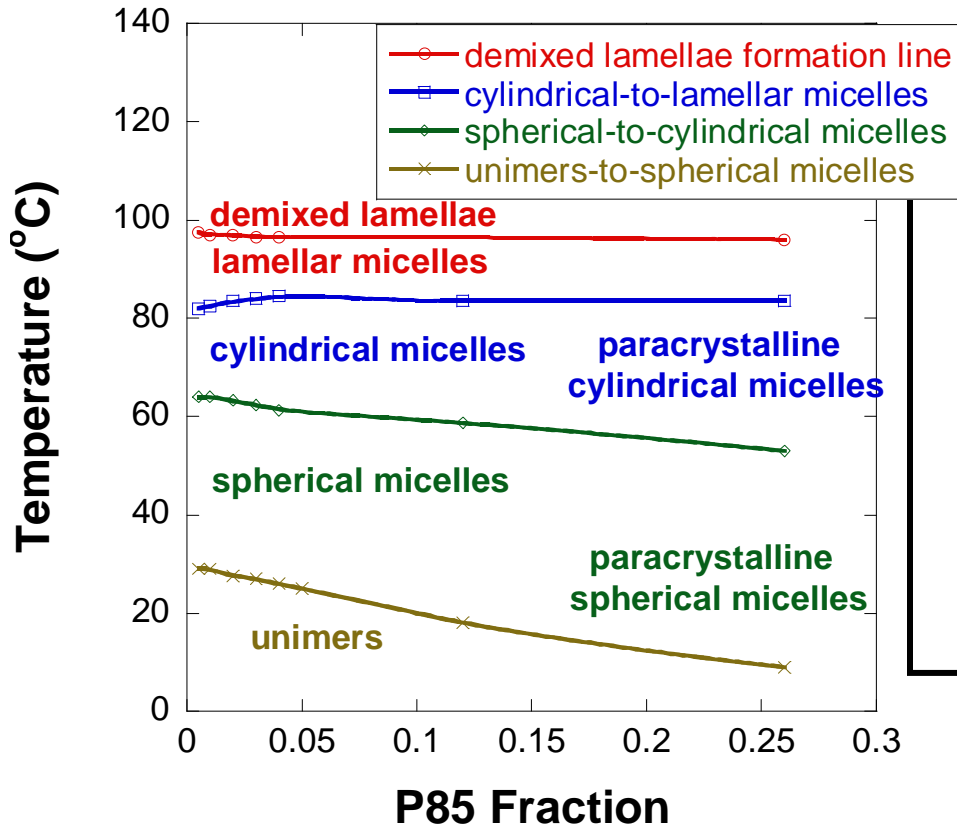
Micelles Phases

0.5 % P85 in d-Water

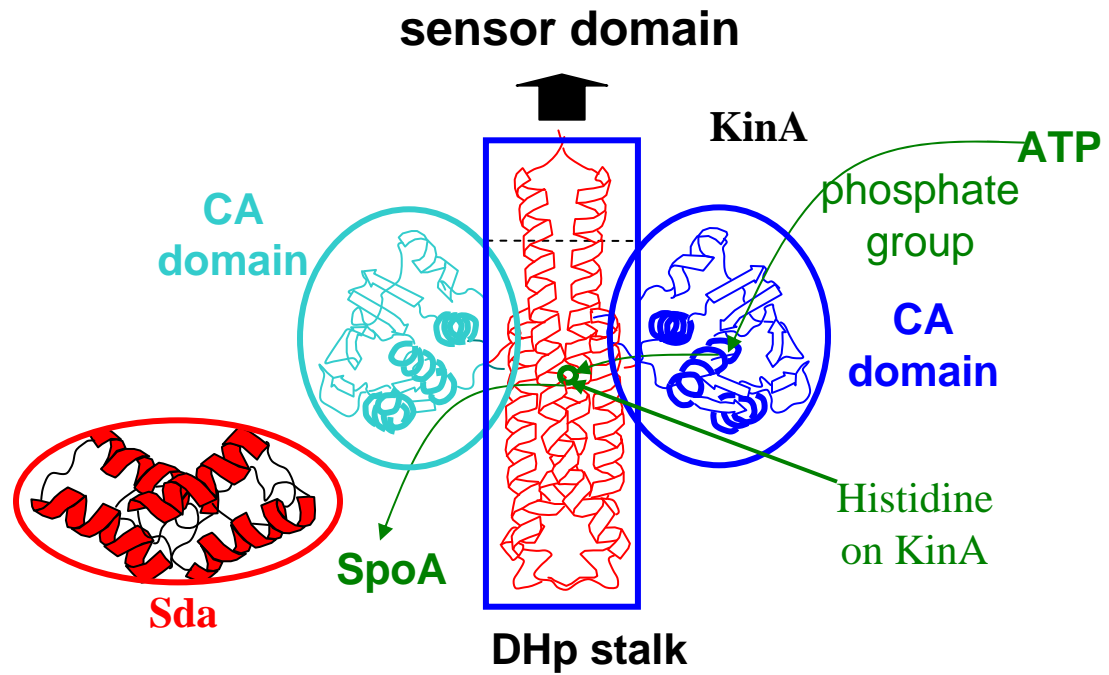


Phase Diagram

