KINETIC AND HYDRODYNAMIC REPRESENTATIONS OF CORONAL EXPANSION AND THE SOLAR WIND

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The small number density of the interplanetary plasma suggests that the overall dynamics of the plasma may be approximated by the outward flight of freely moving ions and electrons evaporating from an exosphere at which the thermal velocity distributions are Maxwellian. The evaporating ions and electrons are constrained by a radial electric field to move together, preserving charge neutrality. The traditional treatment of this kinetic mass loss from the Sun provided only a tenuous subsonic outflow of plasma, which was hardly surprising because together the ions and electrons move adiabatically once they have evaporated from the exosphere.

Some years ago Lemaire and Scherer re-examined the kinetic evaporation formulation and found that the traditional treatment employed an electric field some 20 – 40 percent too weak to force equality of the escaping ion and electron fluxes. Using the correct electric field their numerical computation of the individual particle trajectories provided a net supersonic wind, similar to the observed quiet day solar wind. The challenge, then, is to understand why the Lemaire – Scherer evaporation is so different from the traditional subsonic wind, keeping in mind that the electric field holds the ions and electrons together but gives no net lift.

The question is readily answered by (a) taking advantage of the smallness of the electron-proton mass ratio m/M and (b) noting that the large-scale bulk motion of a collisionless gas conforms to the familiar hydrodynamic equations. It turns out that, in the limit of small m/M, the electrons form an isothermal atmosphere extending to infinity, from which the supersonic outflow follows directly from the hydrodynamic equations.