# Melting and dynamics in dehydrated phospholipid bilayers


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# Collaborators

Lipid bilayers:

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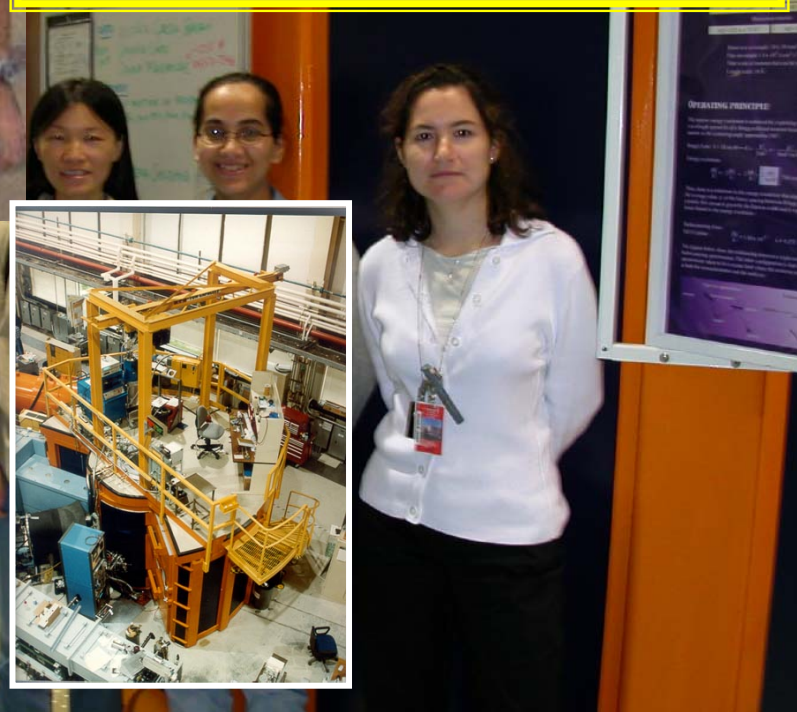

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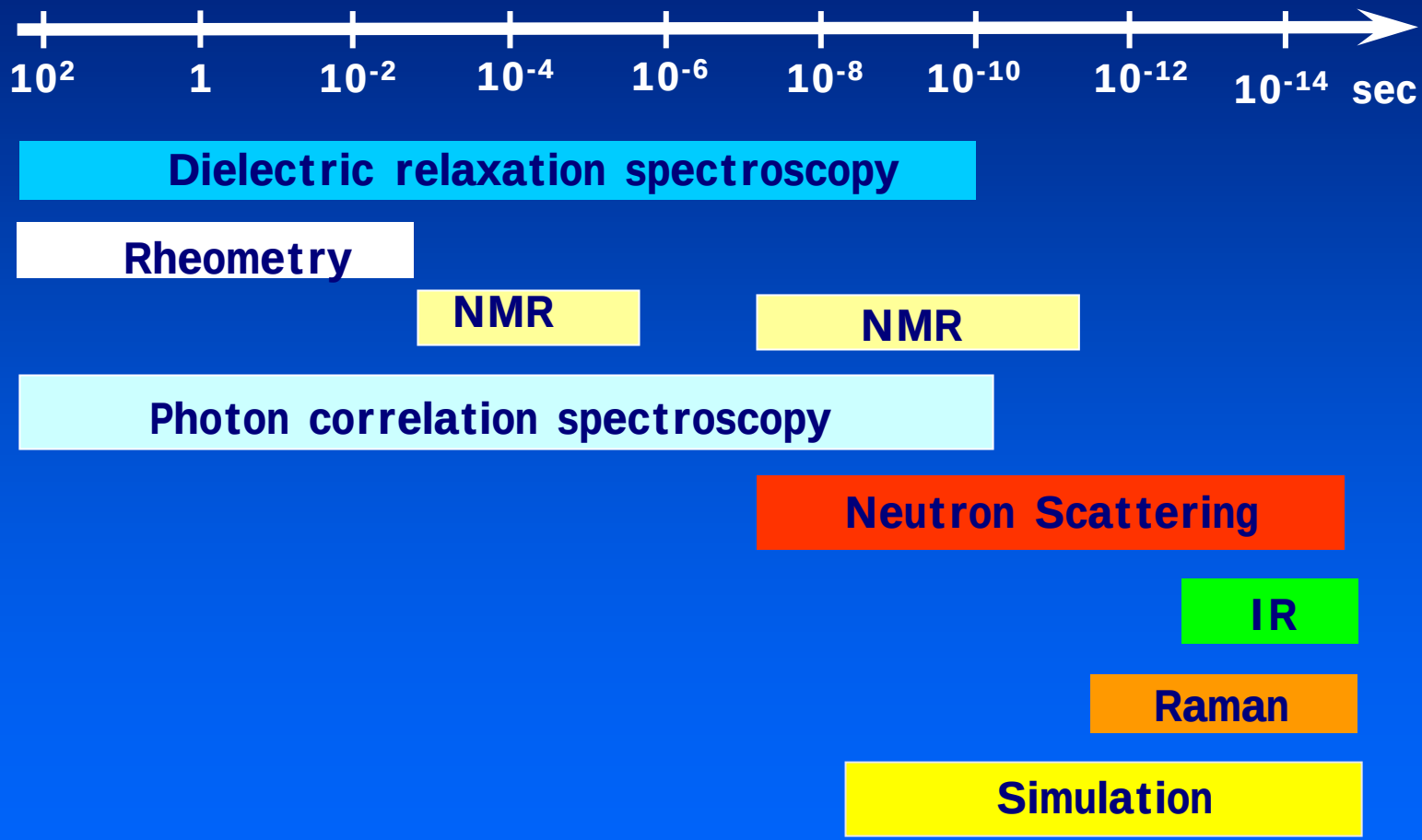
NIST Center for neutron research

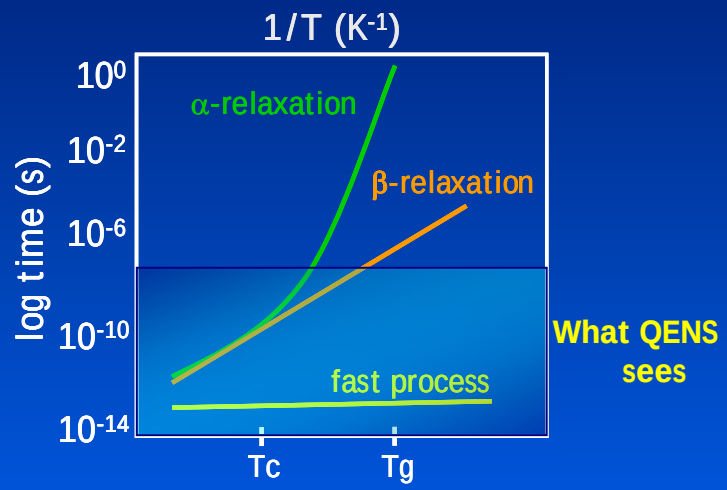
# Techniques to Explore Dynamics



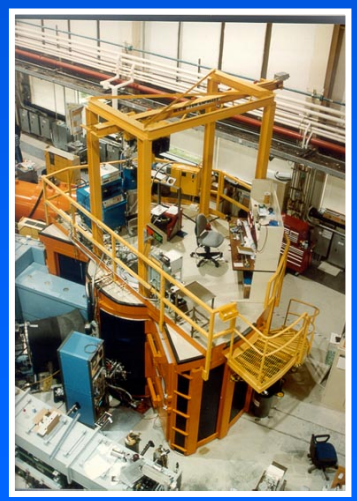
# Quasi-elastic neutron scattering

Resolves *spatially* and *temporally* simultaneously

*Spatial scale: Q ~2π/r*




**HFBS (backscattering spectrometer)**

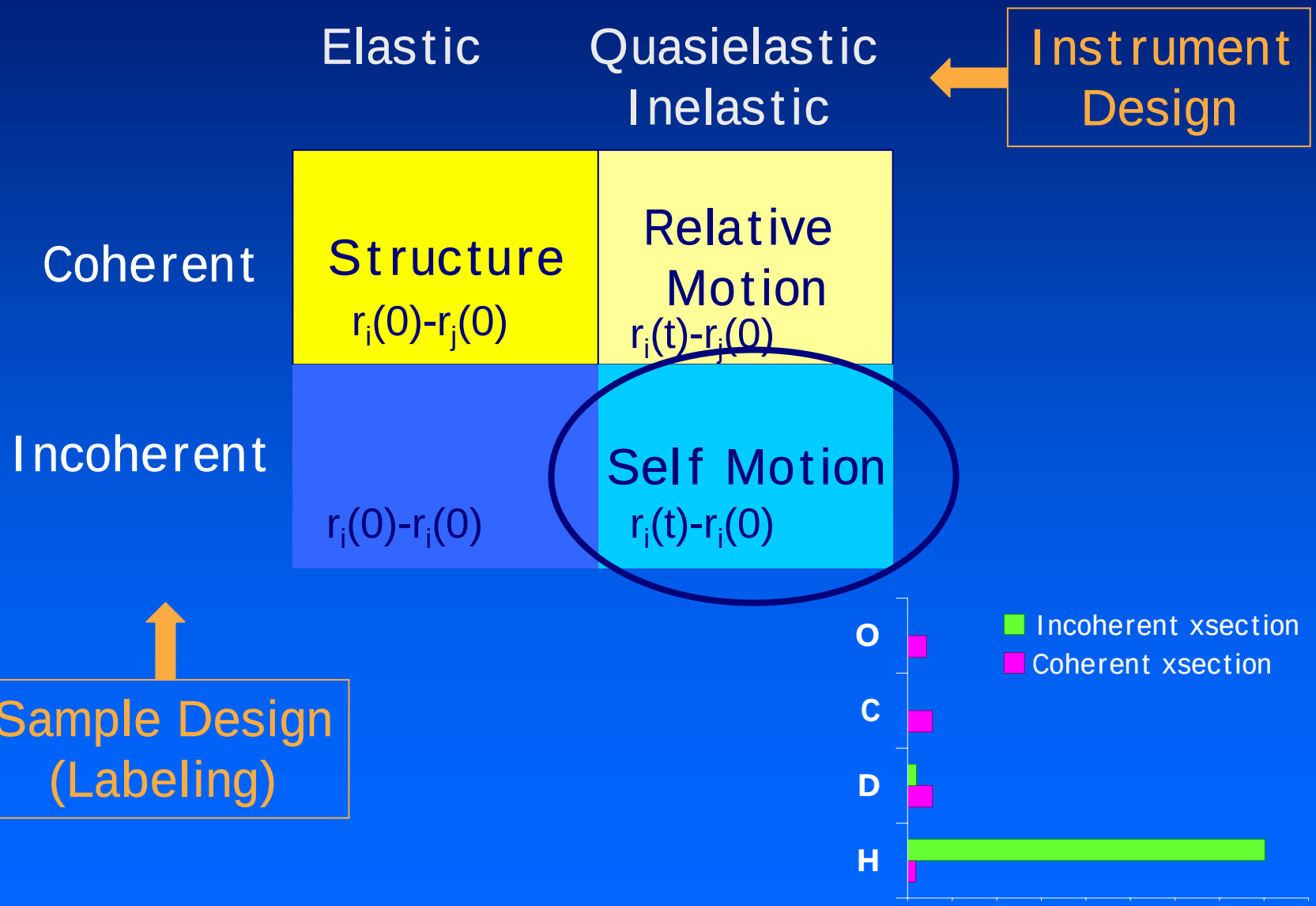


**DCS (disk-chopper spectrometer)**

Deuterium labeling

direct comparison with molecular simulation

# Labeling


Elastic
Quasielastic
Inelastic
Instrument Design
Coherent
Incoherent
Structure
$r_i(0)-r_j(0)$
Relative Motion
$r_i(t)-r_j(0)$
$r_i(0)-r_i(0)$
Self Motion
$r_i(t)-r_i(0)$
Sample Design (Labeling)
O
C
D
H
Incoherent xsection
Coherent xsection