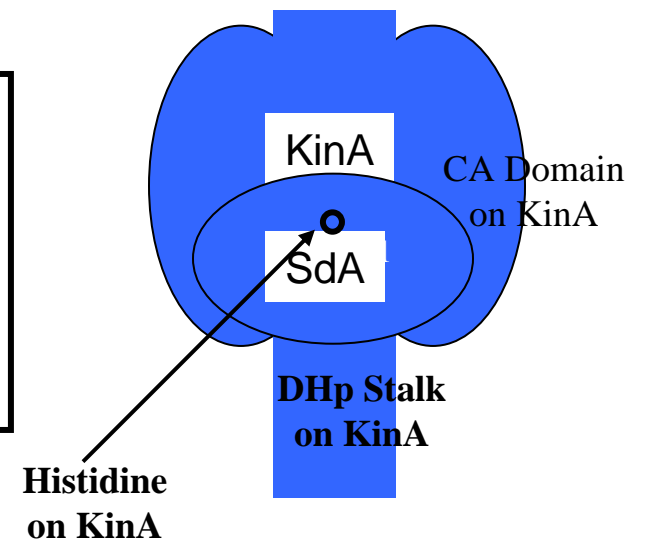
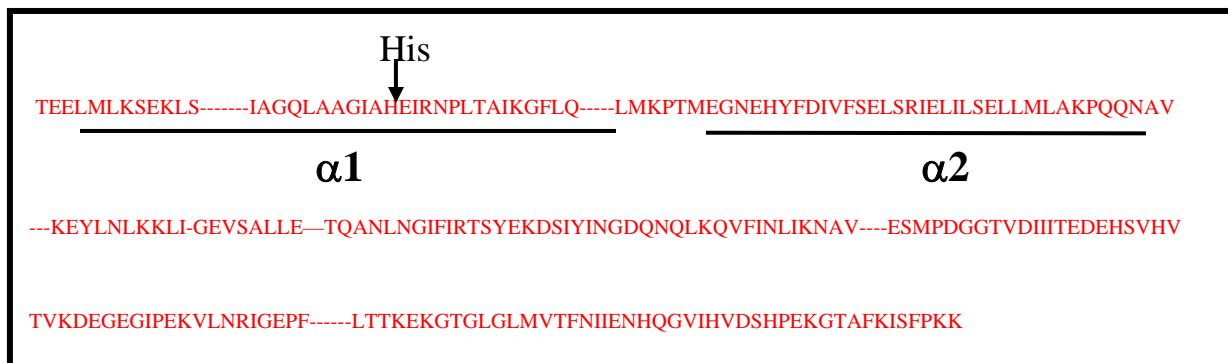
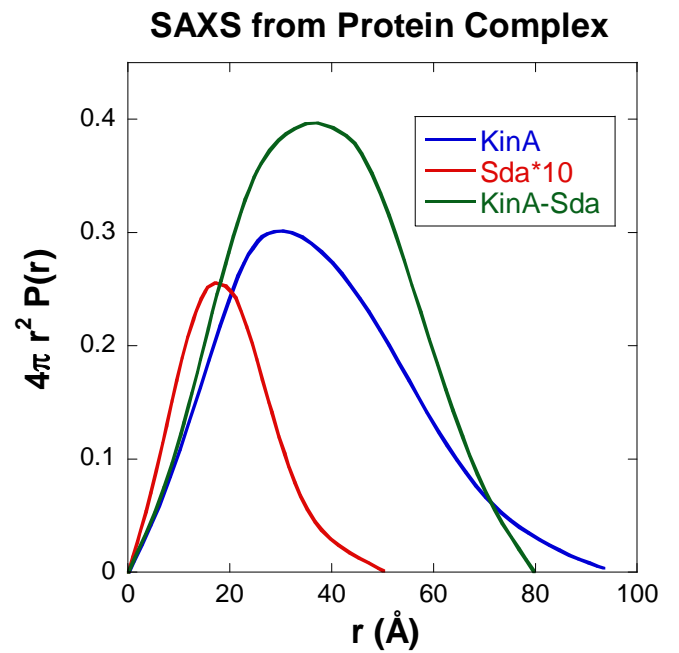
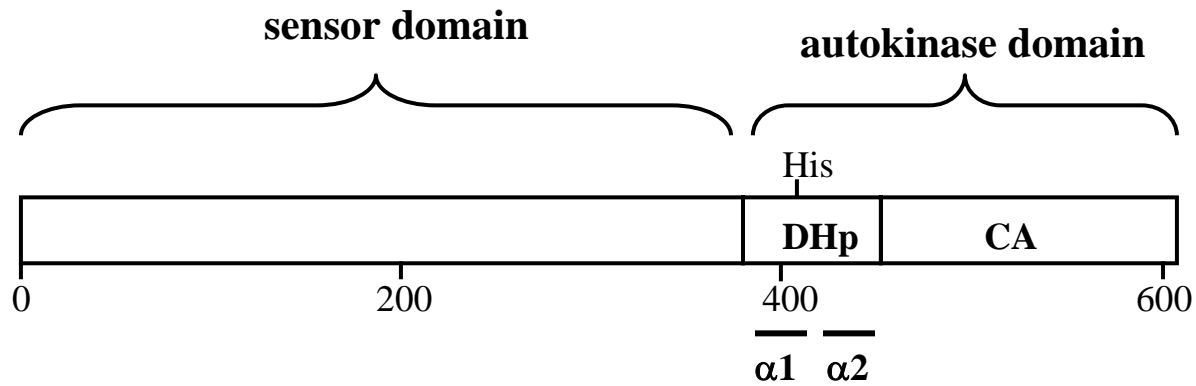
P85/d-Water



