Designing Soluto-Inertial Suspension Interactions

A. Banerjee, I. Williams, R. Nery-Azevedo, M.E. Helgeson, T.M. Squires

Department of Chemical Engineering, University of California, Santa Barbara

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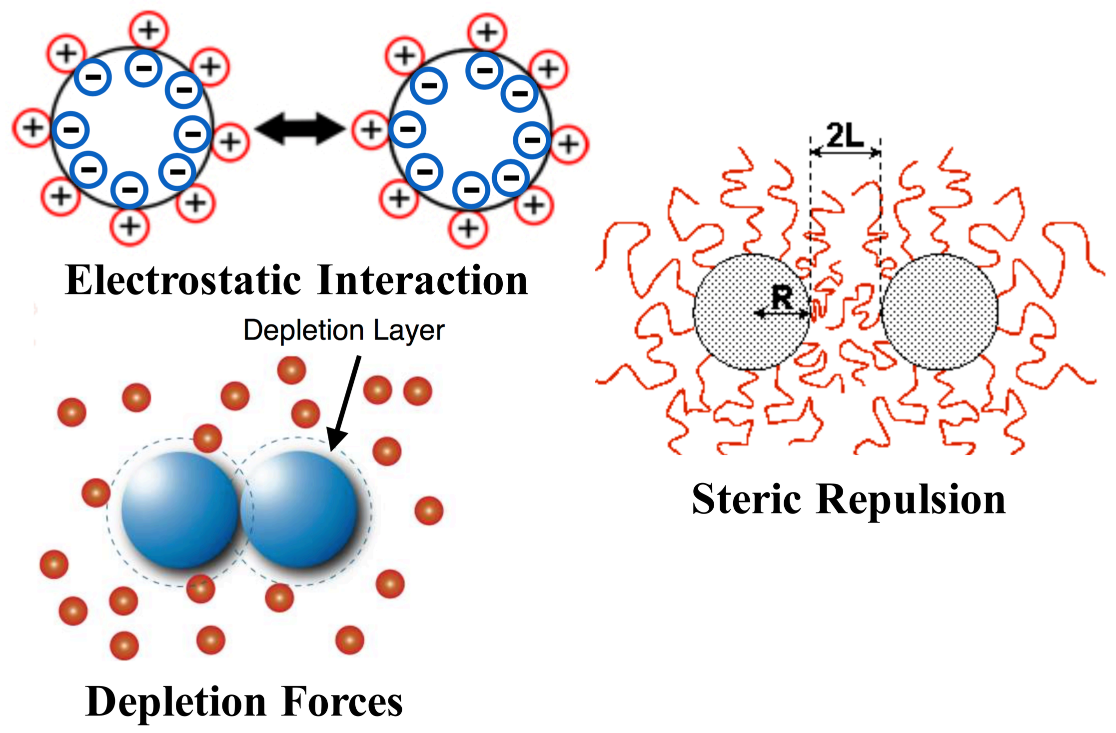
INTRODUCTION

The ability to tune colloidal interactions is crucial to the operation of products like shampoos, inks & paints



Equilibrium suspension interactions are however limited to less than 1 μm in water

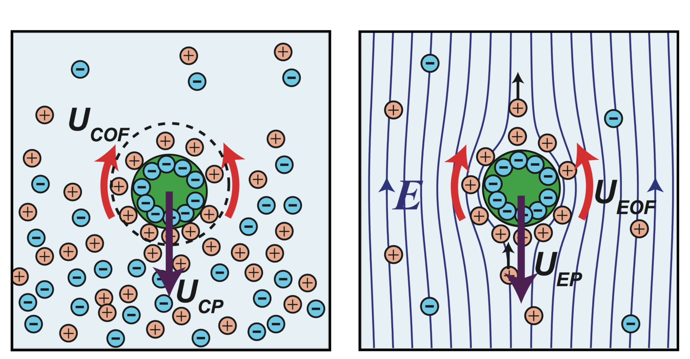
OBJECTIVE

Here we present a concept to design and engineer non-equilibrium interactions in suspensions, which

