Ordering in 2D
Ordering processes in a system of interacting particles in 2D behave in different ways depending on the uniformity of its constituents: Monodisperse ensembles crystallize very well, not only by slow annealing but also after temperature quenches. Polydisperse ensembles, instead, are good glass-formers, not only through quenching protocols but also with annealing, so avoiding crystallization.

Cluster-forming ability
Systems of particles interacting via potentials with a negative minimum in the effective Fourier transform, develop cluster structures. While these structures are known to form crystals and quasi-crystals in 2D, its dynamics is still unknown, both in the equilibrium and non-equilibrium regimes.

The model
We consider a system of monodisperse particles interacting via a generic ultrashort-range interaction of the form

$$U(r) = U[1 + (r/\gamma)^{K-1}]^{-1}$$

Figure 1: Pair-wise interaction potentials with cluster-forming ability. Red line: generic interaction of $U(r)$ [1]. Blue line: specific interaction $U(r)\gamma = 2.5$. We study the physical properties of this ensemble following annealing and temperature quenches, by means of molecular dynamics simulations with a Langevin thermostat.

Findings
1. The cluster-crystal at equilibrium presents a two-step relaxation, similar to that in glass forming liquids. It arises from the hopping of individual particles over the ordered array of clusters. This picture is a classical analog of the quantum superliquid phases. A solid with diffusion.
2. The non-equilibrium regime develops a (cluster) crystal-to-glass transition. The disordered phase establishes below certain temperature, via a self-generated polydisperse clusters array. For which particles hopping is arrested. A glassy phase in a 3D monodisperse aperiodic system without quenched order.
3. The phenomenology described here can be addressed in many real experiments, from colloidal suspensions to 2D superconductor layers. It may be of interest for phase change materials.

Application: 1.5-Superconductors
Vortices in layered 1.5 superconductors can interact via an effective potential of the form

$$U(r) = \sum_{i=2}^{N} C_i K_i \left( \frac{r}{\lambda_i} \right)$$

Figure 4: Left: MSD, temperature decrease from up to down; c) non-gaussian parameter $o=2$ (vertical axis) vs $T$; d) evidence of dynamic heterogeneity; b) distribution of coordination number for clusters with different occupation [number of particles] in the glassy phase. Right: snapshot of the glassy phase.

Further readings