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Large-scale Motion of Solar Filaments

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Abstract. Precise measurements of heliographic position of solar filaments were used for determination of the proper motion of solar filaments on the time-scale of days. The filaments have a tendency to make a shaking or waving of the external structure and to make a general movement of whole filament body, coinciding with the transport of the magnetic flux in the photosphere. The velocity scatter of individual measured points is about one order higher than the accuracy of measurements.

Key words. Sun—filaments—horizontal motions.

1. Introduction

The aim of our study was focused on the feasibility of obtaining detailed information about the horizontal displacement of filaments in solar atmosphere. According to the papers of Glackin (1974), Adams & Tang (1977), Brajša *et al.* (1991) and Japaridze & Gigolashvili (1992), there exists a large scatter of the zonal averages of zonal displacements. Another conclusion is that the rotation rate, derived for the solar filaments (Van Tend & Zwaan 1976), differs from rotation rate of solar photosphere. Both conclusions can be understood in terms of the radial dependence of solar rotation rate.

Filaments are vertically structured phenomena, projected on the solar disc. Although the outer structure of filaments appear to vary in time, long-lived reference points are absent. The 'seeing' dependent contrast of the H_α pictures is the source of uncertainties during the measurements on the contour and the feet of filaments. On the other hand, all filaments are located above the neutral line of largescale background magnetic fields. This shows that the position of the filament is above all determined by the distribution of magnetic field in the solar photosphere.

2. Results of measurements and conclusions

Heliographic position of the filaments is measured on the full disc H_α pictures taken at the Kanzelhöhe solar observatory (KHSO) during the regular patrol program. Our measuring procedure is based on the method of multiple measurements of contour points around the filament during the whole observing day. The initial data set contain about 170 thousand position measurements. The possible errors due to the projection (Roša *et al.* 1998) of the vertical structure on the sphere are much lower than the adopted error limit 100 ms^{-1}. Conversion to the heliographic co-ordinates was made according to the standard procedure, developed at KHSO. Each final velocity value is the best fit from zonal velocities, derived from more than 20 (maximum is 144) measurements per day. The most accurate values are determined with an error 20ms^{-1}.

The filament velocities are relative to Carrington reference system time dependent from day to day. Sometimes, the obtained velocities have a different magnitude on opposite sides of the filament and they change also in orientation in some cases. The different parts of the filament move with different velocity. Filaments make the shaking (oscillations) perpendicular to the filament axis or wave-like movement in direction of the filament axis on the time scale of one day. The average velocity of all points characterizes a general displacement of the whole filament body.

The latitude dependence of the zonal velocities of the filaments is presented in Fig. 1. The scatter plot of the zonal velocity values is combined with the set of fitted curves of the rotation laws, derived by different authors. The scatter of the curves is lower than 200 ms^{-1} and the scatter of the individual velocity values is nearly 800 ms^{-1}, although the internal accuracy of the measured points on the filament edge is only 100 ms^{-1}. From such differences, one can conclude that the possible axially symmetric flow is combined with the much more spatially variable velocity field, dependent on the latitude and longitude position on the solar surface. The great scatter of the individual velocity values is probably caused by small-scale displacements, related to the random walk of small-scale magnetic elements in solar photosphere.