- are particle surface-dependent,
- may last for hundreds of seconds, and
- extend hundreds of times farther than is currently possible

BACKGROUND

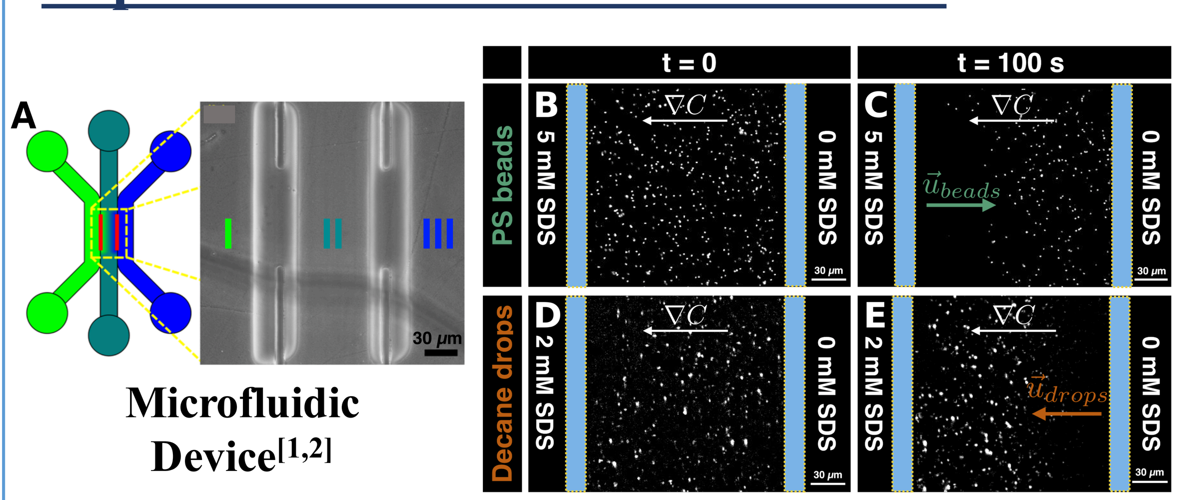
These interactions rely on **diffusiophoresis** (DP), which refers to the migration of suspended particles in response to chemical gradients in solution



Two mechanisms for DP:

- **Chemi-DP** : Due to osmotic pressure gradient
- **Electro-DP**: Due to electric field generated by ambipolar diffusion

Experimental Demonstration of DP



(B-C) DP of PS particles occurs **down** SDS gradients (∇C) whereas (D-E) decane drops migrate **up** SDS gradients