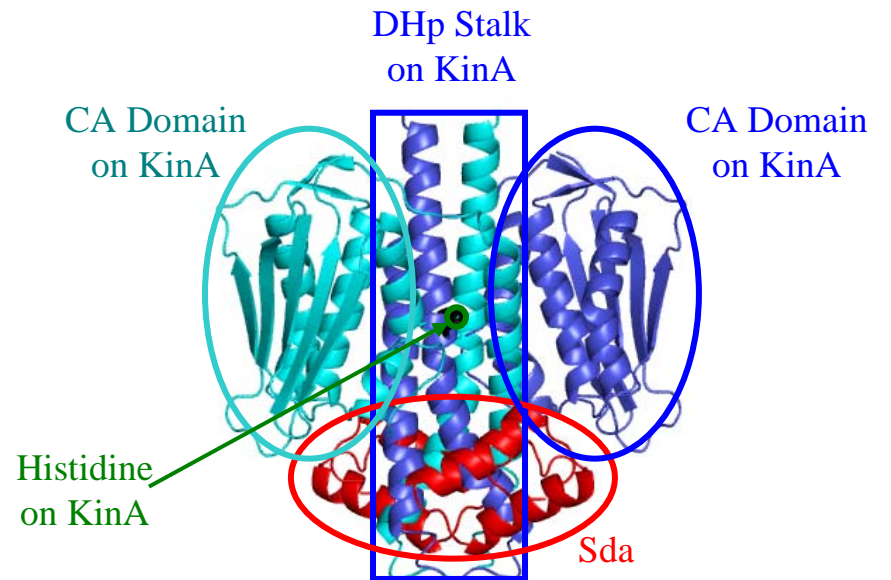
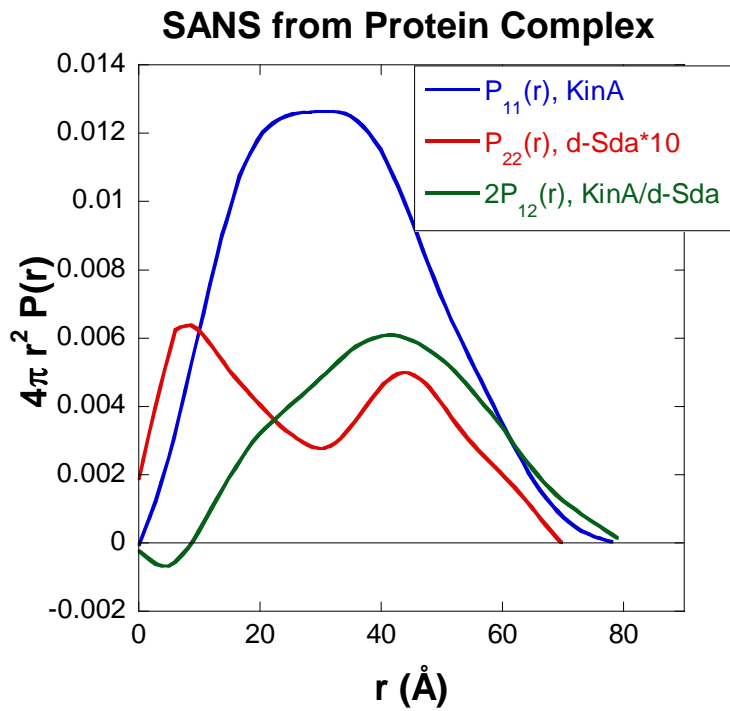
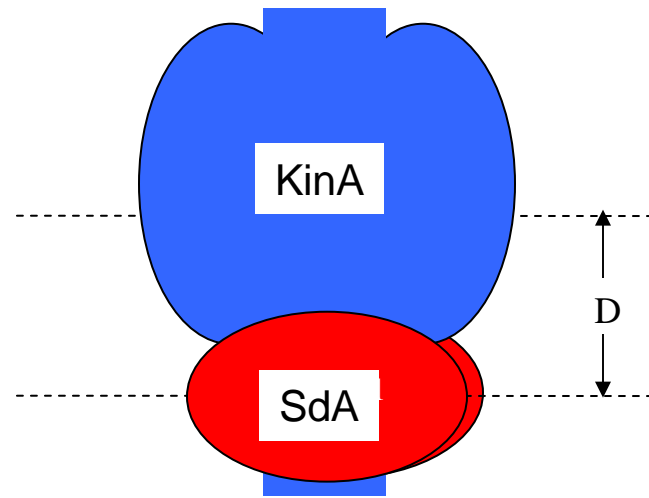
C – Protein Complex



