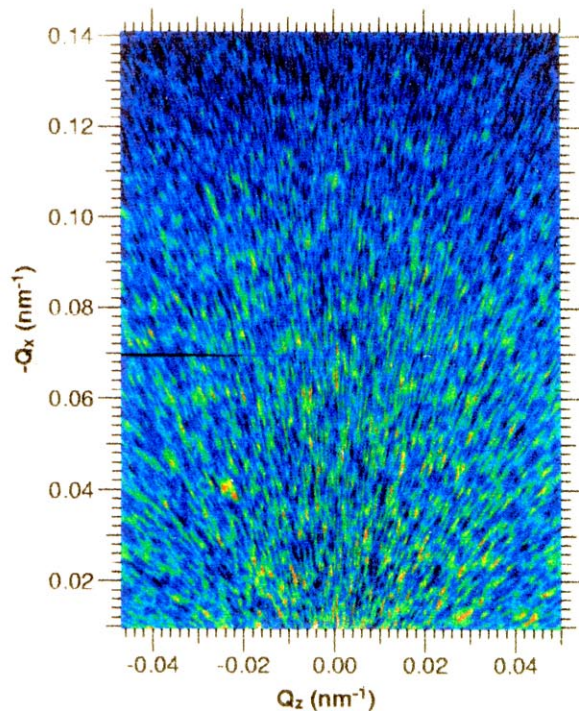
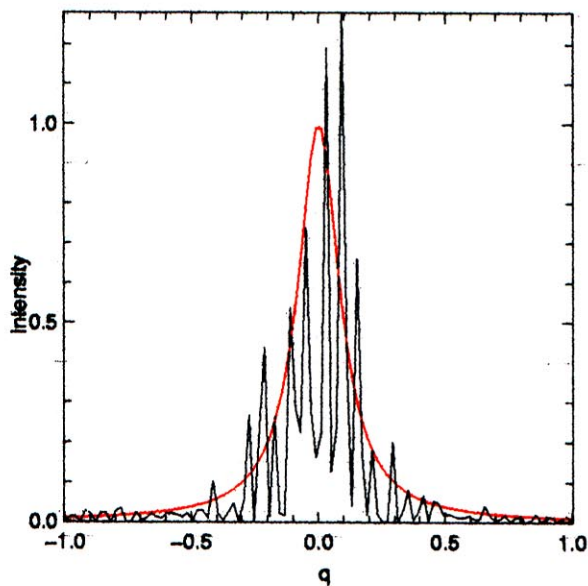
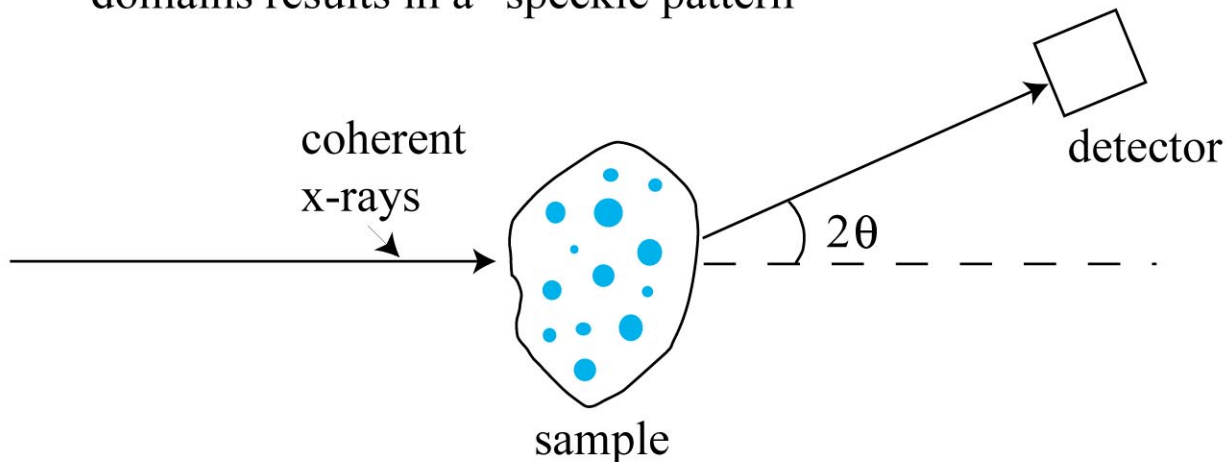