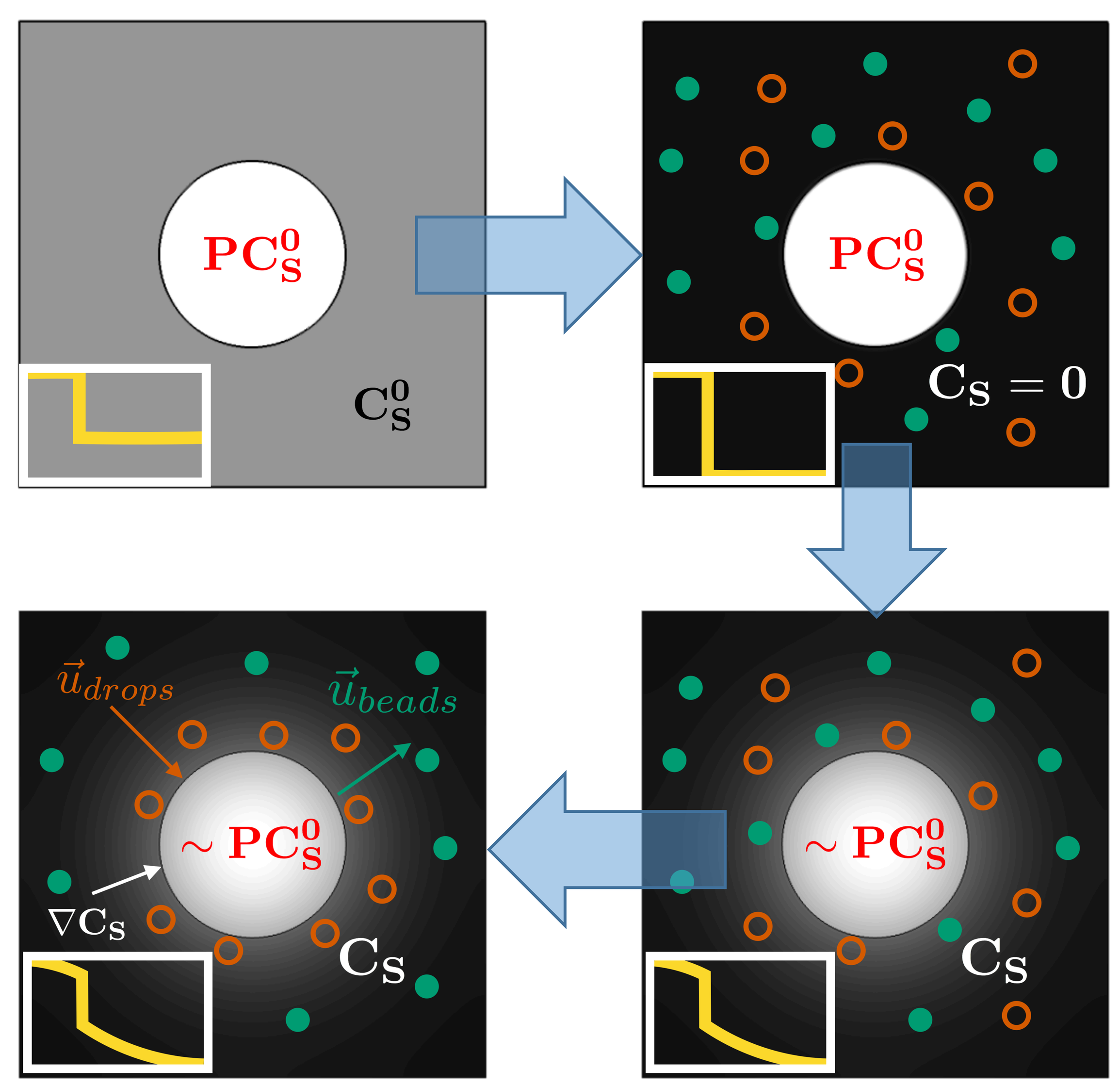
SOLUTE-INERTIA

The duration of these interactions depends on how long the gradients in solution last. To have long lasting gradients, we use the concept of solute-inertia (SI)

Solute-inertia: degree of slowness with which the **concentration** of solute in a material approaches that of it's surrounding

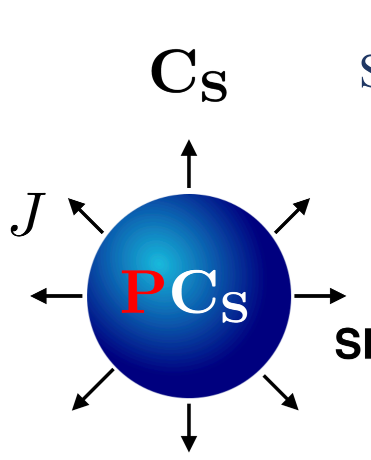
Analogy to Thermal Inertia

The Soluto-Inertial Beacon



Three ingredients for SI interactions: i) A chemical **"beacon"** (gray circle) that establishes and maintains gradient, ii) solute that mediates interaction, iii) particles (orange & green) that respond and migrate via DP

