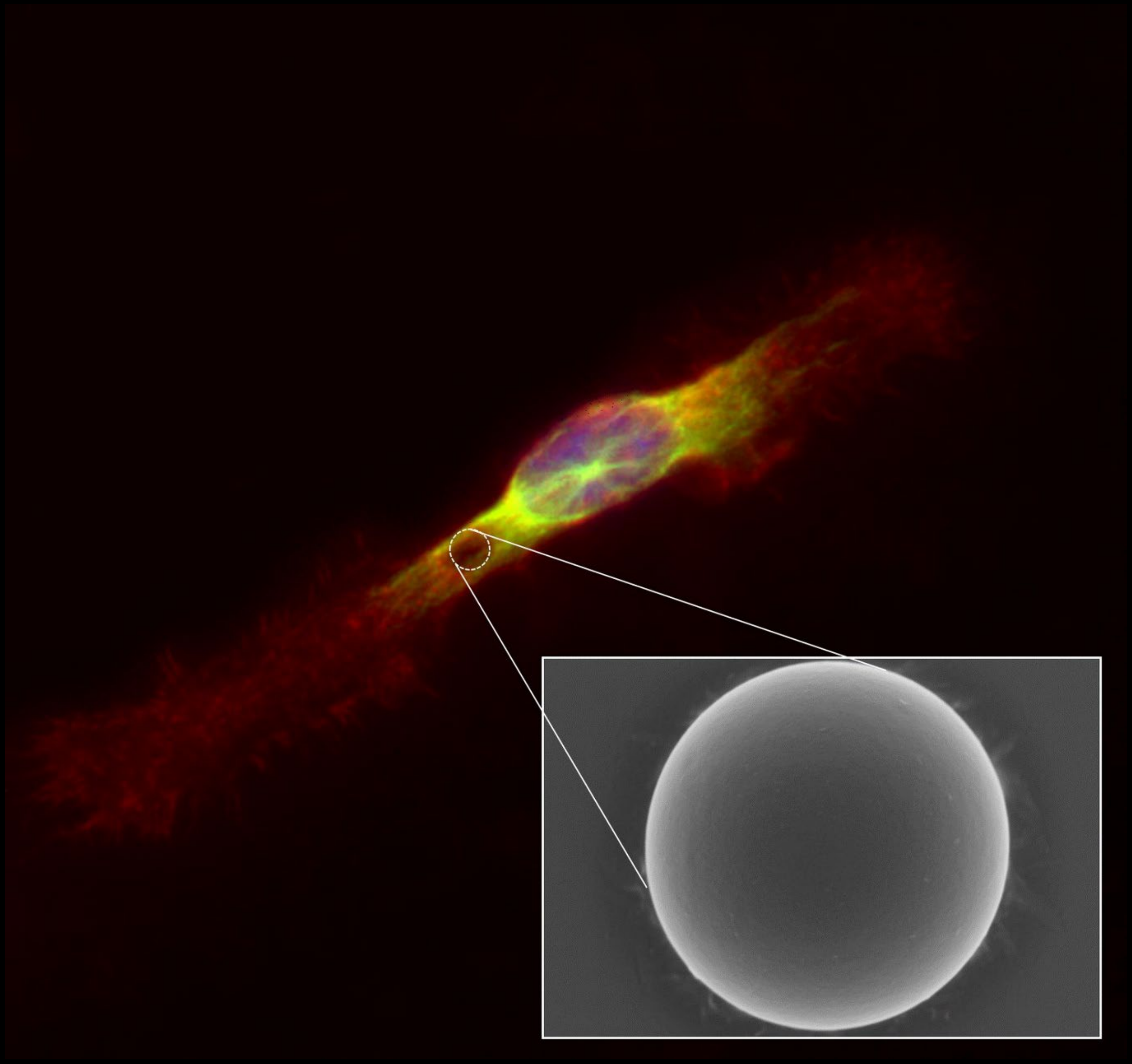
Lost in parameter space – Can we reduce the complexity in microplastic research?



Holger Kress
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UNIVERSITÄT BAYREUTH

