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Electron heat-flux transport in the solar wind

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The solar wind is a magnetized plasma outflow, mainly composed of electrons and protons, emanating from the sun and streaming through the interplanetary space. In-situ measurements of the electron velocity distributions reveal not only a bulk quasi-thermal (core) component, at lower energies, but also suprathermal populations enhancing the high-energy tails of the distributions. There is an ubiquitous suprathermal halo component, and a magnetic-field-aligned beam, usually called the strahl and enhanced in the fast winds. This peculiar suprathermal formation carries an important amount of heat-flux in the solar wind. However, the observations show that the heat-flux carried by the solar wind is suppressed below the values provided by collisional models with increasing heliocentric distance[1,2].

At the same time, the implication of particle-particle collisions decreases, and beyond 0.5 AU, when electrons and ions are practically collisionless, other self-consistent mechanisms should be at work. Wave-particle interactions through kinetic instabilities have been proposed as a mechanism responsible for shaping the electron distribution, reducing the suprathermal skewness, and hence regulating the heat transport. Depending on the solar wind conditions, more specifically, on the relative drift between the quasi-thermal core and the strahl, several heat-flux related instabilities can be triggered[3]. These instabilities, from different natures, i.e., electromagnetic, electrostatic or hybrid, propagating parallel or obliquely to the magnetic field, etc., can be predicted using linear theory and may have different effects on the velocity distributions.

Moreover, using particle-in-cell simulations (PIC), we study their relaxation and possible role in the scattering of strahl electrons and the consequent regulation of the electron heat-flux in the solar wind[4,5,6]. We pay special attention to the wide spectrum of whistler heat-flux instabilities, propagating parallel and obliquely to the background magnetic field. The combined effect of these instabilities modify the velocity distribution, generating a halo-like population at the expense of the strahl. As a result, a significant decrease of the heat-flux is obtained, which may explain the solar wind observations[5,6].

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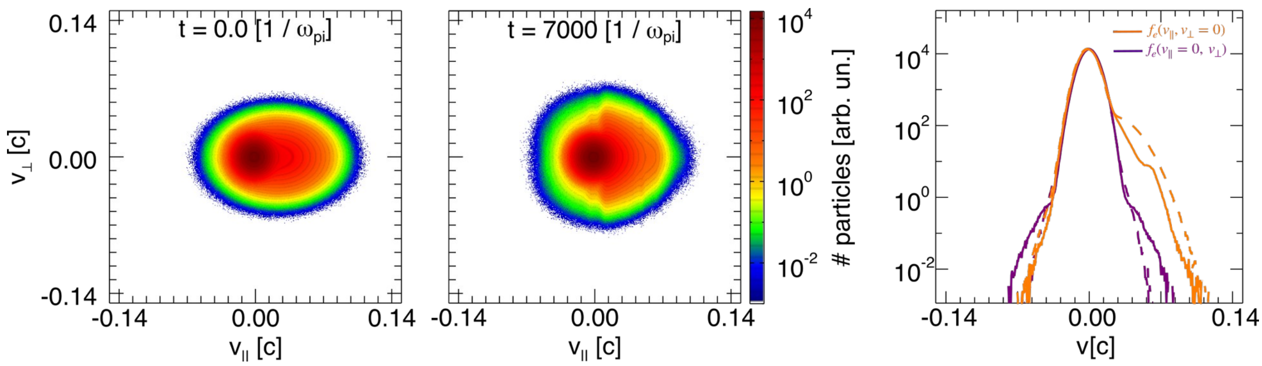

Figure 1.Total electron velocity distribution function at the beginning and the end of the simulation. The right panel shows cuts at parallel and perpendicular directions of the same cases: dashed lines for the initial distributions and solid lines for the final.