Scaling Analysis



Spherical Beacon Of Size R_B

SI beacons may be made from materials that strongly partition solute

$$C_B = PC_S, \quad P \gg 1$$

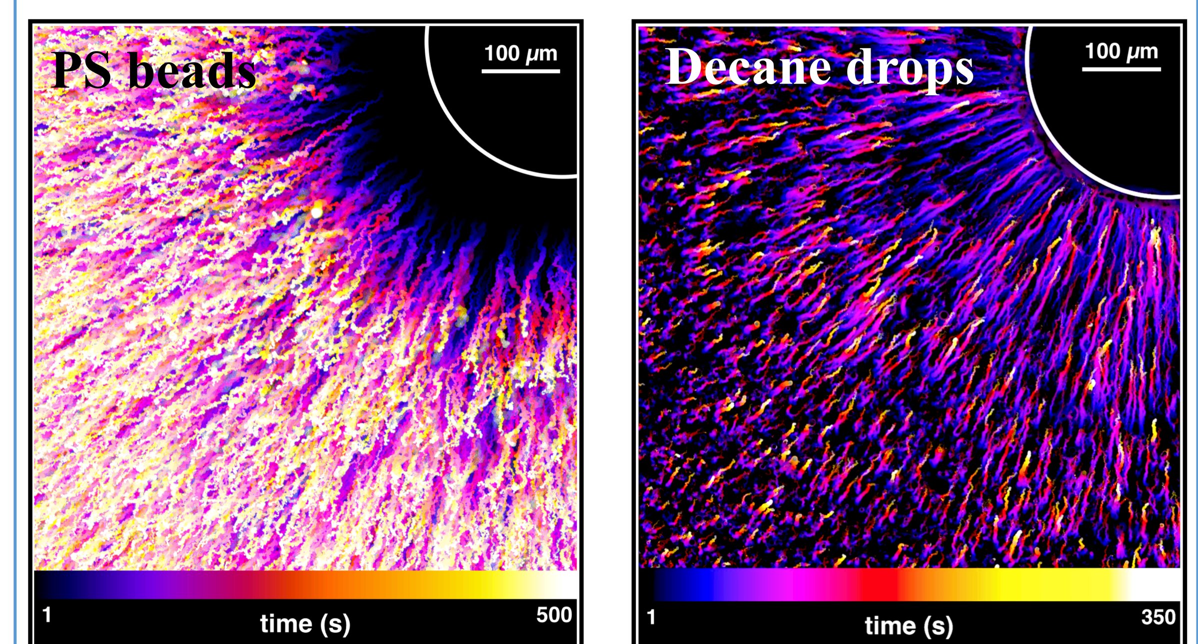
SI Time = $\dfrac{\text{No. of solute molecules inside beacon}}{\text{Diffusion limited out-flux}}$