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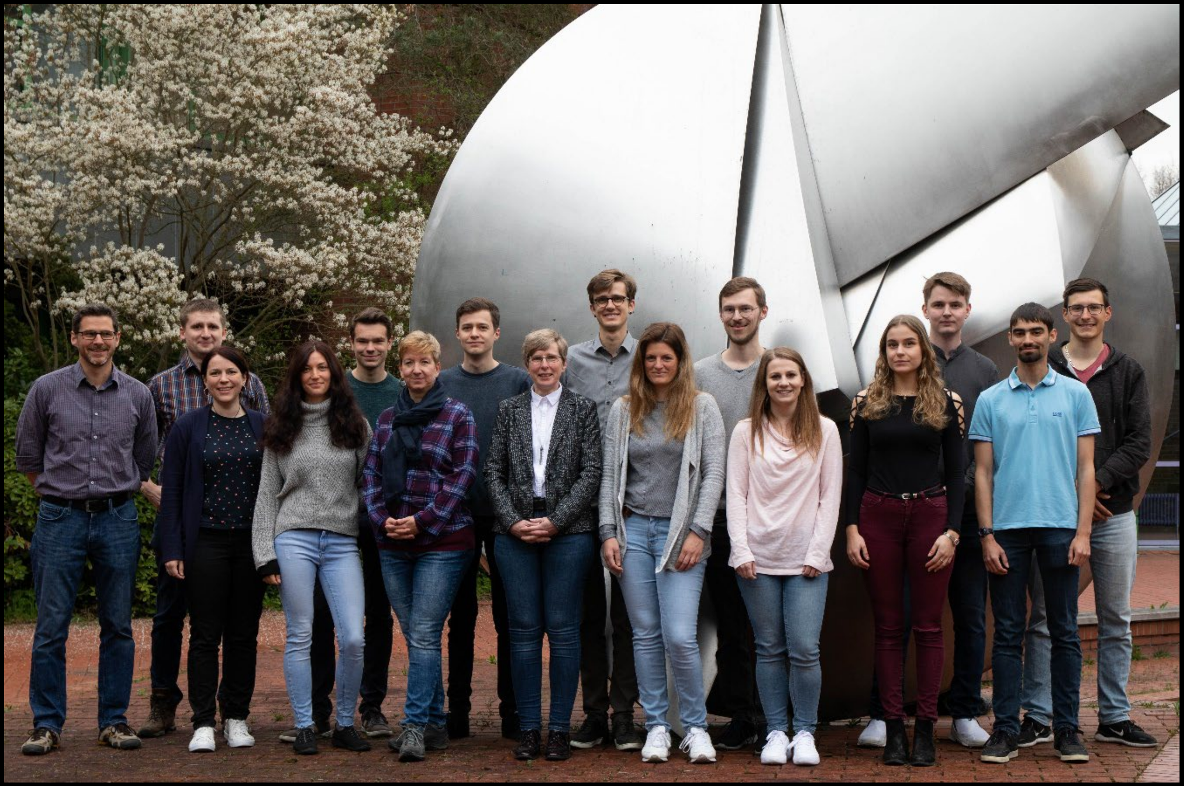

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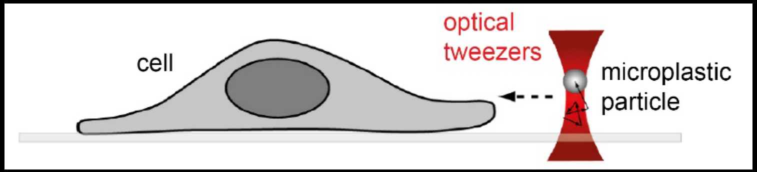
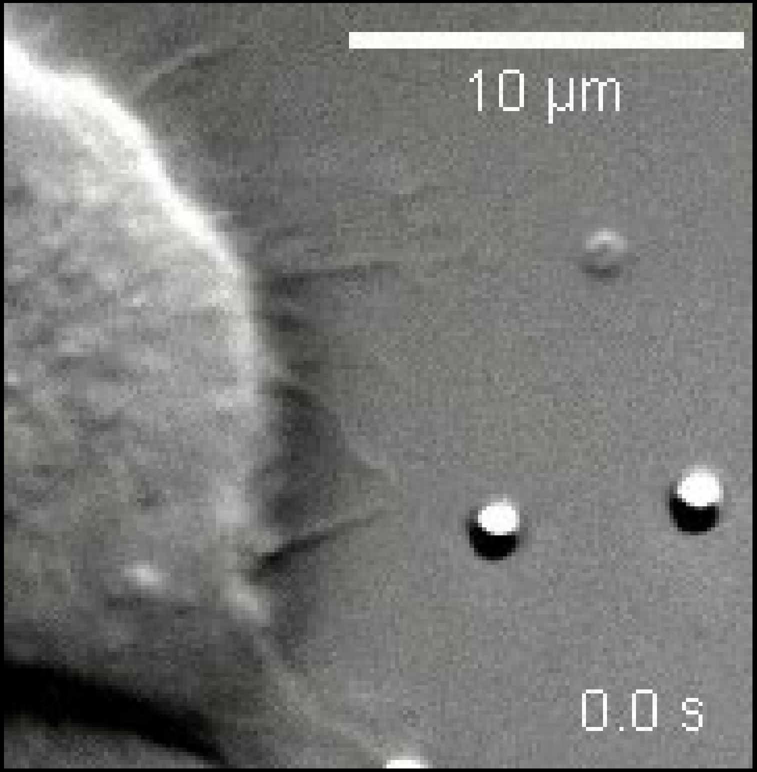
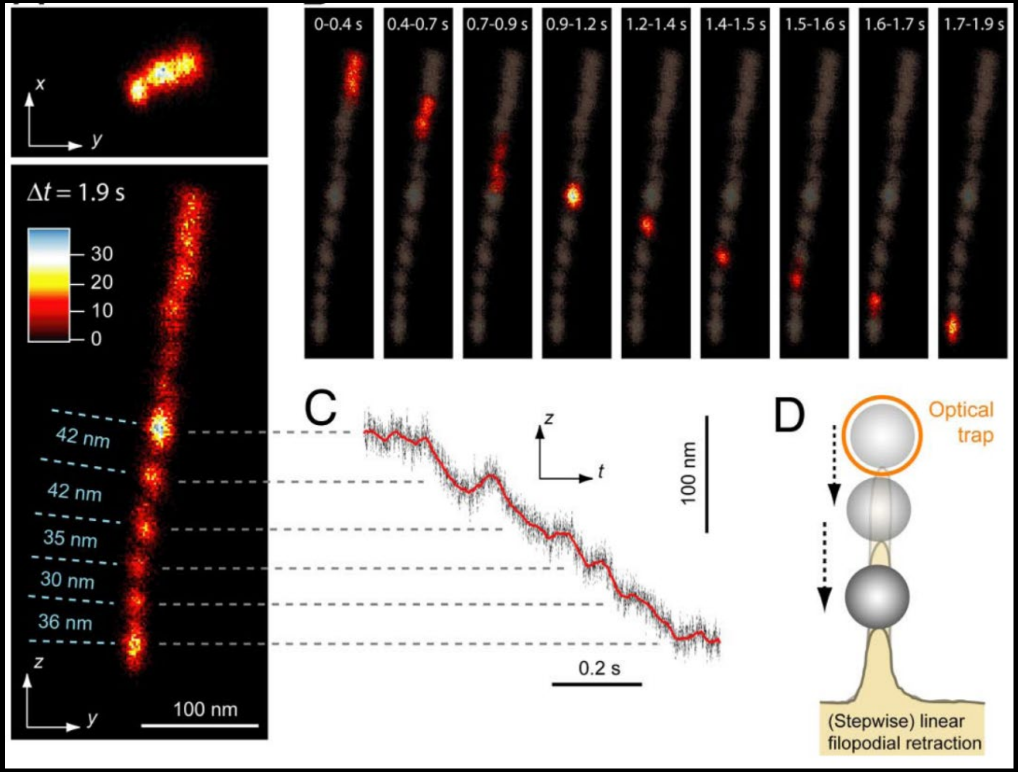
SFB MIKROPLASTIK

