# IDEAL GLASS TRANSITIONS BY RANDOM PINNING

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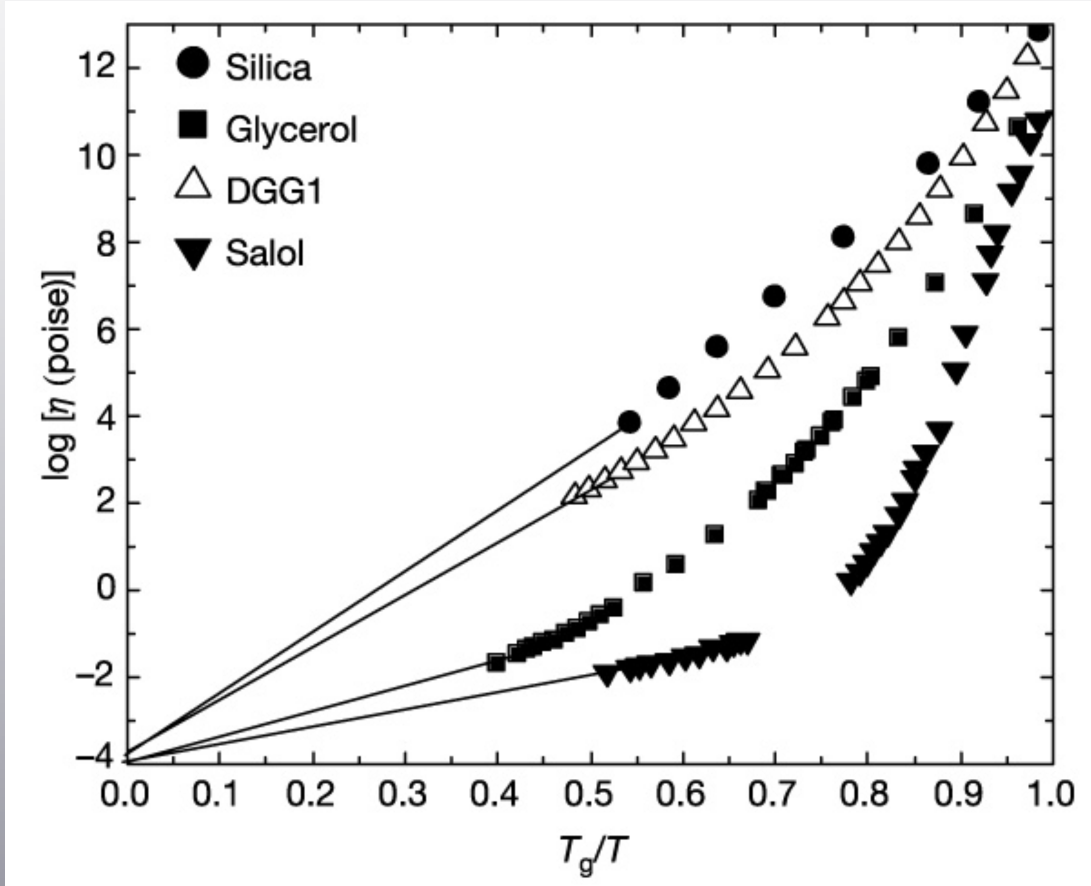
# Supercooled liquids & the glass transition




Vogel-Fulcher-Tammann (VFT) law:

$$\tau = \tau_0 \exp(A/(T - T_0))$$

- Does the ideal glass transition at $T_0$ exist really?
- How can one test glass transition theories?
- How can one study the critical properties?

