Microrheology using laser light scattering

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http://www.deas.harvard.edu/projects/weitzlab/

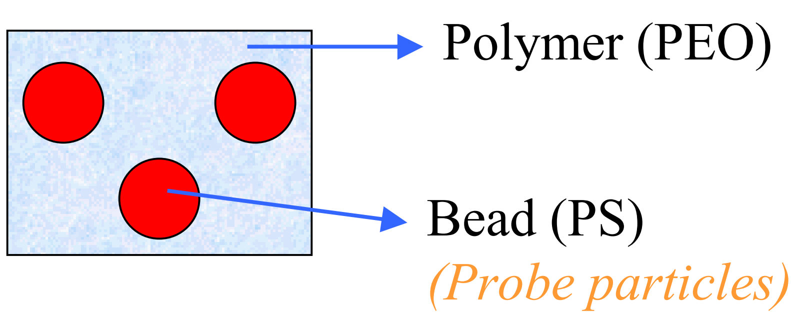
Objective:

To compare rheological data with μ-rheology

Why Microrheology?

- Small strains (~ $k_B T$)
- Small sample volumes (~ml)
- Larger frequency range

How do we do Microrheology?



Measure the motion of these beads

Viscous limit : $\Delta r^2 = 6 D \tau$

Elastic limit : $G = \dfrac{k_B T}{\pi a \Delta r^2_{max}}$

Experimental system:

Choose a simple flexible polymeric system

Use different bead sizes to check for homogeneity of the sample at the different length scales

Polyethylene oxide (PEO)

200K and 900K at various conc. above c*.

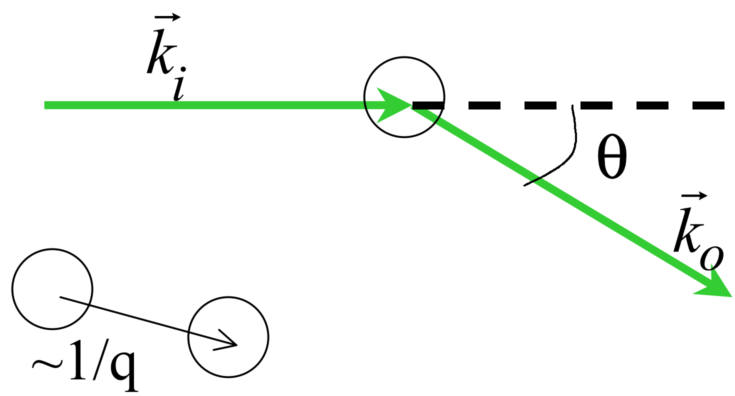
Polystyrene beads (PS)

0.46µm to 2µm in diameter.

Light scattering techniques:

