Correlated Rigidity Percolation and Gelation of Colloidal Particles

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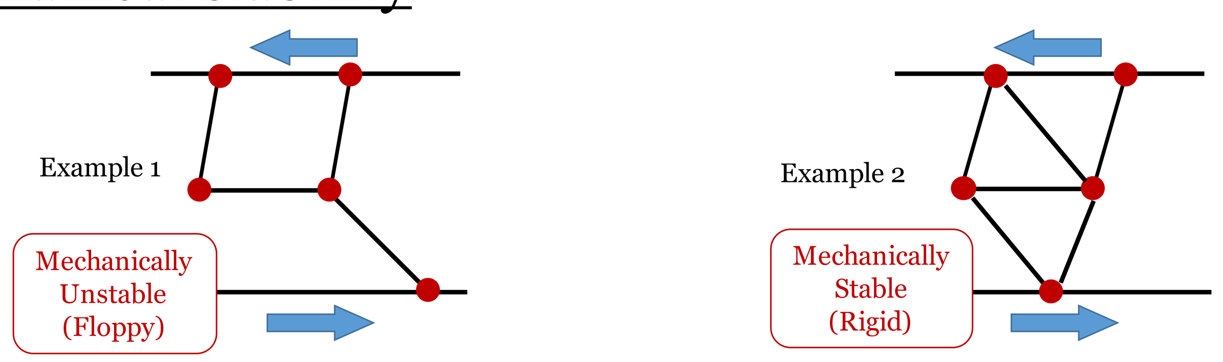
Objective

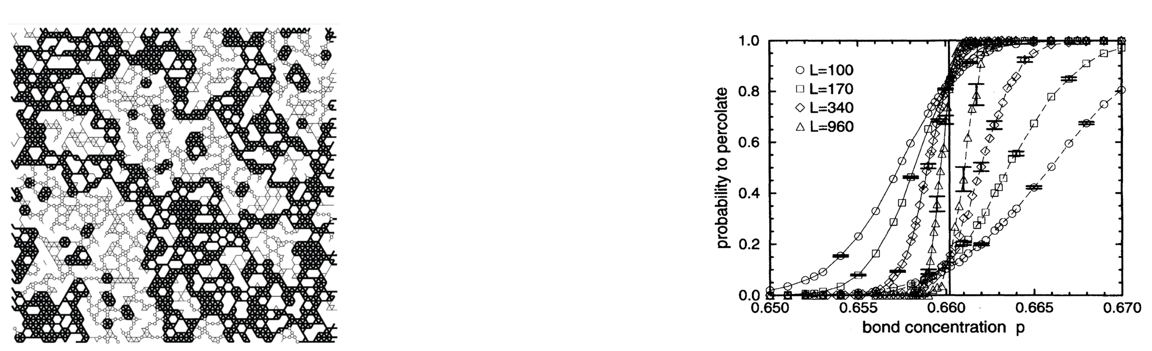
- How can correlation affect rigidity percolation?
- What can we learn about the mechanical stability (rigidity) of colloidal gels from rigidity percolation?

Introduction

- Mechanical stability



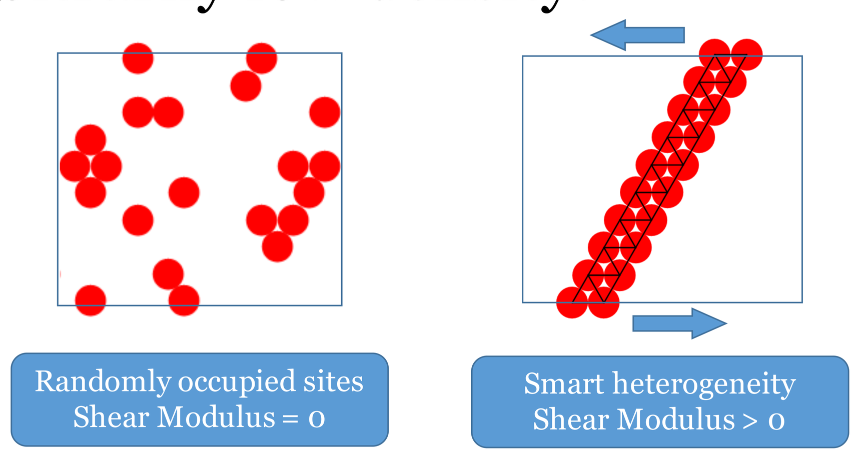
- Rigidity percolation in triangular lattice: (Percolation of rigid clusters)



	Bond Dilution	Site Dilution
Critical Threshold	0.66020 ± 0.0003	0.69755 ± 0.0003

Model

Idea: "smart" structural heterogeneity leads to rigidity at arbitrarily low density.



