SOLAR MASS FLOW IN FINE-SCALE STRUCTURES

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Abstract. Observations of transient and steady velocities at chromospheric, transition region and coronal temperatures in the quiet Sun and coronal holes are reviewed. The relevance of fine-scale structures in governing the mass balance of the solar atmosphere is stressed. At present, a coherent picture of these mass flows does not exist. However, the current observational base of transition region and coronal velocity information is limited but should greatly improve with measurements from the SOHO satellite.

Key words: Sun – flows – velocities

1. Introduction

A major goal of the SOHO program will be to examine the transport of plasma through the solar atmosphere. HRTS spectra of Si IV formed in the transition region at $7 \times 10^4$ K, shown in Figure 1, graphically demonstrate the necessity of using high resolution data to understand the various flow patterns present on the sun. High velocity explosive events are denoted by the arrows but considerable variation on very small scales is also seen in the more typical profiles.

In the context of the SOHO mission, it is useful to try to understand the flows at various temperatures relative to the measured outflow in the solar wind. Table 1 presents estimates of the physical parameters needed to calculate the mass transfer through typical structures into the solar wind. With these it is possible to predict the steady-state velocities required to provide a mass flux equal to that in the solar wind. The net mass flow $F$ out of or into various structures is estimated by specifying the density $n$, the velocity $v$, the filling factor $f$, and the surface area $A$ of the volume through which the material passes: $F = nvfA$. The filling factor can be important in estimating the area when the emitting plasma does not completely fill the volume of a resolution element of the observing system. The values included in the table have been used with little regard for the fine-scale nature of many of the flows and it is assumed that the solar wind originates in the polar regions.

For the chromosphere we have used parameters characteristic of spicules which cover roughly 0.6% of the solar surface. At these temperatures, a spicular flow of 2 km s$^{-1}$ is needed to supply the mass flux requirements of the solar wind. Consequently the 25 km s$^{-1}$ flows in spicules are more than...
sufficient. The small fill factor in the transition region comes from the fact that features that appear to be resolved must consist of numerous subresolution structures that are sparsely distributed throughout the volume (Dere et al., 1987). The mass flux requirements for the transition region lead to velocities of 100 km s\(^{-1}\) and this presents a real problem. Velocities of this order are observed but they are associated with transient events and do not seem to carry sufficient mass. Observations of doppler shifts of coronal lines in coronal holes (Rottman et al., 1982) indicate velocities of the order required.

For transient eruptions and ejections, the net mass transfer from some solar region is evaluated with the expression \( F = (\int_{\Delta V} n dV) \cdot B \cdot A \). The integral is the total number of particles involved in each ejection, \( B \) is the birthrate (cm\(^{-2}\) s\(^{-1}\)) and \( A \) is the area (cm\(^2\)) of interest. Note that the velocity does not explicitly enter the equation.

### 1.1 Filling Factors

The filling factor can be a major unknown in determining the mass flux. It is the ratio of volume actually filled with emitting plasma compared to the total observed volume of the structure. Usually the filling factor is determined by comparing the intensities of lines produced with different sensitivities to the electron density in the source volume. For example, densities from a number of density sensitive line intensity pairs were compared with densities derived from emission measure-volume analyses.