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Numerical simulations of electron transport in the solar wind

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A conventional fluid approach is in general insufficient for a correct description of electron transport in weakly collisional plasmas such as the solar wind. The classical Braginskii or Spitzer-Härm theory is only valid when the Knudsen number (mean free path divided by length scale of density or temperature variation) is greater than $\sim 10^{-2}$. Despite this, the classical heat transport coefficient is widely used in situations with relatively long mean free paths. For realistic Knudsen numbers in the solar wind, the electron distribution function develops suprathermal tails, and the departure from a local Maxwellian can be significant at the energies which contribute the most to the heat flux moment. To accurately model this a kinetic approach is required, and different techniques have been used previously, e.g. particle simulations (Landi 2003), spectral methods (Pierrard 2001), the so-called 16 moment method (Lie-Svendsen 2001), and approximation by kappa functions (Dorelli 2003).

In the present study we solve the Fokker-Planck equation for electrons in one spatial dimension and two velocity dimensions. The distribution function is solved for using a finite element method in energy and pitch-angle, and finite differences are used in the spatial dimension. The ion temperature and density profiles are assumed to be known, but the electric field is calculated self-consistently to guarantee quasi-neutrality. The kinetic equation is of a two-way diffusion type, for which the distribution of particles entering the computational domain in both ends of the spatial dimension must be specified, leaving the outgoing distributions to be calculated. The long mean free path of the suprathermal electrons has the effect that the details of the boundary conditions play an important role in determining the particle and heat fluxes as well as the electric potential drop across the domain.

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