Developing an Optical Microscopy Method for Identifying Microplastics in Environmental Samples

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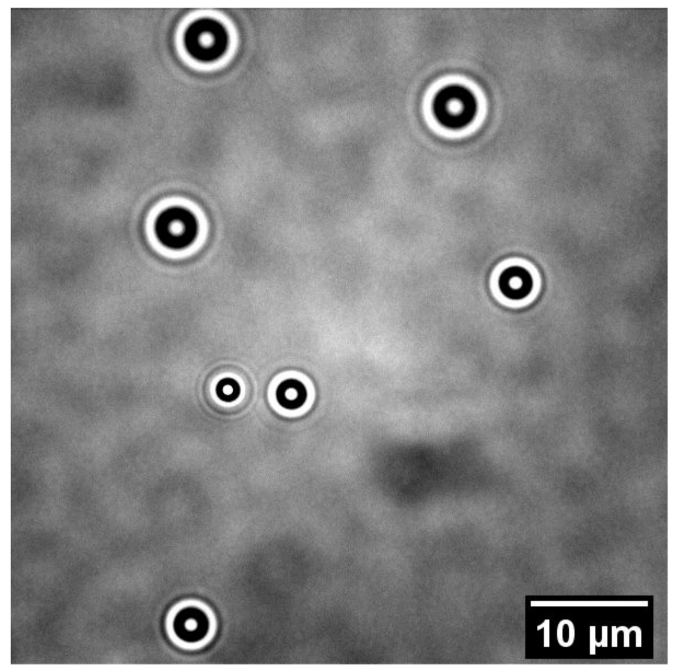
BACKGROUND

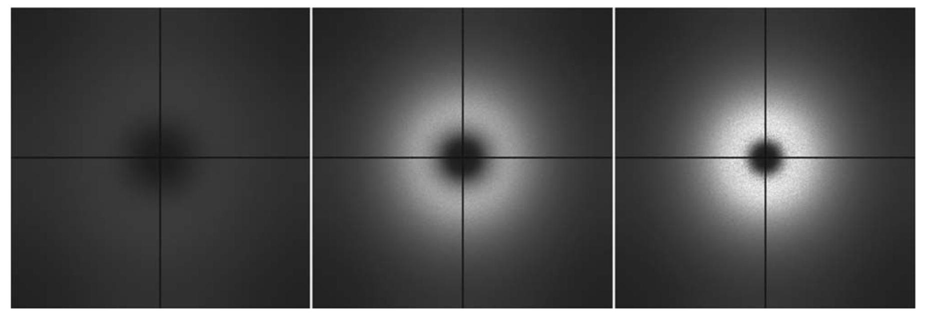
- Microplastic particles often result from the degradation of larger plastic materials [1].
- Their presence in coastal environments poses a growing threat to ecosystems and human health [1].
- Current detection methods are limited by lengthy processing times, high costs, low accessibility, and weak signal detection in complex samples [2].
- Developing an identification method using particle dynamics through microscopy imaging would provide valuable information to help track microplastics, identify their sources, assess exposure risks, and inform mitigation strategies [3].



How can particle dynamics and light scattering patterns observed with microscopy be used to identify the size and composition of microplastics?

DIFFERENTIAL DYNAMIC MICROSCOPY (DDM)

- Differential Dynamic Microscopy (DDM) is an image analysis technique that extracts statistical information from light intensity fluctuations [4,5].



$$I(x,t+\Delta t) - I(x,t) = \Delta I(x,t;\Delta t) \xrightarrow{\text{Fourier Transform}} |\Delta\hat{I}(q,t;\Delta t)|$$

