Eos, Vol. 89, No. 9, 26 February 2008

MEETINGS

Kinetic and Hydrodynamic Models of the Solar Wind and Polar Wind

A Focus Group of the Solar-Terrestrial Interactions From Microscale to Global Models (STIMM-2) Workshop; Sinaia, Romania, 13 and 15 June 2007

PAGE 86

Following the publication of the first hydrodynamic models of the "solar wind" (supersonic neutral outstream of solar charged particles) in 1958, and the "solar breeze" (the evaporation of solar particles with a subsonic mean velocity) in 1960, scientists for decades have debated about which description most accurately models the acceleration of particles leaving the solar corona. This debate tends to pit magnetohydrodynamic oriented scientists against holders of a more kinetic description, particularly regarding the mechanisms by which ions and electrons evaporate from the solar corona. A rather similar controversy started in 1969 about hydrodynamic and kinetic modeling of the "polar wind," which streams out from the terrestrial polar caps.

Fortunately, hydrodynamic and kinetic modelers are starting to realize that their modeling efforts are complementary and not opposed. This realization fostered members in both orientations to convene in Sinaia, Romania, for a "modeling focus group" that took place during the Solar-Terrestrial Interactions From Microscale to Global Models (STIMM-2) meeting. The aims were (1) to review the approximations commonly used to model the supersonic plasma outflow from the solar corona and the polar caps, and (2) to outline the main advantages and limitations to using such approximations.

Solar wind models based on kinetic theory of collisionless plasma were reviewed by Hervé Lamy (Belgian Institute for Space Aeronomy (IASB), Brussels). Kinetic solutions for solar and polar wind that take into account collisions (Fokker-Planck) were presented by Viviane Pierrard (IASB and Centre for Space Radiation, Louvain-La-Neuve, Belgium). The kinetic treatment reveals the microscopic structure (how the velocities of particles are distributed, in a statistical sense) of the transition from a collision-dominated flow, at lower altitudes, to supersonic collisionless evaporation at high altitude.

Fokker-Planck solutions are obtained using appropriate mathematical methods (polynomial expansions and finite differences representations); they reveal the complex intermingling between the two plasma regimes. The key feature is the formation of a double-humped velocity distribution function (VDF). This type of VDF is quite different from the singly peaked distribution functions assumed (postulated) in multifluid approaches (Chapman-Enskog and Grad-like expansions, based on drifting/displaced Maxwellian VDFs). Double-humped VDFs are fundamental and invariable features of the microscopic structure of solar and polar wind plasma. They were first obtained for the polar wind using direct Monte Carlo simulations (DMCS), reviewed at Sinaia by Abdallah Barakat (Center for Atmospheric and Space Sciences, Utah State University, Logan). Two-peak VDFs were obtained for the solar wind with time-dependent hybrid models discussed at Sinaia by Sunny Tam (Massachusetts Institute of Technology and National Cheng Kung University, Taiwan). Time-dependent solutions and improved moment/fluid models were analyzed and discussed by Pierre-Louis Blelly (Centre National de la Recherche Scientifique, Orléans, France), and by Oystein Lie-Svensden (Norwegian Defense Research Establishment, Oslo), respectively.

The discussions of the focus group strengthened the conclusion that both kinetic and hydrodynamic approaches are important and together provide deeper insight into solar wind and polar wind acceleration. The kinetic description gives a detailed representation of the VDF as imparted by the gravitational, electric, and magnetic forces, by collisions and thermal escape. The spatial distributions and temporal evolutions of the macroscopic plasma variables can be derived more easily by integrating the hydrodynamic (Euler or five-moment) equations with amenable heat and momentum source terms. If the spatial or time-dependent distributions of higher-order moments of the VDF would be required, it is clear that the 16-moment equations should be integrated with appropriate initial and boundary conditions.

Workshop participants expect that models coupling the microscopic/kinetic description with a hydrodynamic treatment at large scales will ultimately offer more insight into the dynamics of an inherently multiscale system like solar and polar wind.

The presentations of all invited talks are available at http://iss30.nipne.ro/gpsm/ws_ro/stimm2/pres.php.

The full text of this meeting report can be found in the electronic supplement to this *Eos* issue (http://www.agu.org/eos_elec/).

—J. F. Lemaire, Belgian Institute for Space Aeronomy, Brussels; E-mail: lemaire@astr.ucl.ac.be; M. Echim, Institute for Space Sciences, Bucharest, Romania