# Effective Interactions Between Permeable Colloidal Disks in an Active Bath

Mahmoud Sebtosheikh and Ali Naji
School of Physics, IPM, Iran

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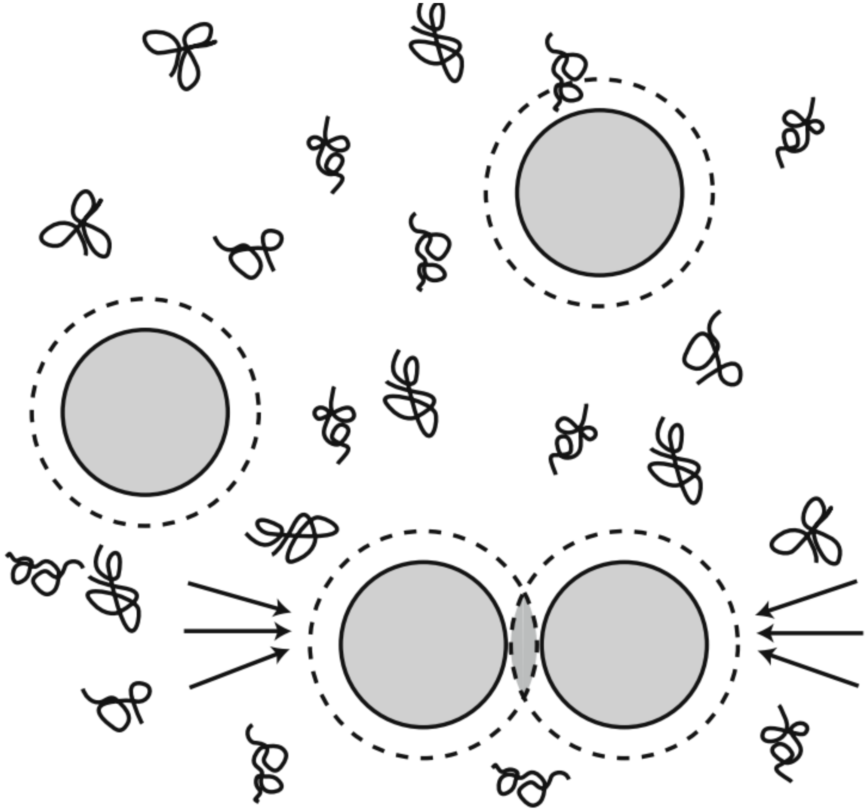
# Depletion Force

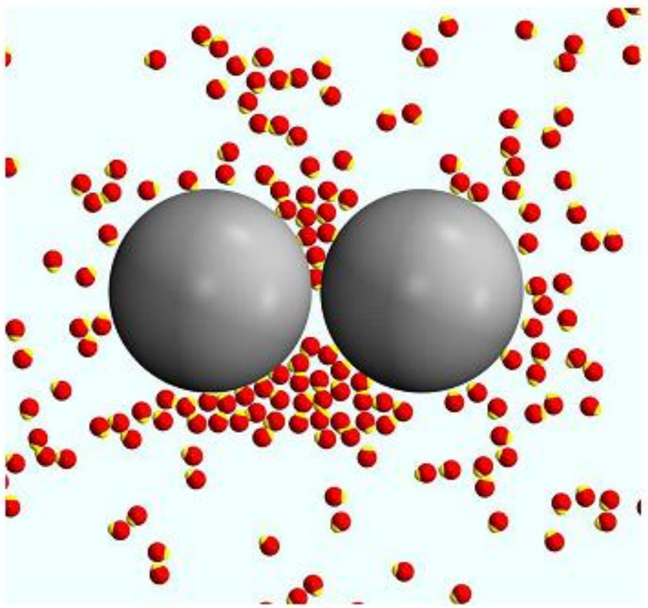
- Depletion force arises between colloids surrounded by passive Brownian particles. This force is attractive and in high concentration of Brownian particles causes phase separation.