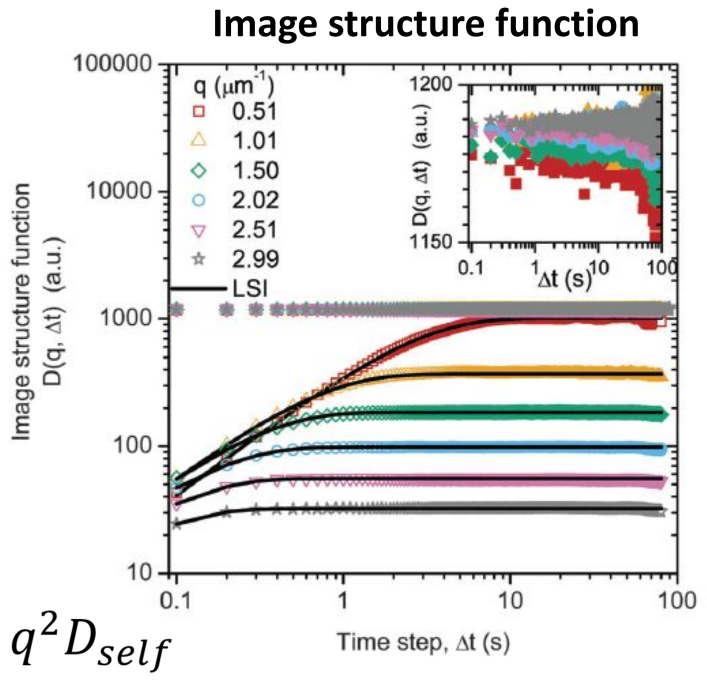
Image Structure Function $D(q,\Delta t) \equiv \left\langle \left|\Delta\hat{I}(q,\Delta t)\right|^2 \right\rangle$

- The dynamic image structure function decomposes analytically into three sub-functions:

$$D(q,\Delta t) = A(q)[1 - g(q,\Delta t)] + B(q)$$

- where A(q) is Amplitude function and B(q) is the background noise.
- For Brownian motion, the Intermediate Scattering function (g):

$$g(q,\Delta t) = exp(-\Gamma(q)\Delta t) \longrightarrow \Gamma(q) = q^2 D_{self}$$



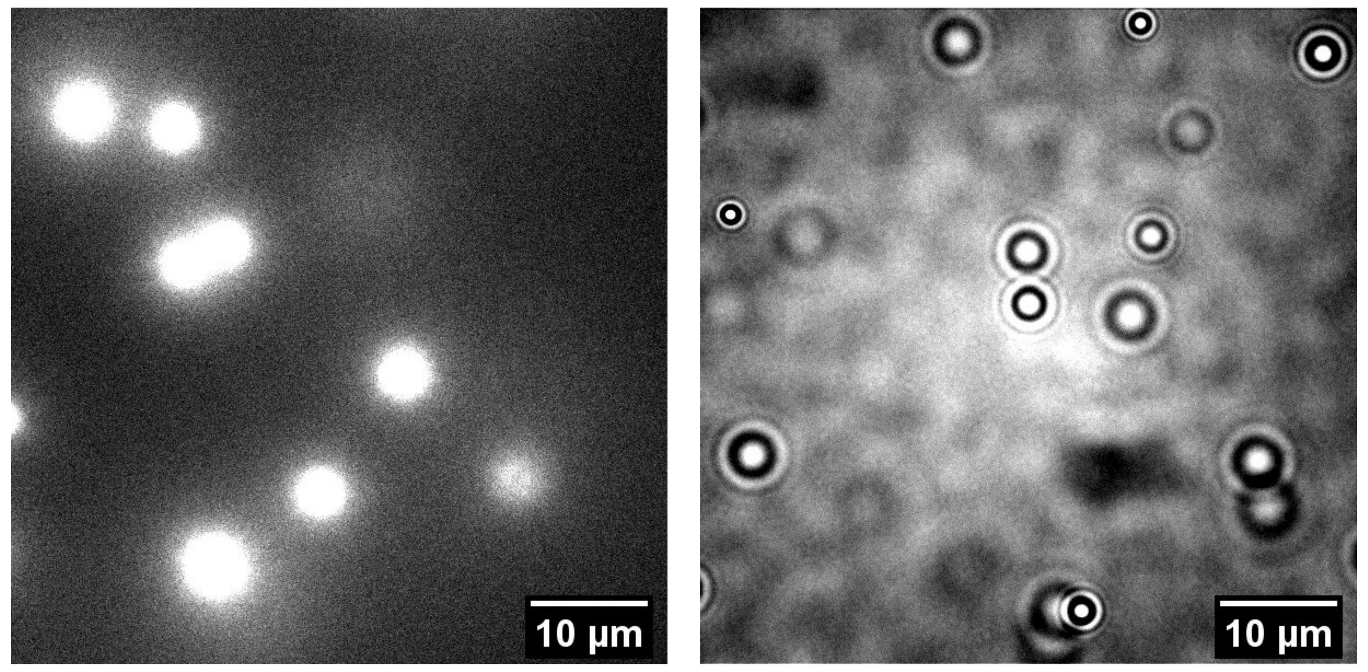
How can we use DDM analysis to extract key information about different microplastic chemistries?