KinA-Sda Complex

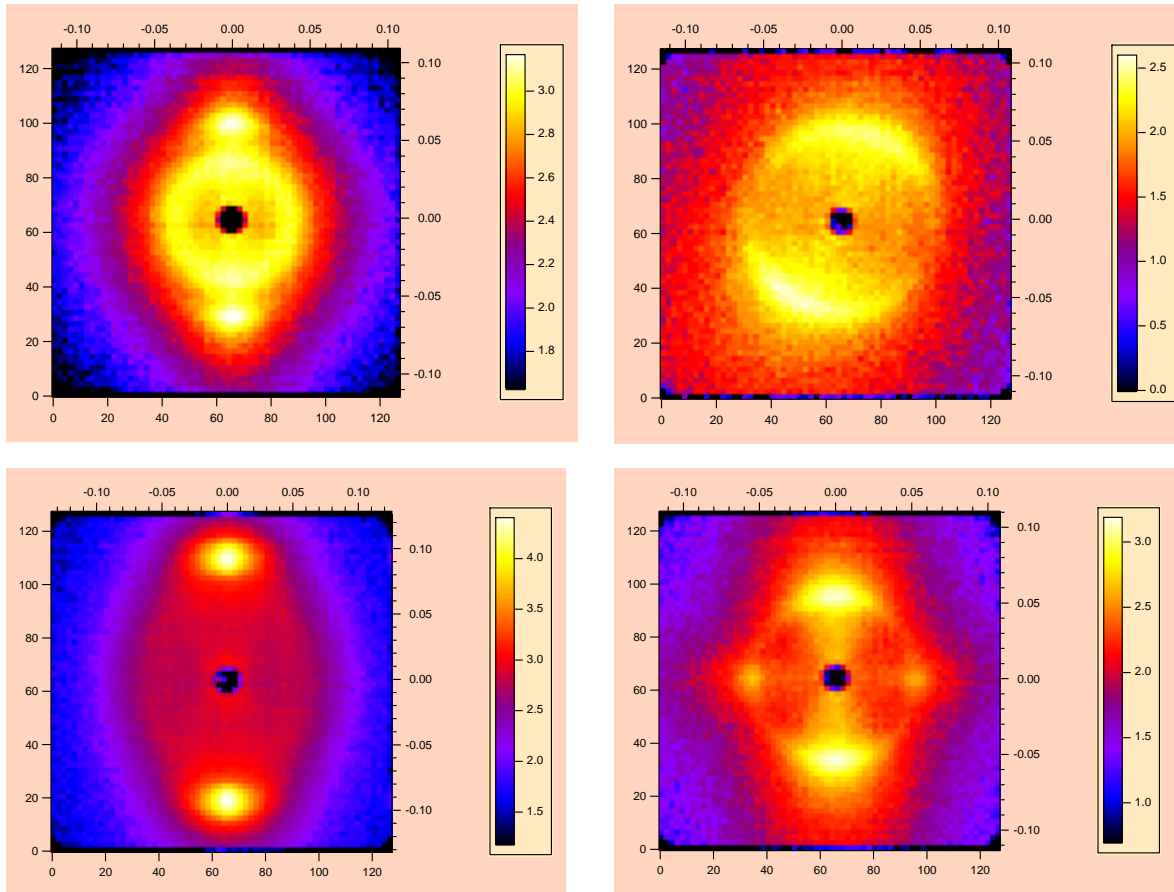


KinA-Sda Complex



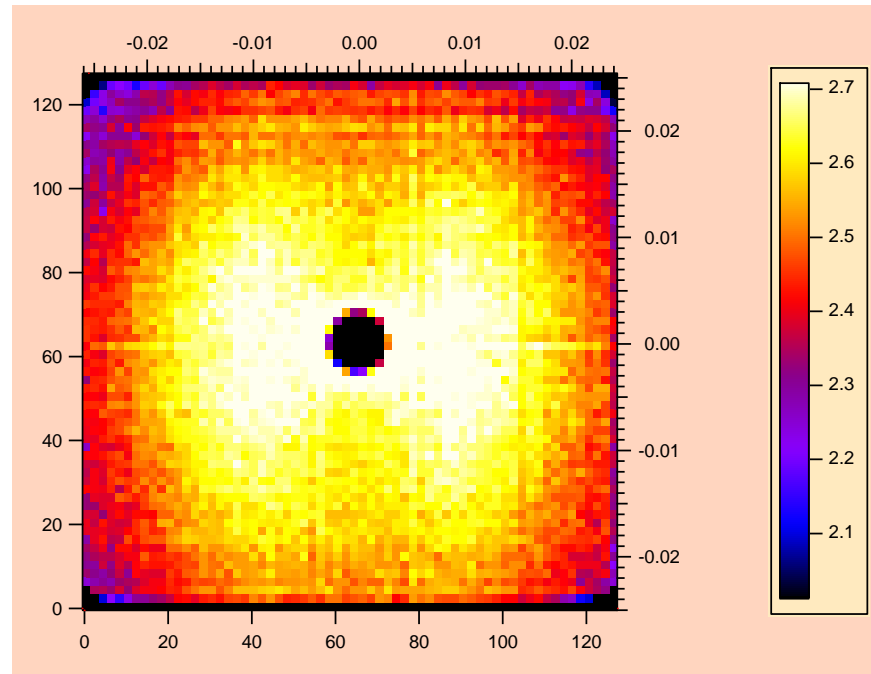
5. GALLERY OF SANS DATA IMAGES

Sheared Multilayer Vesicles



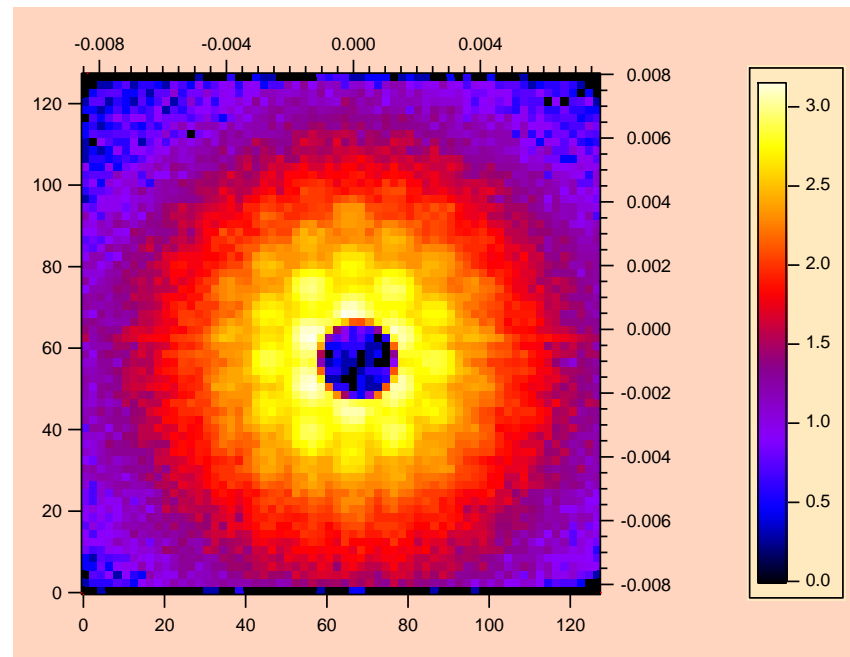
AOT in brine/D₂O multilayer vesicles sheared in a Couette shear cell.