# A new kind of phase transition

- A lot of metastable states below a characteristic temperature

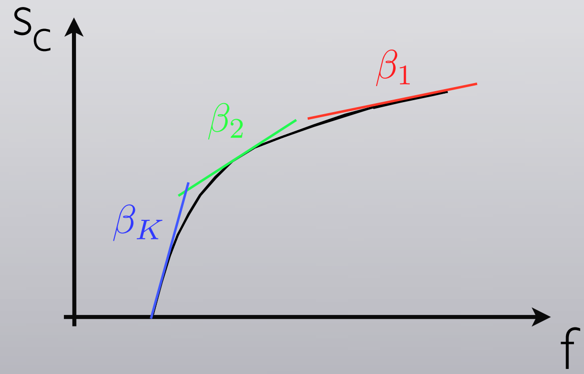
$$\mathcal{N}(f) = \exp(N s_c(f))$$

- Competition between free-energy and configurational entropy

$$Z = \int df \mathcal{N}(f) \exp(-\beta N f)$$

$$\phi(f) = f - T s_c(f)$$

1RSB transition at $T_K = 1/\beta_K$

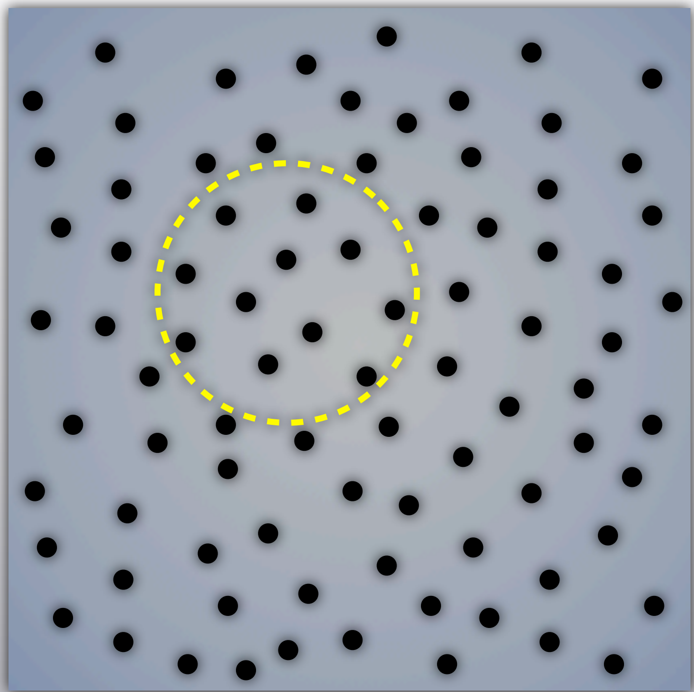



Above the transition many states dominate the equilibrium measure

Below the transition few amorphous states with the lowest free energy dominate

*Random Energy Model (Derrida) and many other mean-field models*

# The Random First Order Transition theory



$$\mathcal{N}(f) = \exp(l^d s_c(f))$$

$$\Delta F_I = \Upsilon l^\theta$$

$T s_c(T) l^d$ vs $\Upsilon l^\theta$

A kind of microphase-separated system with a huge number of phases

$$l_s = \left(\frac{\Upsilon}{T s_c}\right)^{1/(d-\theta)}$$ coherence length diverges when $s_c$ goes to zero