# *Use of sugars in the preservation of biologicals*

**Resurrection Plant (Selaginella)**

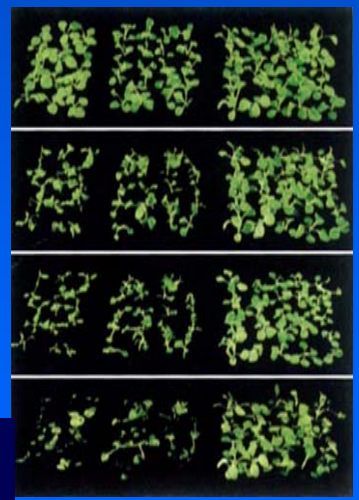
**Brine shrimp (Artemisia Salina)**

**Active Tardigarde**

**Anhydrobiotic**

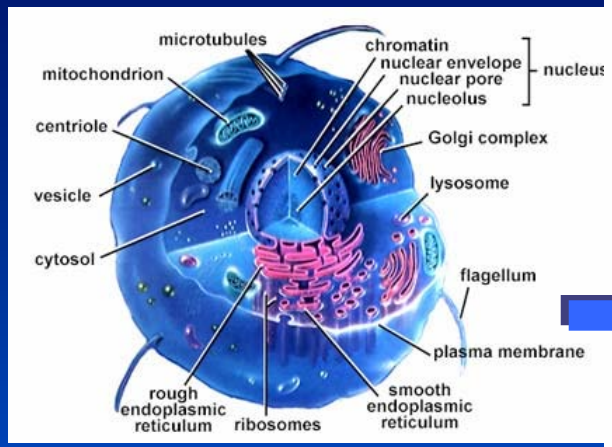
**Trehalose has been found to accumulate in some animals and plants capable of survival under severe stress of dehydration**

Trehalose and sucrose are being used in preservation of many biologicals including proteins (i.e. enzymes, antibodies) and cells (i.e. stem cells, platelets, bacteria, sperm, seed embryos).

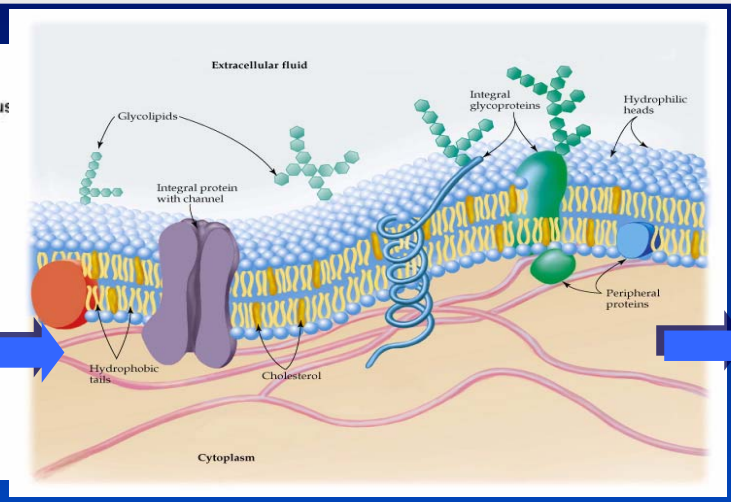


**Engineered Trehalose Synthesis in Tobacco**

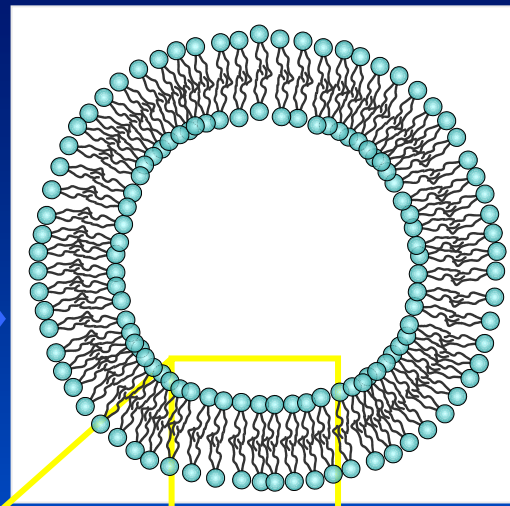
# design of cell models



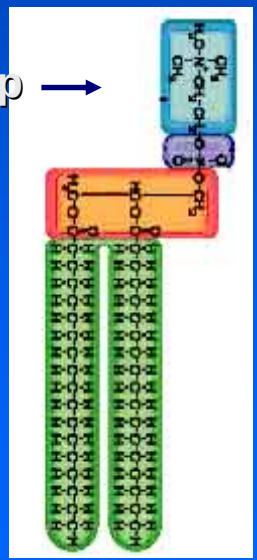

Cell (black box)



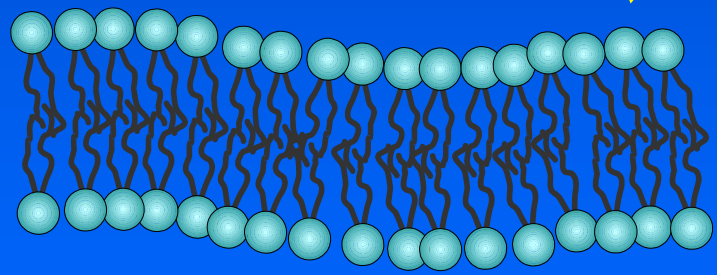

Cell membrane



Liposome (controlled)



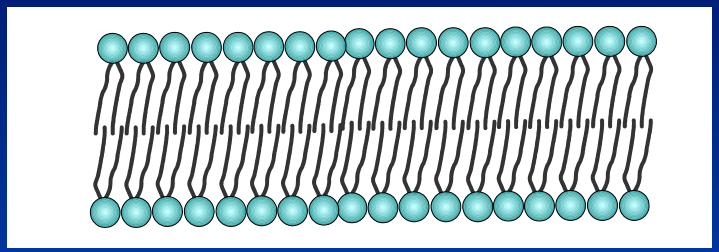

Phospholipid



Phospholipid bilayer

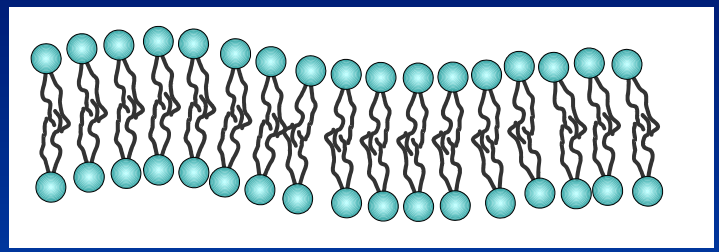
# phase transition

**Gel** | **Liquid crystalline**



$L_{\beta'}$ ⟷ $L_{\alpha}$

Cell damage

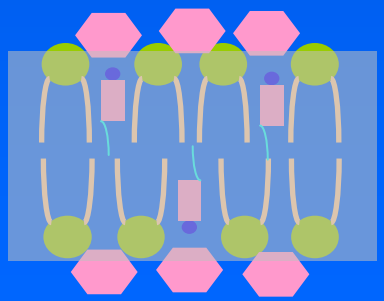


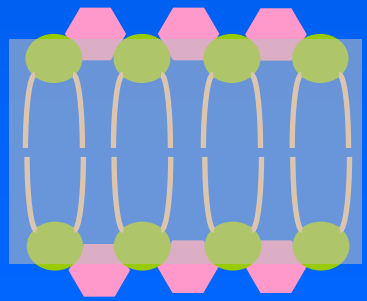
- **Solid-like phase**
- **Ordered**
- **Low molecular mobility**

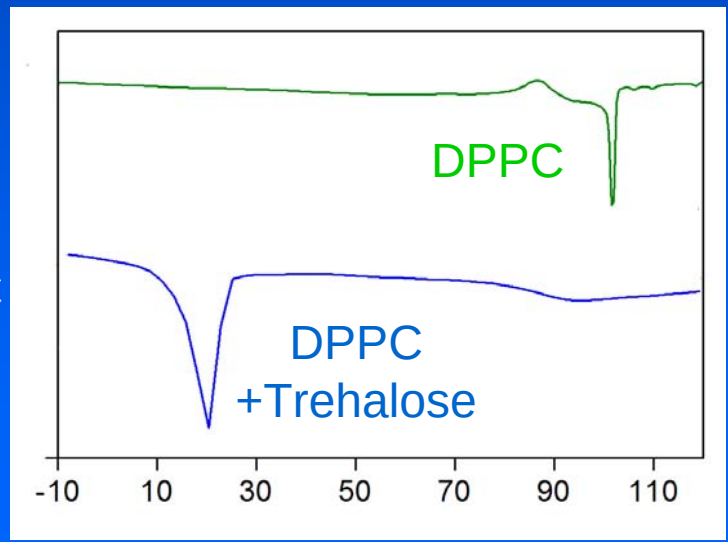
- **Liquid-like phase**
- **Disordered**
- **High molecular mobility**

## The effect of trehalose

DPPC fully hydrated $T_m$ = 42°C
DPPC dehydrated $T_m$ = 103°C
DPPC + trehalose dehydrated $T_m$ = 24°C





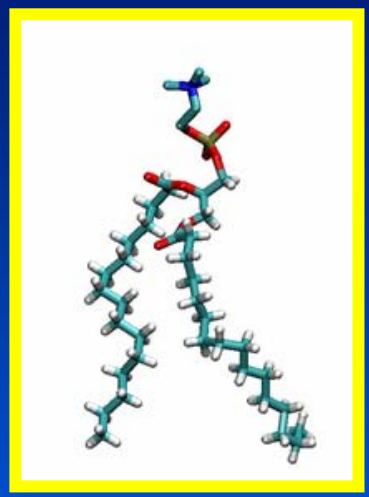


# Systems investigated

1. Dehydrated DPPC

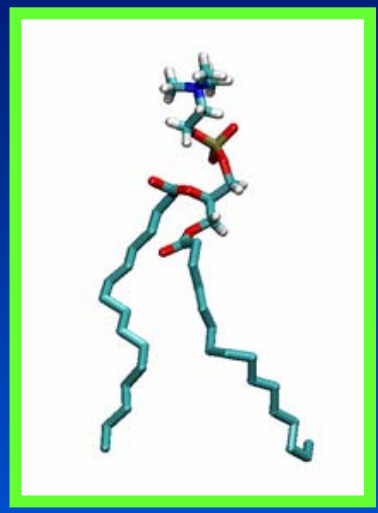
   What is melting?