$$\tau_{SI} \approx P\frac{R_B^2}{3D_S}$$

Higher the P, longer the equilibration time

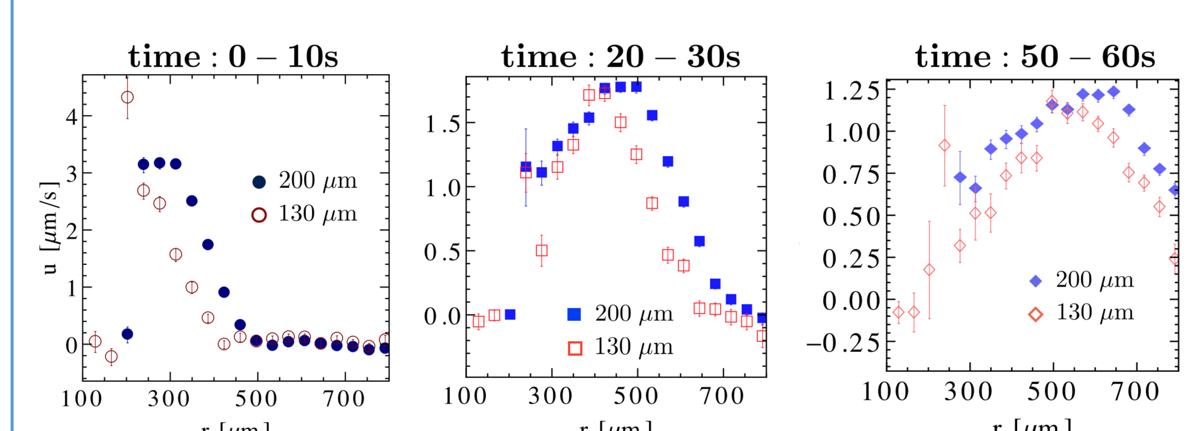
RESULTS

SDS is known to associate with polyethylene glycol (PEG), motivating the use of PEG diacrylate (DA) hydrogel posts as SI beacons

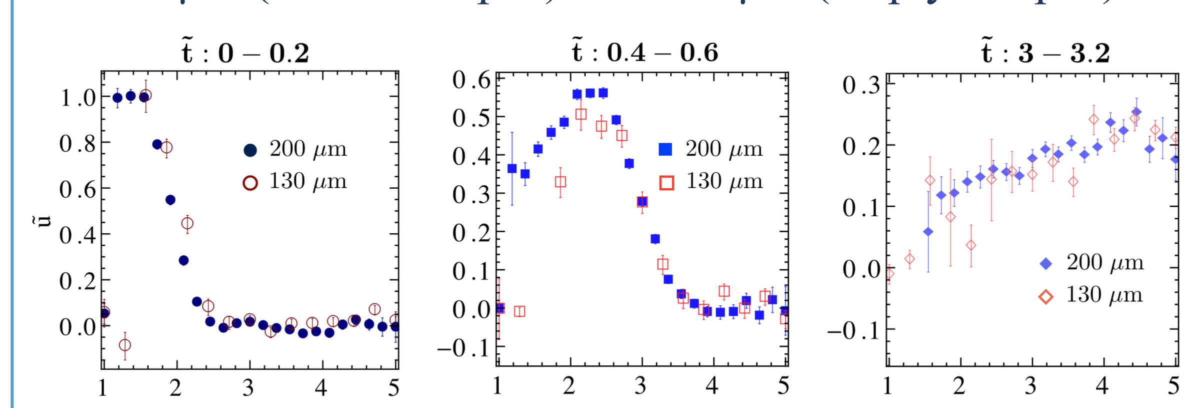


SI interactions between the PEG hydrogel beacons and the PS & decane particles are found to be **oppositely directed**, last for at least **1000 s** and extend over **300 to 400 μm**

Migration Velocity of PS Particles



- Velocities are plotted as a function of radial distance from the center of the beacon, at different times
- Profiles are compared for cylindrical beacons of radii 200 μm (filled blue pts.) and 130 μm (empty red pts.)



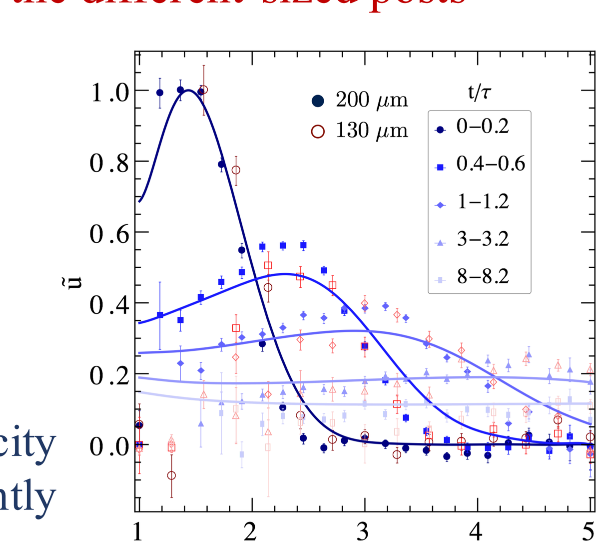
Scaling distance, time, velocity according to SI arguments, collapses measured data for the different-sized posts