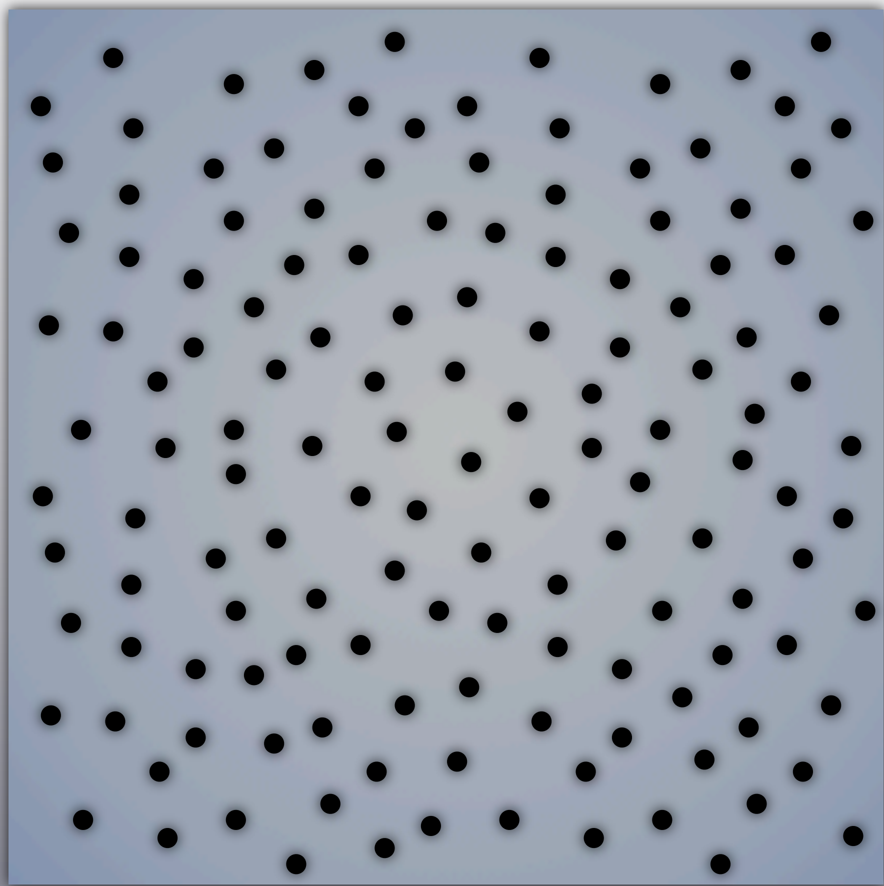
Below the transition an amorphous state with low free energy spans the system

$$\tau = \tau_0 \exp\left(A l_s^\psi / T\right)$$ the correlation time diverges exponentially


T. R. Kirkpatrick, D. Thirumalai, and P. G. Wolynes, Phys. Rev. A 40, 1045 (1989)

J.-P. Bouchaud and G.B., J. Chem. Phys. 121, 7347 (2004)

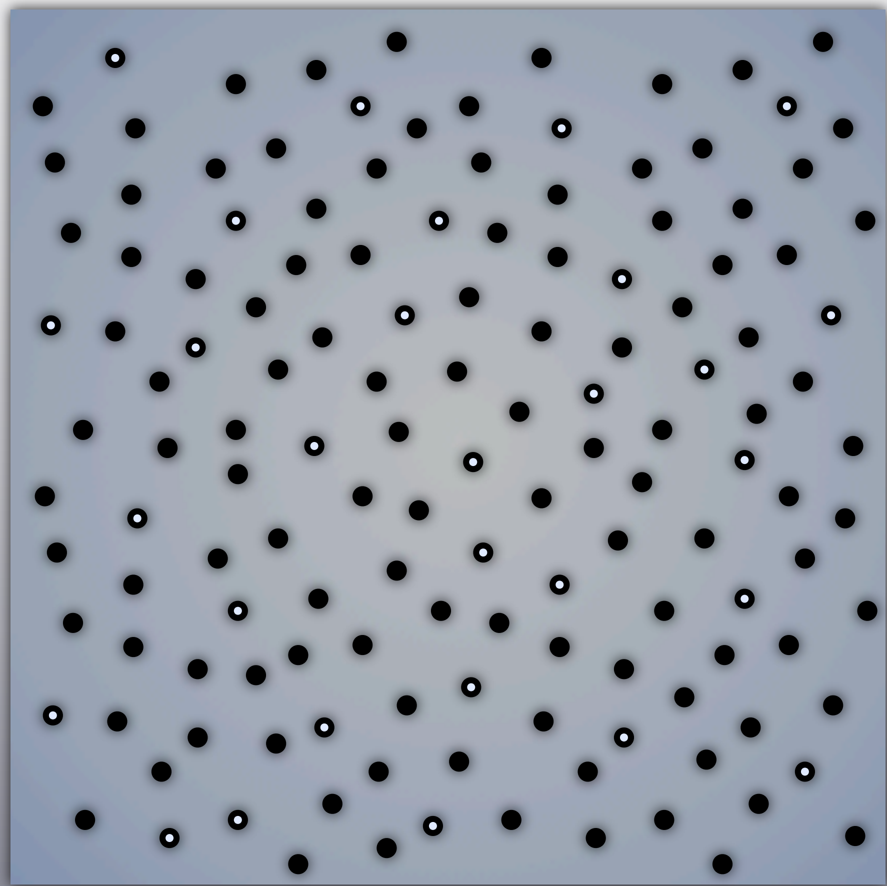
# Glass Transition by Pinning Particles



# Glass Transition by Pinning Particles

We freeze a fraction $c$ of particles randomly chosen in an equilibrium configuration