# X-Ray Photon Correlation Spectroscopy Using an Energy Recovery Linac Source

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Department of Physics  
University of Michigan

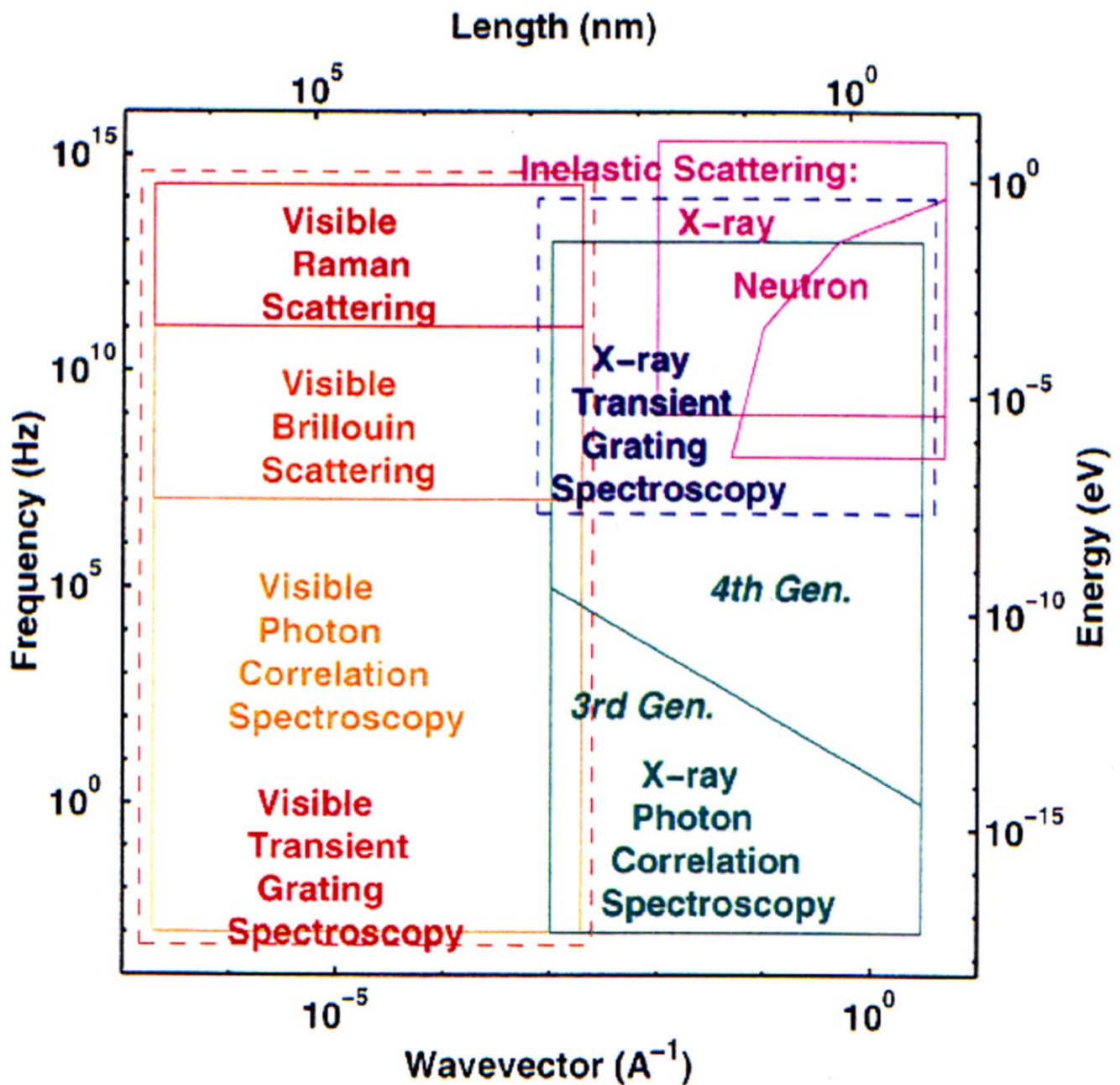
## Coherent X-Ray Scattering from Disordered Sample Produces "Speckle"