Interactions between cells and microparticles: Phagocytosis research



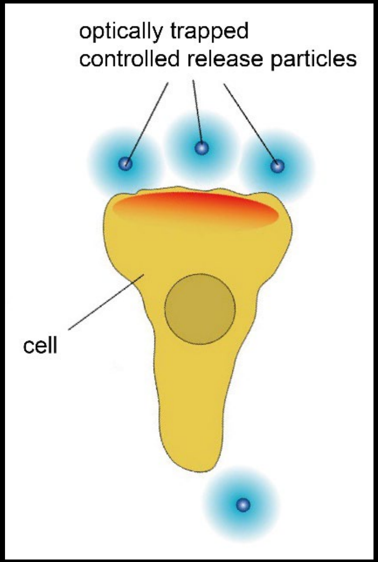
Filopodia (membrane protrusions) act as tentacles and pull particles towards cells



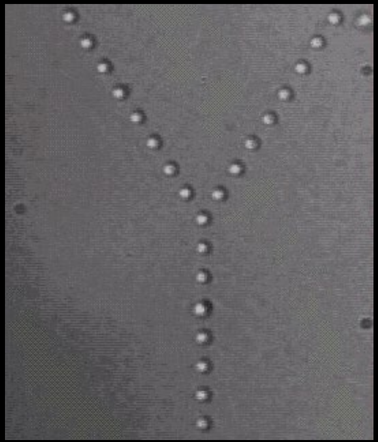


Kress et al., PNAS (2007)

Optically trapped controlled release microparticles: Chemotaxis research



Holographic optical traps

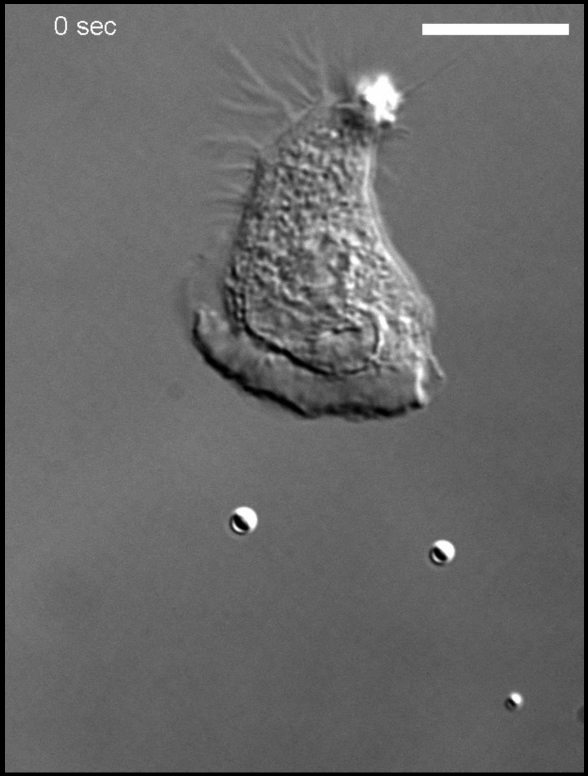


Chapin et al. (2006)

Particle releasing a chemoattractant (fMLP)

Kress et al., Nature Methods (2009)

Particles releasing F-actin inhibitor (cytochalasin D)



CRC Microplastics

Collaborative Research Centre 1357 Microplastics
@ University of Bayreuth (since 2019)

Understanding the mechanisms and processes of **biological effects**, **transport** and **formation**:
From model to complex systems as a basis for new solutions

