Efros-Shklovskii Coulomb gap without disorder

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Glass

Solid but **not ordered**

Not equilibrated:
non-ergodic

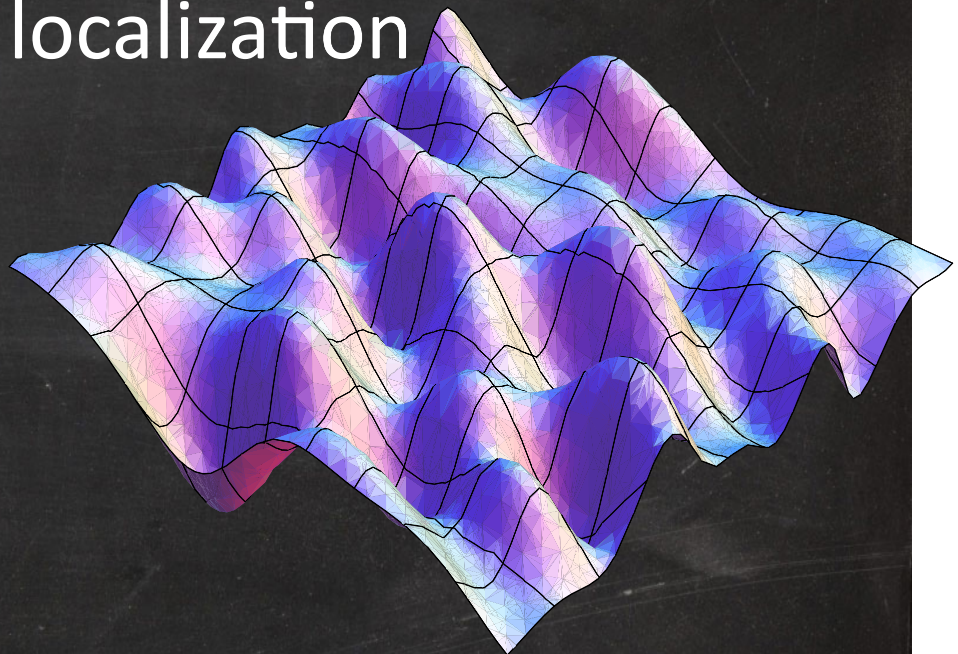
Microscopic degrees of freedom **localized**

Also works for electrons!

Quenched disorder

Parameters in Hamiltonian are **random**

No interactions: **Anderson** localization



$$H = \sum_i \mu_i n_i$$

Interactions: **Coulomb**

$$H_I = \frac{1}{2} \sum_{ij} \frac{V}{|r_{ij}|} \left(n_i - \overline{n}\right)\left(n_j - \overline{n}\right)$$

Efros-Shklovskii gap (1)

Energy to remove or add a particle:

$$\epsilon_i = \mu_i + \frac{1}{2}\sum_{j\neq i}\frac{V}{|r_{ij}|}\,(n_j - \overline{n})$$

What is the **distribution** $g(\epsilon)$ of energies ϵ_i ?

(in the ground state)

Stability when electron moves from i to j:

$$\Delta E = \epsilon_j - \epsilon_i - \frac{V}{|r_{ij}|} > 0$$

Efros-Shklovskii gap (2)

