Statistical Physics and Computational Complexity
--- Order, Geometry and Materials
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Condensed matter & Optimization

• Common thread: complex systems with many metastable states.

• Prototypical problems.

• Deep connection between algorithms and physics: identifying relevant degrees of freedom and connections in the dynamics.

• Increased knowledge for application to other, more “standard” problems?
Flux lines in point AND columnar disorder.

- Response of flux lines in type-II superconductors to \textit{transverse} fields.
- Competition between columnar disorder (straightens lines) and point disorder (causes wandering).

Random field Ising magnet.

- Empirical guide for parameters to use in algorithm.
- Explanation of algorithmic slowing down.
- Visualization of algorithm for exploration of variants.
Spherical Crystals

Flat space hexagonal close packing of colloidal beads with no defects – all beads are 6-fold coordinated.

Packing on a sphere in the C60 buckyball. There are 12 5-fold coordinated vertices at the center of the 12 pentagonal carbon rings.

The packing of more than 500 colloidal beads on the surface of a ball leads to the proliferation of scars – these are linear arrays of dislocations (5-7 pairs) with one excess disclination (5).

Grain boundaries in the flat space image on the right extend all the way across the sample whereas the scars to the left (experiment) and below (simulation) are freely terminating.
1 µm diameter beads adsorbed on spherical water droplets in oil self-assemble into 2d spherical crystals with 12 *scars* - freely terminating grain boundaries.

Theoretical defect configurations are obtained by numerical minimization of a Hamiltonian of defects in an elastic background.
2 D Melting KTHNY

Liberation of: => Loss of:
1. Dislocations => Translational order
2. Disclinations => orientational order
Tomato bushy stunt virus

Poliovirus

Simian virus 40

Satellite tobacco necrosis virus

Figure 3–31 part 1 of 2. Molecular Biology of the Cell, 4th Edition.
Cell Membranes of Erythrocytes

Figure 10–27. Molecular Biology of the Cell, 4th Edition.
Radiolarians
Bacterial – S-Layers

Archaebacterium: Methanocorpusculem sinense

On the sphere define

Then

The ground state for $M$ particles on interacting via an arbitrary pairwise repulsive potential is the generalized Thomson problem

Map to the problem of the interacting defects treating everything else as a continuum elastic background
Geodesic Domes (by Buckminster)
Screening of elastic strain by dislocation arrays
Isolated Defect

Central Defect screened by Dislocations!!!
Defect Scars

\[ (R/a)_c \approx 5 \]

\[ N_{ex} \approx 0.41 \frac{R}{a} \]

Summary

Spatial Curvature (geometry) changes order of 2d crystals

Novel grain boundaries (scars) are present at zero temperature

May lead to novel materials – supra-molecular assembly

Colloidal simulations on curved surfaces interesting