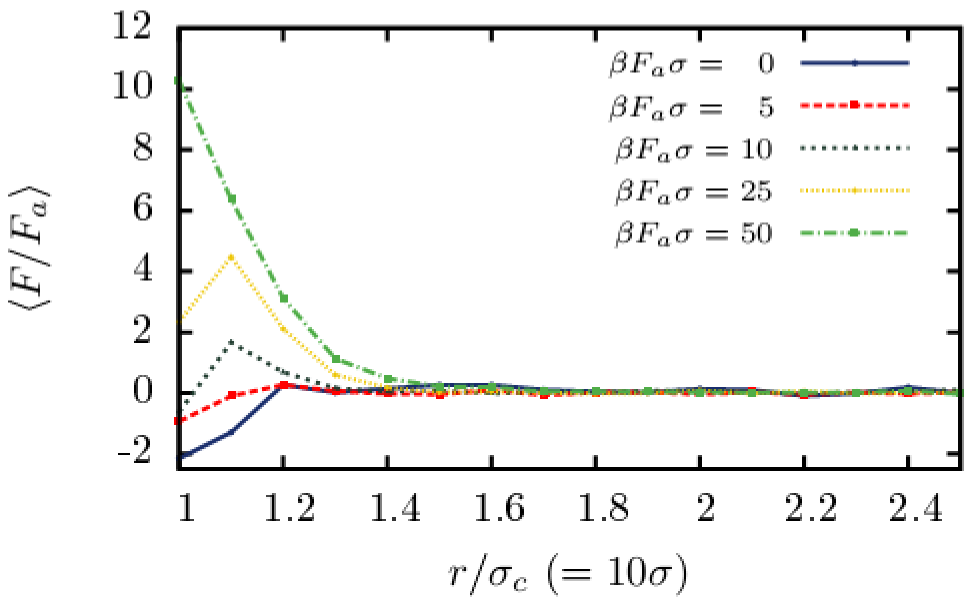


Lekkerkerker, Henk N.W., Tuinier, Remco, Colloids and the Depletion Interaction, Springer (2011)

# Active Depletion Force

- Unlike passive depletion, effective force between two colloidal disks in an active bath, is repulsive.

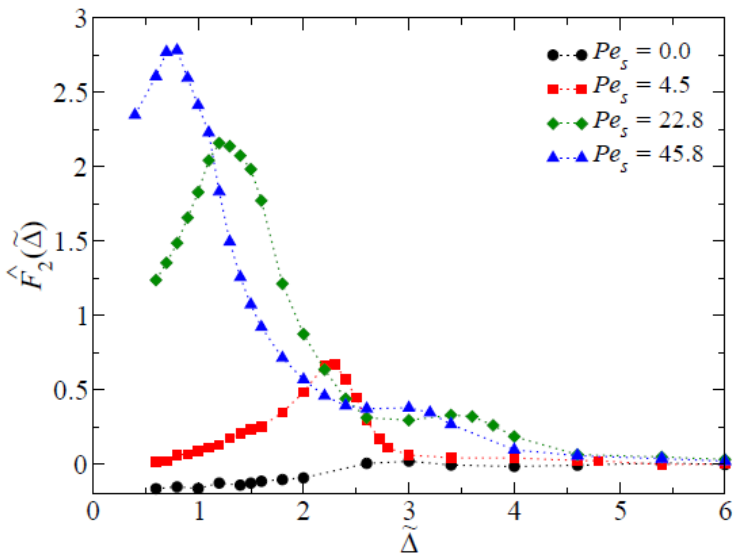


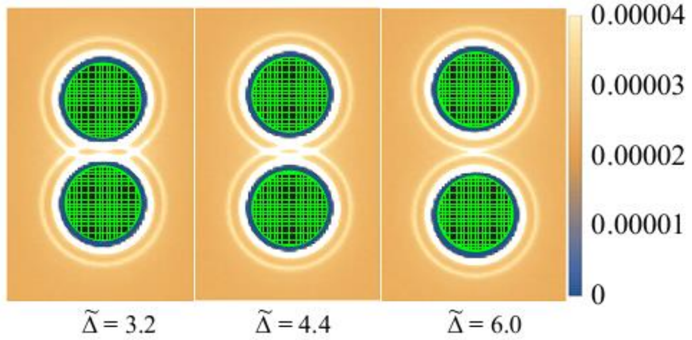



Harder, J., S. A. Mallory, C. Tung, C. Valeriani and, A. Cacciuto, 2014, J. Chem. Phys.141, 194901.

