Percolation transition in the packing of bidispersed particles on curved surfaces

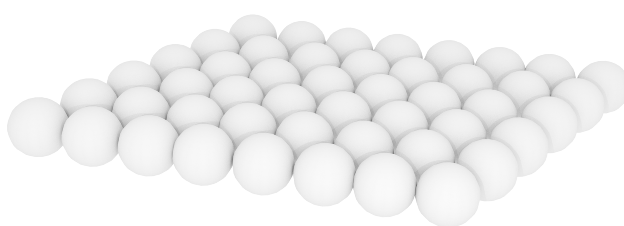
Andrew Mascioli, Christopher Burke, Timothy Atherton

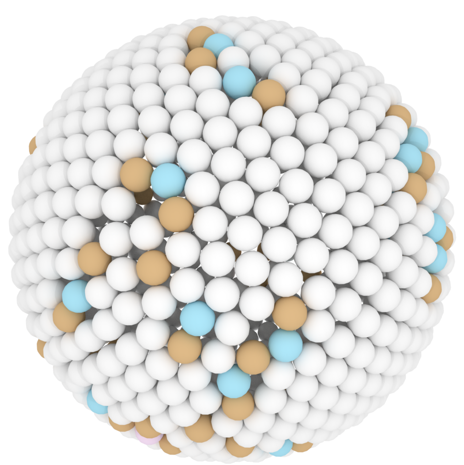
Department of Physics and Astronomy, Tufts University

Tufts UNIVERSITY

1. Introduction

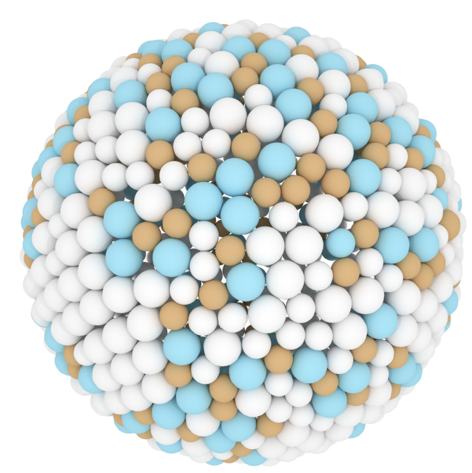
Packing monodispersed particles on a plane results in a hexagonal crystalline lattice.





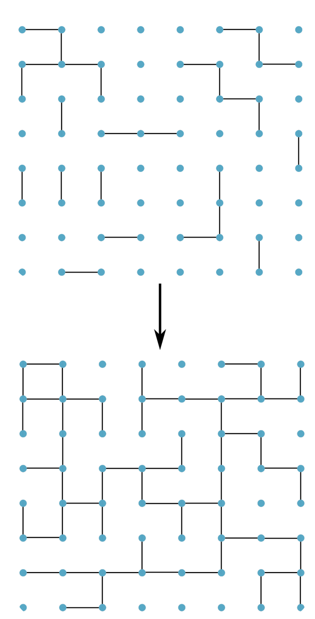
Introducing curvature necessitates the formation of defects, non-hexatic particles, often in the form of chains or **scars** that deteriorate the quality of the packing.