Parameters of the problem: $T \quad c$



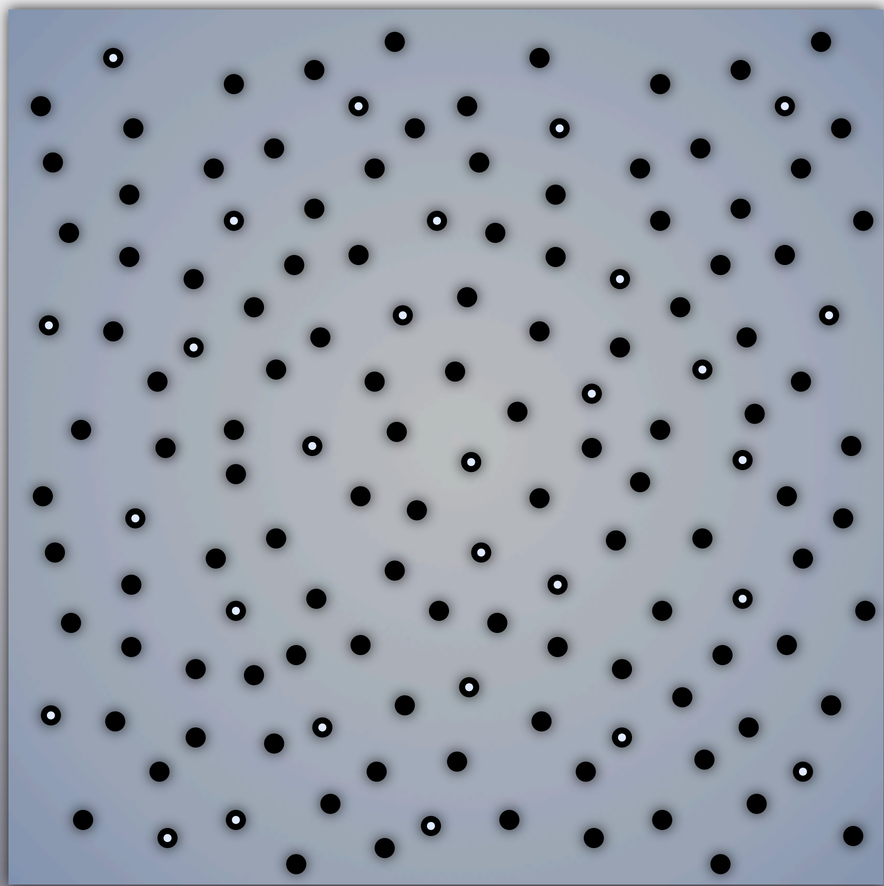
# Glass Transition by Pinning Particles

We freeze a fraction $c$ of particles randomly chosen in an equilibrium configuration

Parameters of the problem: $T \quad c$

Pin particles $s_c \downarrow$

$l_s^p \quad \uparrow\uparrow \qquad \tau^p \quad \uparrow\uparrow$



# Glass Transition by Pinning Particles

We freeze a fraction $c$ of particles randomly chosen in an equilibrium configuration