# Active Depletion Force

- It has been shown active depletion force varies non monotonically with distance between colloids.
- Non monotonicity stems from ring like structure made by ABPs surrounding colloids.




M. Zaeifi Yamchi and A. Naji , J. Chem. Phys. **147**, 194901 (2017)

# Effective Force Between Two Penetrable Disks

- The effective force between two permeable disks can be repulsive or attractive.

$$\dot{\mathbf{r}}_\mathbf{i} = v_s(\mathbf{r}_i)\mathbf{n}_i - \mu_T \frac{\partial U(\{\mathbf{r}_j\}, \{\mathbf{R}_J\})}{\partial \mathbf{r}_i} + \boldsymbol{\eta}_i(t)$$

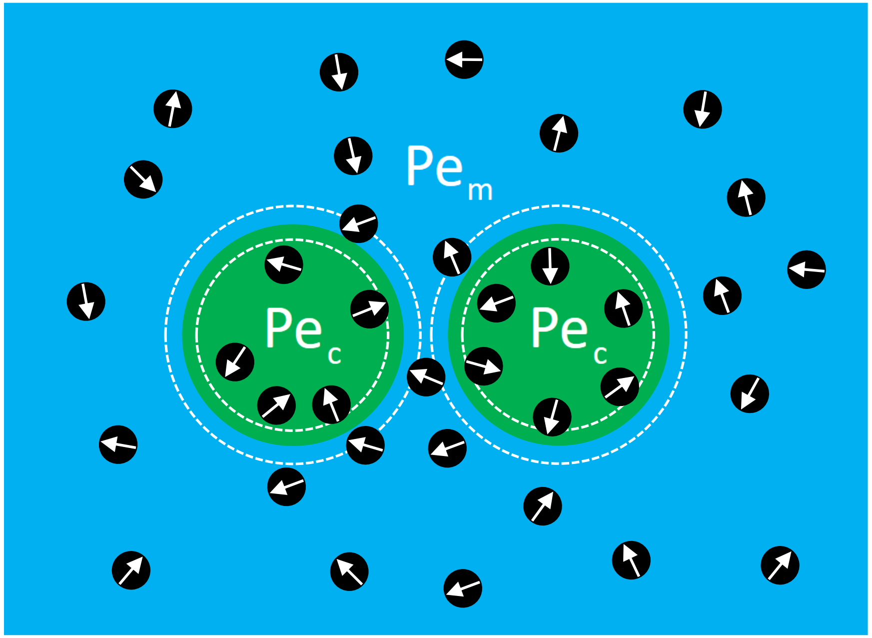
$$v_s(\mathbf{r}_i) = v_c + (v_m - v_c)\Theta(|\mathbf{r}_i - \{\mathbf{R}_J\}| - \sigma_c)$$

$$\dot{\theta}_i = \zeta_i(t)$$

$$\langle \boldsymbol{\eta}_i(t) \rangle = \langle \boldsymbol{\zeta}_i(t) \rangle = 0$$

$$\langle \boldsymbol{\eta}_i(t) \cdot \boldsymbol{\eta}_j(t') \rangle = 2 D_T \delta_{ij} \delta(t' - t)$$

$$\langle \boldsymbol{\zeta}_i(t) \cdot \boldsymbol{\zeta}_j(t') \rangle = 2 D_R \delta_{ij} \delta(t' - t)$$



