“Probing Soft Matter: Long-Range Forces and Shear-Induced Phenomena in Compliant Systems”

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Most studies on surface forces to date have focused on interactions between rigid objects, yet many systems of interest—particularly in biotribology—require understanding the behavior of compliant materials. Unlike rigid bodies, where deformations are localized near the contact zone, compliant surfaces can deform over much larger distances, making long-range surface forces critically important.

We investigate the mechanics of compliant systems under shear, including supported gels and thin membranes. Our work on microgel films reveals that long-range, distance-dependent repulsive interactions significantly influence contact mechanics, limiting surface approach under pressure due to pressure-induced contact stiffening. Additionally, we observe substantial normal (lift) forces between compliant surfaces in relative motion, with critical implications for lubrication—especially under small applied normal loads. This shear-induced repulsive pressure arises from elastohydrodynamic coupling and the symmetry breaking of the contact geometry under shear.

Membranes, with their slender and highly compliant nature, serve as prototypical examples of deformable boundaries. To accurately characterize their rheological properties and the resulting mechanical consequences, we have developed a modified Surface Forces Apparatus (SFA). This device directly measures the forces acting on a compliant membrane by evaluating its deformation field, enabling the study of membrane rheology and novel elastohydrodynamic effects—without requiring an external measurement spring. Our approach opens new avenues for probing the interplay between elasticity, hydrodynamics, and surface forces in soft matter systems.