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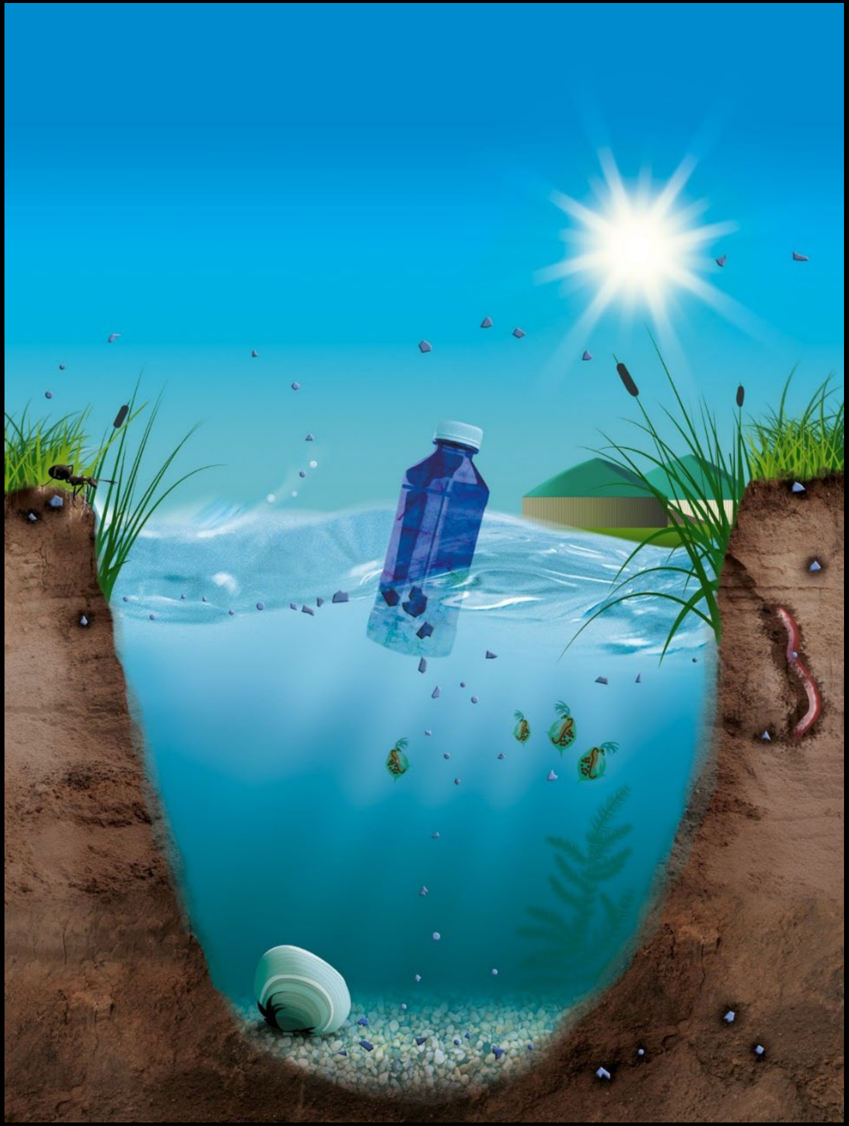
SFB MIKROPLASTIK



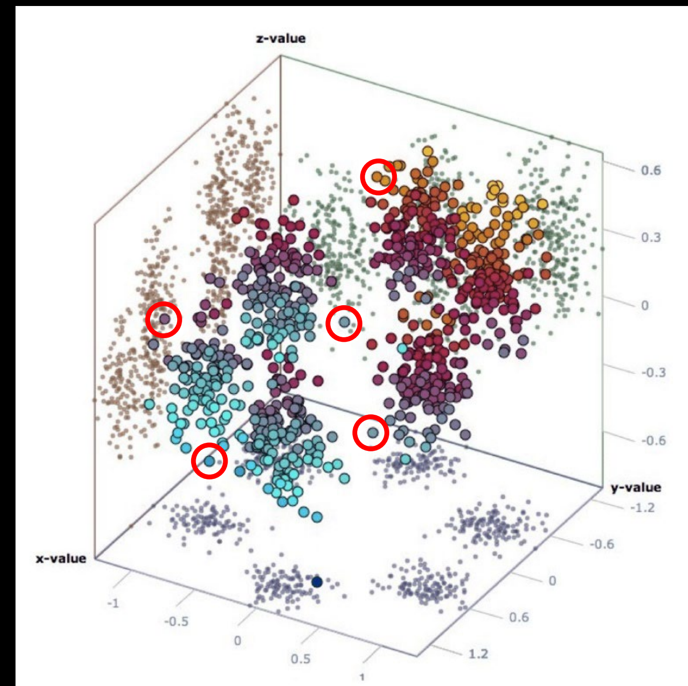
Huge multidimensional parameter space in microplastics research

Risk assessment of microplastic particles

Albert A. Koelmans, Paula E. Redondo-Hasselerharm, Nur Hazimah Mohamed Nor, Vera N. de Ruijter, Svenja M. Mintenig and Merel Kooi

Abstract | Microplastic particles are ubiquitous in the environment, from the air we breathe to the food we eat. The key question with respect to these particles is to what extent they cause risks for the environment and human health. There is no risk assessment framework that takes into account the multidimensionality of microplastic particles against the background of numerous natural particles, which together encompass an infinite combination of sizes, shapes, densities and chemical signatures. We review the current tenets in defining microplastic characteristics and effects, emphasizing advances in the analysis of the diversity of microplastic particles. We summarize the unique characteristics of microplastic compared with those of other environmental particles, the main mechanisms of microplastic particle effects and the relevant dose metrics for these effects. To characterize risks consistently, we propose how exposure and effect thresholds can be aligned and quantified using probability density functions describing microplastic particle diversity.