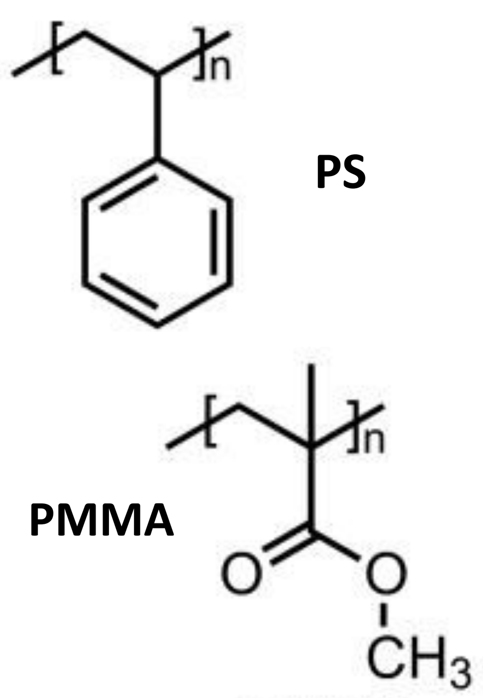
RESULTS AND DISCUSSION

Microscope Imaging

- Poly(methyl methacrylate) (PMMA) and polystyrene (PS) spheres (≈ 1 µm in diameter) were dispersed in water, and videos were recorded.

Fluorescent　Bright Field

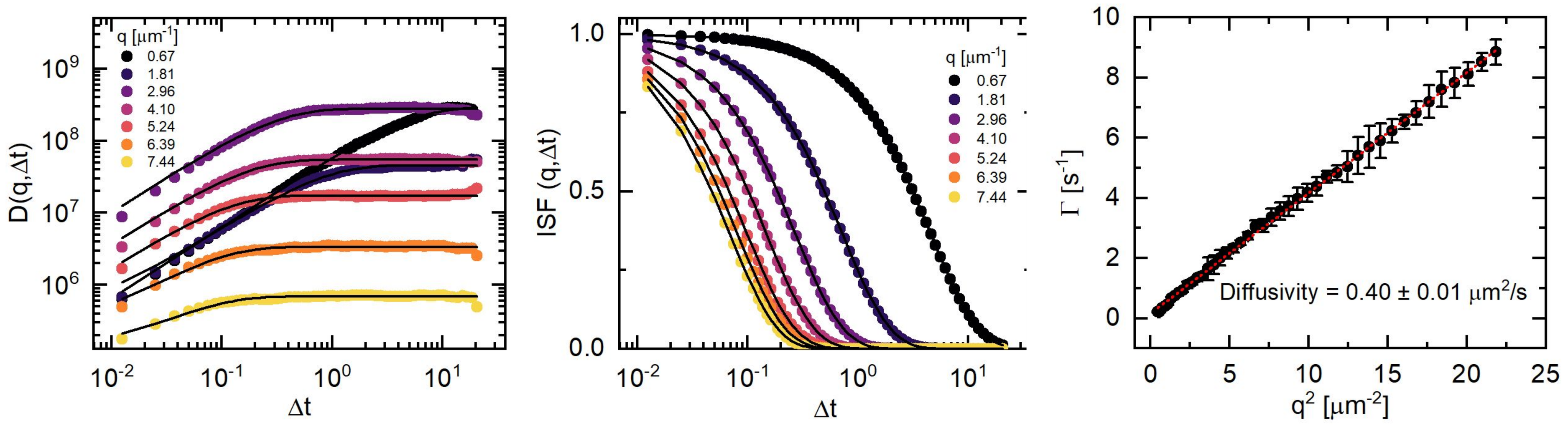




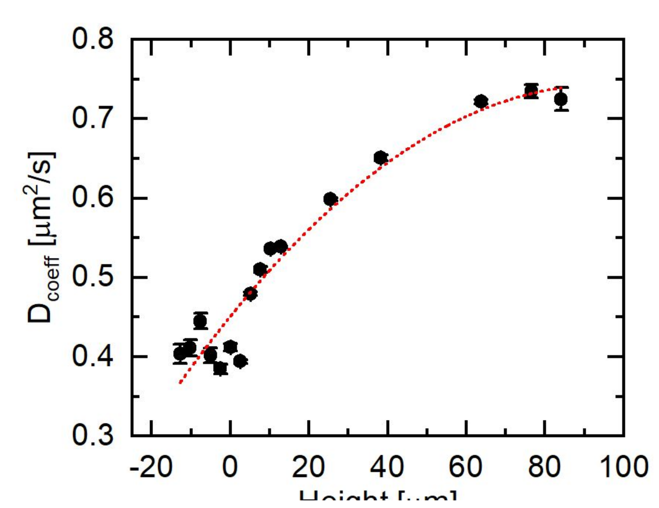
MATLAB Analysis

- More than 60,000 video frames were analyzed.