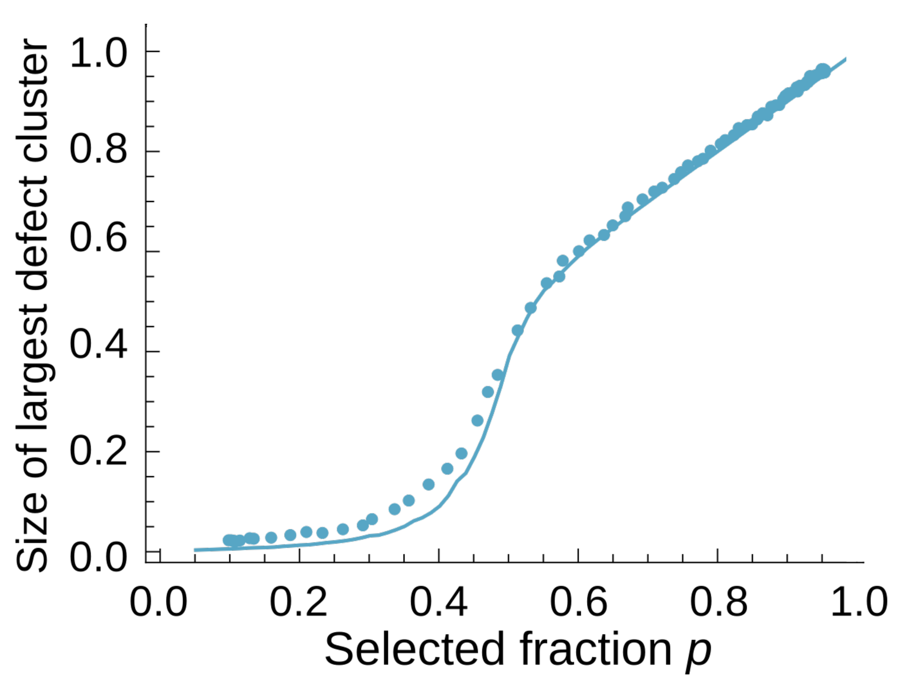
Bidispersity, or two different sized particles, further affects the quality of the packing. At times the size dispersity can be either beneficial or detrimental to the overall quality.



2. Percolation transition

Consider a graph where edges are drawn between neighbors. If we randomly draw a fraction of edges, the graph will spontaneously connect at a critical fraction. This behavior is a **percolation transition**.