The Butterfly Pattern



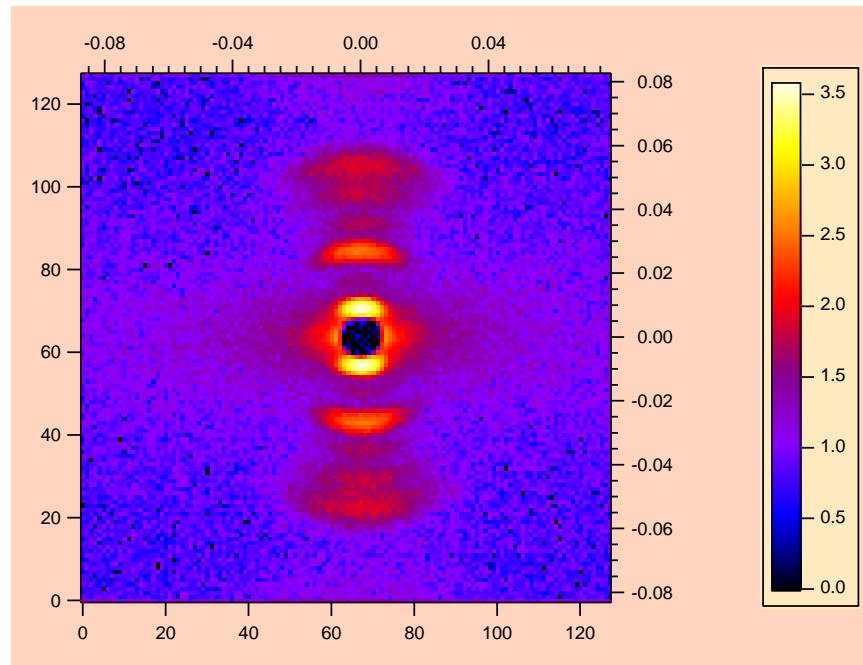
Butterfly SANS pattern from stretched poly(dimethyl siloxane) gel consisting of a mixture of crosslinked and (deuterated) linear polymer chains.

Packed Spheres



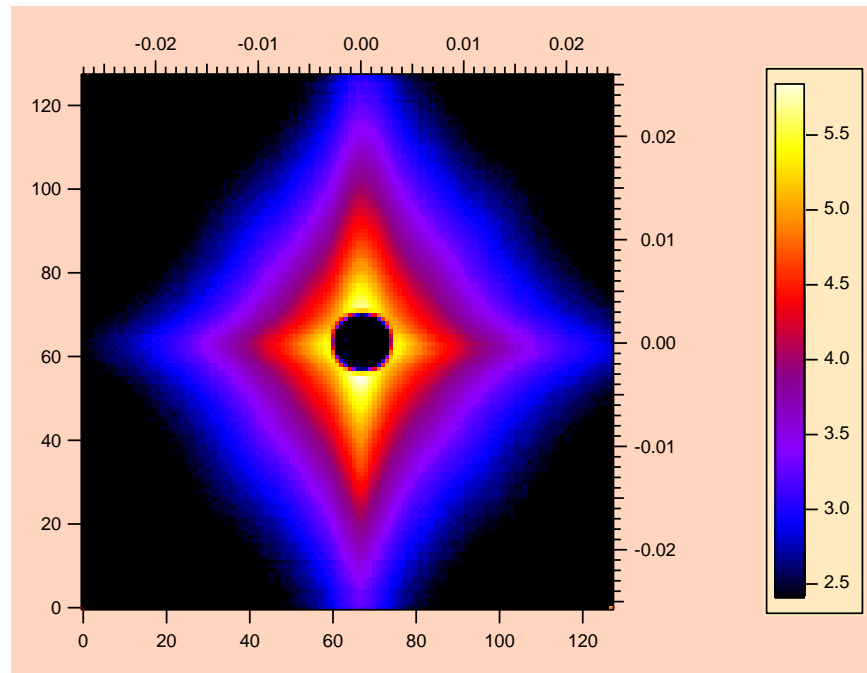
Single crystal diffraction pattern obtained from highly packed silica particles under gentle shear and in D_2O .