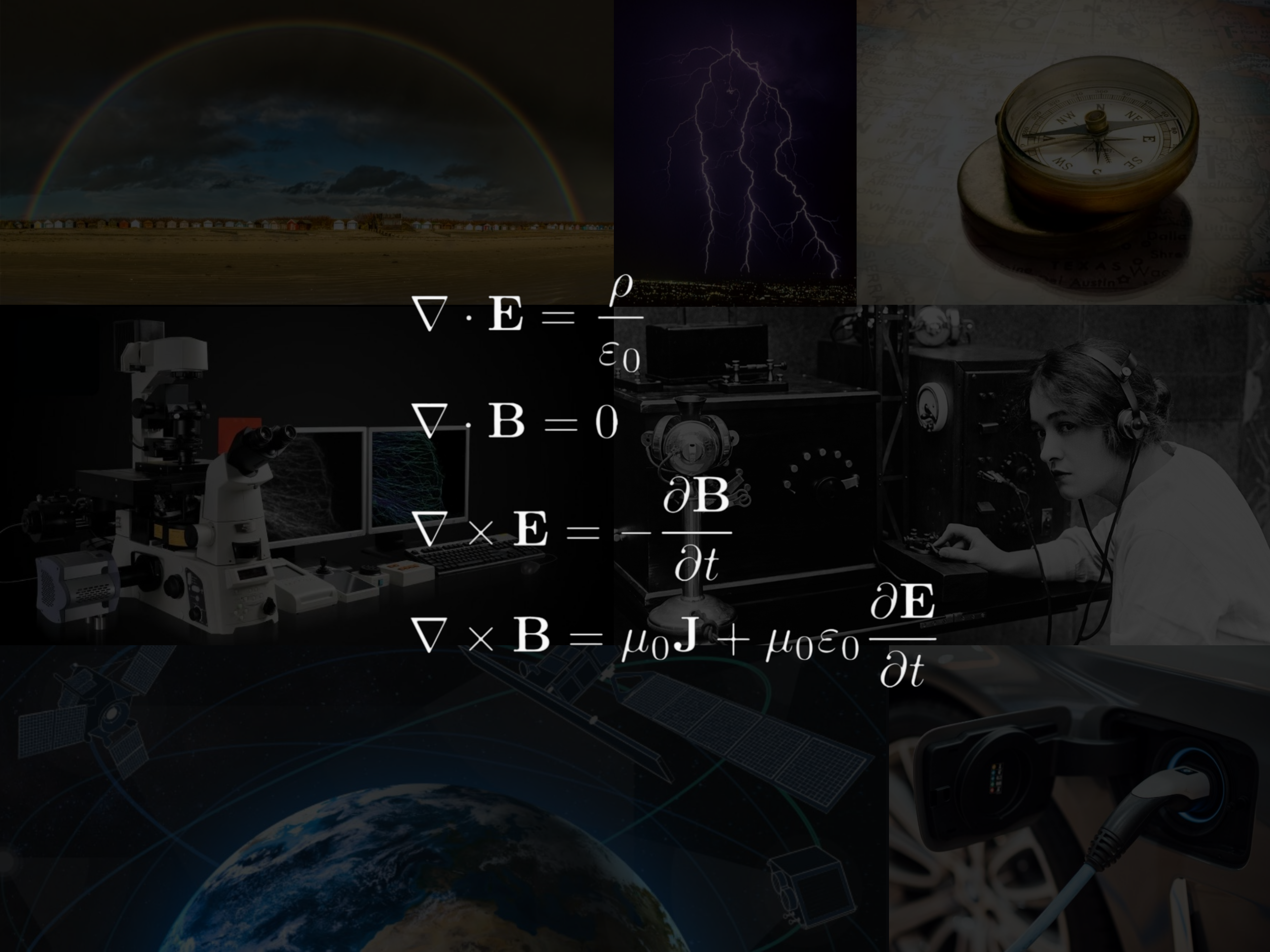
Koelmans et al., *Nature Reviews Materials*, 7, 138–152 (2022)



www.doka.ch/Excel3Dscatterplot.htm

Dimensions:

- **Polymer material (PS, PE, PP, PET, PVC, …)**
- **Size (sub-µm- up to mm-range)**
- **Shapes (spheres, fibers, fragments, …)**
- **Surface properties (plain, specific functionalizations, …)**
- **Model organisms / cells (fish, mussels, … / macrophages, epithelial cells, …)**
- **…**



$$\nabla \cdot \mathbf{E} = \frac{\rho}{\varepsilon_0}$$

$$\nabla \cdot \mathbf{B} = 0$$

$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

$$\nabla \times \mathbf{B} = \mu_0 \mathbf{J} + \mu_0 \varepsilon_0 \frac{\partial \mathbf{E}}{\partial t}$$

Can we reduce the complexity in microplastic research?

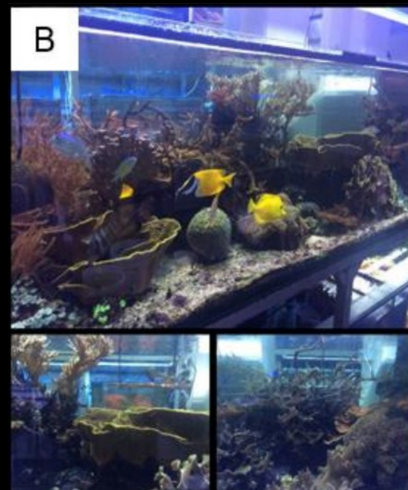
Can we reach a mechanistic understanding of the effects of microplastics?