# Effective Force Between Two Penetrable Disks

Interaction Between Two Active Particles:

$$U_{WCA}(r) = \begin{cases} 4\epsilon\left(\left(\frac{\sigma}{r}\right)^{12} - \left(\frac{\sigma}{r}\right)^{6} + \frac{1}{4}\right) & r \leq 2^{1/6}\sigma \\ 0 & r > 2^{1/6}\sigma \end{cases} \qquad \epsilon = 10\, k_B T$$

Interaction Between an Active Particle and a Colloidal Disk:

$$U_{SWCA}(r) = \begin{cases} 4\epsilon'\left(\left(\frac{\sigma'^2}{(r-\sigma_c/2)^2+\alpha^2}\right)^6 - \left(\frac{\sigma'^2}{(r-\sigma_c/2)^2+\alpha^2}\right)^3\right) + U_\cdot & |r-\sigma_c/2| < \sigma' \\ 0 & |r-\sigma_c/2| \geq \sigma' \end{cases}$$

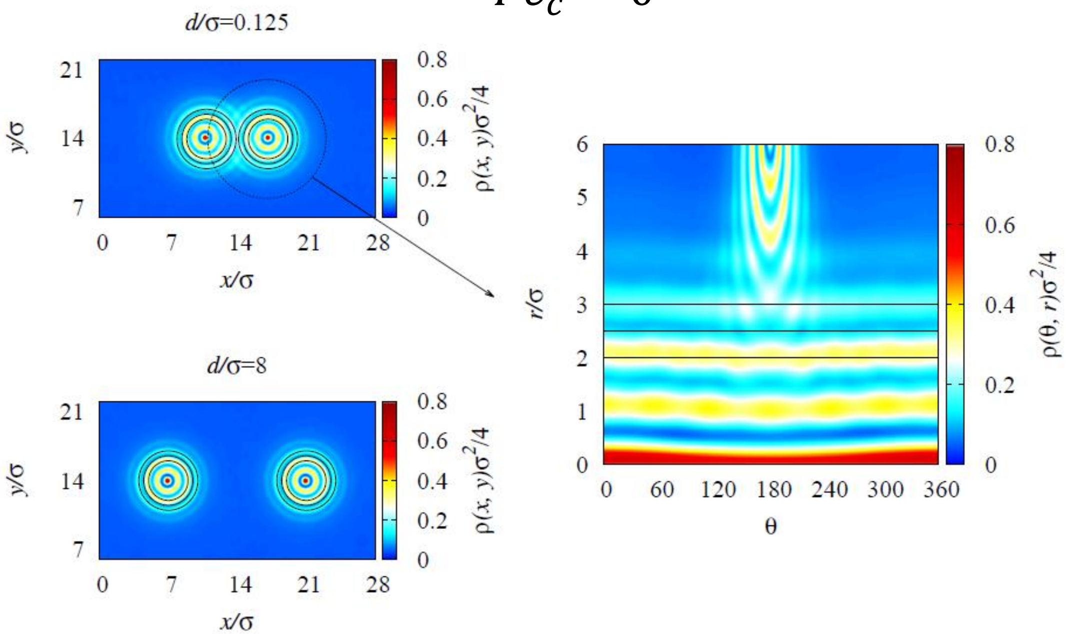
$$\epsilon' = 0/0127 k_B T \qquad U_\cdot = 4\epsilon'\left(\left(\frac{1}{1+(\alpha/\sigma')^2}\right)^6 - \left(\frac{1}{1+(\alpha/\sigma')^2}\right)^3\right)$$

$$\sigma' = (\sigma + w)/2 \qquad \alpha = \sigma'(2^{\frac{1}{3}} - 1)^{\frac{1}{2}}$$

# Effective Force Between Two Penetrable Disks

- In close distance, ABPs ring like structure intersect each other and asymmetry appears in distribution of ABPs.
- This asymmetry causes effective force between colloids and decreases with increasing distance.