Kangaroo Tail Tendon



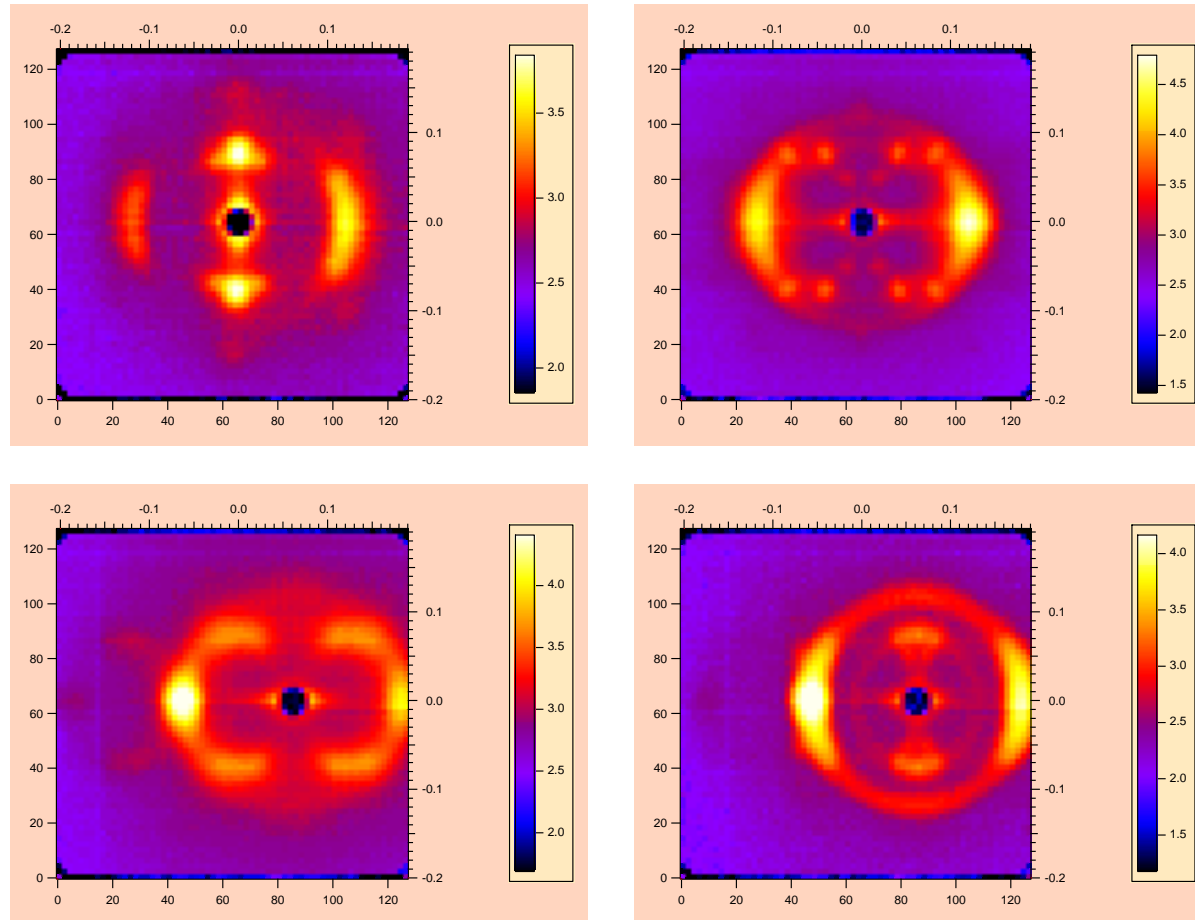
Scattering pattern from collagen from a kangaroo tail tendon. The ordered structure is along the fibers