PS particles in water

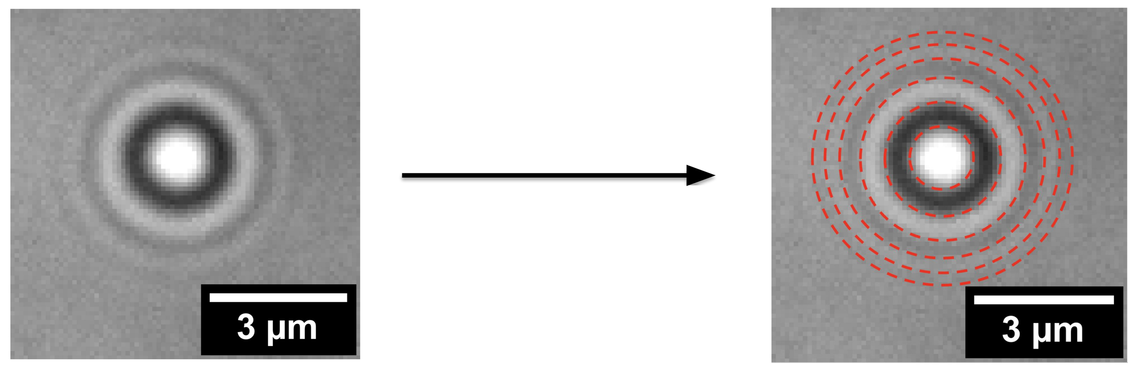


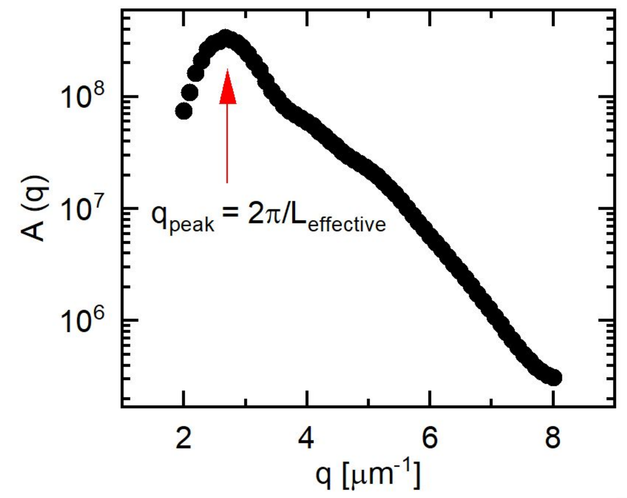
PMMA particles in water



- The diffusivity increases from the bottom of the glass slide up to the middle of the sample, reaching a plateau where particle motion becomes completely random.