To extract the mean square displacements of the probe particles

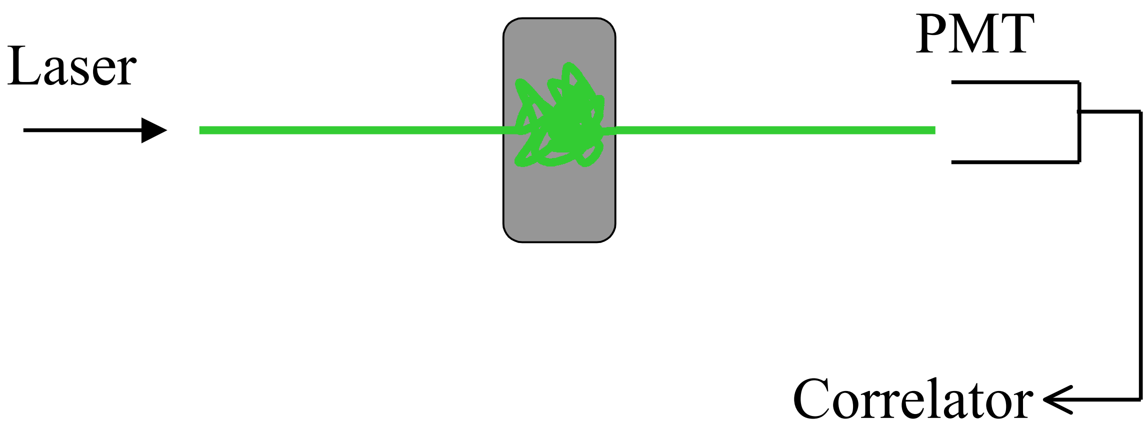
(A) Single scattering

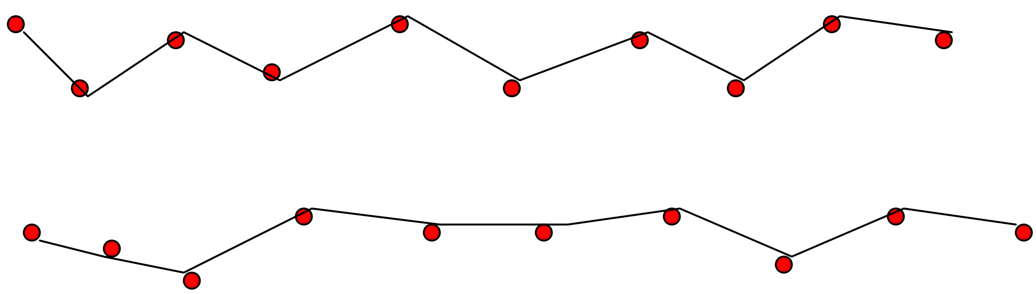


Measure time averaged intensity fluctuation

Probe length scale (~0.5μm) of the order of the wavelength of the light

(B) Diffusing wave spectroscopy (DWS)