and has a d-spacing of 667 Å.

Twinned Crystal



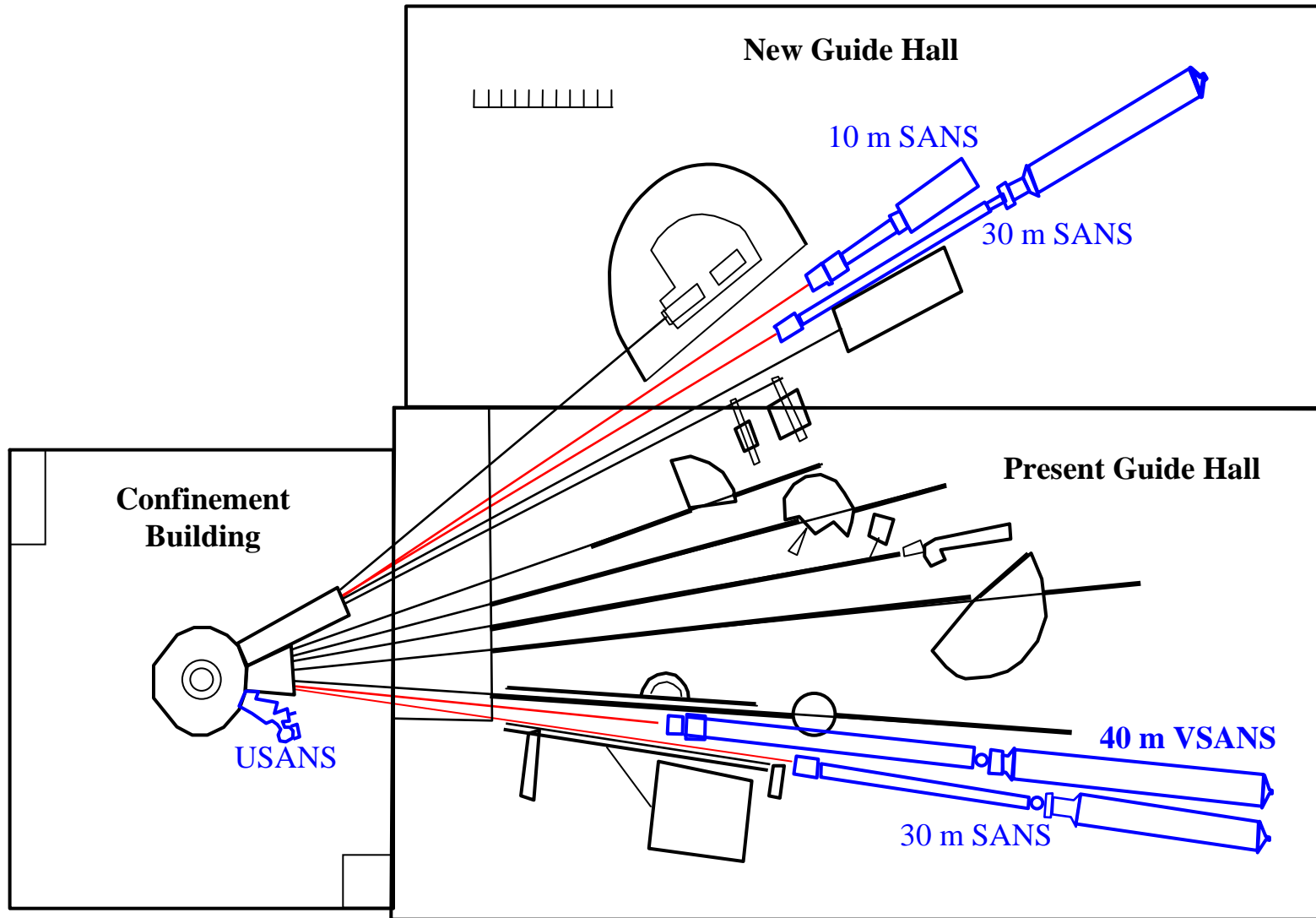
SANS data from the high T_c superconducting cuprate NdBa₂Cu₃O₇ at 100 K.