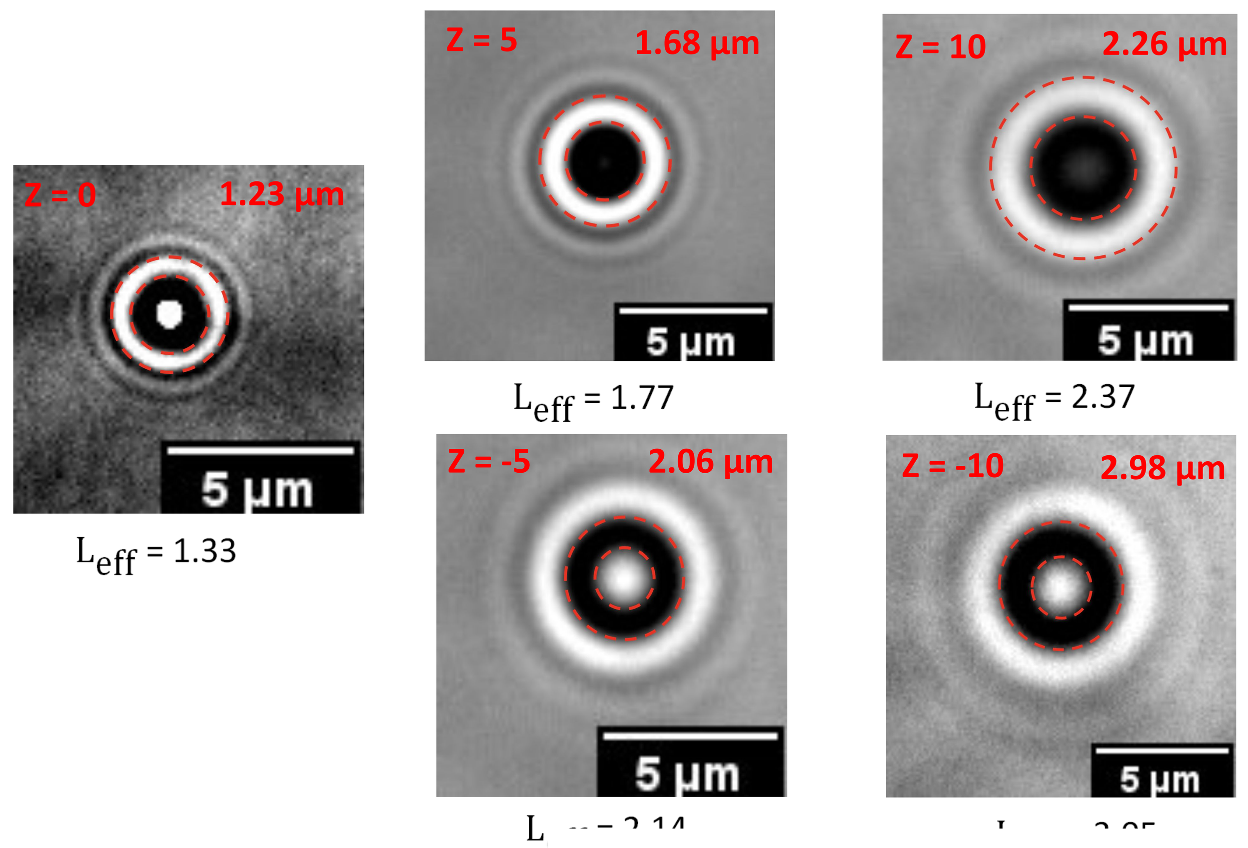
- Amplitude Function A(q) and Scattering halo of an individual particle:





- Investigating the relationship between amplitude A(q) and the effective length scale of the particles

- PS at different heights



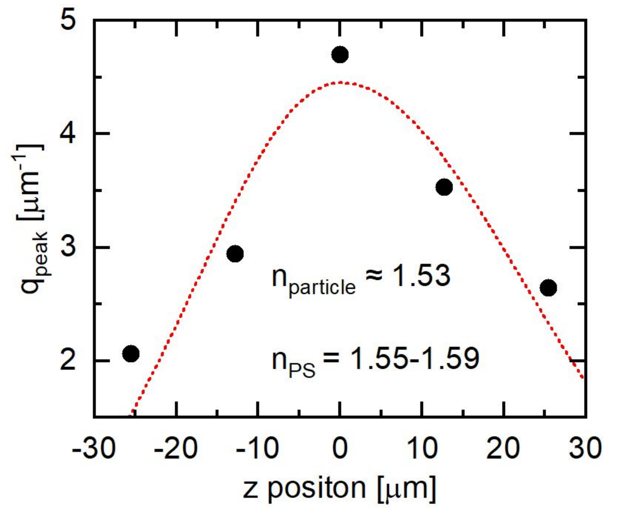
- q_{peak} vs heights

$$q(z) = q_0 \exp\left(-\left(\frac{z}{w}\right)^2\right)$$

$$q \propto n_{particle} - n_{medium}$$

$$\downarrow$$

$$q(z,n_p) = C(n_{particle} - n_{medium})\exp\left(-\left(\frac{z}{w}\right)^2\right)$$



CONCLUSION & FUTURE WORK

- Microscopy imaging combined with DDM provides valuable insights into the physical properties of microplastics.
- DDM is a powerful technique for probing the dynamics of microplastics in water.
- The peak of A(q) corresponds to an effective length scale, $L_{eff} = \frac{2\pi}{q_{peak}}$
- Additional measurements with different plastic types are needed to broaden the analysis and validate trends.
- Measuring at multiple heights (z-positions) can improve the fitting.
- Analyze mixtures of various plastics

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