- Random constructive + destructive interference by sample domains results in a "speckle pattern"



- Speckle pattern depends on exact arrangement of domains, not just domain size distribution
- If incident x-rays are not coherent, resolution is insufficient to observe speckle pattern
- XPCS measures slow dynamics ( $10^{-5}$  -  $10^2$  sec) at large wave-vectors

## Accessible Ranges of Frequency and Wavevector for Various Techniques



**Scientific Problems  
which could be addressed  
by XPCS  
with a sufficiently brilliant source**

***Simple Liquids*** - Transition from the hydrodynamic to the kinetic regime

***Complex Liquids*** - Effect of the local structure on the collective dynamics

***Polymers*** - Entanglement and reptative dynamics

***Glass Formers*** - Relaxational modes in the mesoscopic space-time region

***Dynamic Critical Phenomena*** - Order fluctuations in alloys, liquid crystals, polymer mixtures, etc.

***Charge Density Waves*** - Direct observation of sliding dynamics

***Quasicrystals*** - Nature of phason and phonon dynamics

***Surfaces*** - Dynamics of adatoms, island, and steps during growth and etching.

***Defects in Crystals*** - Diffusion, dislocation glide, domain dynamics

***Ferroelectrics*** - Order-disorder vs. displacive nature; anisotropic correlations and size effects

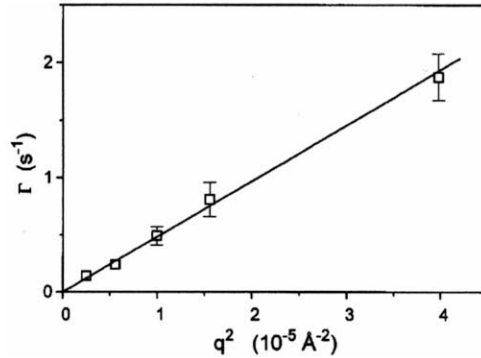
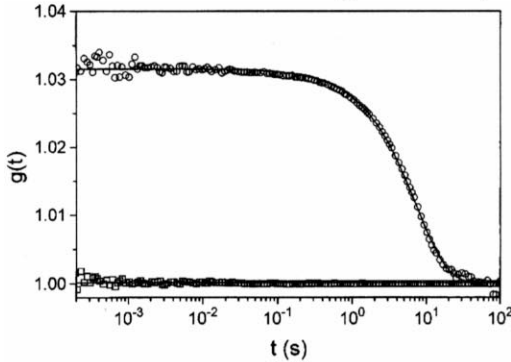
***Magnetism*** - Random field systems, magnetic stripe domain dynamics



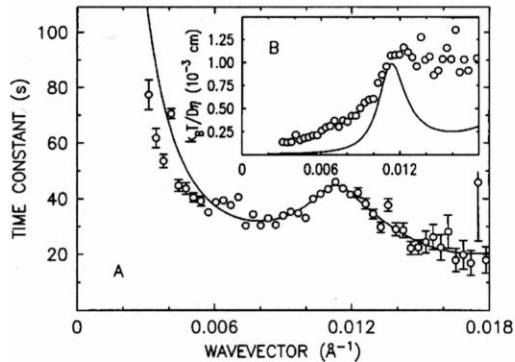
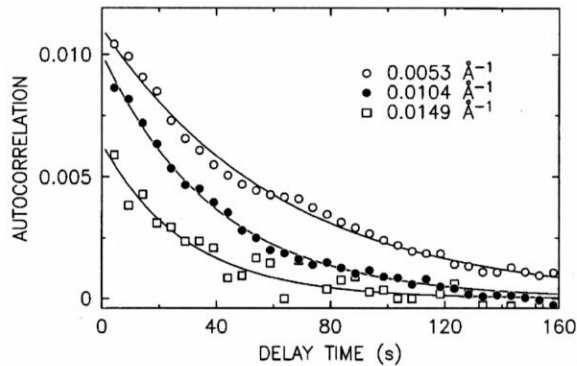
# Examples of Current Experiments