Peptides Oriented in Membranes



SANS data from peptides embedded into membranes and oriented between quartz slides.

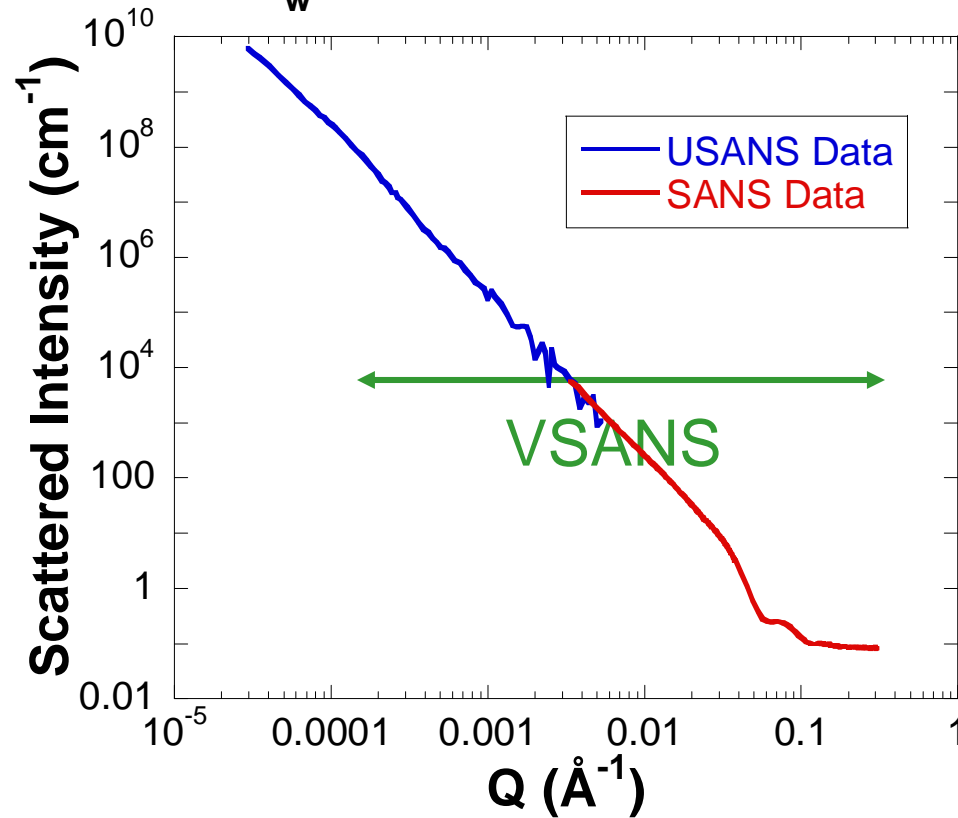
Upgrade and VSANS



SANS, VSANS and USANS Ranges

4% PEO/d-Ethanol,

$M_w = 42,900$ g/mole, $T = 25^\circ\text{C}$



Final Words

THE SANS PROGRAM AT NIST

200 experiments per year

15 theses per year

80 publications per year

FUTURE OUTLOOK

Past 20 years – NCNR development

Next 20 years – NCNR expansion

ACKNOWLEDGMENTS

Steve Kline, Derek Ho, Jill Trehwella

RECENT REFERENCES

- B. Hammouda “SANS from Polymers - Review of the Recent Literature”, *Polymer Reviews* 50, 14-39 (2010)

- B. Hammouda, “Probing Nanoscale Structures – **The SANS Toolbox**”, (2009). Book available online.