   Heads vs. tails



mark tails:
deuterate heads
dhDPPC

mark heads:
deuterate tails
hdDPPC

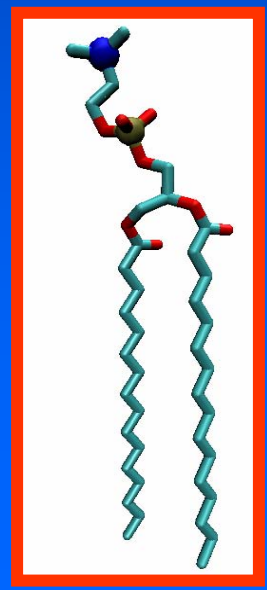


2. Dehydrated DPPC with trehalose

   Is melting the same?

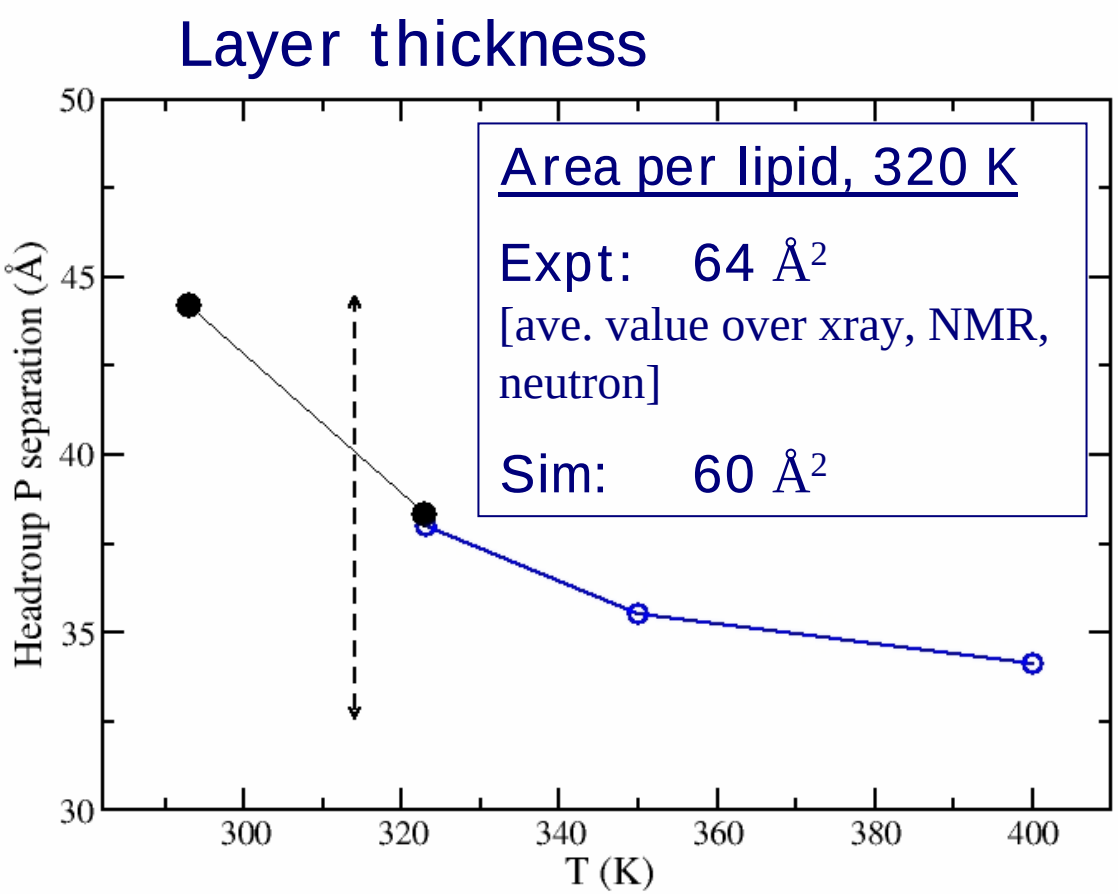
   Mobility with & without trehalose

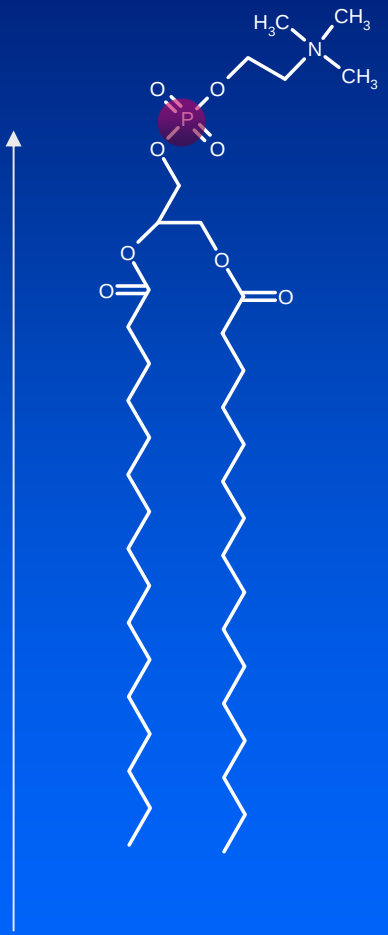
   Mixing of lipid headgroups & trehalose



dDPPC

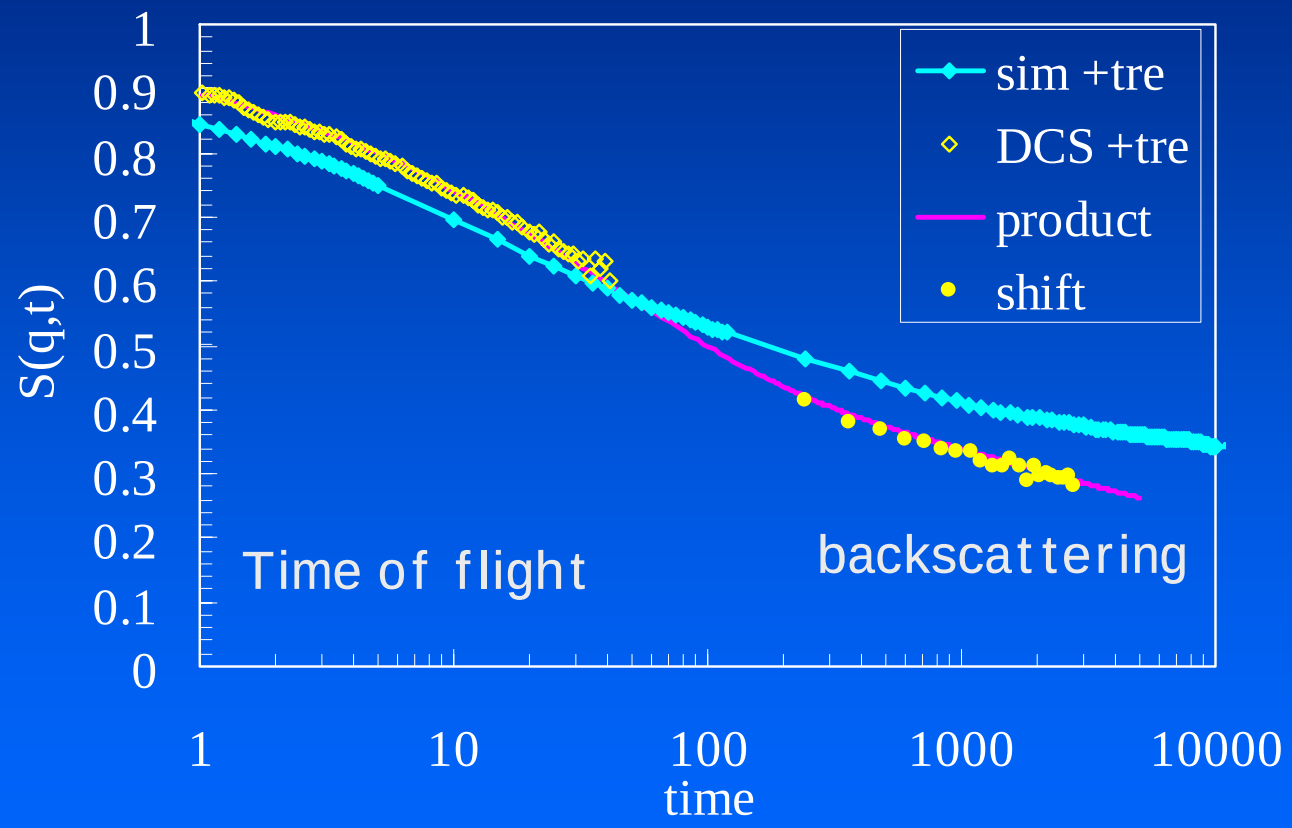
# Simulation verification: hydrated, static



