SÉMINAIRE MATIÈRE CONDENSÉE
Jeudi 5 février 2026 à **14h**
LPS, bât 510, **Moyen amphi + ZOOM** (en ligne)
Meeting ID: 926 0633 0651; Password: LPS91405

Low-energy theory of strongly disordered superconductors

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Macroscopic electromagnetic response of a superconductor is described by a finite superfluid stiffness, which underlies hallmark phenomena such as dissipationless current flow and the Meissner effect. In conventional superconductors a hard excitation gap allows these properties to persist at finite temperature and frequency, enabling advanced superconducting technologies. The standard Mattis-Bardeen framework further predicts that increasing disorder reduces the superfluid stiffness, thereby raising the kinetic inductance—a desirable trait for microwave-device applications.

However, heavily disordered samples deviate from the conventional BCS-like theory in numerous ways. For example, both the phase diagram and tunneling spectroscopy reveal a hard "pseudogap" persisting above the transition temperature and unusually large sub-gap dissipation. Furthermore, the suppression of the superfluid stiffness with temperature follows an unexpected power law spanning more than a decade of temperature [1], and the microwave dissipation shows a non-monotonic temperature trend that cannot be explained by conventional means [2, 3].

I will briefly review the aforementioned experiments and present a theoretical framework that connects these measurements to intrinsic material parameters, while also exposing the limits of existing models. A combination of numerical simulations and theoretical analysis links the key features of the macroscopic electromagnetic response to disorder-induced spatial inhomogeneity of the superconducting state. By analytically characterizing the associated statistical distribution, I derive expressions for both the superfluid stiffness and low-frequency dissipation that agree with experimental data [1, 3].

The analysis identifies the low-energy excitations responsible for the anomalous behavior as localized collective modes emerging from intrinsic inhomogeneity of the superconducting state that appear phenomenologically similar to two-level systems. These insights help explain the non-monotonic shape of the superconducting transition line in the temperature–disorder plane [2].

References:

[1] AVK, Thibault Charpentier, Nicolas Roch, Benjamin Sacépé, Mikhail V. Feigel'man, Phys. Rev. B 109, 144501 (2024)
[2] Thibault Charpentier et al, Nature Physics 21, 104-109 (2025)
[3] AVK and Mikhail V. Feigel'man, arXiv:2512.11636