Distance between states close to Fermi level

$$|r_{ij}| > \frac{V}{\epsilon_j - \epsilon_i}$$

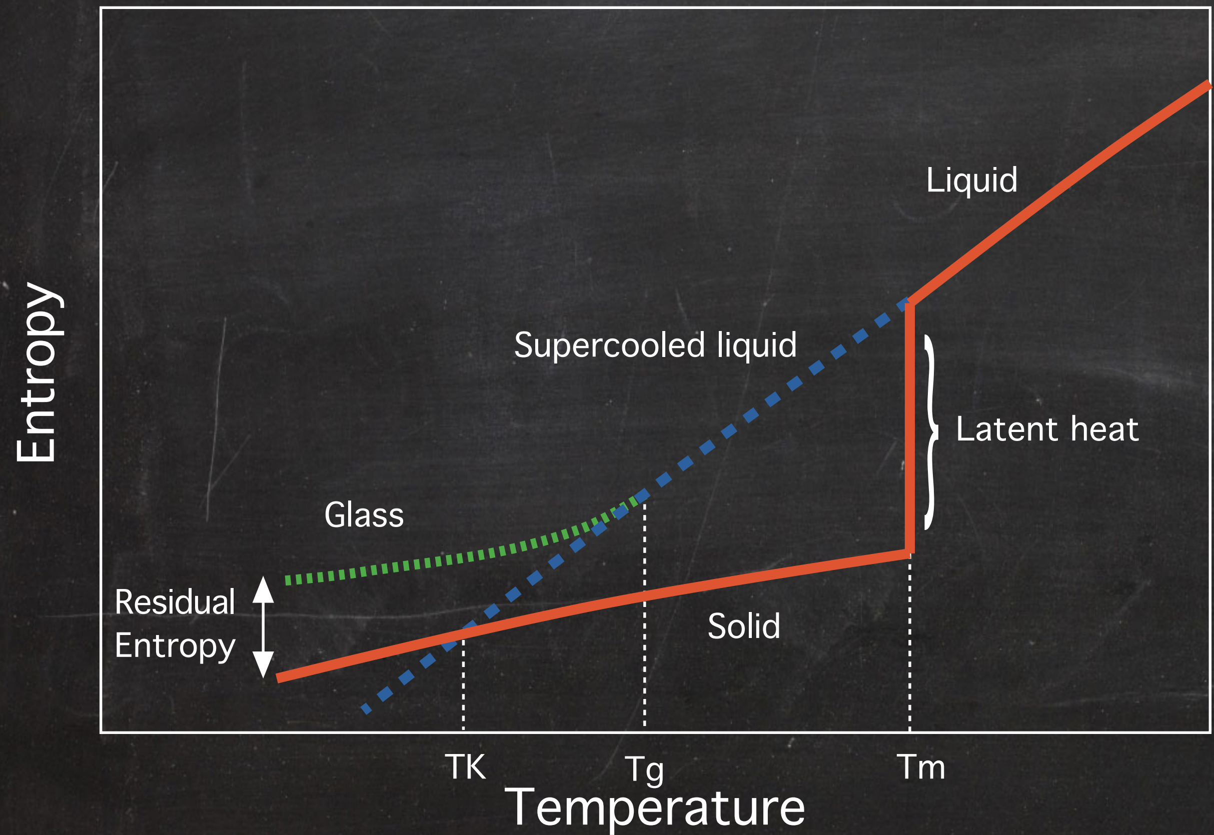
Stability sets upper **bound** for density of states

$$g(\epsilon) \leq \frac{d}{2\pi}|\epsilon|^{d-1}$$

Efros Shklovskii 1975

Wait.... glass?

Laws of physics (Hamiltonian) are **not random**!



Real glass = 😎 supercool liquid

What about electrons?

Disorderfree electron glasses

Quarter-filled triangular compound θ-RbZn

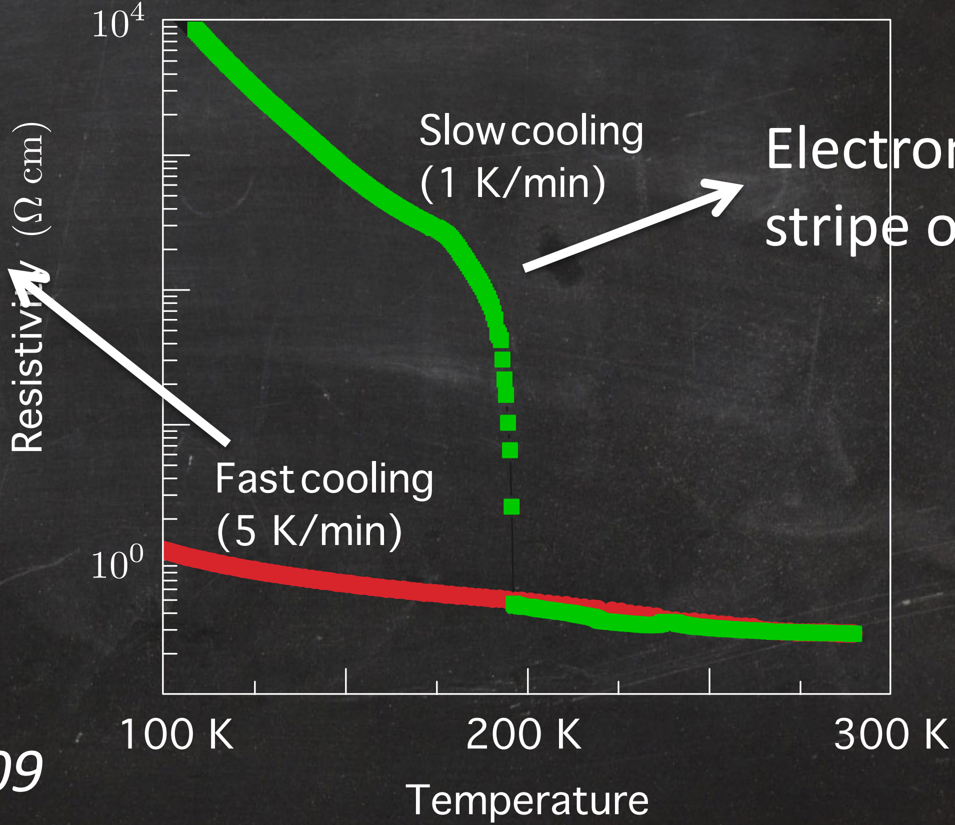
Supercool electron liquid!