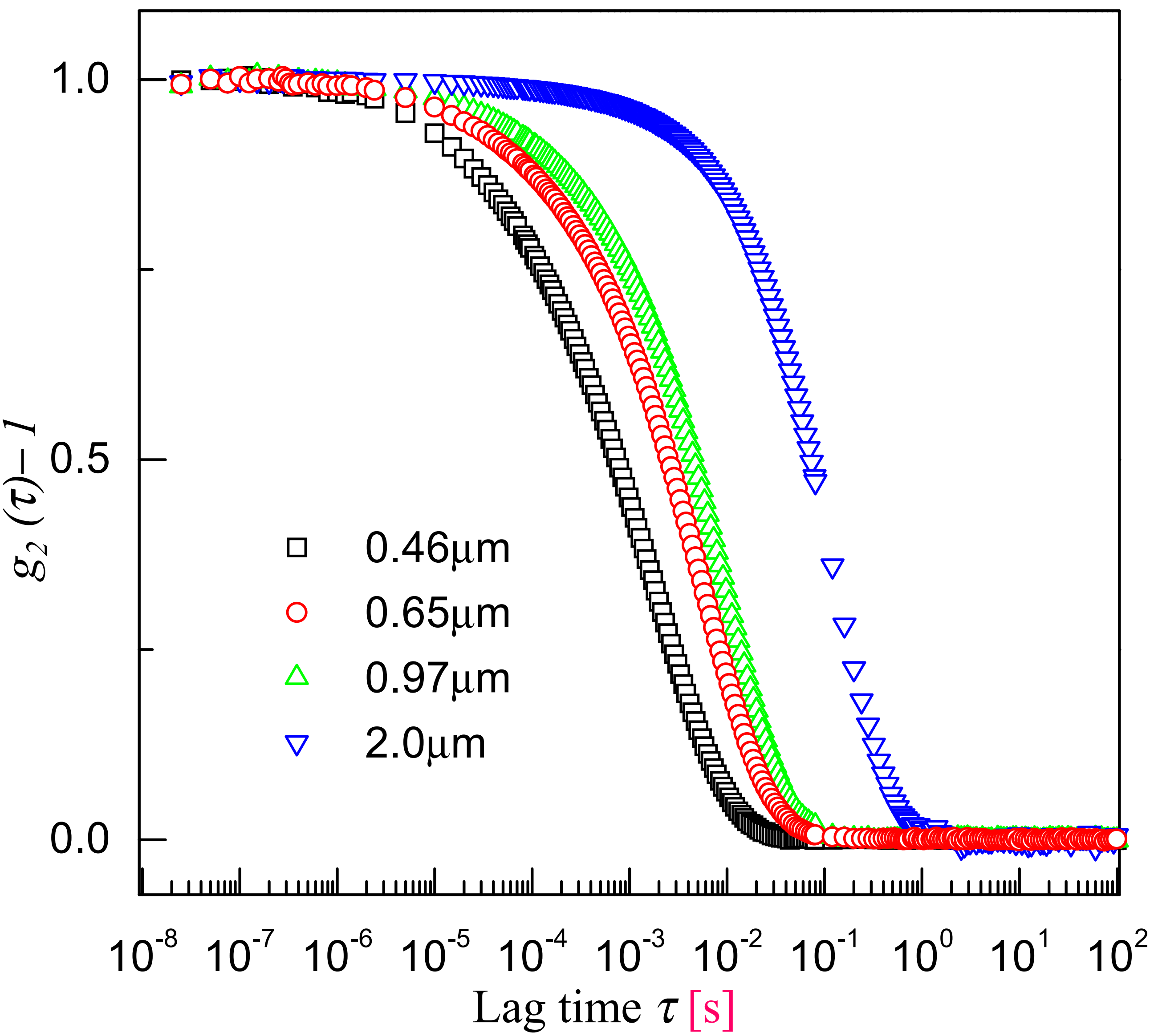


Total path length changes by the wavelength of light

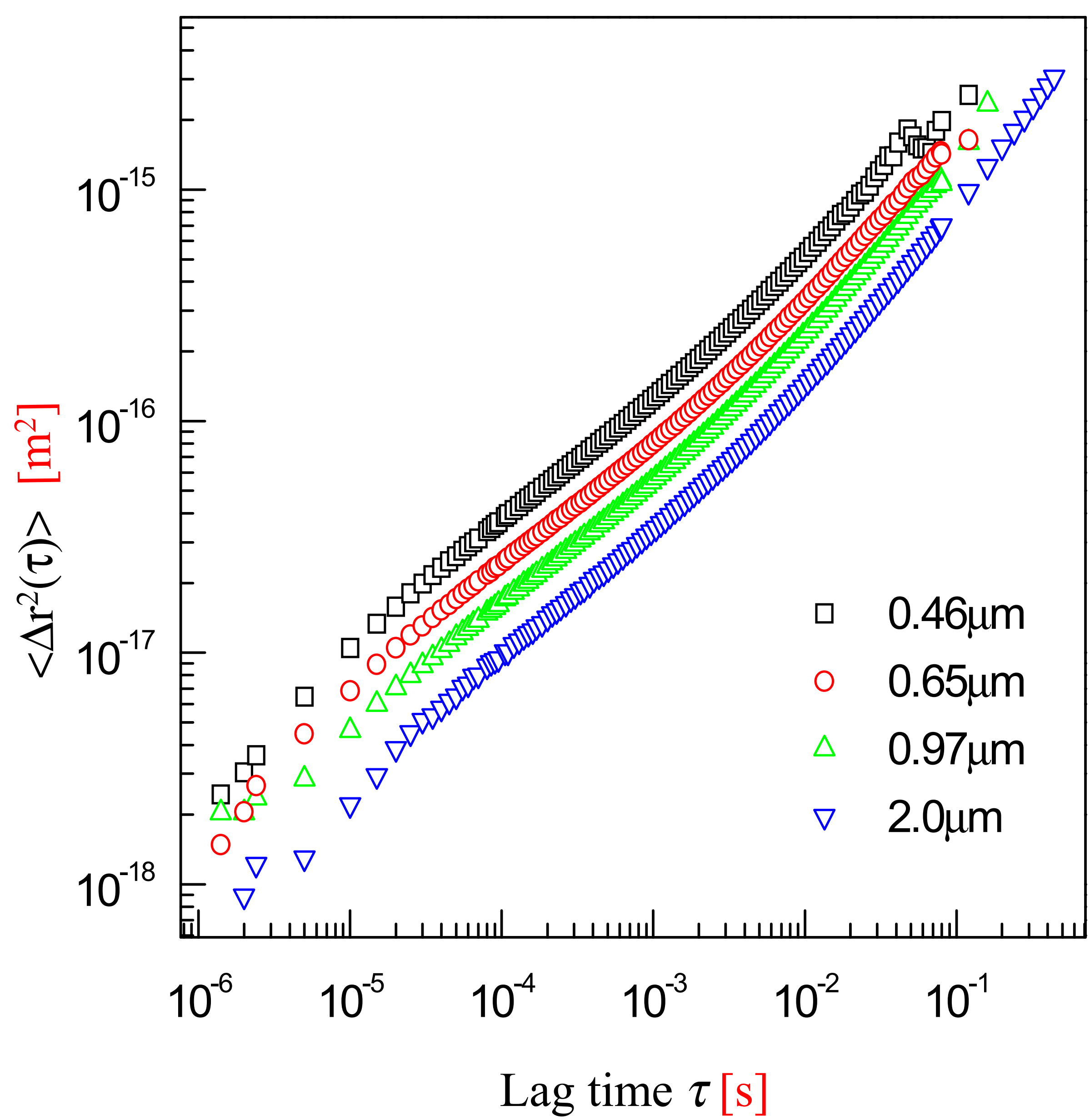
Multiply scattering (opaque) samples

Can probe shorter length scales (~ nm) than conventional light scattering

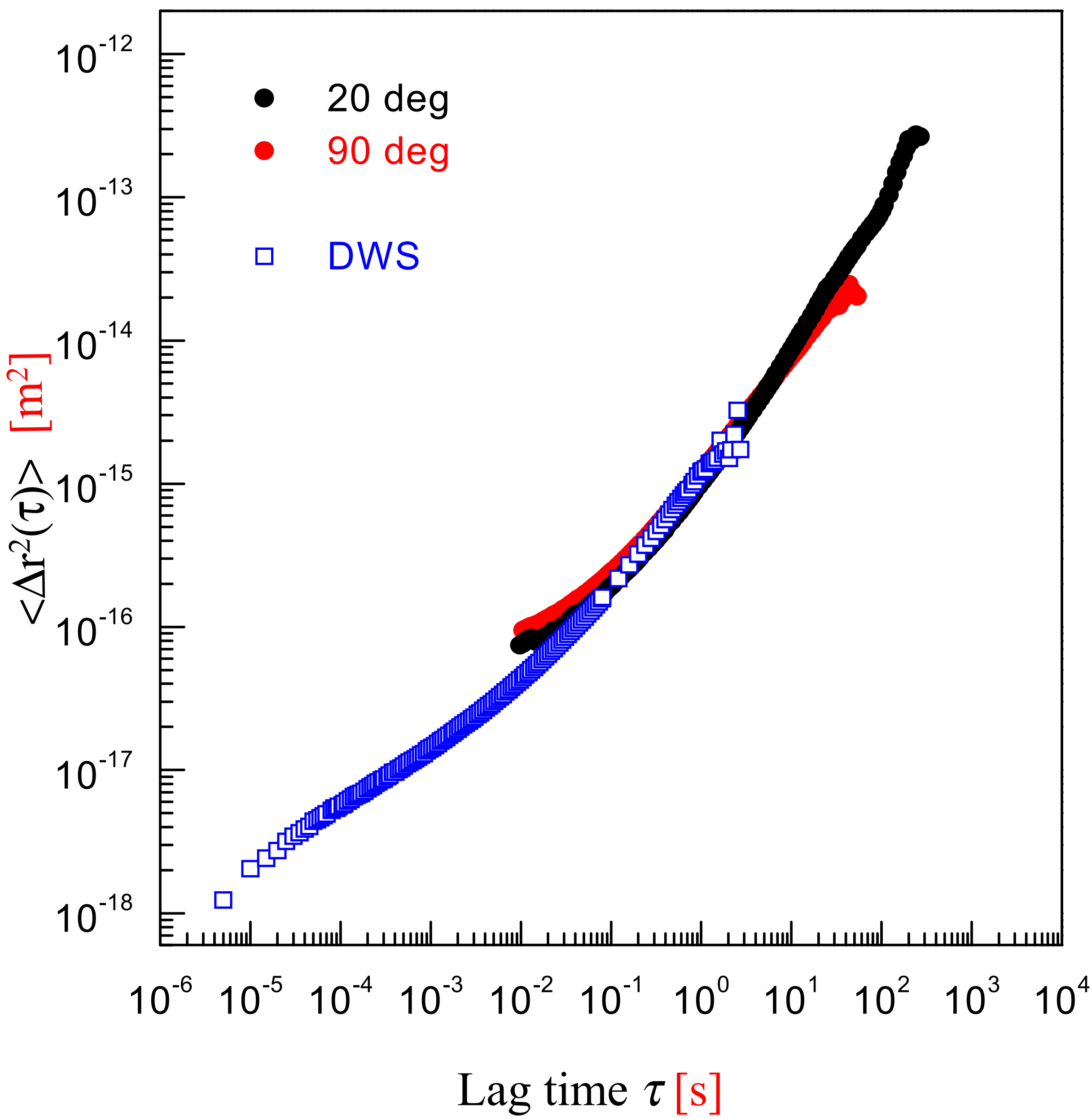
Correlation function for 2.2% 900K PEO with 1% PS beads measured using **DWS**



Mean square displacement curve for 2.2% 900K PEO with 1% PS beads measured using **DWS**



Mean square displacement curve for 4% 900K PEO with 0.97μm PS beads measured using **DWS** and **single scattering**



Microrheology :

