# Master Projects: Local model adaptivity in multiscale dynamics

One of the main topics we study in the Multiscale Dynamics group are electric discharges. Discharges occur in various forms in nature and technology, such as in lightning strikes or in the spark plugs in a car engine, and they often grow nonlinearly due to their own electric charge. Electric discharges often have a multiscale nature, meaning that phenomena take place over a range of spatial and temporal scales.

In our numerical models the use of adaptive mesh refinement greatly speeds up simulations. However, since we use a global time step, a common problem is that time step restrictions in a small part of the domain cause the whole simulation to become inefficient. These small time steps can be addressed in multiple ways. Below, we list three possible directions, each of which could individually be a master project:

1. To spatially couple implicit and explicit temporal discretizations, by dividing the domain in implicit and explicit blocks. This generic concept has been applied once before [1], but never to the simulation of electric discharges. Note that using an implicit method in the full domain would be too expensive for our 2D and 3D simulations.

2. To develop reduced models as in e.g. [2], in which the equations are locally approximated so that they can be solved with larger time steps. In many cases, the physics in the small $\Delta t$ regions can be approximated, for example when a CFL condition restricts the time step in regions where the density is almost zero.

3. To use different time steps on different refinement levels, which would partially alleviate the problem. This is a classic idea [3] that we have not yet experimented with because it requires spatial and temporal interpolation, which could be challenging for the equations we consider.

For reference, relatively simple equations can be used to describe discharges, and the main one you will be dealing with is of the following form:

$$\partial_t n + \nabla \cdot (\vec{v} n) = \nabla \cdot (D \nabla n) + S, \tag{1}$$

where $n$ is a density, $\vec{v}$ a velocity and $D$ a diffusion coefficient. You would for example start out with a simplified model system in 1D. The aim would be to extend the chosen approach to more realistic 2D/3D cases with adaptive refinement.

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## References


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