Arrhenius Law dynamics

$$\tau \sim e^{\Delta/T}$$

Local charge correlations

Mahmoudian et al
APS March 2015 Q21.00009
arXiv:1412.4441



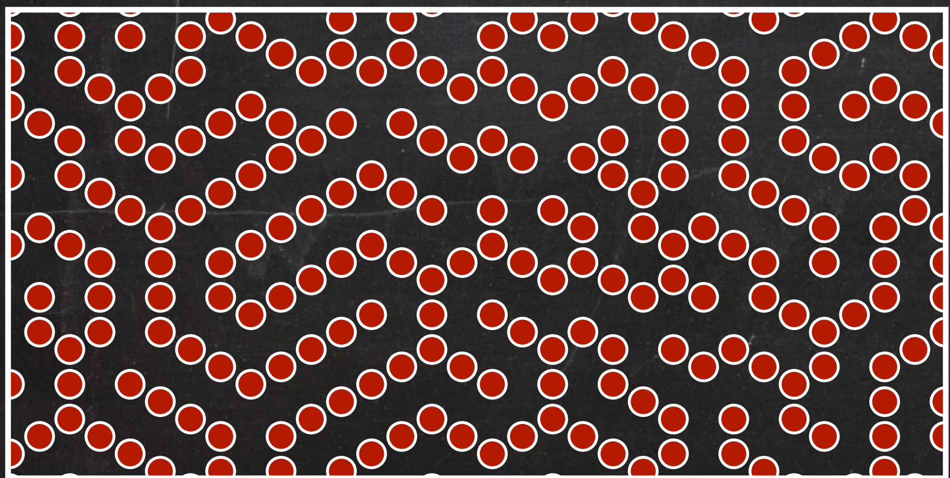
Kagawa, Nat Phys 2013

Metastable states

Glassiness: existence of **metastable states**

Metastability = electron move increases energy

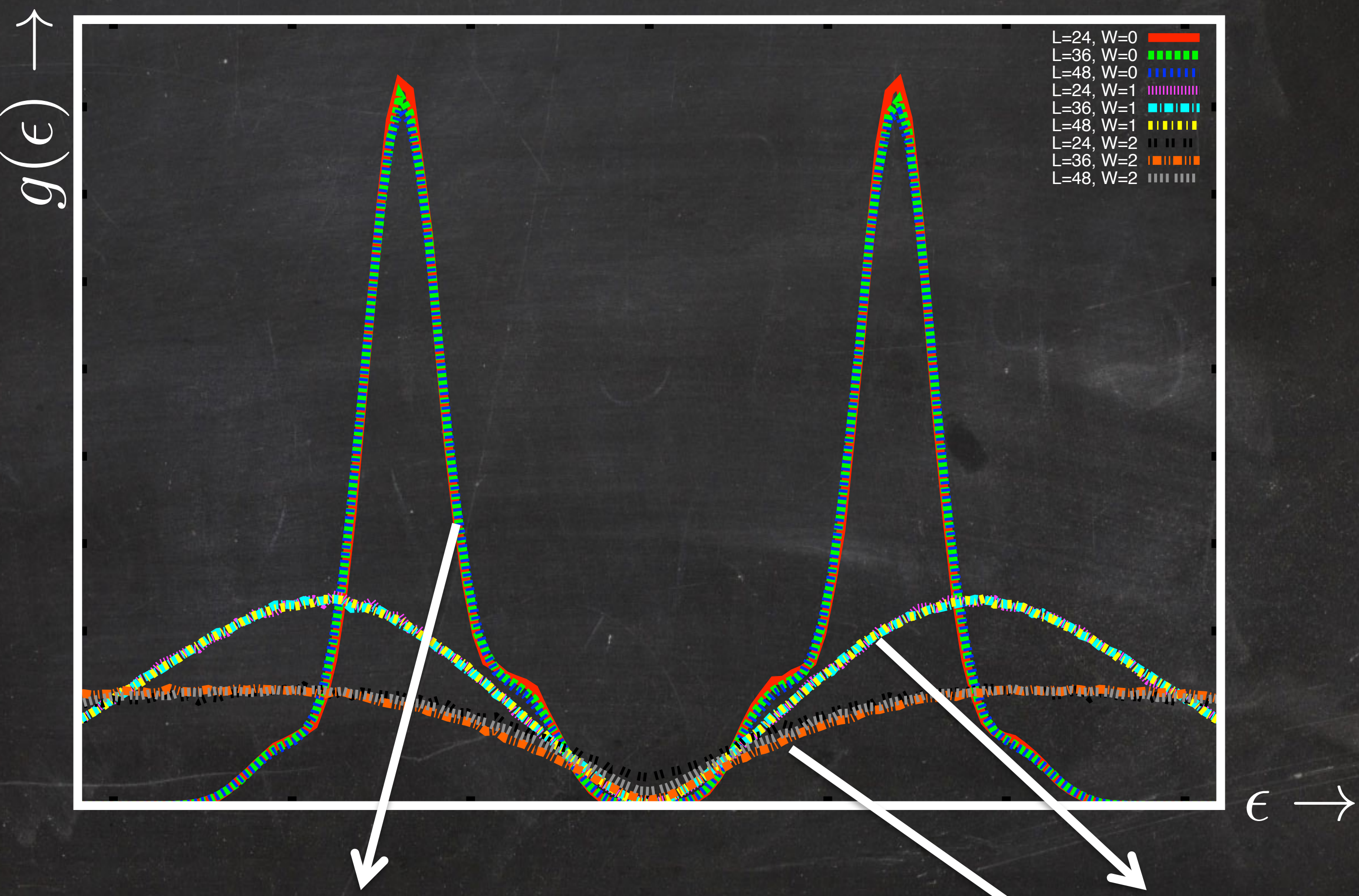
$$\Delta E = \epsilon_j - \epsilon_i - \frac{V}{|r_{ij}|} > 0$$