- **Possible long-term effects due to particle integration into tissue: Internalization into cells relevant**
  - ➢ **Experiments with cells and particles < 10 µm**

- **Interactions between a microparticle and a cell strongly depends on particle surface properties**

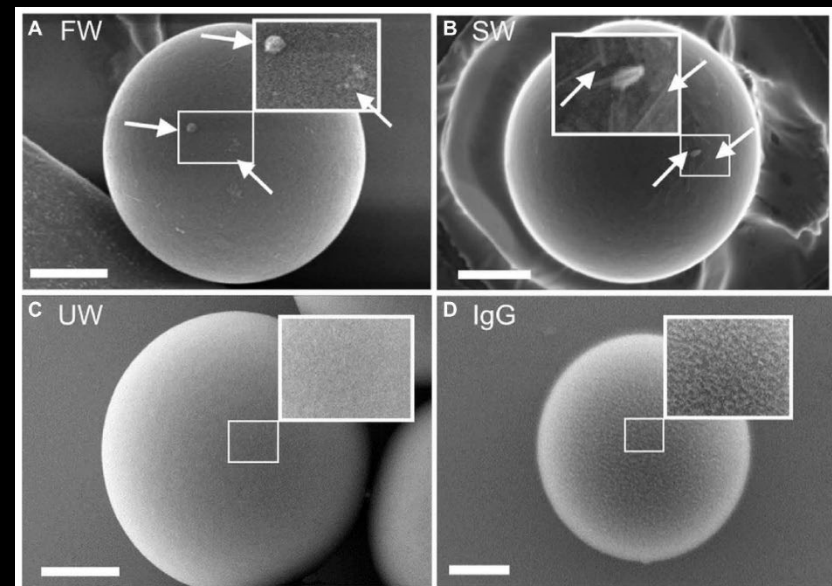
Microplastic incubation in environmental media

Marine aquaria



Fresh water

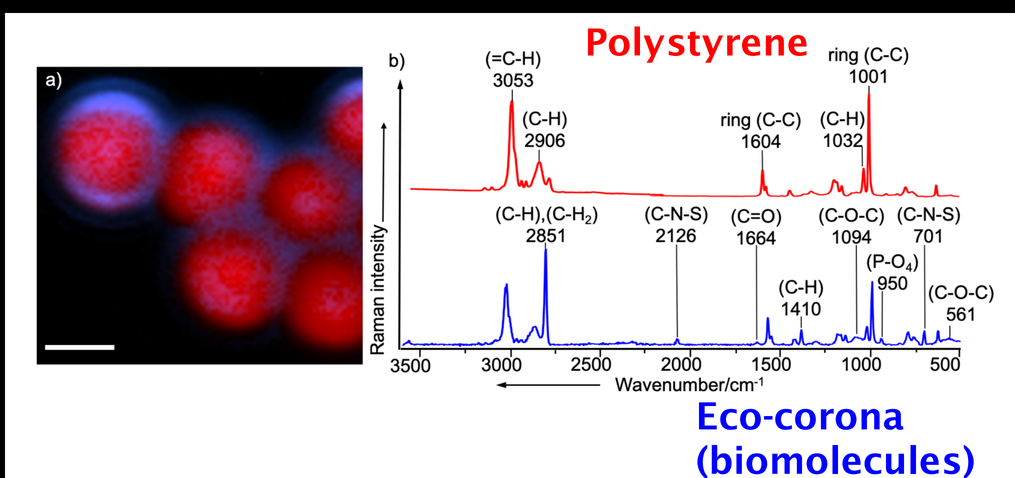
Salt water



Ultrapure water
(neg. control)

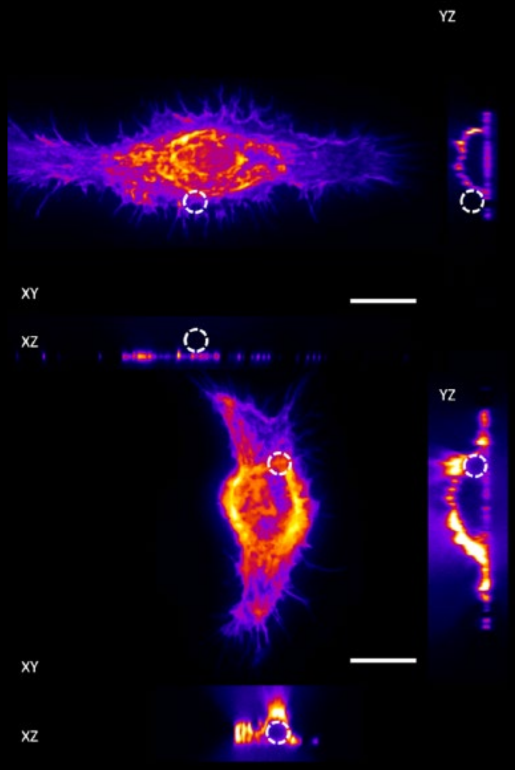
Antibody coating
(pos. control)

