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OBSERVATIONS OF THE Ca II K LINE IN He10830A DARK POINTS ON AUGUST 3, 1985

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INTRODUCTION

In this paper we address the question: Is the velocity field of the solar chromosphere at the location of bright points (BP) different from that of the chromosphere in other regions of the sun? We have used dark points in He10830A spectroheliograms as ground-based proxy indicators of BP both in coronal holes and non-hole regions of the Sun, and we have obtained spectra of such points in the vicinity of the CaII K 3933A line. As a measure of differential chromospheric velocity, we have used the shift of the K line center relative to a nearby photospheric FeI line. We presume the K line center to be formed high in the chromosphere. We find that in helium dark points in general, the distribution of K line shifts is skewed towards the blue; in helium dark points which lie within coronal holes, the blueward skewing is more pronounced. Our results are of some interest in the context of spacecraft detections of outflows from BPs, and in the context of correlations of high speed solar wind streams from coronal holes.

On August 3, 1985 we observed five He-10830A dark points. Taken all together, the spectra of the five points that day show an average blue shift of 0.5 ±.3km/s with respect to the spectra from random points on the Sun. Four of the five points showed blue shifts of approximately 1 km/s, and the fifth point (observed late in the day and less reliable than the others) showed a red shift of approximately 1 km/s. The CaII K spectra on August 3 show a pattern of blue shifts that is consistent with the overall pattern observed in helium dark points observed on 25 days over a 14-month period (Holt and Mullan, 1986). The overall pattern for the fourteen months shows a small blue shift between 0.1 and 1.2 km/s for average spectra from He 10830A dark points which are not within coronal holes. There is also greater dispersion of the wavelength shifts than for spectra from random points. The points on Aug 3 were not within coronal holes. For dark points within coronal holes a fraction of the spectra, one-tenth, show a more pronounced blueshift--about 3.7 km/s.

DATA ACQUISITION: TARGET IDENTIFICATION

To identify coronal holes and BP, we use spectroheliograms taken in the light of HeI 10830A at the National Solar Observatory Vacuum

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Telescope on Kitt Peak (Livingston et al, 1976). The He 10830A image is relayed via telephone multiplexer (Colorado Video Expander 275) to the Swarthmore/Bartol Observatory, where the image is recorded digitally and also displayed on a video monitor. The resolution of the digital image is approximately 8 arcseconds per pixel.

On the He 10830A images, small dark points frequently are observed. Some lie within the coronal holes but their distribution is not obviously biased towards or away from coronal holes. During the Skylab mission, it was found that there was a close correlation between the He10830A dark points and BP (Harvey et al, 1974; Harvey and Sheeley, 1977). If Zirin's (1975) explanation of radiative pumping of the triplet level of HeI of weak He10830 absorption in coronal holes is correct, it would provide a natural explanation for enhanced absorption in He10830A in the chromosphere underneath a BP. However, even without knowing the details of the physical process, we adopt the empirical correlation (albeit imperfect) and assume that He10830A dark points are proxy indicators of BP. We use the He10830 images to identify not only BPs, but also to identify the coronal holes on any particular day.

The spectroheliograms are recorded once per day at Kitt Peak National Observatory, conditions permitting. Each spectroheliogram requires 45 minutes to complete. We receive the image within minutes after its completion. We identify the target points, calculate coordinates, and begin recording spectra usually within 30 minutes. The mean lifetimes of BPs are on the order of hours (Golub et al, 1977). The dark points on the HeI 10830 spectroheliograms have comparable lifetimes. On August 3, 1985 clouds delayed our observations for nearly three hours after we received the spectroheliogram. Spectra were recorded between 19:44 and 23:10 UT.

For each spectroheliogram, we find the center of the solar disk by triangulation from points on the circumference. We then locate our target points and determine their positions with respect to the center. Calculating from the solar tilt angles for each day, we then account for solar rotation at the latitude of each point during the time elapsed since that portion of the spectroheliogram was recorded. After scaling the image coordinates to match our telescope image guider, we position each point of interest on the entrance pinhole of our spectrometer. Our procedure for positioning the targets is uncertain by an amount which may be as large as about 10 arcsec. Most of the He 10830 dark points are of order 10-30 arcsec in size. We do not know whether or not the associated features in CaII K light would have the same size.

