Contribution ID: **4** Type: **not specified**

Fractional diffusion equations: a numerical linear algebra perspective

This mini-course focuses on Fractional Diffusion Equations (FDEs), which extend classical diffusion equations by replacing standard derivatives with fractional ones. These models naturally capture non-local interactions, allowing for a more accurate description of anomalous diffusion phenomena arising in several applications, such as plasma physics and network dynamics.
The intrinsic non-locality of fractional operators improves the physical modeling of the underlying processes but also leads to important computational challenges. In particular, when FDEs are discretized, the resulting coefficient matrices typically lose the sparsity structure that characterizes classical discretizations of partial differential equations, making the associated linear systems significantly more demanding from a computational perspective.
After introducing the main modeling ideas behind FDEs, we focus on the structural and spectral properties of the matrices arising from standard discretizations and on how these can be exploited to design efficient iterative solvers for the resulting linear systems. In particular, we will highlight strategies based on preconditioning techniques and multigrid methods, showing how suitable matrix analysis can lead to fast and scalable numerical algorithms.

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