Parameters of the problem: $T \quad c$

- RFOT phenomenological argument

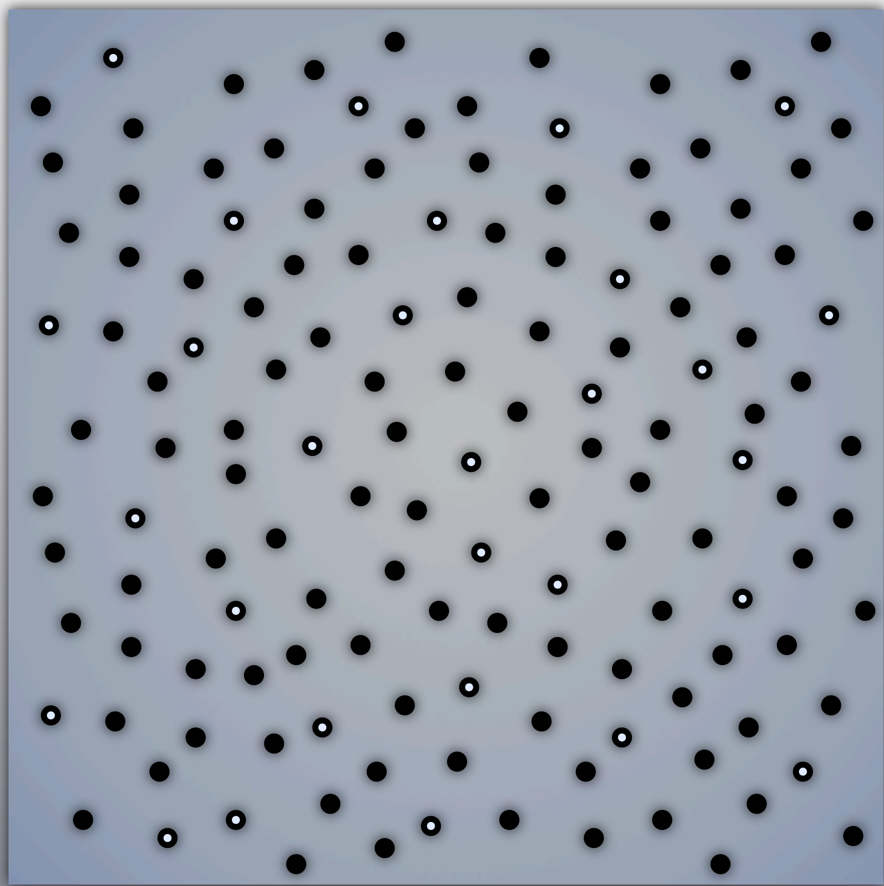
$$s_c^P(T,c) \simeq s_c(T) - cY(T)$$

$$l_s^P = \left( \frac{\Upsilon}{T(s_c - cY)} \right)^{1/(d-\theta)} \gg l_s$$

$$\tau^p \sim \exp\left[ A(l_s^p)^\psi / T \right]$$

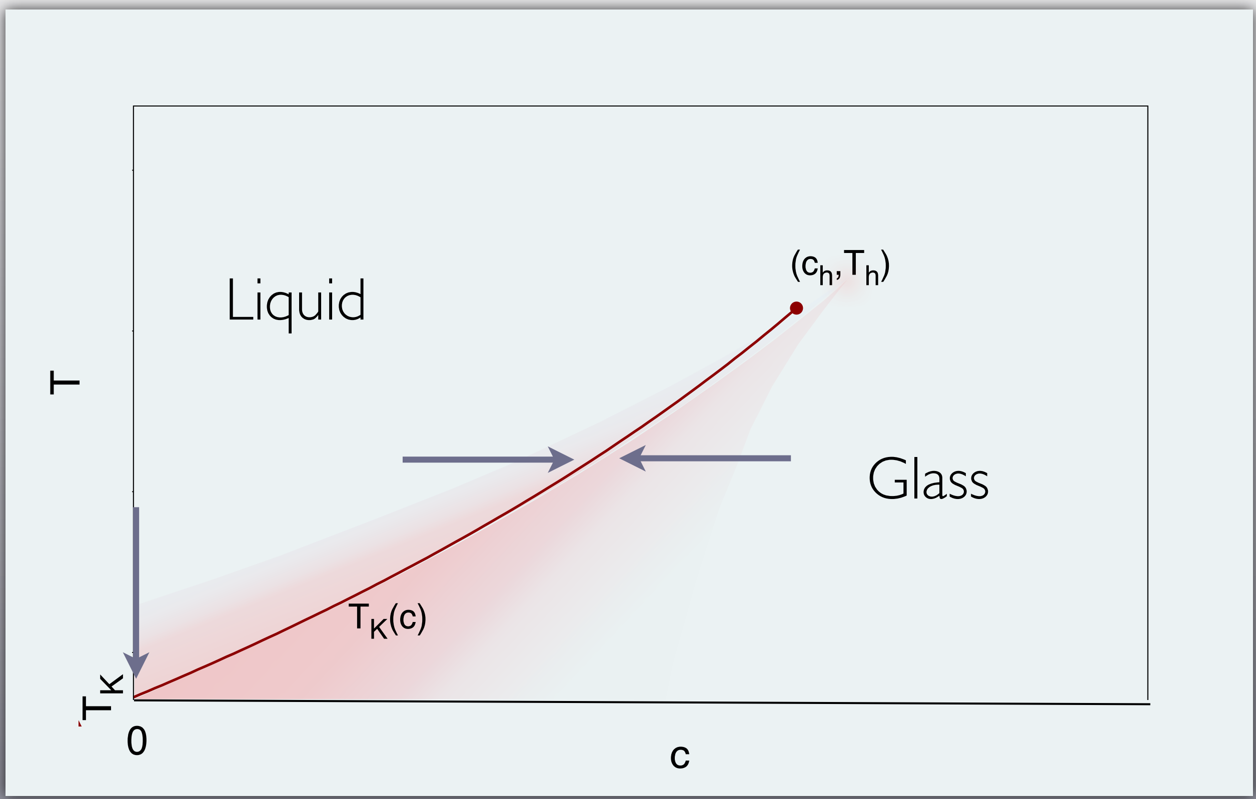
$$c_K(T) = s_c(T)/Y(T)$$

Outcome: A line of ideal glass transitions



# The Glass Transition by Random Pinning

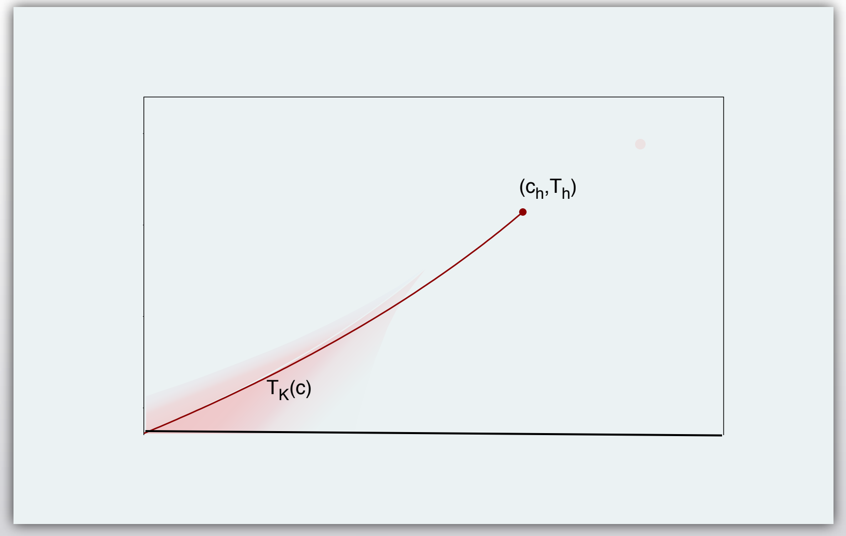
- Phase diagram c,T obtained by mean-field and real space RG analysis




- Same scaling approaching the transition by increasing c or lowering T
- Overlap with initial configuration jumps at the transition
- The relaxation timescale diverges exponentially at the transition

# The low temperature (ideal glass) phase is known!

The configuration chosen to pin particles provides the best glass configuration




- Equilibrium can be observed in the glassy phase
- The transition (and its existence) can be approached from both ends, hence studied in a much more stringent way
- Several scaling predictions for equilibrium and out of equilibrium dynamics in presence of pinned particles.
- Some numerical confirmations, others (including some experiments) on the way.