"Bridge-like" structures

Model: site diluted triangular lattice with positional correlation

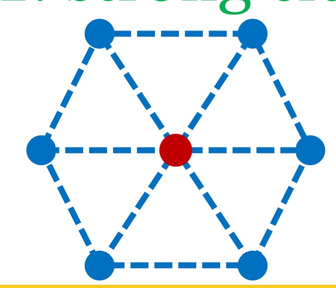
- Total # of sites on whole lattice: N_{total}
- Put in $N = pN_{total}$ particles on sites one-by-one
- Probability of putting a particle on a site:

$$P_{fill} = (1-c)^{6-n}$$

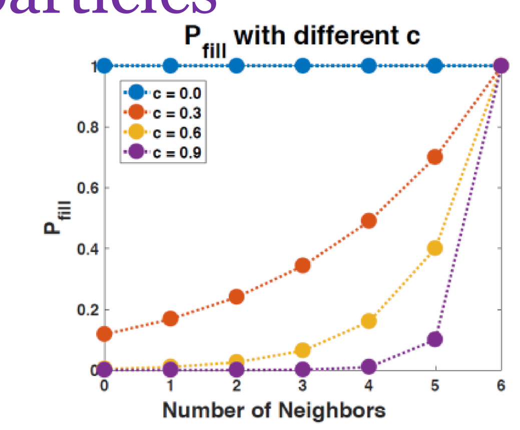
c: control parameter of correlation

$c = 0$: uncorrelated

$c \to 1$: strong clustering

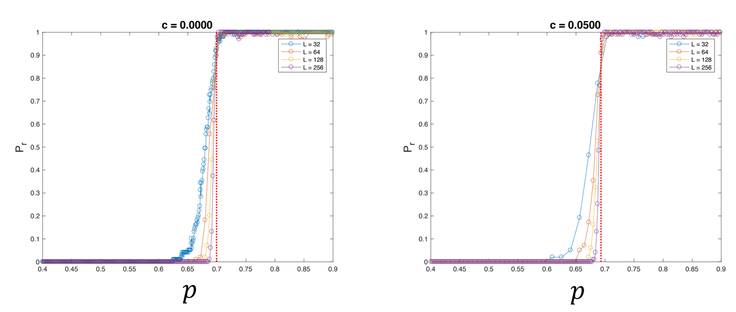


n: number of existing NN particles



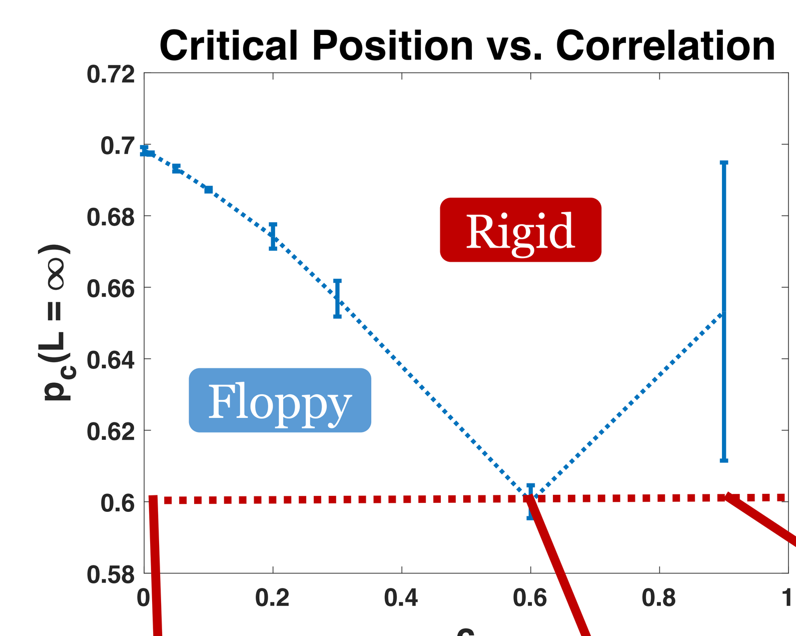
Results

- Phase transition of correlated RP

