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Statistical Study of the Large-scale Structure of the Chromospheric Doppler Velocities from 2D-spectroscopy within the HeI 10830Å line

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Abstract. The map of the large-scale chromospheric Doppler velocities (V_{D}) on the solar disk, obtained from 2D-spectroscopy within the HeI 10830Å line for June 4 2002, is presented. Velocity field structures larger than the supergranulation cells are studied. Statistical relations between V_{D} and 1) the intensity in the core of the HeI 10830Å line and 2) the sign and strength of the longitudinal photospheric magnetic field are obtained and discussed.

HeI 10830Å is the strongest helium line in the solar spectrum, available from the Earth's surface. It is excited by radiative recombination of photoionized helium in the low-temperature ($T < 10000\,\mathrm{K}$) regions, and also by collisions in the high-temperature ($T > 20000\,\mathrm{K}$) regions (Milkey et al. 1973). According to Dupree et al. (1992), for Doppler mapping, this line has a number of advantages over the strong chromospheric lines of visible spectrum.

In our observations of the large-scale Doppler velocity field we are using the 2D spectroscopy method within the HeI 10830Å line (Kulagin & Kouprianov 2004). Since the final spatial resolution, after applying the median filter, is about $45''$, we concentrate on studying the structures that are larger than supergranulation cells. The central zone, namely 3/4 of the full solar disk area (i. e. $\cos\theta \geqslant 0.5$), was used in our statistical study.

As an example, we present here the Doppler shift map for June 4 2002 and compare it with other observational data. First, in Fig. 1 (*left*) we show the solar disk image approximately in the core of the HeI 10830Å line. This is indeed the third of five filtergrams used to obtain the Doppler shift map, which itself is shown in Fig. 1 (center). The maximum negative and positive Doppler velocity values seen in this map are about $-10\,\mathrm{km/s}$ and $+5\,\mathrm{km/s}$, respectively. In the right-hand part of Fig. 1, we give the photospheric longitudinal magnetic field map for the same date, obtained in FeI 8688Å at Kitt Peak.

In Fig. 2 (*left*), the statistical dependence of the Doppler velocity on the intensity in the HeI 10830Å core is given (cf. Fig. 1 *center* and *left*). Limb darkening is eliminated. The intensity I is normalized by the mean intensity I_0 in the central zone. One can see an evident correlation of these two quantities. Intensities $I/I_0 < 0.95$ correspond mainly to positive $V_{\mathrm{D}} \approx 1\ldots3\,\mathrm{km/s}$. Large negative Doppler velocities up to $-(8\ldots10)\,\mathrm{km/s}$ are observed mostly for intensities $I/I_0 > 1.025$. This fact is due to the decrease of the UV emission of corona, which is responsible for the helium excitation, above the coronal holes (see Milkey et al. 1973). This statistical correlation complements the observations of polar zones by Dupree et al. (1996). In agreement with their results, the plasma upflow regions could be considered as the sources of fast solar wind at the chromosphere level.

In Fig. 2 (*right*), the statistical relation between the Doppler velocity and the strength of the photospheric longitudinal magnetic field is presented. When obtaining this plot, we

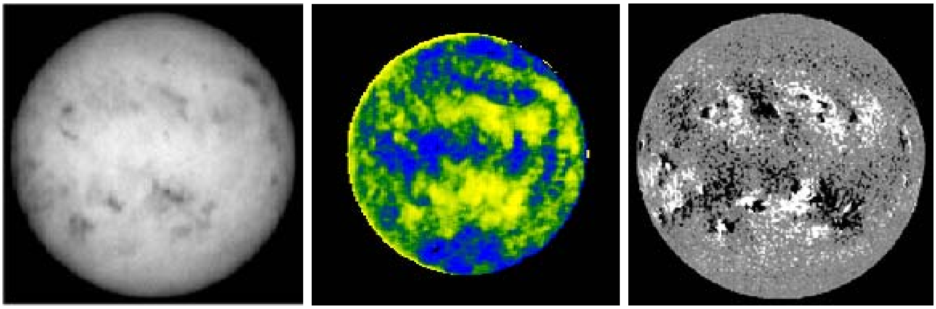

Figure 1. Solar disk images for June 4 2002: *left* – HeI 10830Å core; *center* – Doppler shift map: yellow (light in black-and-white) – positive velocities (downflow); blue (dark in black-and-white) – negative velocities (upflow); *right* – photospheric longitudinal magnetic fields

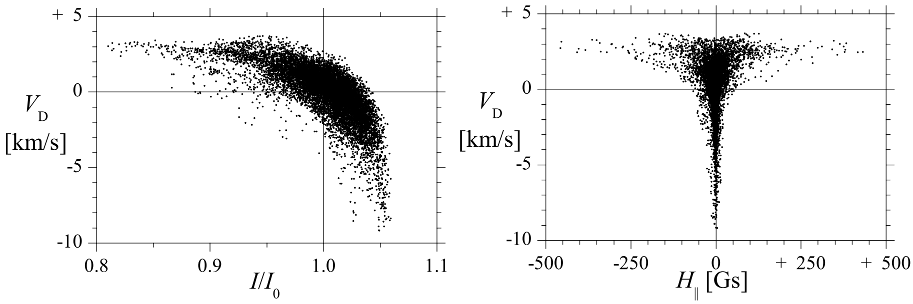

Figure 2. Doppler velocity versus normalized HeI 10830Å core intensity (*left*) and FeI 8688Å magnetic field strength (*right*)

applied the correction for non-simultaneity of the maps, since the Kitt Peak observations have been carried out 9.5 hours later than the ours. From the figure one can see that, while the areas of weak magnetic field strength ($|H_{||}| < 100$ Gs) can have the Doppler velocities in the whole $[-10$ km/s, $+5$ km/s$]$ range, the strong magnetic field areas ($|H_{||}| > 100$ Gs) correspond to the positive velocities only, regardless of the field sign.

It is shown by Kulagin & Kouprianov (2004) that 4% of the mass flux going out of the large-scale chromospheric structures is sufficient to produce the fast solar wind. We suppose that most of the remaining upflow mass flux is trapped by coronal magnetic arches and flows down to their footpoints in the active regions. This can explain the observed excess of falling plasma in the active regions (Brueckner 1980).

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