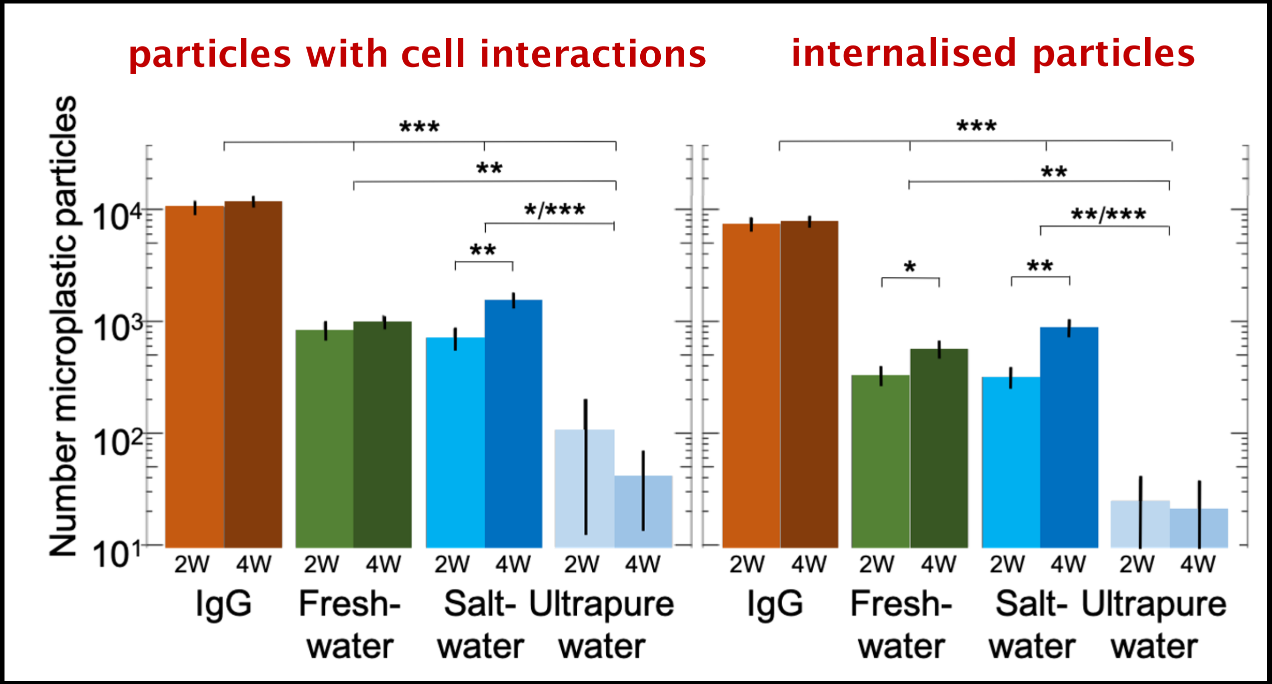
Micro-Raman-Spectroscopy of freshwater-incubated particles



Ramsperger, et al., *Science Advances* 6, (2020)

Attachment to and uptake into cells





Ramsperger, et al., *Science Advances* 6, (2020)

➢ **Incubation in fresh- and saltwater (eco-corona) strongly influences attachment and uptake**

Reduction of complexity?

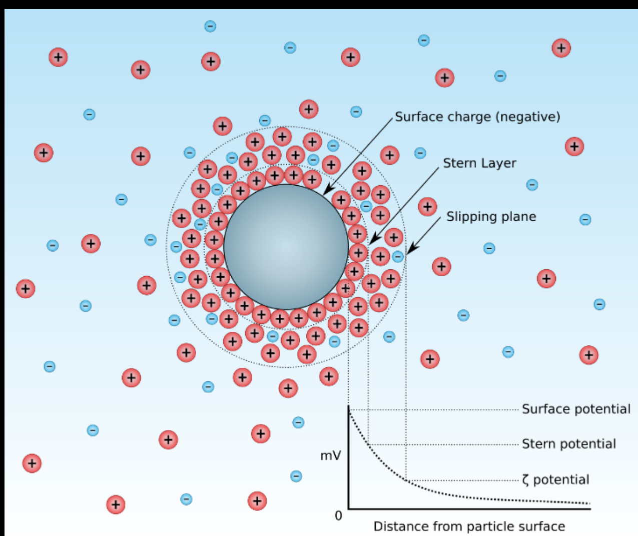
Dimensions:

- Polymer material (PS, PE, PP, PET, PVC, ...)
- Size (sub-µm- up to mm-range)
- Shapes (spheres, fibers, fragments, ...)
- Surface properties (plain, specific functionalizations, ...)
- Model organisms / cells (fish, mussels, ... / macrophages, epithelial cells, ...)
- & Particle history (pre-incubation > eco-corona ✓, weathering ?, ...)
- ...