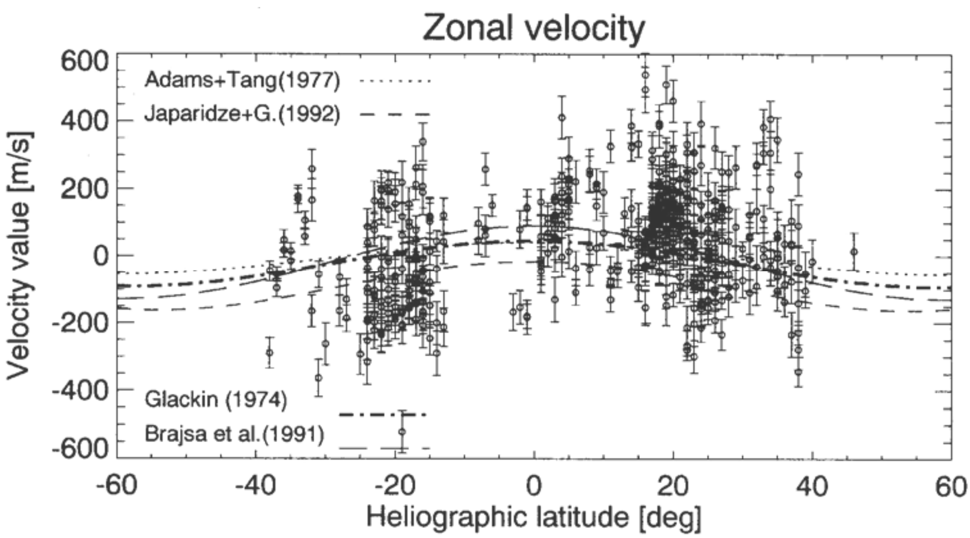

Figure 1. Latitude distribution of measured zonal and meridional velocities. Each measured value is drawn with the corresponding error bar. Only the measurements with errors lower than 100 ms^{-1} are used. The plot of the axially symmetric rotation rate curves, derived according to the different authors, demonstrate the presence of the non-axially symmetric component of the velocity field, oriented zonal or meridional.

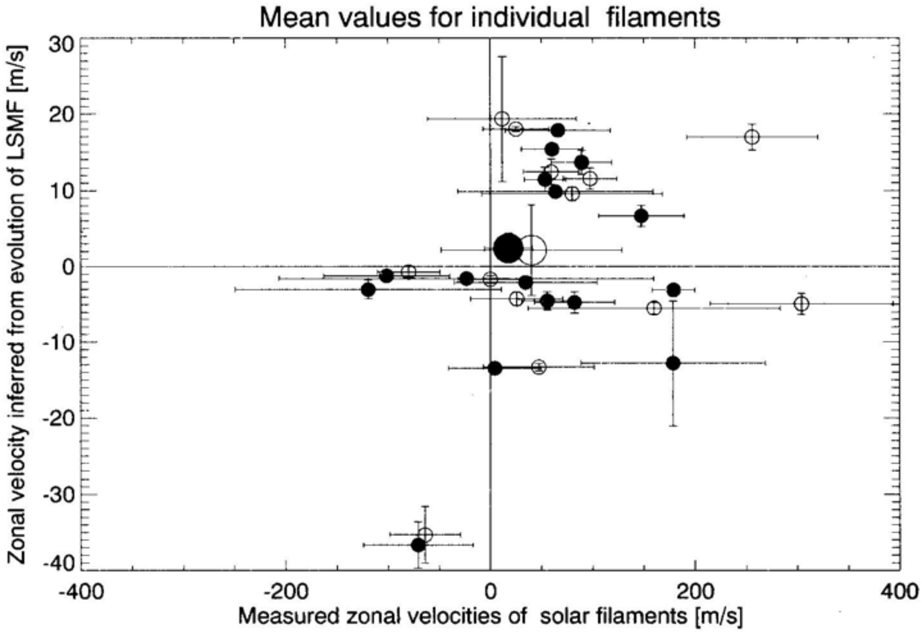

Figure 2. The scatter plot of the corresponding mean values of zonal velocities, as derived from filament displacements and from evolution of the large-scale magnetic field. The full and empty circles are related with the left and right contour of the filament, respectively. The pair of large circles show the position of the total averages of all measurements.

The plotted velocities relate with fine parts of the filaments, and do not characterise the filaments as whole.

Corresponding values of the zonal velocity field in the photosphere can be also derived from the temporal evolution of large-scale magnetic field. The magnetic data from Wilcox Solar Observatory of Stanford University were transformed into series of spherical harmonic functions with maximal principal index l= 12. Only the large scale long-lived structures were used. The velocity structure, responsible for the time evolution of large scale magnetic flux was inferred (Ambrož 1993, 2000) with help of the "Local correlation tracking" method (November, 1986) applied on the pair of consecutive magnetic synoptic charts.

Two arrays of corresponding velocities are plotted in Fig. 2. A substantial number of the plotted points is located mainly in the first and also in the third quadrant. It supports our assumption about the large-scale magnetic field displacement due to the large-scale velocity flow: Proper motions of filaments relate proportionally with a displacement of the magnetic inversion line. Except three points with extremely great errors, the error bars of other points penetrate into the third quadrant. Only one point cannot be explained by relationship with the large-scale velocity transport.

The use of filaments as "tracers" for detection of large-scale velocities is possible if the accuracy is better than 100 ms^{-1}. On the chart of horizontal velocities, inferred from the displacement of the magnetic flux, the filaments do not coincide with regions of the velocity extremes and are located in regions with high velocity gradient (zonal or meridional).

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