$$H = \frac{1}{2}\sum_{ij} \frac{V}{|r_{ij}|} \left(n_i - \overline{n}\right)\left(n_j - \overline{n}\right)$$

Numerically:
Rapid **quench** to get metastable state

Coulomb gap without disorder!



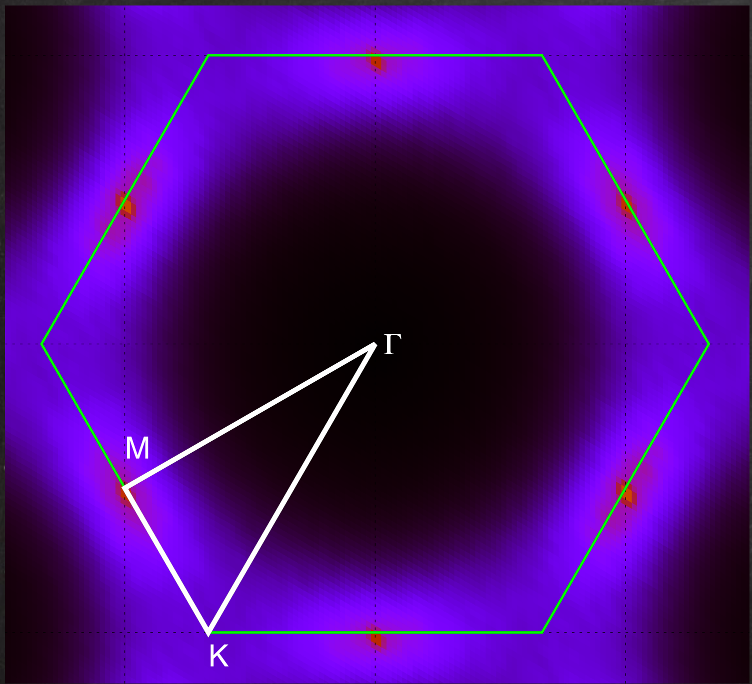
Stronger Coulomb gap in absence of disorder!

$$g(\epsilon) \sim e^{-\Delta/|\epsilon|}$$

Linear ES gap with disorder

Why stronger gap?

Metastable states have **local charge correlations**



Restricts the available sites hence lower d.o.s.

Analytical expression

$$g(\epsilon) \sim |\epsilon|^{-2} e^{-V/\xi|\epsilon|}$$

Conclusions & Thanks!

Disorder-free supercool 😎 electron glass displays **stronger Coulomb gap**

Metastable states in disorderfree electron glass are strongly charge-correlated

Reference: Mahmoudian, Rademaker, et. al., arXiv:1412.4441 on disorder-free glasses; gapwork to be published.

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