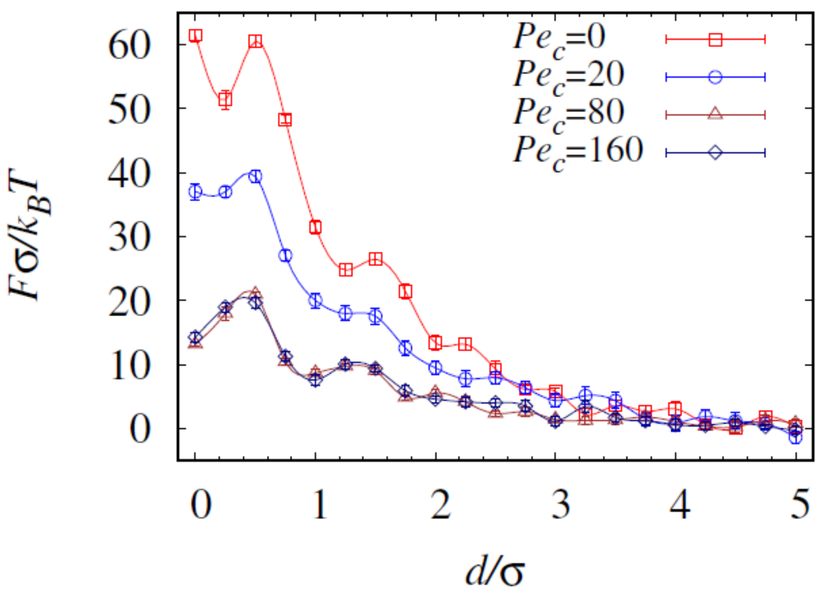
$$Pe_m = 40,$$
$$Pe_c = 0$$



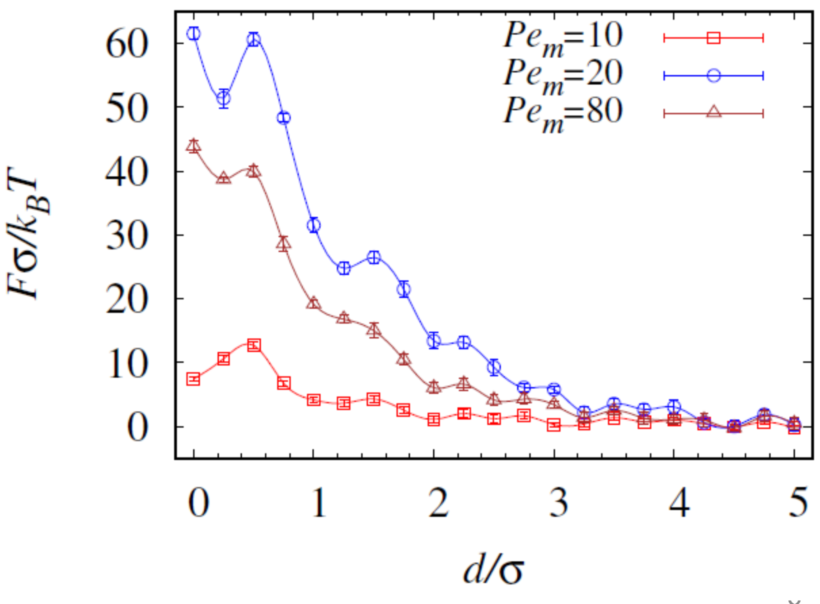
# Effective Force Between Two Penetrable Disks

- By increasing $Pe_c$, effective force decreases until reaches a constant value. By increasing $Pe_m$, effective force increases up to a maximum then decreases.