Quasi-steady MT model:

$$\frac{\partial C_S}{\partial t} = \frac{D_S}{r}\frac{\partial}{\partial r}\left(r\frac{\partial C_S}{\partial r}\right)$$

DP velocity [3]:

$$u_{DP} = D_{DP}\nabla \ln C_S$$



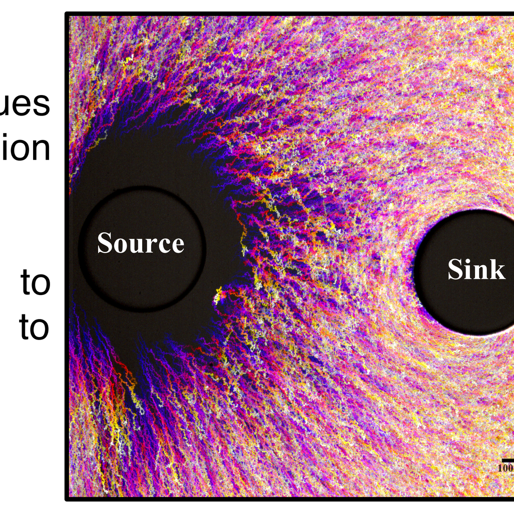
Theoretically predicted velocity profiles (solid lines) excellently capture experimental data

CONCLUSIONS & FUTURE WORK

- Established a conceptual framework for designing long-range, long-lived, particle-surface specific SI interactions
- The generality & versatility is highlighted by combining the slow SI release of solute with DP migration [4,5]
- Such interactions will provide new routes for directing suspension behavior & synthesizing novel materials

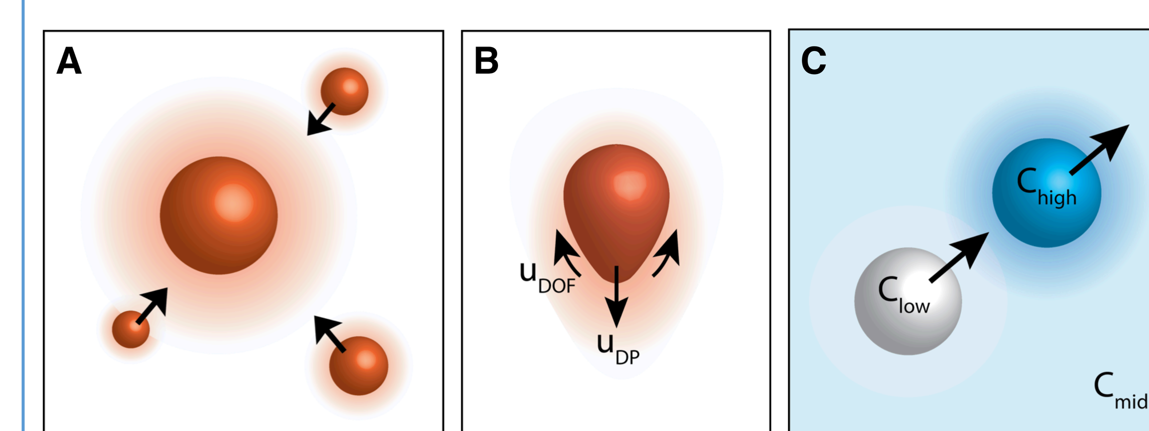
Triggering Suspension Flocculation

- Common flocculation techniques rely on diffusion limited aggregation (DLA) of particles
- SI phenomenon may be utilized to target particles to specific sites to enhance flocculation



SI "sources" and "sinks" give ability to incorporate strong local gradients & enable directed colloidal migration

Suspended SI Beacons



Colloidal beacons may (A) act as sites for nucleation, (B) self propel due to anisotropy or (C) even chase each other

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ACKNOWLEDGEMENTS

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CONTACT

Web: http://squerver.chemengr.ucsb.edu
Email: a.banerjee@engineering.ucsb.edu
squires@engineering.ucsb.edu
Phone: +1 (805) 403-7175