## ● Gold/Pd/Sb<sub>2</sub>O<sub>5</sub>/Latex Colloids

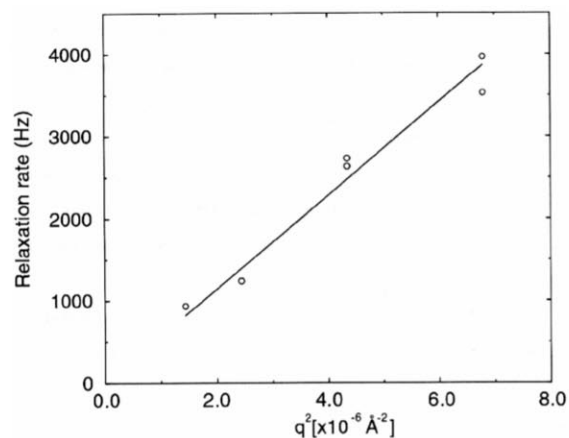
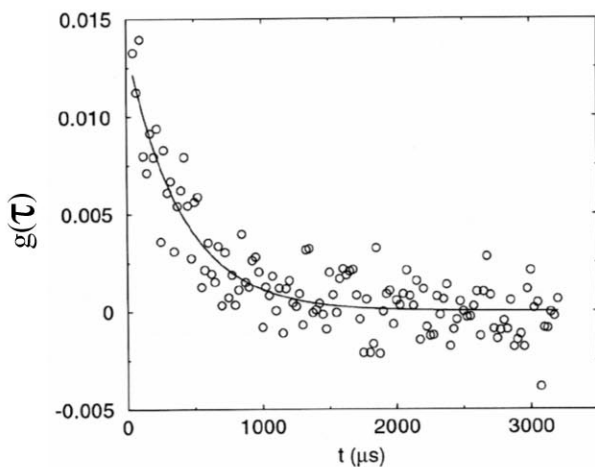
Pd Colloids in Glycerol (Thurn-Albrecht, et. al., 1996)



## ● PS-PI Block Copolymer Micelles in PS (Mochrie, et. al., 1997)



## ● Hexane/Nitrobenzene binary fluids (Dufresne, et. al., 2000)



## ● Anti-phase domains in metal alloys

## ● Phase separation in sodium borosilicate glasses

## ● PS/PB homopolymer mixtures

## Impact of an ERL Source

Current range of relaxation times:  $\sim 10^{-4}$  to  $10^2$  seconds.

Many exps use area detection for increased collection efficiency.

Most of these exps are limited by current 3<sup>rd</sup> generation sources.

- Need increased coherent flux to probe  
faster times  
higher  $q$ 's  
more weakly scattering samples

Coherent Flux  $\sim Br \times \lambda^2 \times (\Delta\lambda/\lambda)$

- Need increased brilliance

At small  $q$ , speckle contrast  $\sim \frac{\text{coherence volume}}{\text{scattering volume}}$

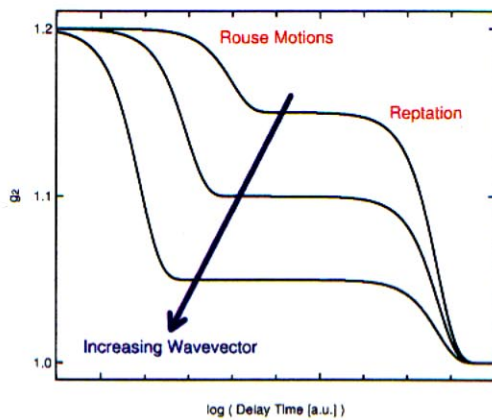
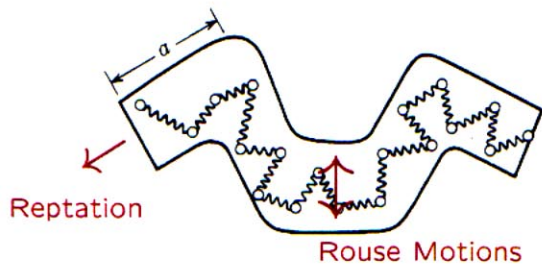
At high  $q$ , contrast decreases as path lengths increase