$Pe_m = 20$



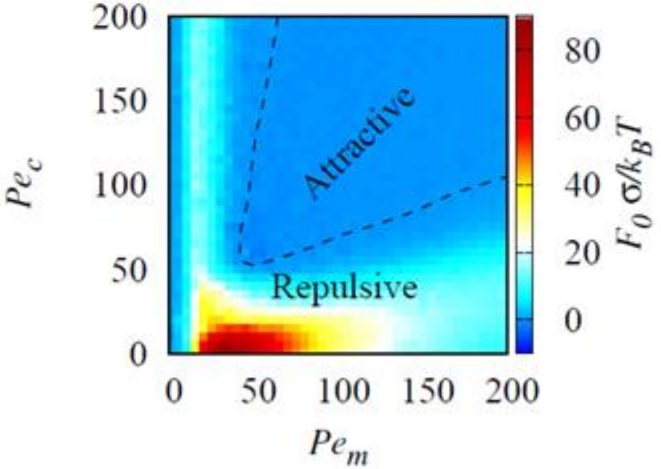

$Pe_c = 0$



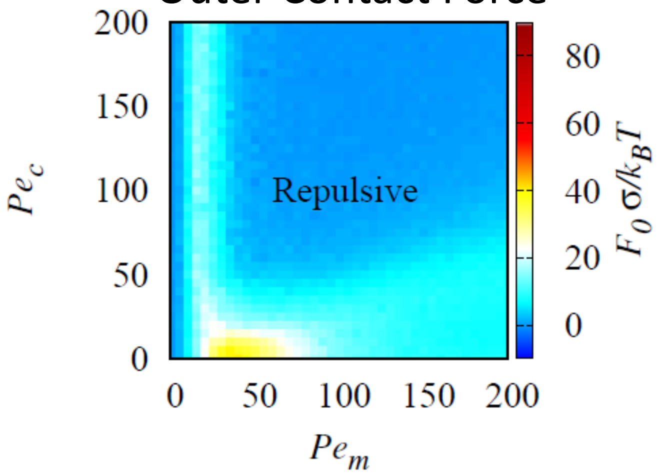
# Effective Force Between Two Penetrable Disks

In some area, total contact force is repulsive and in other area, it is attractive. Outer contact force is merely repulsive while inner contact force can be attractive or repulsive. Resultant of inner and outer contact force determines total contact force.

