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NON-THERMAL VELOCITY DISTRIBUTION FUNCTIONS IN THE INTERPLANETARY MEDIUM : ON THEIR ORIGIN AND CONSEQUENCES FOR THE SOLAR WIND ACCELERATION

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Abstract. Non-thermal electron and ion velocity distribution is permanently observed in the solar wind. The exact origins of such departures from equilibrium Maxwell-Boltzmann distributions remain unclear. It is however believed that the rarity of Coulomb collisions in most of the extended corona and solar wind play a crucial role in the mechanisms which produce and/or maintain such distributions. In this lecture, we will summarize the various observations of those distributions and discuss their possible coronal origin and role in the Solar Wind acceleration processes.

Since the historical work by Parker (1958), numerous sophisticated models of the solar wind have been developed. The different acceleration mechanisms, the origin of the high-speed solar wind as well as the associated problem of the coronal heating have been recently reviewed in a full and comprehensive way by Cranmer (2002). However all the solar wind properties are still far from being well understood. The reason of this difficulty is that the solar wind is neither a collision-dominated medium nor a collisionless one. The Knudsen number K_n, which is defined as the ratio of the particle mean free path and the density scale height, is close to unity at the earth orbit. This means, that neither the hydrodynamic approach nor the pure collisionless one (also called exospheric) are fully appropriate to model solar wind expansion and explain its observed properties.

The classical fluid approach is applicable for the extreme regime where $K_n << 1$ which means that the medium is collision-dominated. In this case, the particle velocity distribution functions (VDFs) are Maxwellians as the medium is assumed to be at local thermodynamic equilibirum. The Euler or Navier-Stokes approximations are applicable resulting in a description of a thermally driven wind out of the hot solar corona. The problem with this approach is that the particle VDFs might well not be Maxwellians at the base of the solar wind. There is an increasing number of both theoretical (Vinas *et al.* 2000, Leubner 2002) and observational evidences (Esser & Edgard 2000) which tend to show that non thermal VDFs can develop and exist in the high corona or even in the transition region. The existence of such distributions could easily be understood through the fact that in a plasma the particle free paths increase rapidly with speed. As a consequence, high energy tails could naturally develop in the weakly collisional corona and solar wind acceleration region. Indeed, it is well known that the solar wind electron VDFs permanently exhibit non thermal tails that can be modelled by a classical halo Maxwellian population (Feldman *et al.* 1975) or by the power law part of a generalized Lorentzian or Kappa function

(Maksimovic *et al.* 1997b). In the frame of the fluid approach, which cannot explain the existence of suprathermal tails, the effect of non thermal VDFs on solar wind acceleration can be understood through the increase of the heat flux (Holweg *et al.* 1978, Olbert 1981).

Another way of taking into account the possible effects of coronal non thermal particle distributions is to adopt a kinetic approach. Among the various kinetic approaches for the solar wind, the simplest one is probably the exospheric one, which totally neglects binary collisions between particles over an altitude called the exobase. The first solar wind model of this type has been developed by Chamberlain (1960) by analogy to the evaporation of planetary atmospheres. This first exospheric model has resulted in a solar breeze, assuming that the radial expansion of the solar corona results from the thermal evaporation of the hot coronal protons out of the gravitational field of the Sun. The small solar wind speeds resulting are due to the use of the Pannekoek-Rosseland electrostatic potential which is based on the contradictory assumption of a hydrostatic equilibrium. The real electric potential is higher than the former one, assuming the quasi-neutrality of the plasma and a zero electric current. Models using this latter correction (Lemaire & Scherer 1971, Jockers 1970) have reproduced supersonic wind speeds, although not sufficent for explaining the high speed values of the fast wind.

More recently, Maksimovic *et al.* (1997a) have modelled the solar wind using the assumption that the velocity distribution function of the electrons in the corona, is a non-Maxwellian one, e.g. a generalized Lorentzian or Kappa function. Such non-Maxwellian functions containing suprathermal tails result in a higher electrostatic potential needed for zero charge and current, and therefore in larger terminal bulk speeds. This model yields a rather good description of main features of the solar wind giving densities and temperatures within the ranges observed at 1 AU. Its main advantage is the prediction of high speeds without unreasonably large coronal temperatures and without additional heating of the outer region of the corona, as needed in hydrodynamic models to achieve the same solar wind speed. More generally, the main advantage of exospheric models is that they exhibit clearly a driving mechanism for the solar wind, in this case the interplanetary electrostatic potential involving the only assumption of the VDF at the exobase.

In this lecture, we will review briefly the various solar wind models, summarize the relevant observations and discuss the possible processes for the Solar Wind acceleration.

References

Chamberlain, J.W.: 1960, *Astrophys. J.*, **131**, 47.
Cranmer, S.R.: 2002, *Space Sciences Rev.*, **101**, 229.
Esser, R., Edgar, R.J.: 2000, *Astrophys. J. Lett.* , **532**, L71.
Feldman, W.C., *et al.*: 1975, *J. Geophys. Research*, **80**, 4181.
Hollweg, J.V.: 1978, *Rev. Geophys. Space Phys.,* **16**, 689.
Jockers, K. : 1970, *Astron. Astrophys.*, **6**, 219.
Lemaire, J., and Scherer, M.: 1971, *J. Geophys. Research*, **76**, 7479.
Leubner, M.P.: 2002, *Astrophys. Space Sci.*, **282**, 573.
Maksimovic, M., Pierrard, V., Lemaire, J.F.: 1997a, *Astron. Astrophys.*, **324**, 725.
Maksimovic, M., Pierrard, V., Riley, P: 1997b, *Geophys. Research Lett.*, **24**, 1151.
Olbert, S.: 1981, *ESA SP-161*, 135.
Parker, E.N.: 1958, *Astrophys. J.*, **128**, 664.
Vinas, A.F., Wong, H.K., Klimas, A.J.: 2000, *Astrophys. J.*, **528**, 509.