- Need full transverse and increased longitudinal coherence

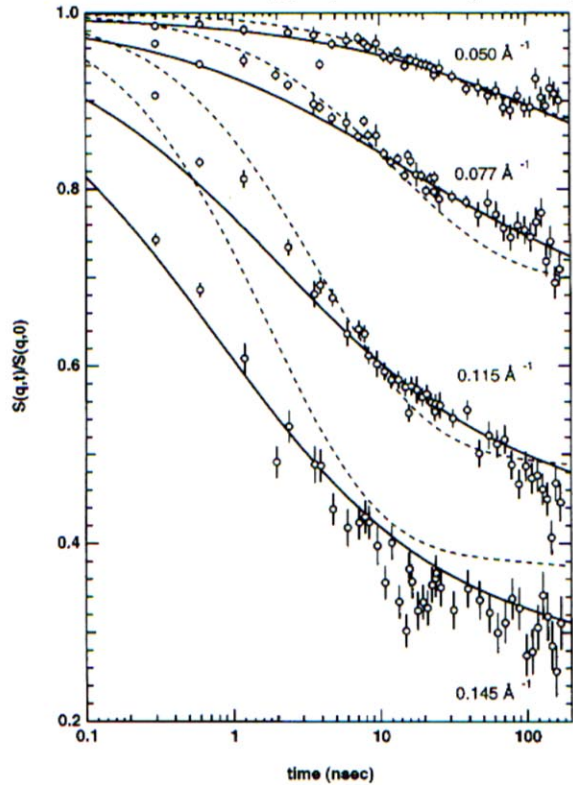
| <u>Source</u>   | <u><math>\Delta\lambda/\lambda</math></u> | <u>Coh. Flux</u>    | <u><math>q_{\text{max}}</math></u> |
|-----------------|---|---------------------|------------------------------------|
| APS (Pink beam) | $2 \times 10^{-2}$                        | $\sim 10^{12}$ ph/s | $\sim 0.02 \text{ \AA}^{-1}$       |
| APS (Ge mono)   | $3 \times 10^{-4}$                        | $\sim 10^{10}$ ph/s | $\sim 2.00 \text{ \AA}^{-1}$       |
| ERL (Pink beam) | $1 \times 10^{-3}$                        | $\sim 10^{14}$ ph/s | $\sim 0.20 \text{ \AA}^{-1}$       |

*Experiments we could do with more brilliance!*

- Cross-over from Reptation to Rouse Dynamics at large  $q$



NSE Schleger, et.al. (1998)

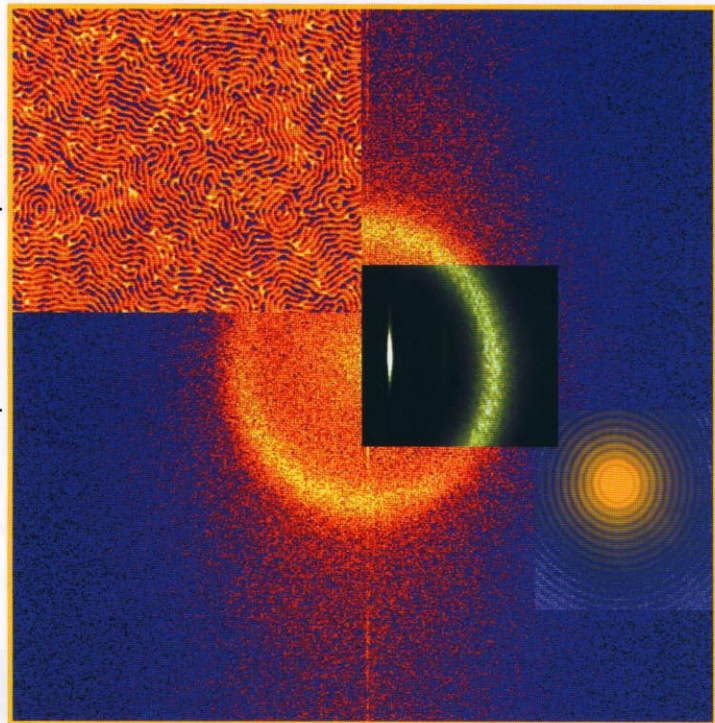


- Fluctuations in Magnetic Systems; Random Field, Stripes, etc.