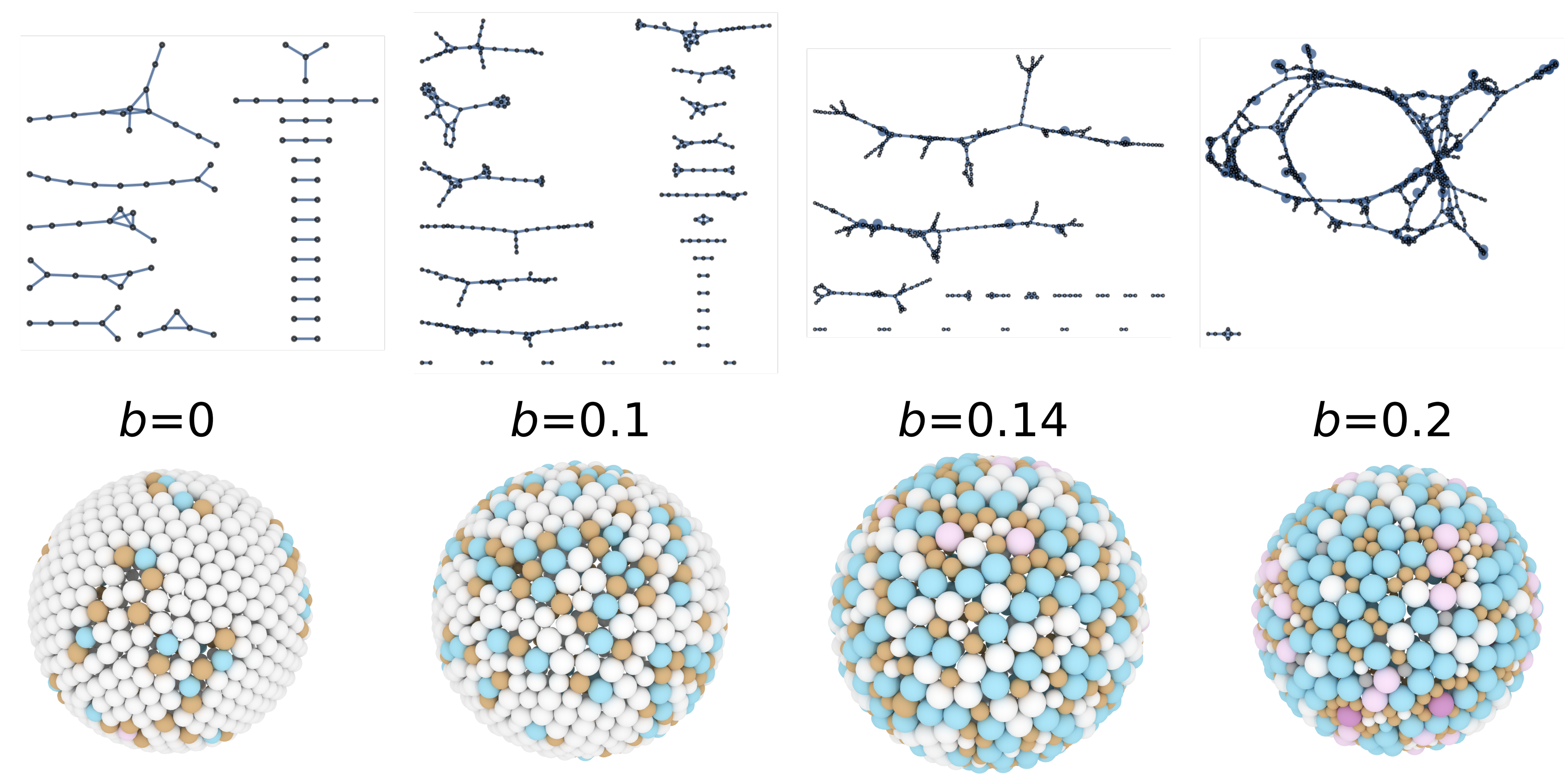


From percolation theory, we predict how the scars in the packing grow. The solid line represents the theory and the points reprent our data. The clear correspondence ensures the growth of the defect network is a percolation transition.

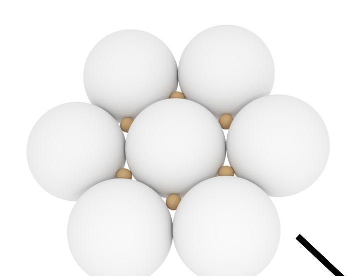
RESEARCH CORPORATION for SCIENCE ADVANCEMENT
A foundation dedicated to science since 1912.

3. Packing fraction analysis

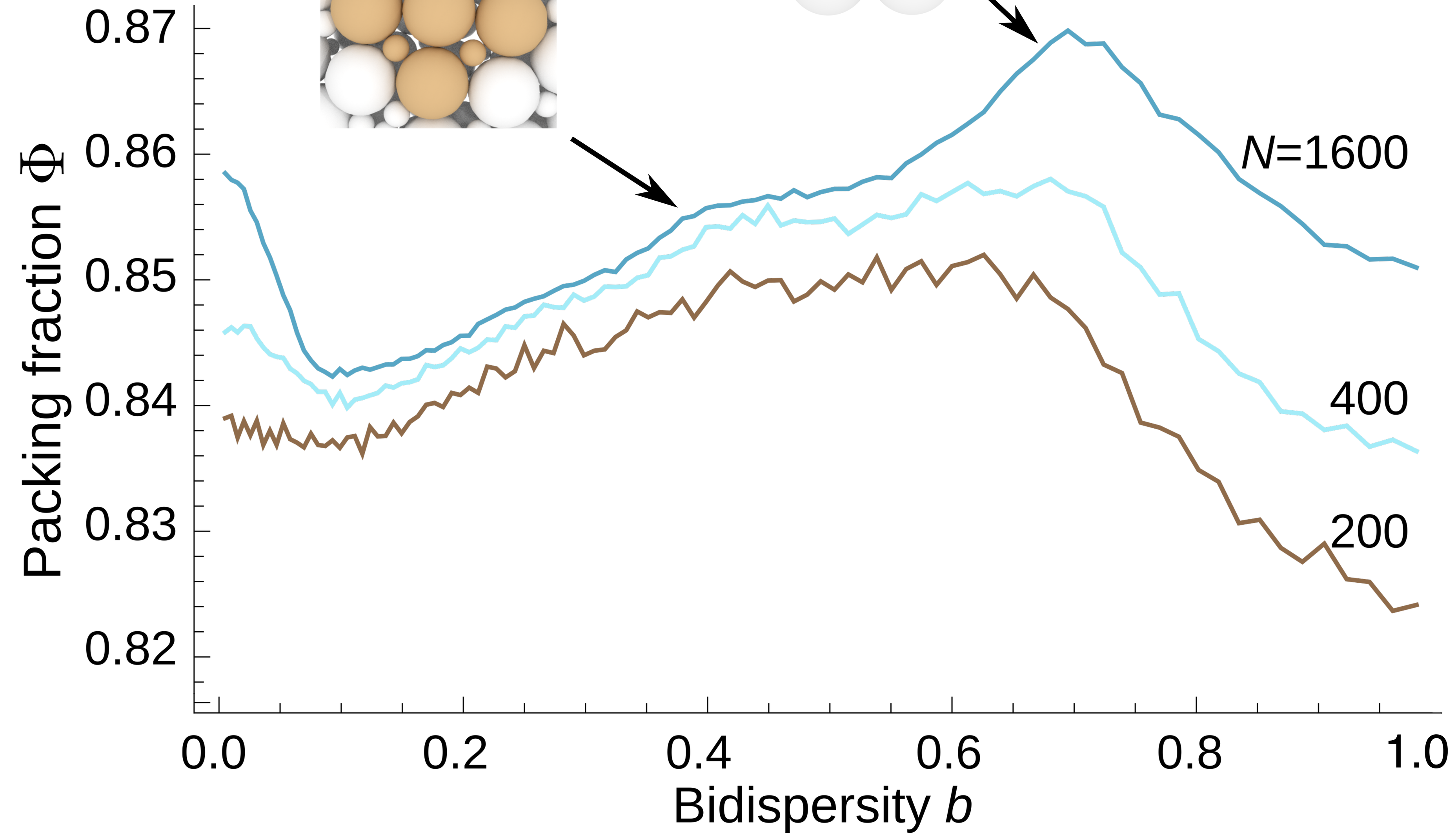
By analyzing the packing fraction, the area of the sphere covered by particles, we get a measure of the overall quality of the packing. As b increases from 0, corresponding to monodisperse particles, to 1, corresponding to half of the particles being vanishingly small, we note an initial decrease in quality followed by a gradual increase towards a maximum. Below we see the percolation of the defect graph occuring about the packing fraction minimum, illustrating its effect.