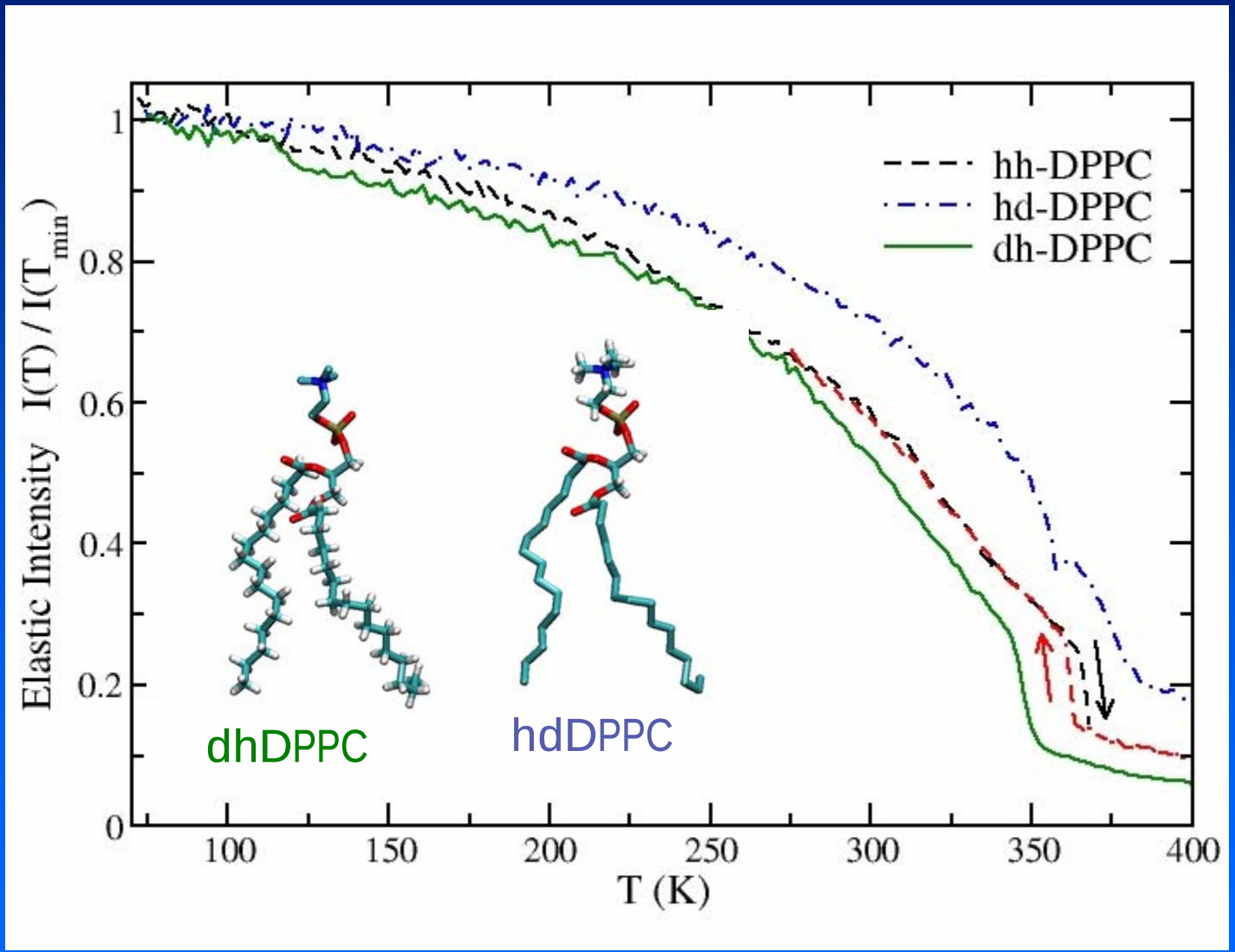
# Simulation verification: dehydrated, dynamic

Tail labelled DPPC + d-trehalose: T = 350 K, Q = 0.62 Å$^{-1}$



# 1. Melting transition in dry lipids

- Melting occurs in tails
- Headgroups behave as an amorphous solid



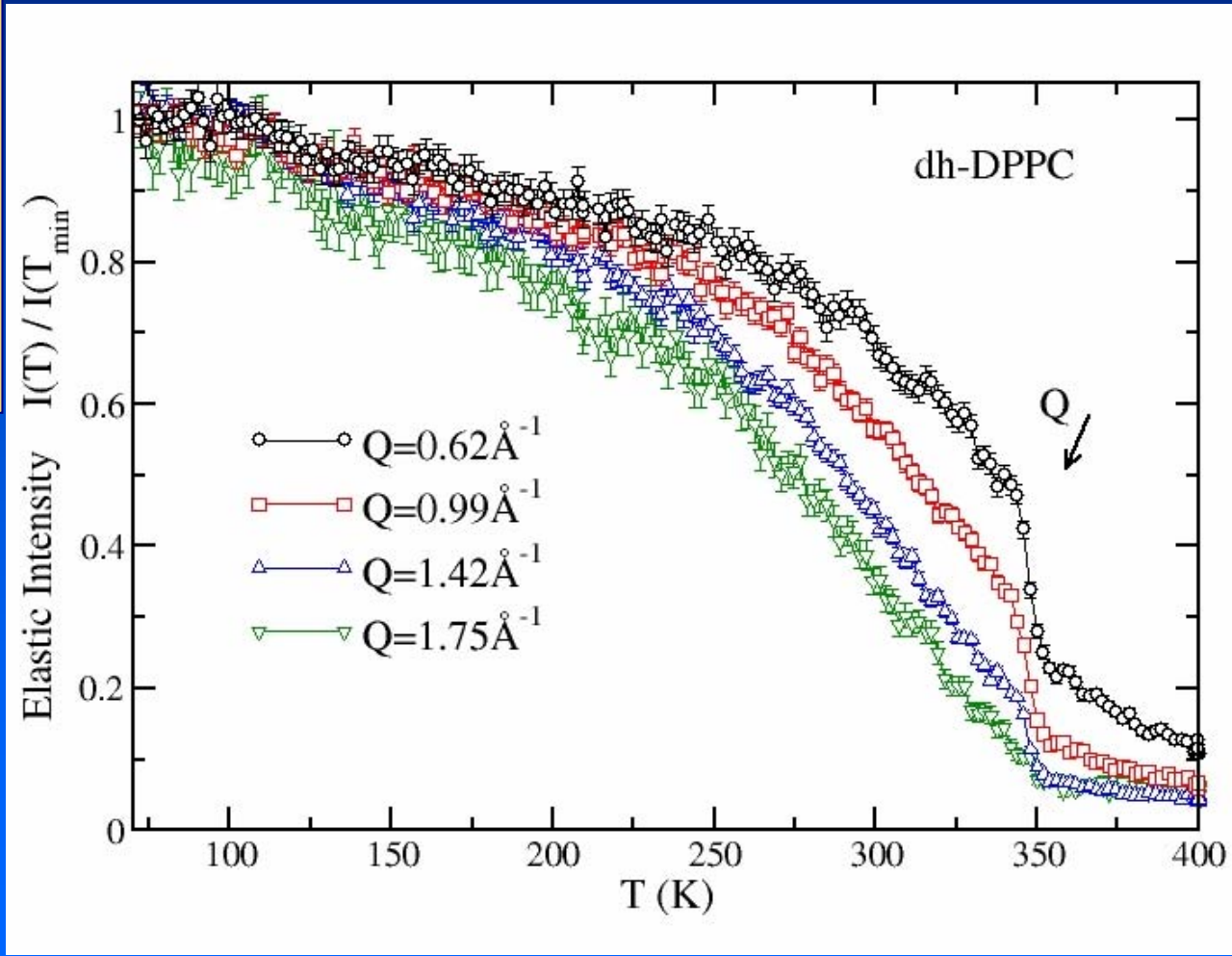
# Spatial dependence of tail melting

below interlipid spacing: Q > 1.5 Å

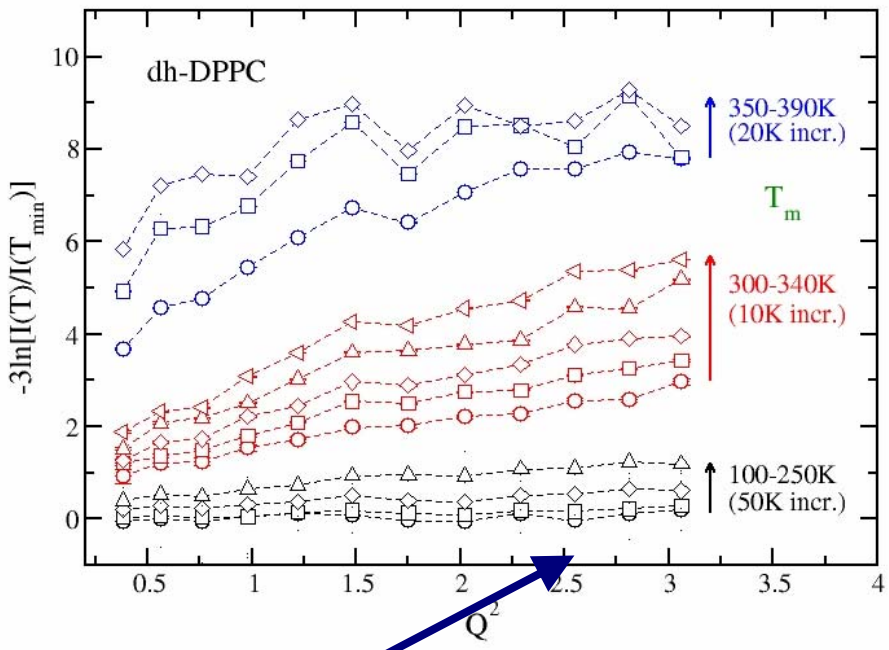
- mobility below Tm
- no sharp gain at Tm