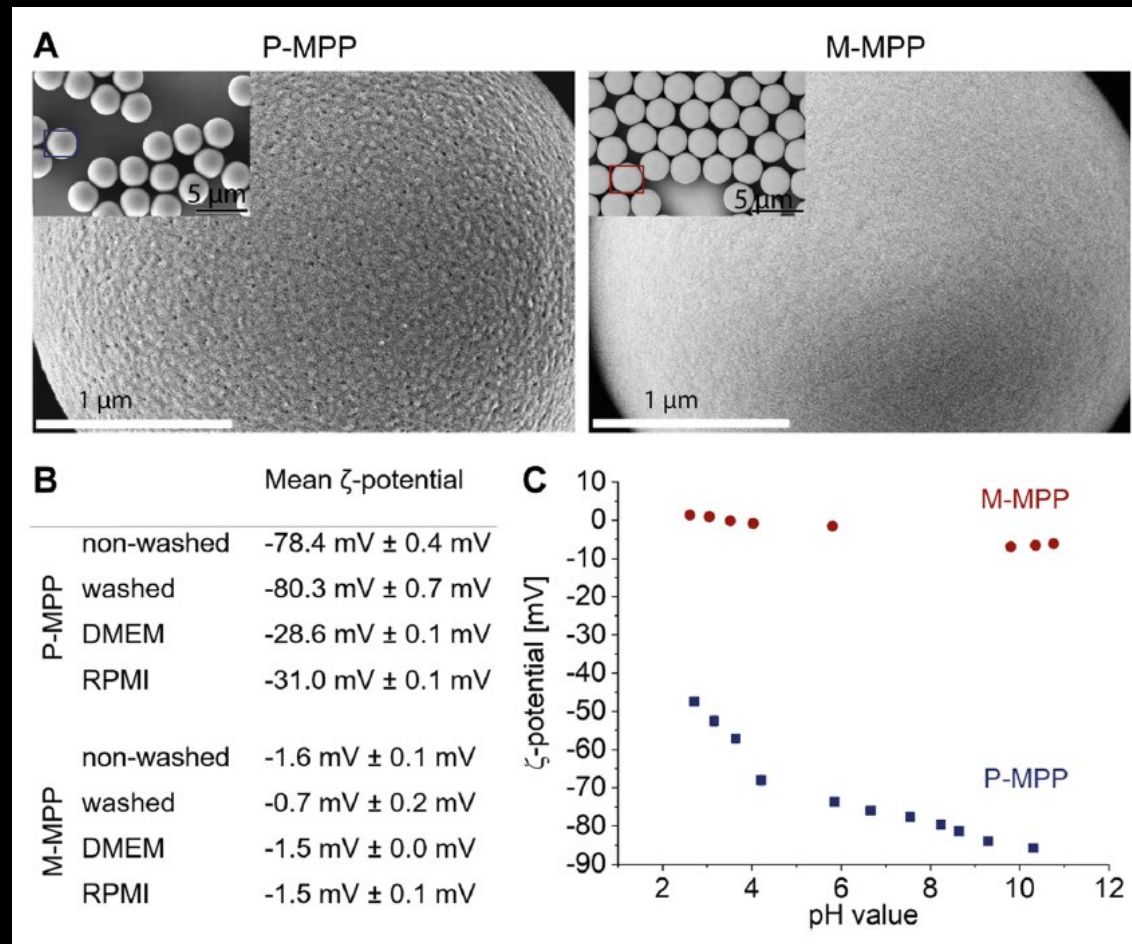
Which surface property could help to reduce complexity?

ζ-potentials of nominally equal microplastics

ζ-potential: Electrical potential at slipping plane.



Spherical 3 µm plain polystyrene microparticles from two different suppliers (Polysciences & Micromod)



		Mean ζ-potential
P-MPP	non-washed	-78.4 mV ± 0.4 mV
	washed	-80.3 mV ± 0.7 mV
	DMEM	-28.6 mV ± 0.1 mV
	RPMI	-31.0 mV ± 0.1 mV
M-MPP	non-washed	-1.6 mV ± 0.1 mV
	washed	-0.7 mV ± 0.2 mV
	DMEM	-1.5 mV ± 0.0 mV
	RPMI	-1.5 mV ± 0.1 mV

Ramsperger et al., *J. Hazard. Mater.*, 425, 127961, (2022)

Nominally equal microparticles from 8 suppliers

unpublished data

Ramsperger, Gross, Wieland et al., *manuscript in revision*

Measuring cell interactions with flow chambers

unpublished data

Ramsperger, Gross, Wieland et al., *manuscript in revision*

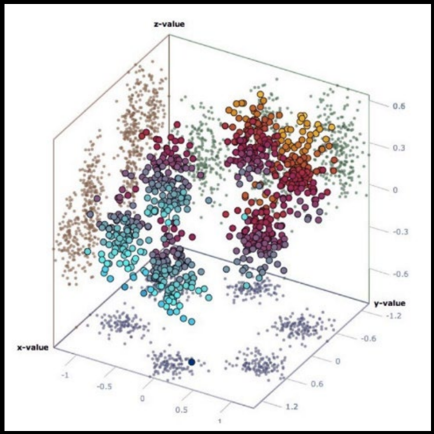
Bound particles under shear force

unpublished data

Final but not conditional internalization depends on ζ

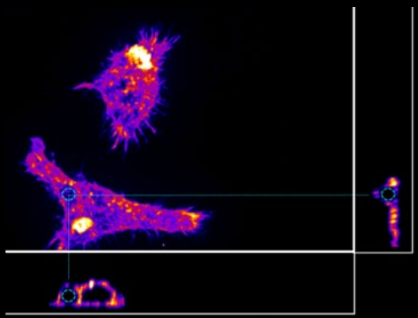
unpublished data

Summary and Conclusions



- Parameter space in microplastics research is huge (polymer material, size, shape, surface properties, model organisms/cells, ...)
  - ➢ Reduction of complexity necessary

- Long-term effect due to integration into tissue: Experiments with cells and particles < 10 µm important, particle surface likely very relevant



- „History“ of the particles (pre-incubation in fresh- or saltwater ➢ eco-corona) can strongly increase binding to cells and uptake into cells

- ζ-potential of nominally equal particles varies drastically

- ζ-potential of plain, functionalized and pre-incubated particles strongly influences the binding to cells and thereby the uptake into cells

➢ Nominally equal particles can vary strongly in their surface properties

➢ ζ-potential might be a key parameter for complexity reduction

unpublished data

Thank you for your attention!