Commensurate packing motifs such as the tetradic tesselation seen here result in the shoulder in the graph.

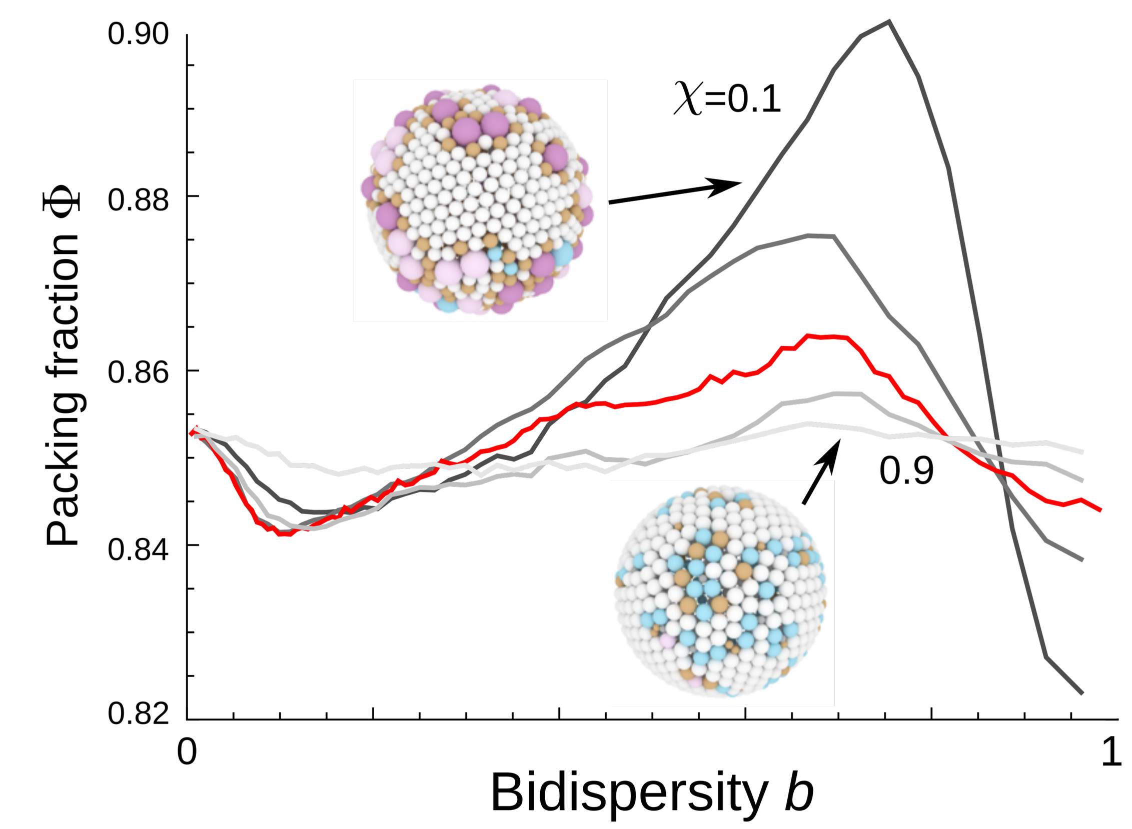


The maximum packing fraction is attained at the Apollonian point, when small particles fit in the gaps between large particles.



4. Intermix analysis

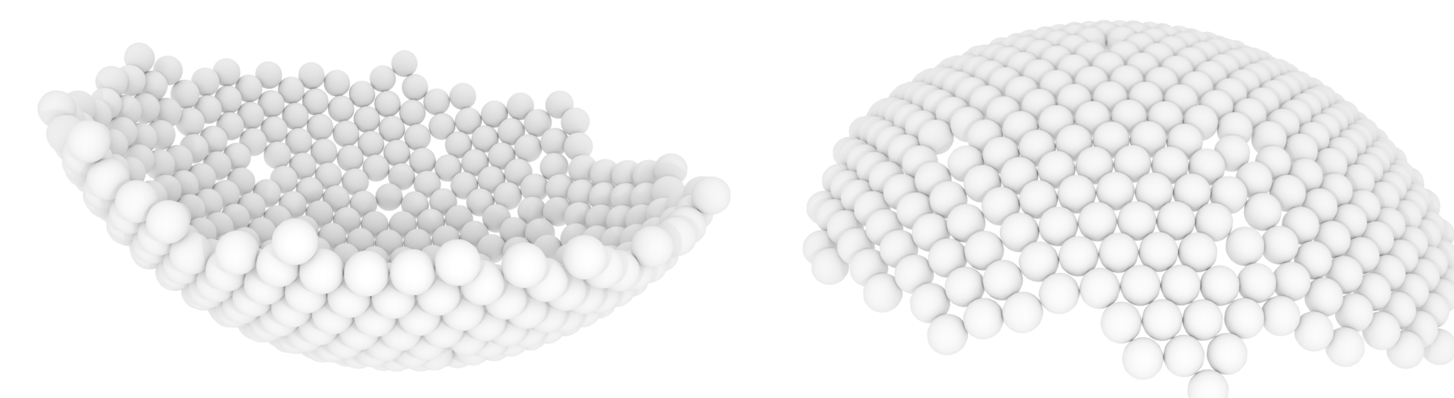
By altering the ratio of large to small particles, otherwise known as the intermix ratio, we can disrupt the percolation transition and prevent the scars from destroying the overall crystallinity of the packing.



The red curve represents the 0.5 intermix ratio seen to the left. Disrupting the percolation by increasing the ratio attentuates the features of the graph, leaving a more crystalline packing.

5. Conclusions and future work

The introduction of bidispersity into our packings non-trivially affects the quality. Beneficial effects result from geometric motifs that effectively fill space. However, at low bidispersity, clusters of defects percolate and break up the inital crystallinity present in monodisperse packings.



Future work will focus on the packing of particles on curved surfaces with open boundaries, such as the model system of the packing of particles in a bowl.

The authors gratefully acknowledge funding from Steven and Joyce Eliopoulos through the Summer Scholars program and the Research Corporation for Science Advancement.

softmattertheory