above interlipid spacing

- small gain in mobility below Tm
- sharp gain at Tm

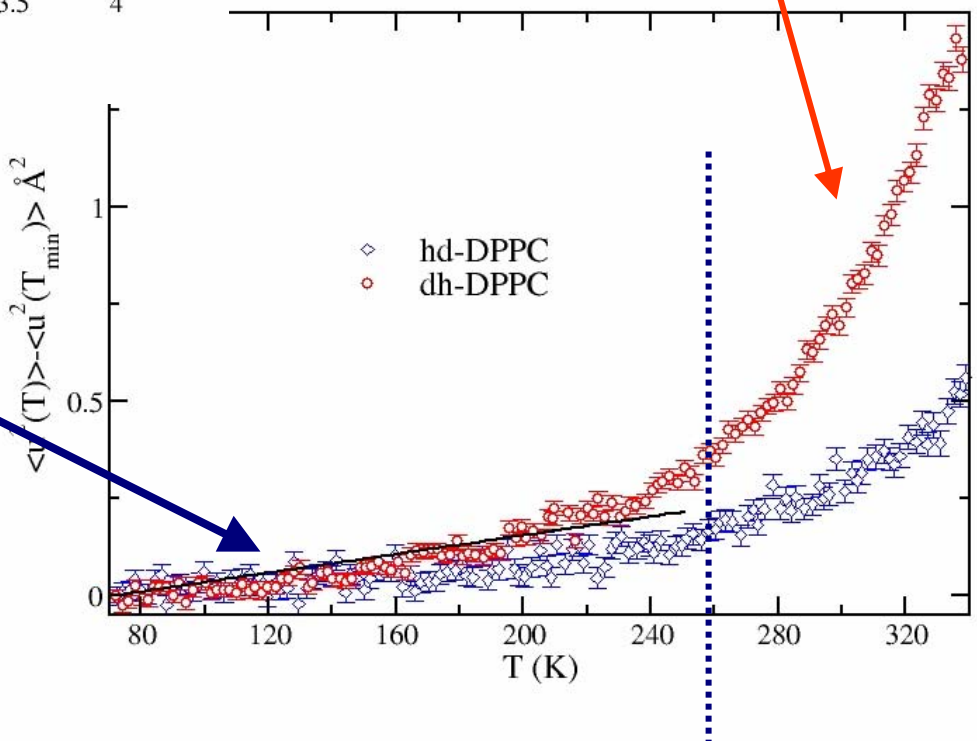


# Mean displacements




Localized motion

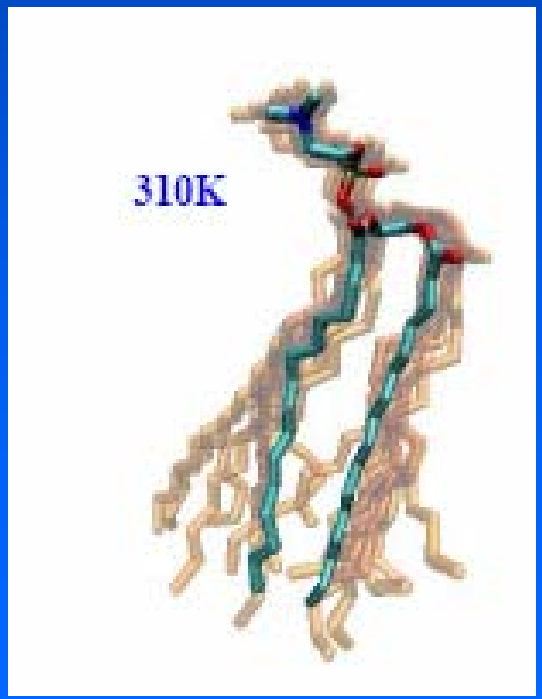
vibrations



# A molecular picture

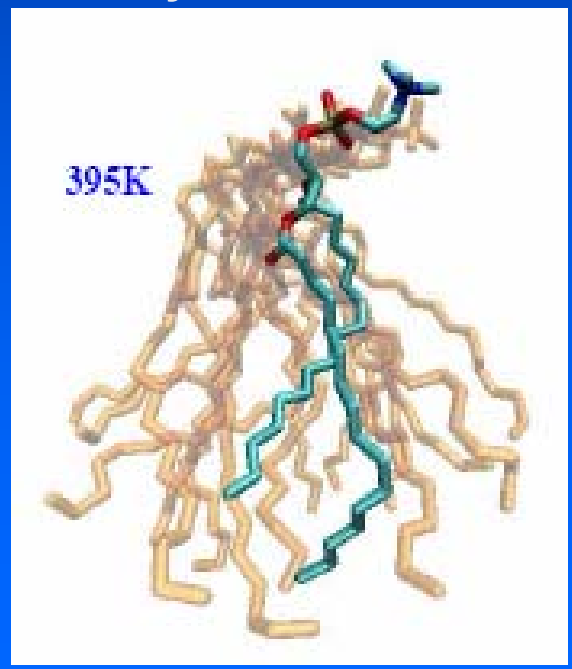
Below Tm:

- Localized motion
- Less than lipid spacing
- Not all protons are mobile



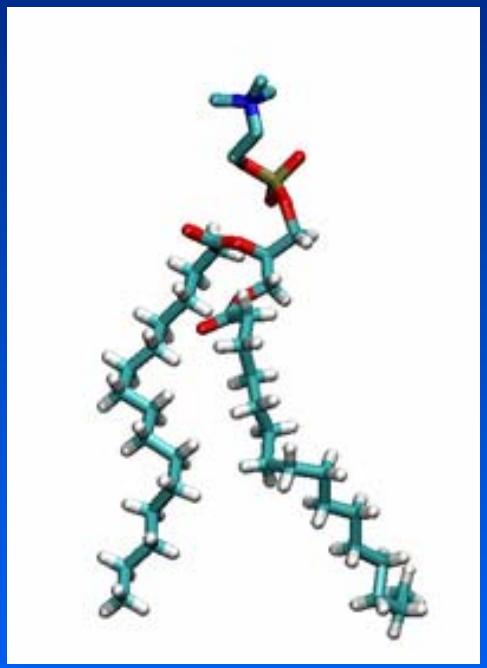

Above Tm:

- Greater than lipid spacing
- Translation
- Some protons continue to gain mobility



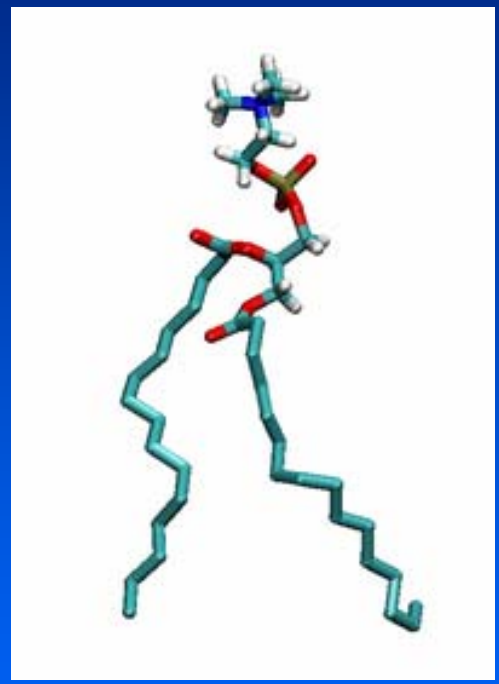
# 2. Melting transition & dynamics: Dry lipids with trehalose

