Magneto-Fluid Coupling in Dynamic Finely Structured Solar Atmosphere – Theory and Simulation

N.L. Shatashvili, S. M. Mahajan, R. Miklaszewski, S.V. Mikeladze, K.I. Nikol'skaya , K.I. Sigua and Z. Yoshida.

We suggest that the interaction of the fluid and the magnetic aspects of a plasma may be a crucial element in creating the enormous diversity in the solar atmosphere - the loop-structures comprising the solar corona can be created by plasma up-flows (source of both mass and energy) interacting with ambient magnetic fields — the primary heating of these structures is caused by the viscous dissipation of the flow kinetic energy [1]. We show that for efficient loop formation, the primary up-flows of plasma in the chromosphere / transition region should be relatively cold and fast. During trapping and accumulation the locally supersonic up-flows thermalize (due to the dissipation of the short scale flow energy) leading to a bright and hot coronal structure. Calculations reveal that the sub-Alfvenic flows develop a substantial, spatially-varying short-scale component leading to "secondary heating". The emerging scenario, then, is: the coronal loop does not "happen" by the filling of some hypothetical virtual loop with hot gas, its formation and heating are simultaneous and the "loop" has no ontological priority to the flow - the dissipation of short–scale component of the velocity field may provide a primary (during very formation) and a secondary (supporting) heating for the coronal structure (closed, open). This picture pertains even for more violent events (flares, erupting prominences and CMEs).

Fast up-flows are generated when primary plasma flows (locally sub-Alfvénic) are accelerated while interacting with ambient arcade-like closed field structures. The relevant time scales, flow speeds (≥100 km/s), and amplification are dictated by the initial ion skin depth, and the local plasma β [2]. In the presence of dissipation, these up-flows play a fundamental role in the heating of the finely structured stellar atmospheres; their relevance to the solar wind is also obvious. The characteristics of a given structure of a finely structured solar atmosphere are determined by the initial and boundary conditions. "New" up-flows could be trapped by other structures with strong/weak magnetic fields and participate in creating different dynamical scenarios leading to: formation/heating of a new structure [1]; explosive events/prominences/CME eruption [3]; creation of a dynamic escape channel (providing important clues toward the creation of the solar wind); and wave-generation could also be triggered.

2.5- dimensional two-fluid dynamical code (containing the Hall term, heat flux, and ion viscosity) was used to study the flow dynamics and the magneto-fluid coupling in Solar Atmosphere. The numerical work is combined with simple analytical arguments to predict, and explain the essential features of the up-flow acceleration, the hot loop-formation/heating processes, and energy redistribution phenomena associated with the interaction of a primary plasma flow with closed field-line magnetic structures.

[1] S.M. Mahajan, R. Miklaszevski, K.I. Nikol'skaya & N.L. Shatashvili. Phys. Plasmas. 8, 1340 (2001).

[2] S.M. Mahajan, K.I. Nikol'skaya, N.L. Shatashvili and Z. Yoshida. ApJ, 576, L161, (2002); S.M. Mahajan,

N.L. Shatashvili, S.V. Mikeladze & K.I. Sigua. ApJ. 634, 419-425 (2005); Phys. Plasmas. 13, 062902 (2006).

[3] Z Yoshida, S.M. Mahajan, S. Ohsaki, M. Iqbal and N.L. Shatashvili Phys. Plasmas, 8, 2125 (2001);

S. Ohsaki, N.L.Shatashvili, Z. Yoshida and S.M. Mahajan. ApJ, 559, L61, (2001); 570, 395 (2002).