How to avoid very large discrete velocity grids in deterministic simulation of rarefied gas flows?

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Most deterministic numerical methods for rarefied gas dynamics are based on a common idea: the kinetic equation is discretized with a finit set of discrete velocities. This set is generally given by a global Cartesian velocity grid, which is the same grid for every point in the physical domain, and for every time. The advantages of this approach is its simplicity, and the strong mathematical properties that inherits the discrete model from the continuous one (stability, positivity, etc.). This is due to the fact that all the distribution functions are discretized on the same grid. However, for some practical problems with strong variations of macroscopic temperature and velocity fields, like in atmospheric re-entry flows, this approach is very expensive: the discrete velocity grid must be very large and very thin in order to capture all the different distribution functions.

In this talk, I will present two new approaches to reduce this cost. First, I will describe a method adapted to steady flows in which one can define a priori a global velocity grid which is locally refined wherever it is necessary (in zones of the velocity space where there are narrow distributions), and coarsened elsewhere (in zones of the velocity space where there are only tails of distributions). Second, I will present a method designed for unsteady flows in which it is even difficult a priori to know which grid should be used. This method uses a discretization of the kinetic equation on local velocity grids: these grids dynamically adapt in time and space to the variations of the width of the distribution functions.