*d-trehalose*



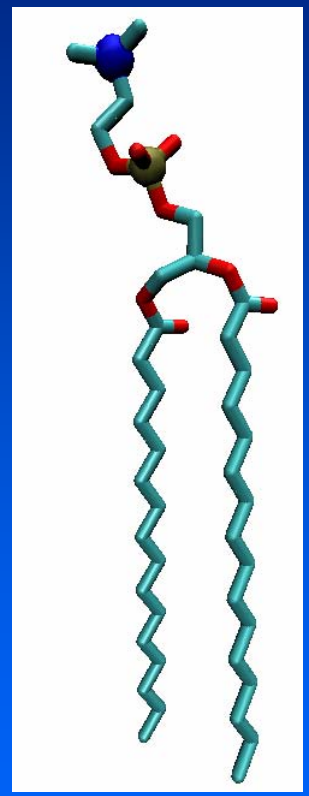
dhDPPC
Tails
hydrogenated

*d-trehalose*



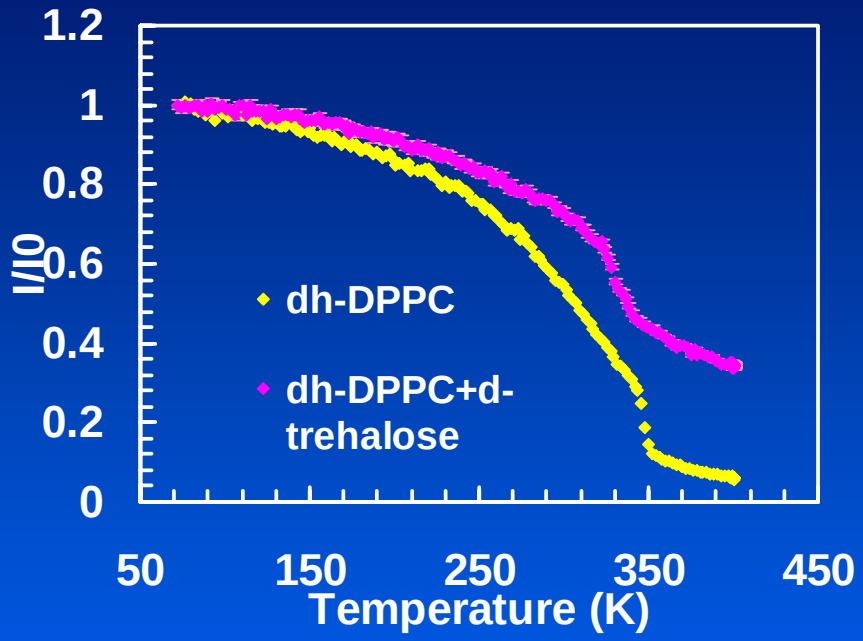
dhDPPC
Heads
hydrogenated

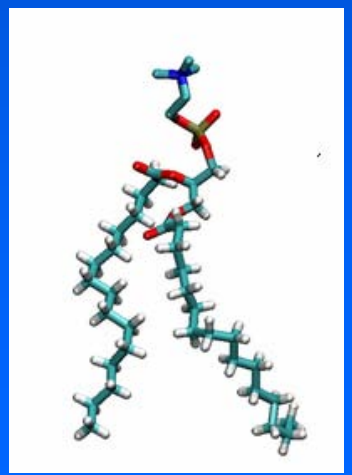
*h-trehalose*



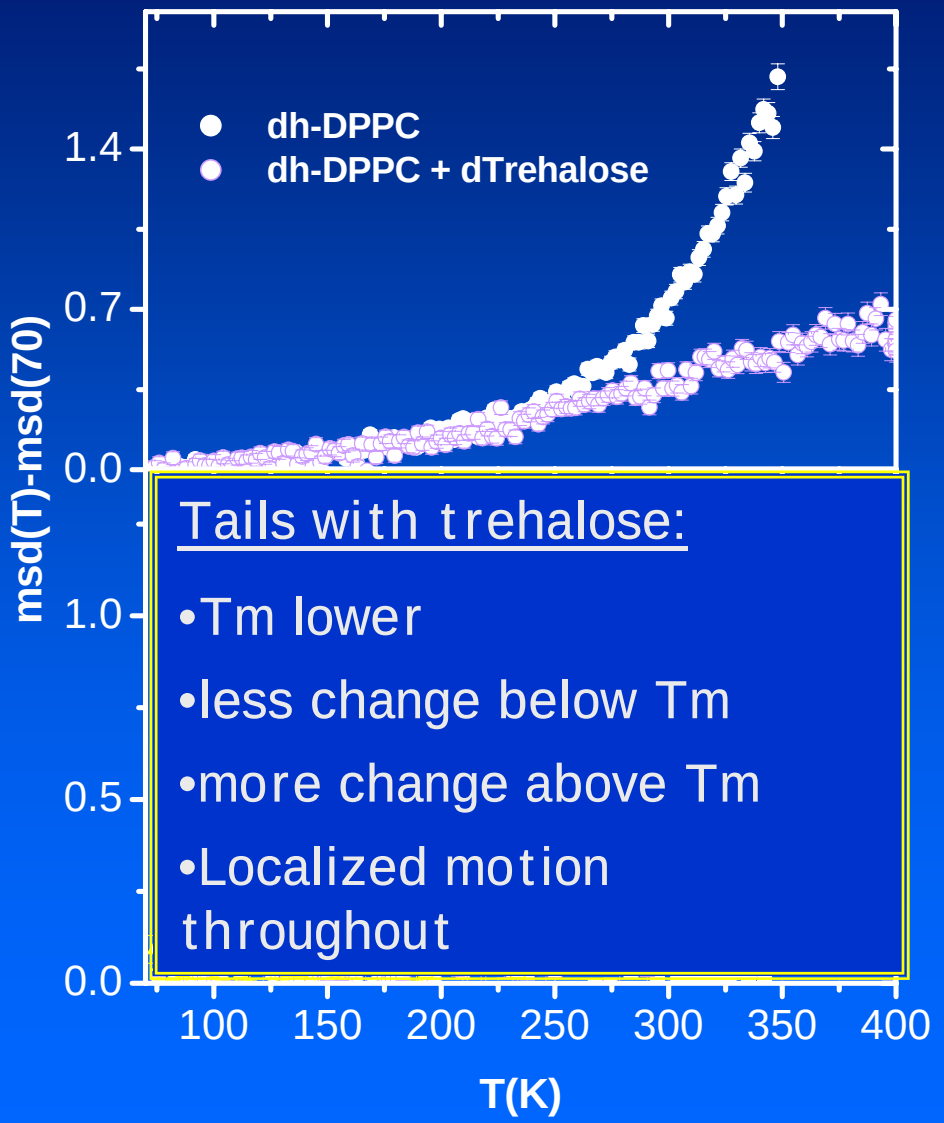
dDPPC
Trehalose
hydrogenated

# Melting transition with trehalose



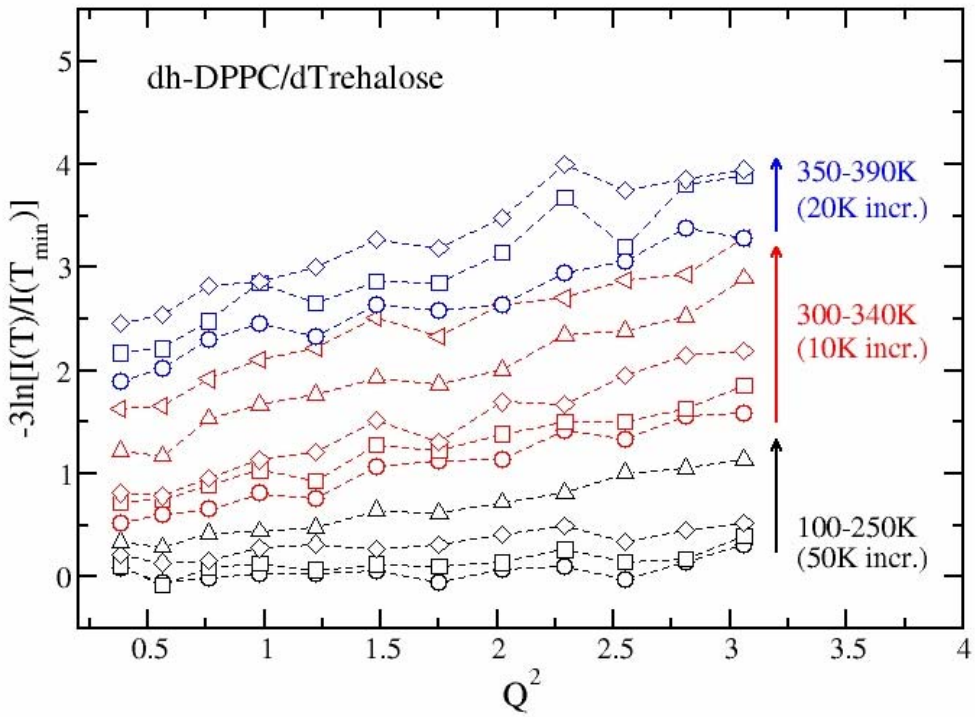
dhDPPC: tail labelled

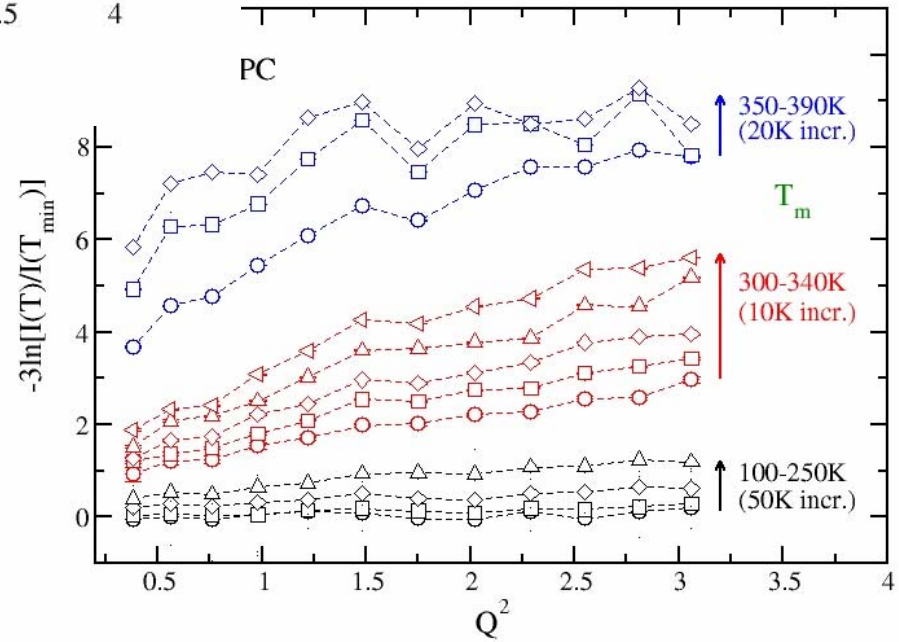



Tails with trehalose:

- Tm lower
- less change below Tm
- more change above Tm
- Localized motion throughout

# Transition?


dh-DPPC/dTrehalose
-3ln[I(T)/I(T_min)]
Q^2
350-390K
(20K incr.)
300-340K
(10K incr.)
100-250K
(50K incr.)


PC
-3ln[I(T)/I(T_min)]
Q^2
350-390K
(20K incr.)
T_m
300-340K
(10K incr.)
100-250K
(50K incr.)