DATA ACQUISITION: CaK SPECTRA

The telescope is a 61-cm Cassegrain reflector mounted in a fixed equatorial position in a laboratory on top of a 50-foot building on the campus of Swarthmore College in Pennsylvania. The telescope is fed by a 91-cm polar heliostat mounted on the roof. This system provides a full solar image with a scale of 16 arcsec/mm, and the stepping motors permit guiding movements as small as 0.1 arcsec in right ascension and 1 arcsec in declination.

The telescope feeds a high resolution spectrum scanner (Wyller and Fay, 1972). For our observations, the spectrometer is used in the Czerny-Turner configuration, and the echelle grating is rotated by a stepping motor so as to sweep the spectrum past an exit slit, where it is detected by a cooled photomultiplier tube (EMI 9789A). The spectrometer entrance pinhole (0.1 mm) is chosen to allow a spatial resolution of 1.6 arcsec on the solar surface. However, local seeing conditions usually degrade the resolution to worse than 2 arcsec. The exit slit size (0.007 mm) is chosen so as to allow spectral line positions to be determined to approximately 0.02 A.

The spectrum is sampled by a PAR-SSR photon counter driven by a computer which also drives the grating motor. The spectrum is sampled at typically 100 points with an integration time of either 0.1 or 0.2 seconds per point, depending on light levels. The spectral scan covers about 2A in the vicinity of CaK (3933A). The FeI line at 3932.64A serves as a photospheric reference line, with respect to which we measure the position of the central absorption (K3) of the CaK line. In addition to spectra of BP candidates, we also record spectra in the same wavelength region of random points on the solar disk. These "random disk points" provide the references to which we compare the wavelength separations of the FeI and CaK lines of BP candidates. The random disk points are generally chosen to be away from regions of strong magnetic activity (as determined from daily magnetograms, also received from Kitt Peak). Preceding and following the recording of the spectra of each target point, we record a number of spectra, usually 6 or more, at random points on the solar disk.

DISCUSSION

From each spectrum we calculate the difference in wavelength between the CaII K minimum and FeI reference line. This wavelength separation is compared to the average of the separations in five random-point spectra taken most recently before and the next five random-point spectra taken after the target point spectrum. If the separation is smaller than this 10-point average, we say that the K minimum has been shifted to the blue with respect to the spectrum of a random point. Conversely, we take a larger separation to be evidence of red shift.

We recorded 47 spectra of BP on August 3, 1985 (Table 1.). The histogram of the wavelength shifts shows a small average wavelength shift of 0.5 ± 0.3 km/s and also an asymmetry toward the blue. Four of the five points have spectra showing blue shifts of approximately 1km/s, which is between 1 and 3 standard deviations for the four points. (A different σ is calculated for the reference random point spectra for each BP spectrum.) The fifth point shows a red shift of about 1km/s which is greater than 2σ from the mean of zero. This fifth point was taken late in the

Table 1.
CaK Spectra of He 10830A Solar Dark Points Aug 3, 1985 Swarthmore

Dark Point Location	Time (UT)		Shift
A N5.3E14.7	19:44-19:56	(8 spectra)	-.8km/sec±.3km/sec
	22:44-23:10	(7 spectra)	
B N18.1E20.2	20:11-20:19	(6 spectra)	-1±1km/sec
C N10.4E14.2	20:34-20:44	(5 spectra)	-1km/sec±1km/sec
D N14.1W21	20:57-21:14	(10 spectra)	-1.0-±.8km/sec
E S5.2W11.1	21:31-21:54	(11 spectra)	+1±.4km/sec