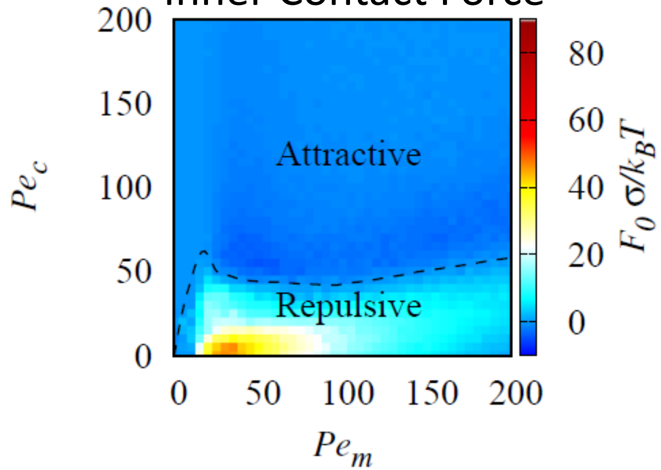
Total Contact Force



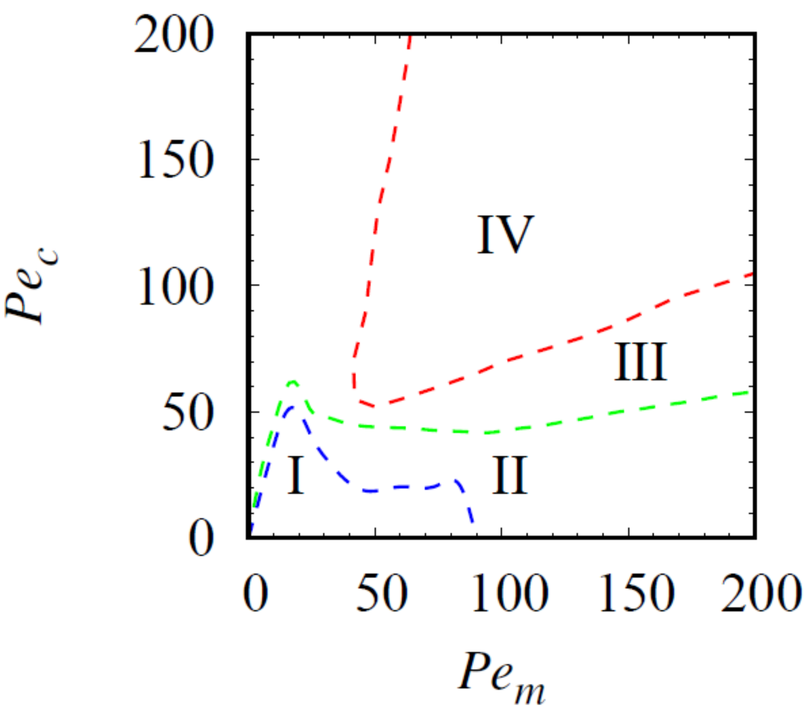

Outer Contact Force

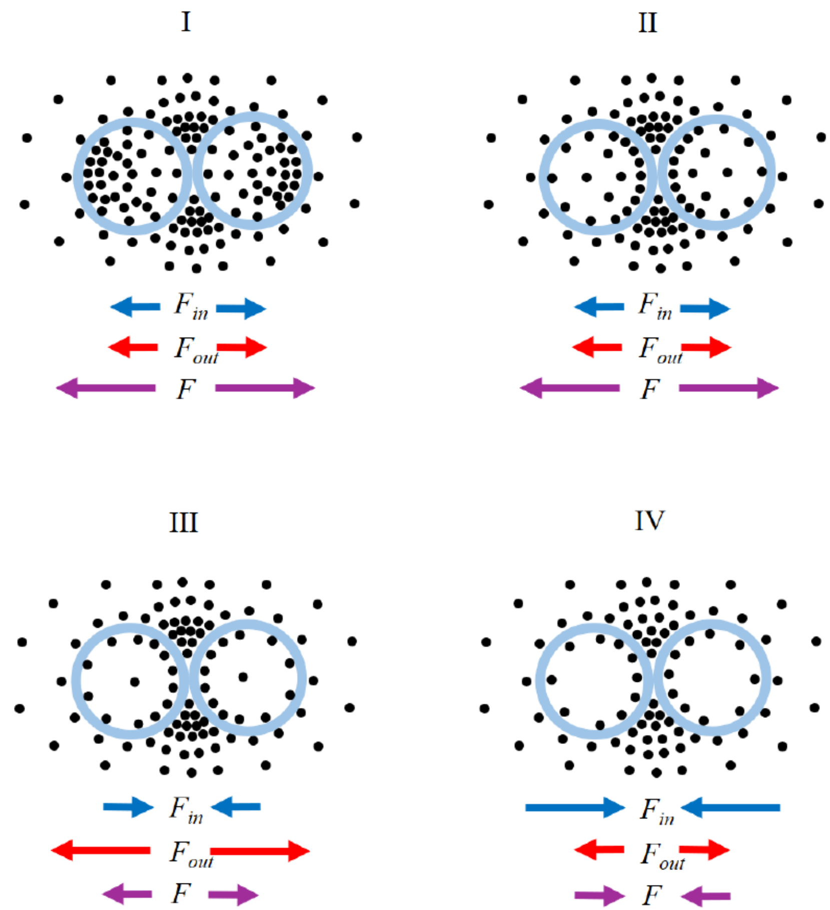



Inner Contact Force



# Effective Force Between Two Penetrable Disks




M. Sebtosheikh and A. Naji, to be submitted (2019)

# Conclusion

- Attractiveness in effective force between permeable colloidal disks, purely stems from permeability of colloids.
- By considering of large variation of effective force, non-trivial phase behavior is predicted for permeable colloidal dispersions.

# Acknowledgement

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Thank You for Your Attention