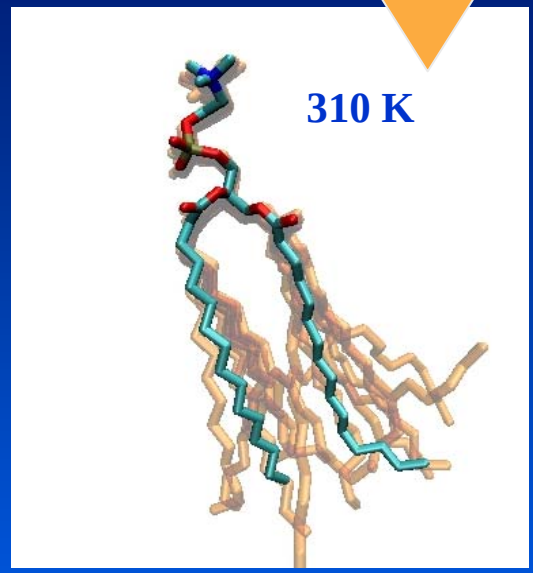
# A molecular view


No trehalose

below Tm

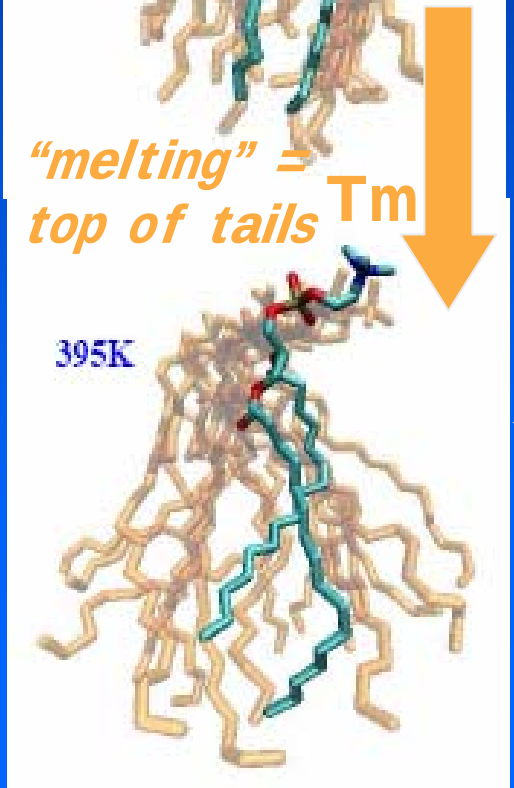
with trehalose

above Tm



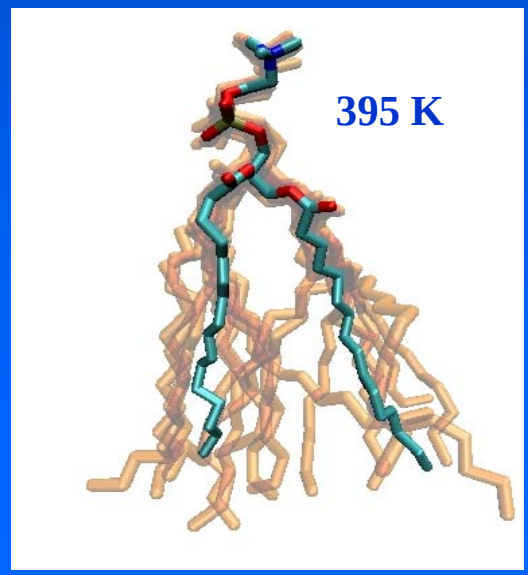

*"melting" = top of tails*

Tm




No trehalose

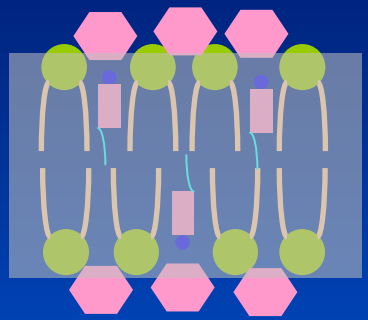
above Tm

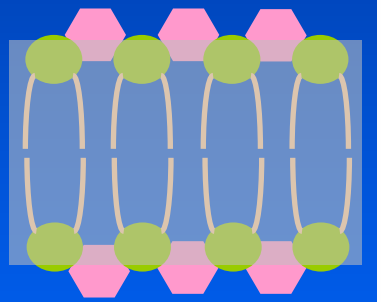



*"melting" = bottom of tails*

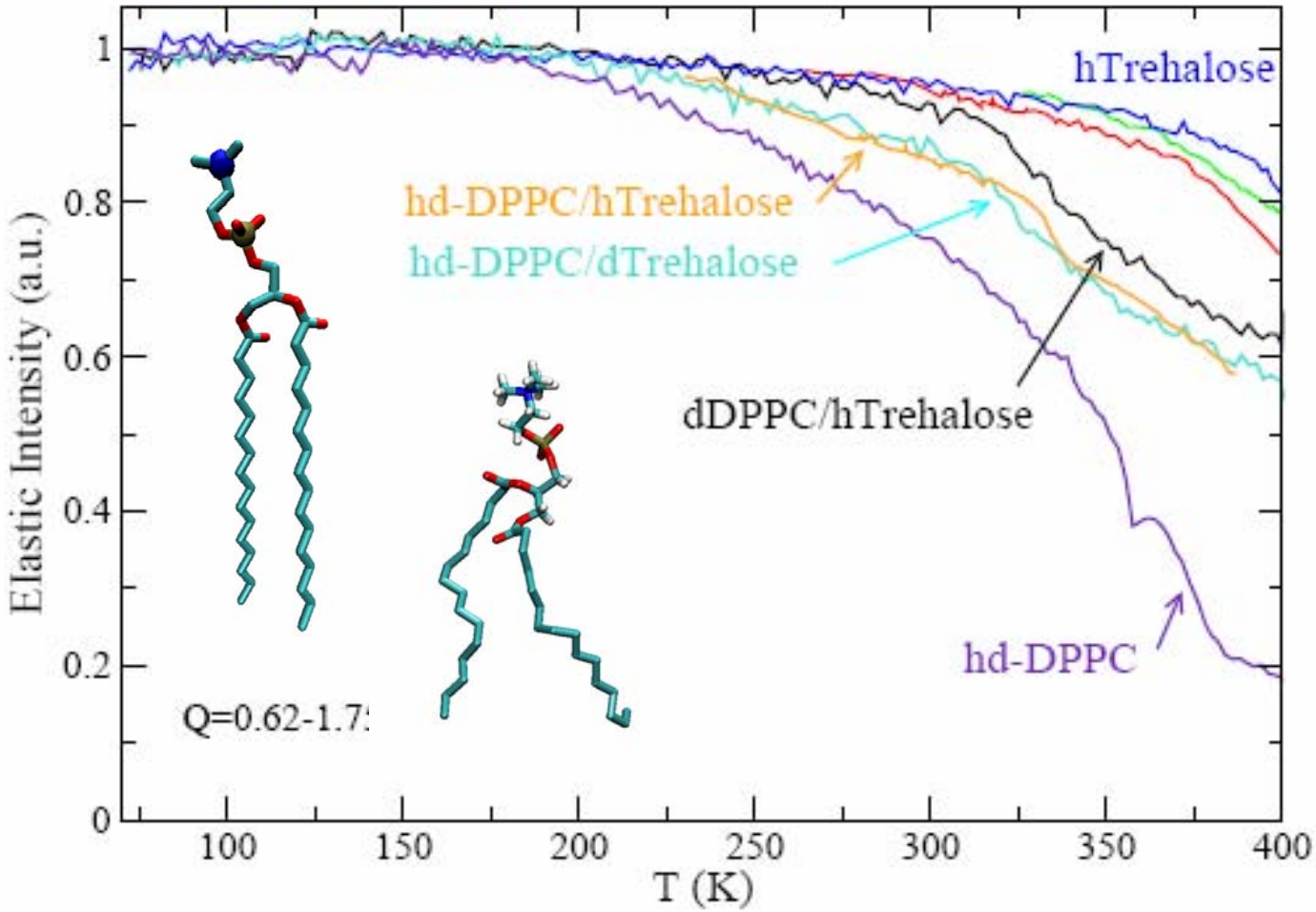
Tm

# Dynamics: dry lipids with trehalose

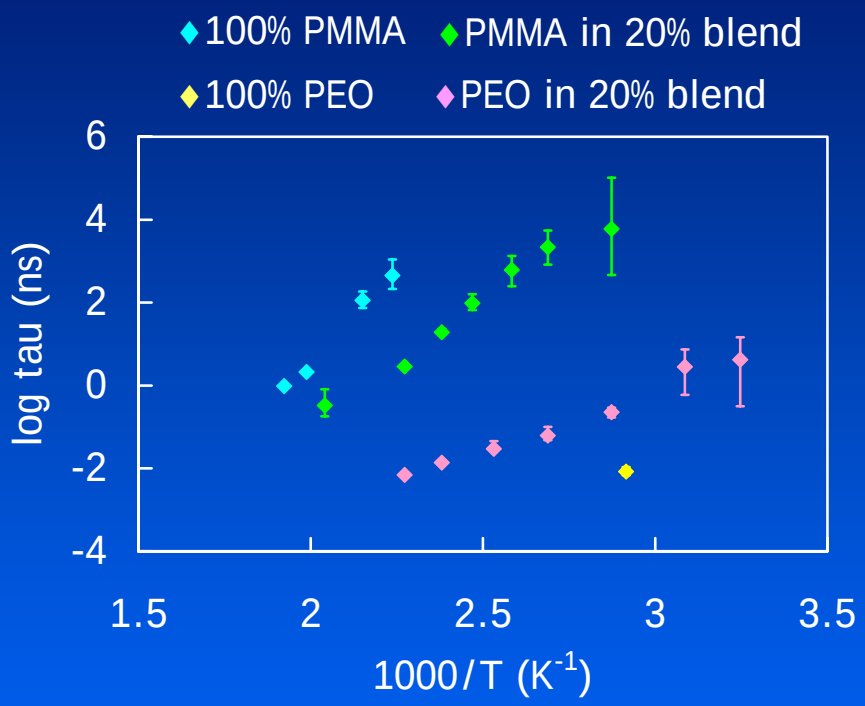




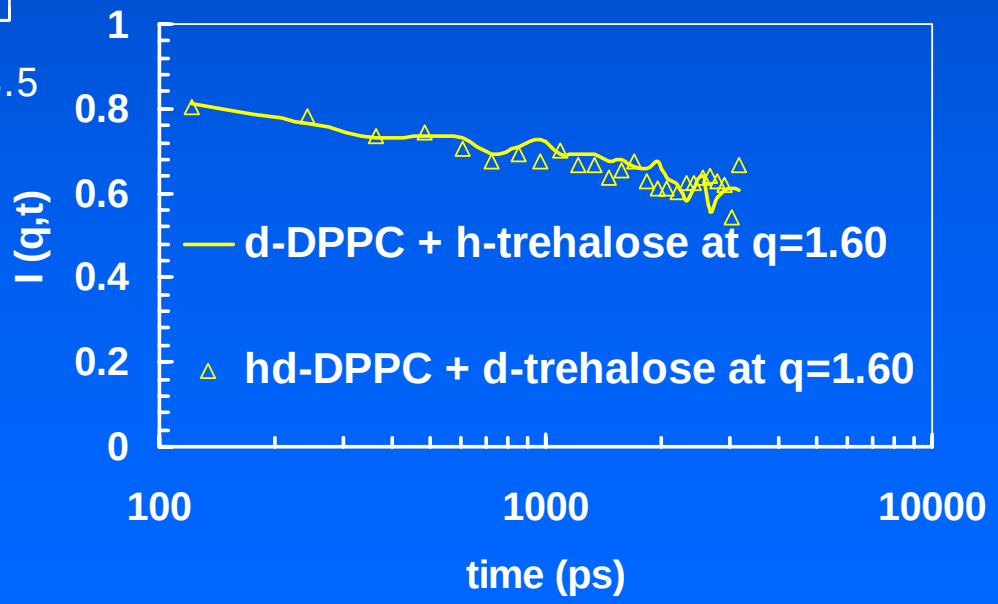
elastic scan



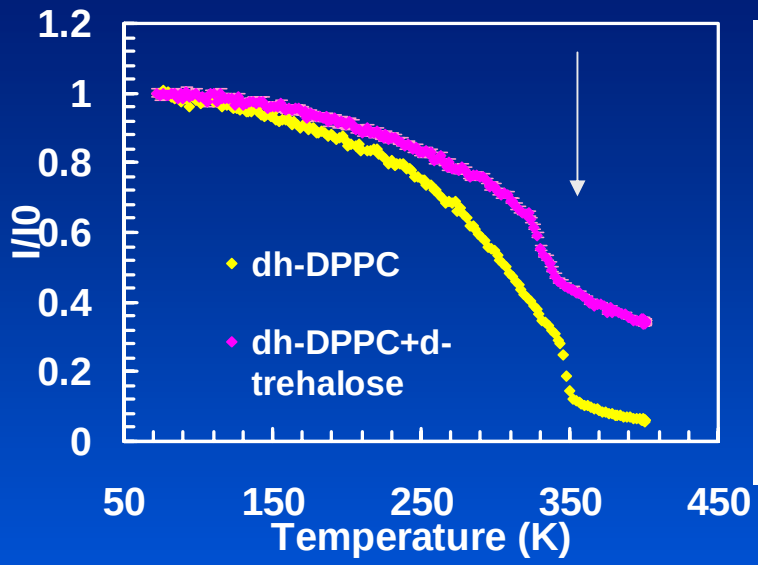
# Analogy to “blend dynamics”