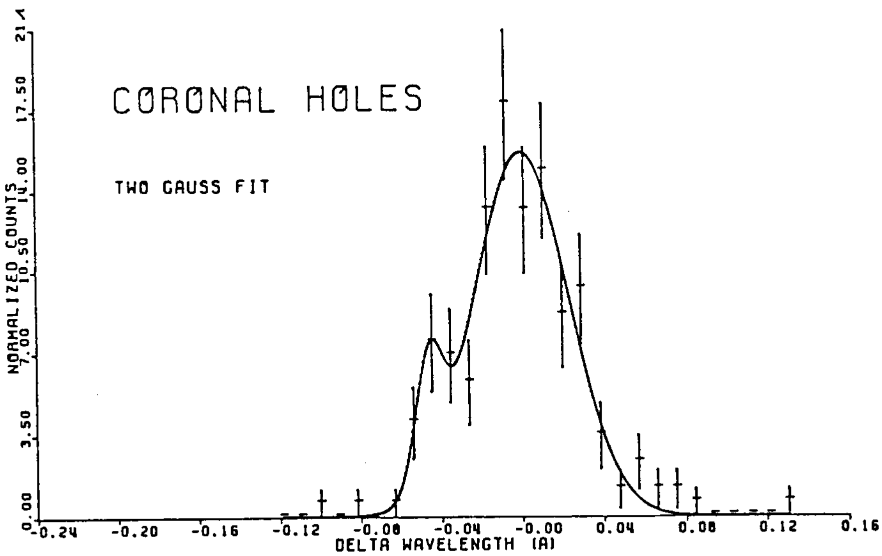

Fig. 1a. Wavelength shift of spectra of BP in coronal holes, relative to spectra of random points

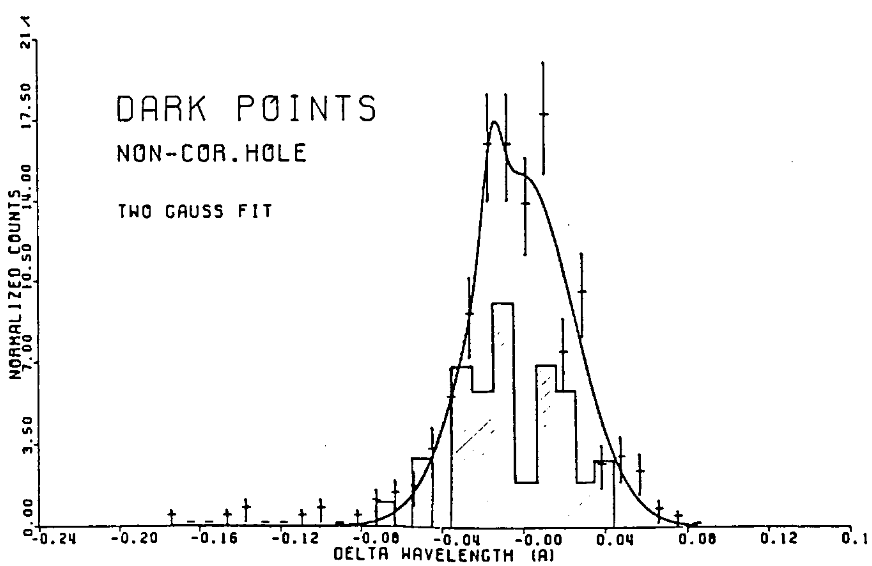

Fig. 1b. Wave length shift of spectra of BP not in coronal holes relative to spectra of random points. Superimposed is the histogram of the wavelengths from BP not in coronal holes observed Aug. 3, 1985

day, more than five and a half hours after the NSO 10830A spectroheliograms had been made, and it is less likely than the other points to have been a dark point.

In Fig.1a we show a two-gaussian curve fitted to the histogram of the wavelength shifts of the K minima of spectra taken of BP in coronal holes during the full 14-month observing program. In Fig. 1b we show a two gaussian fit to the histogram of wavelength shifts for BP not in coronal holes, and along with the smooth curve, we also show a histogram of K minima shifts for 47 spectra taken on August 3, 1985.

The skewness in the distributions is small. We are operating close to the limit of resolution of our system. However, it is noteworthy that the overall effect is a blueshift, especially in the BP's in coronal holes. For BP's not in coronal holes, like the samples of August 3, the blueshifts are less distinct. For BP's in coronal holes the amplitude of the blueshift is several kilometers per second. One should note that if material of chromospheric density moves outward at this velocity, it could supply the mass flux of the solar wind if this chromospheric flow were concentrated in a few dozen sources, each of diameter of a few arcsec.

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