Peters, et.al. (2000)  
GdFe<sub>2</sub> Stripe domains

MFM —

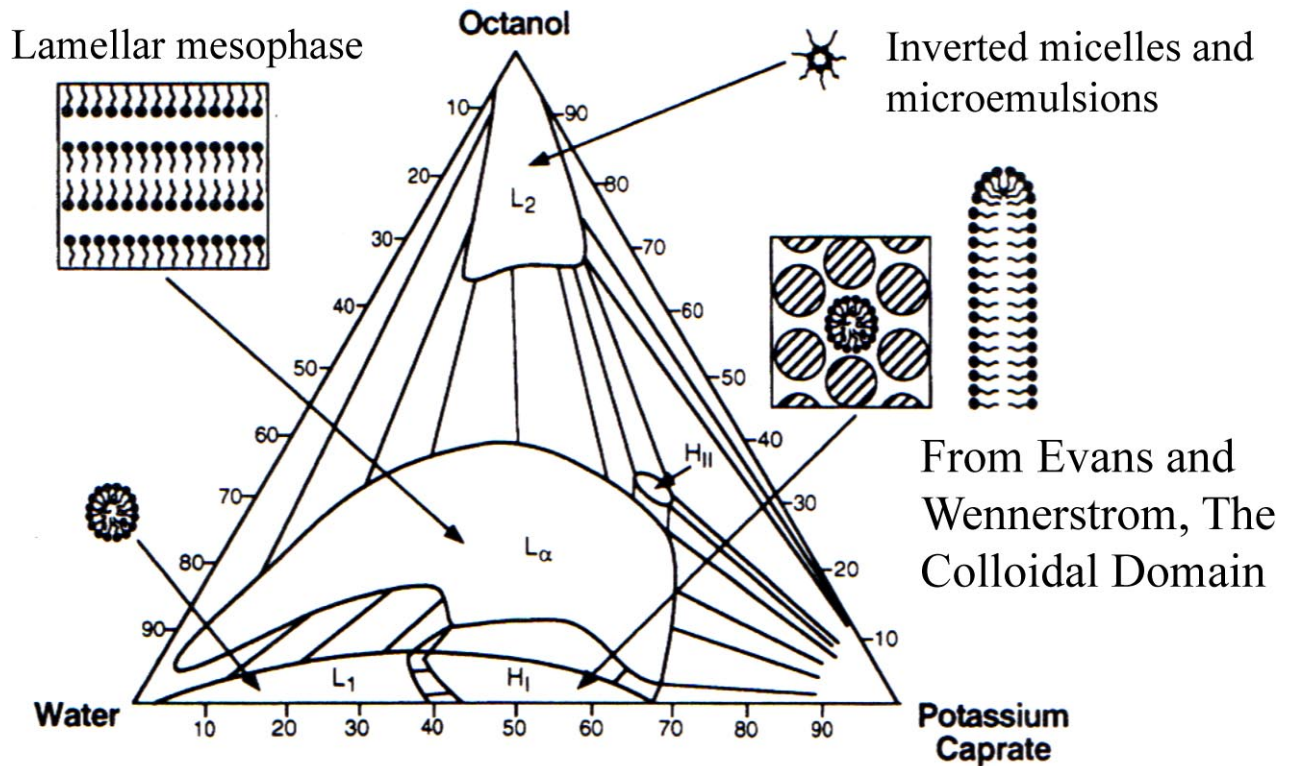
X-Ray Speckle —





# Experiments we could do with more brilliance!

## Surfactants in Binary and Ternary Systems



## Related Structures in Block Copolymers

Possible morphologies of triblock copolymers, Bates & Fredrickson, Physics Today, 1999