To get the moduli from the mean square displacements of the probe particles

Generalized Stokes-Einstein equation

$$\tilde{G}(s) = \frac{k_B T}{\pi a s \langle \Delta \tilde{r}^2(s) \rangle}$$

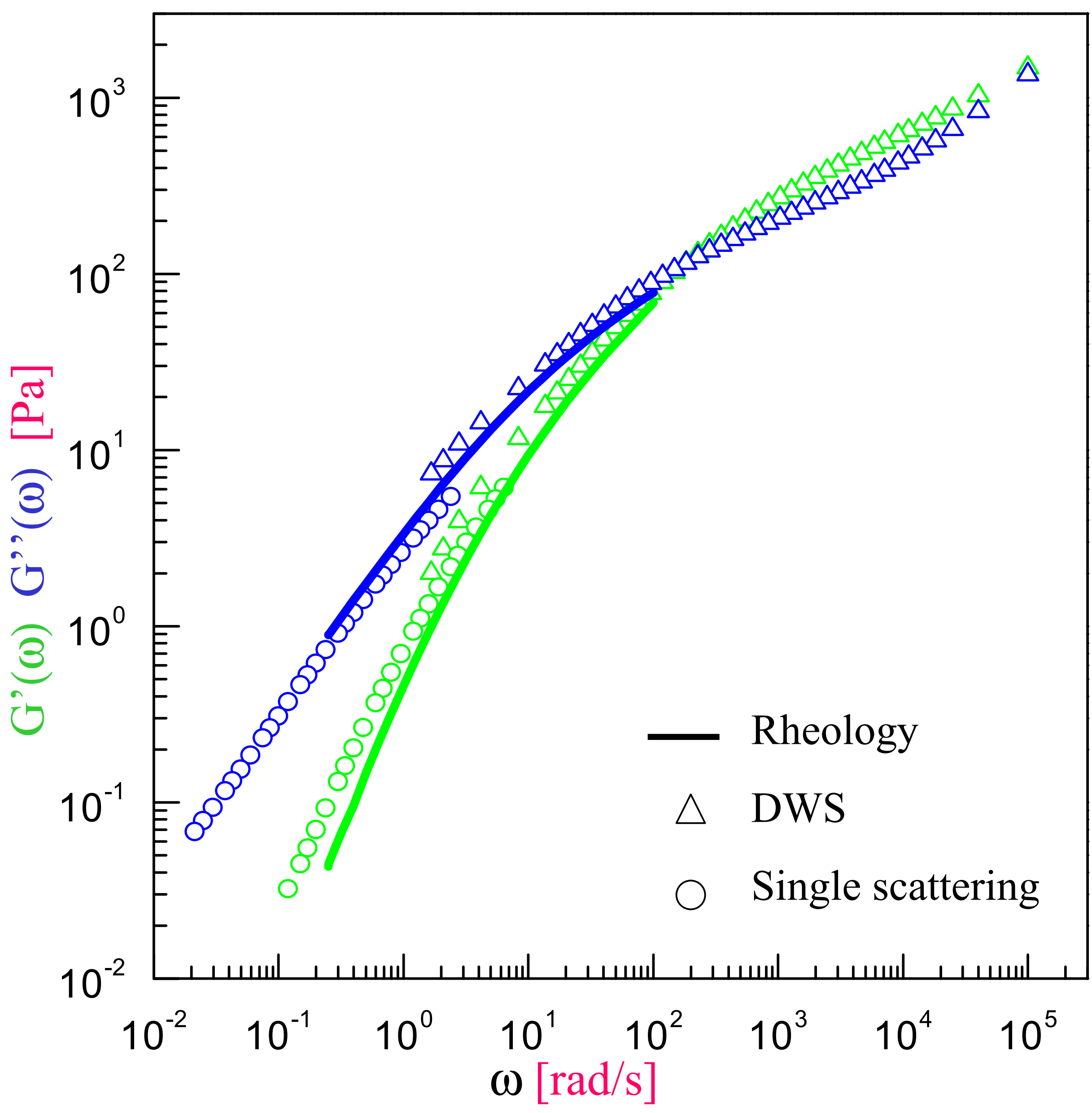
$$\tilde{G}(s = i\omega) = G'(\omega) + iG''(\omega)$$

G' = Elastic (storage) modulus

G'' = Viscous (loss) modulus

Comparison of rheology with μ-rheology using DWS and single scattering

4% 900K PEO and 0.65μm PS beads



Conclusions

- Single scattering and DWS are similar over the region of overlap and we can get roughly 7 decades of data.
- The polymer is homogeneous over the length scale probed by the beads.
- Microrheology compares very well with rheology for this model flexible non cross-linked polymer.

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