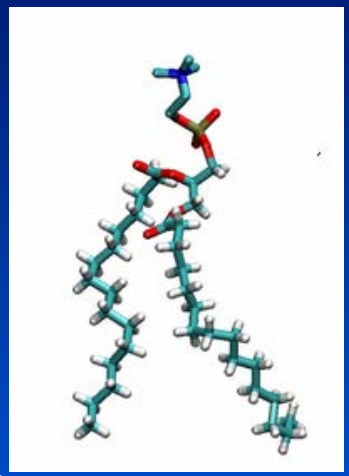


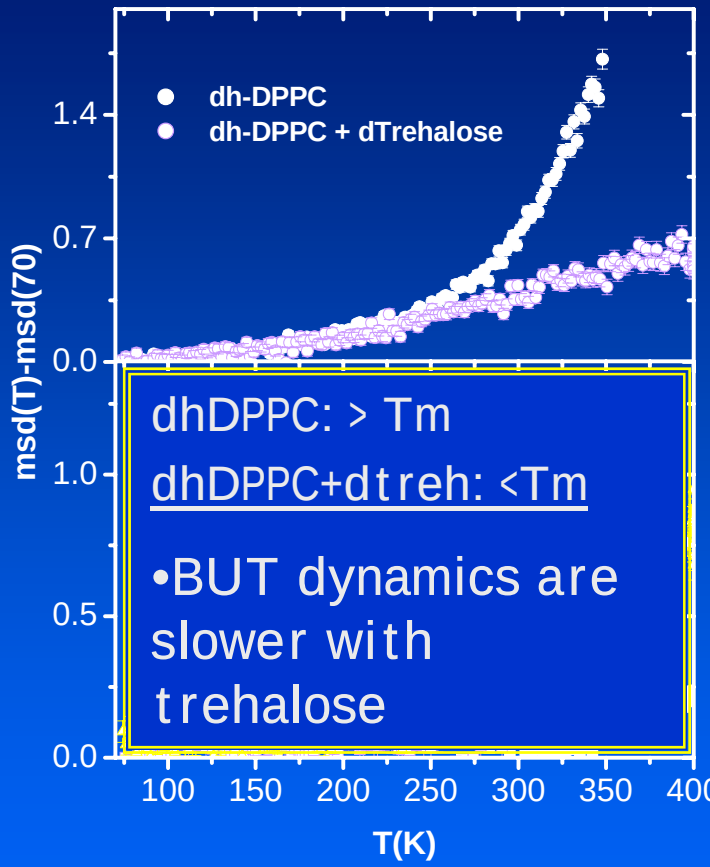

Mixture of two polymers without H-bonding



# Dynamics of tails with trehalose



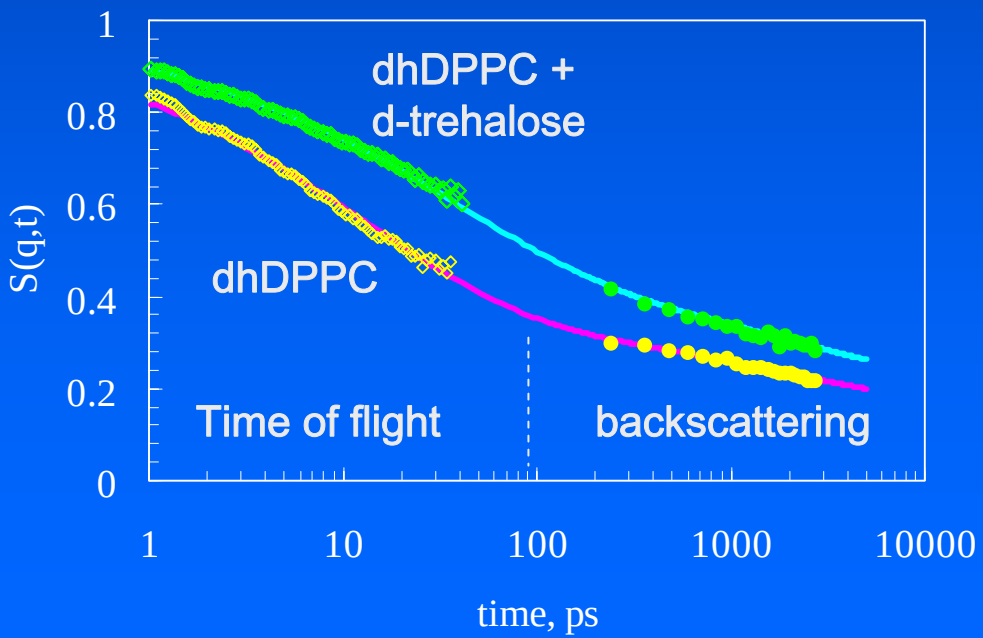






dhDPPC: > Tm

dhDPPC+dtreh: <Tm

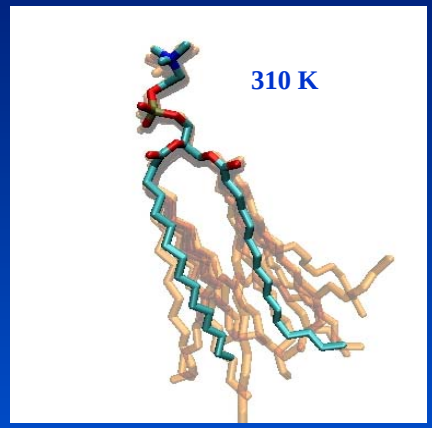
•BUT dynamics are slower with trehalose

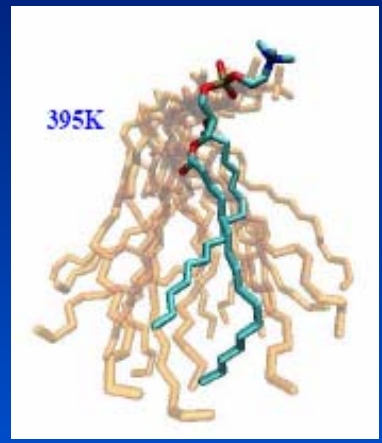



| | τ fast | τ slow |
|---|---|---|
| dhDPPC alone | 13 ps | 1900 ps |
| with trehalose | 36 ps | 2500 ps |

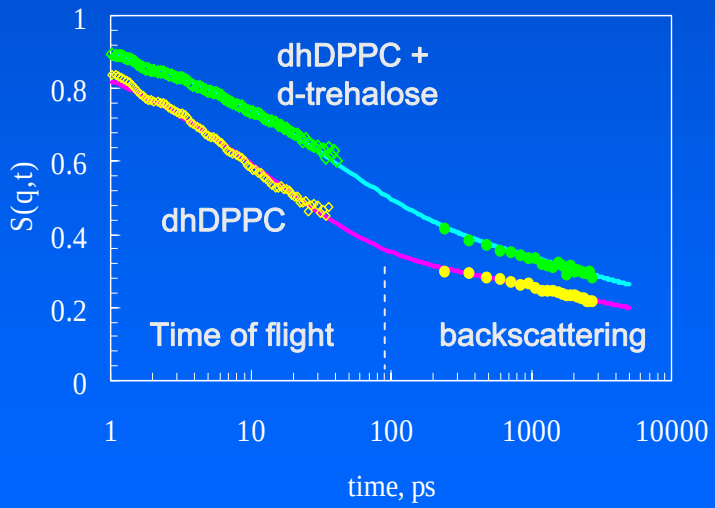
# Summary

- Melting transition:
- dry lipids - tops of tails
- with trehalose – bottom of tails

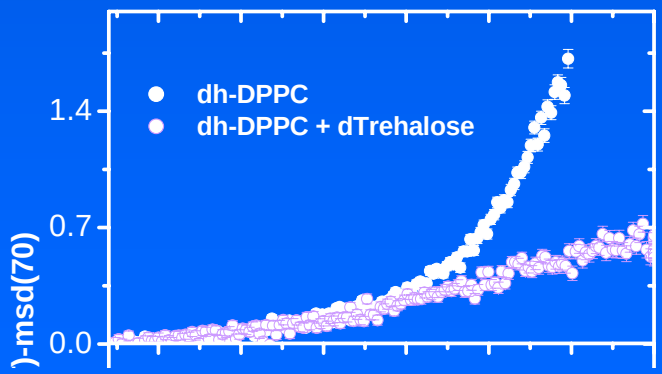


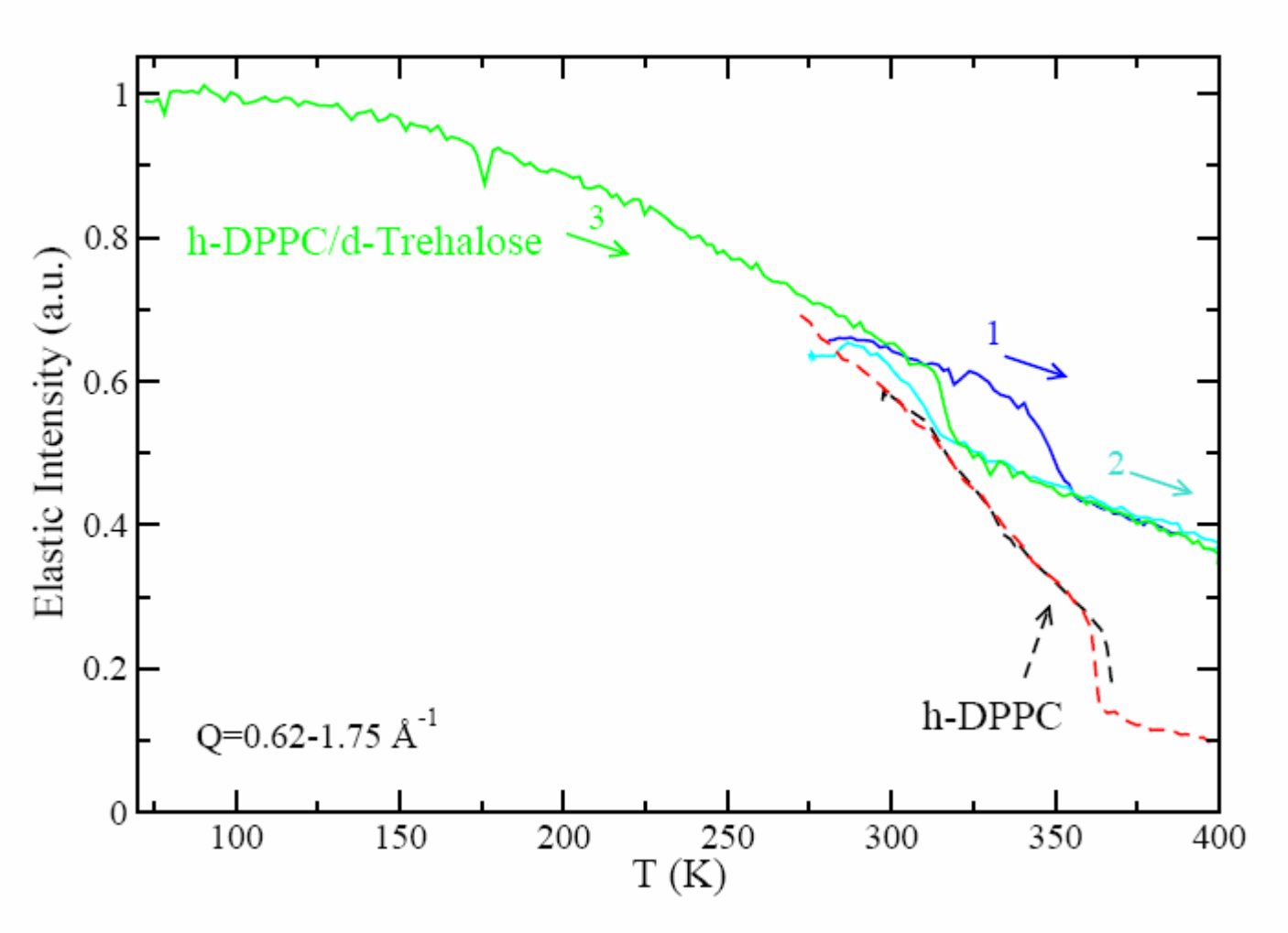

dhDPPC <Tm faster than
dhDPPC+trehalose >Tm




With trehalose: localized
mobility above Tm



# Heat cycles


Elastic Intensity (a.u.)
T (K)
h-DPPC/d-Trehalose
3
1
2
h-DPPC
Q=0.62-1.75 Å$^{-1}$
0
0.2
0.4
0.6
0.8
1
100
150
200
250
300
350
400

# trehalose and tail mobility: time of flight