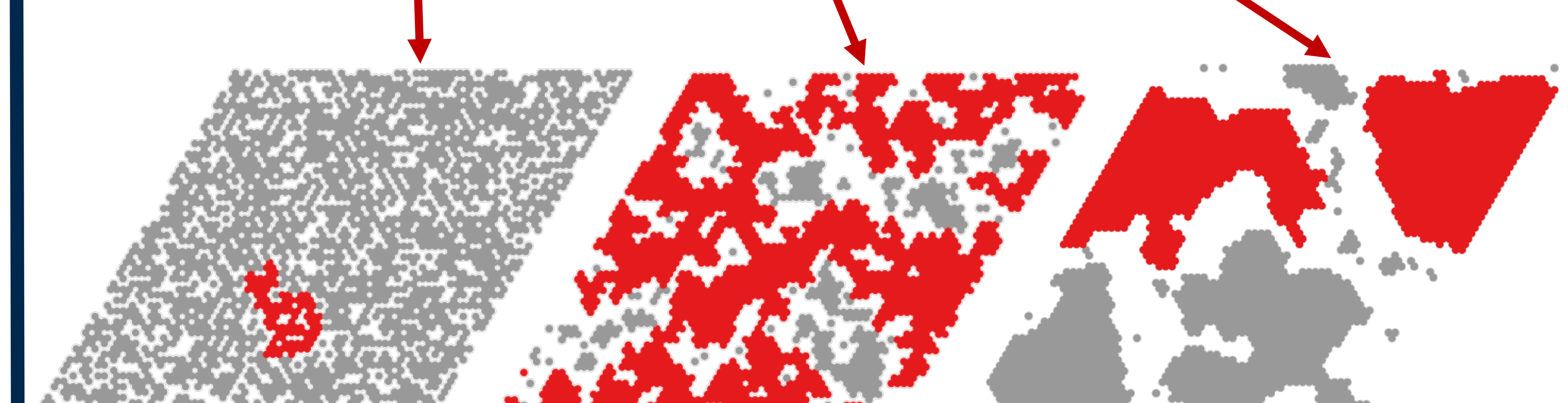


RP remains a **continuous** transition when correlation is introduced

- Phase boundary of correlated RP



Except c too large: Compact clusters, no bridges which lead to rigidity



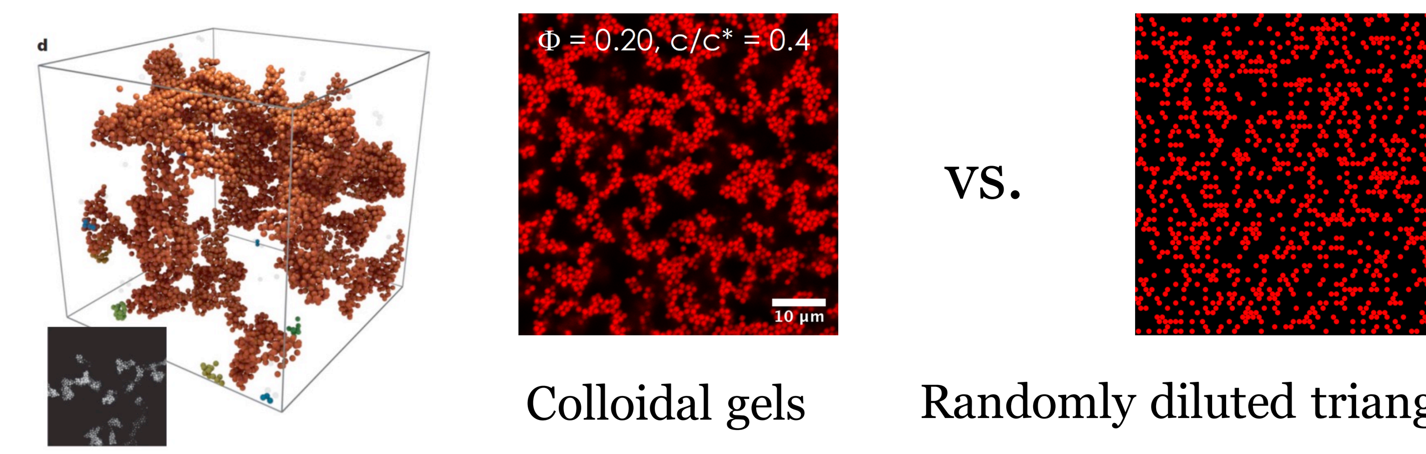
$c = 0.0$ $c = 0.6$ $c = 0.9$

- Fixed point

Correlation length scaling:

$\xi \sim \Delta p^{-\nu}$, $\Delta p_c \sim L^{-1/\nu}$, we find the **same** ν at different c

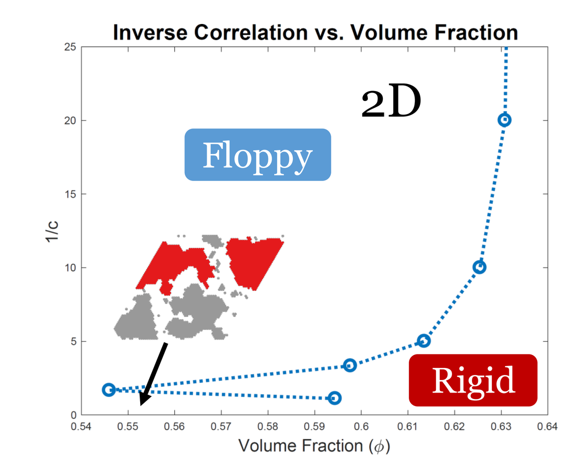
- Comparison with colloidal gel

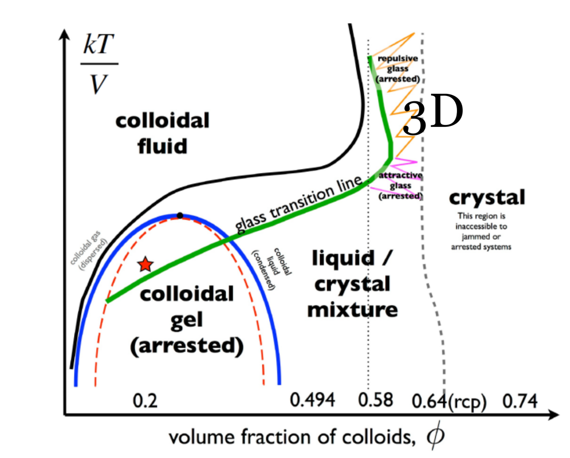


Colloidal gels — Heterogeneous structure

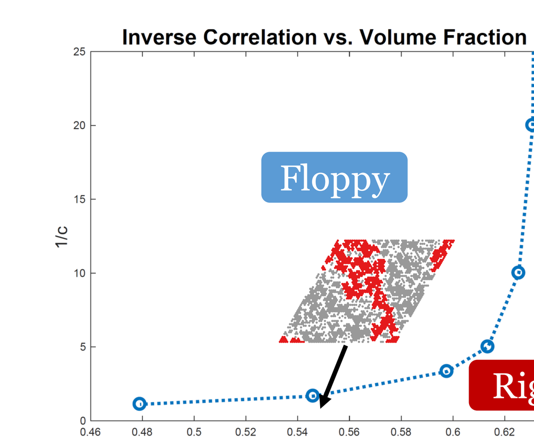
Randomly diluted triangular lattice — Homogeneous structure

Attraction → phase separation → structural heterogeneity → enhanced rigidity?





- Modification: prohibit compact clusters by taking $P_{fill} = 0$ for $n \geq 4$



Conclusions

- Positional correlation between particles (from attraction) lowers the rigidity percolation threshold, and this is a possible mechanism for mechanical stability in colloidal gels.
- Correlation c shifts the transition point and it is an irrelevant perturbation at the central force RP point.

Reference

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