MAGNETIC PROPERTIES OF CIV DOPPLER SHIFT PATTERNS

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Abstract. The relationship between Doppler shift patterns observed in the transition region and magnetic field patterns observed in the photosphere is studied using coaligned pairs of C IV Dopplergrams and Fe I magnetograms. Categories of magnetic features are defined — including neutral lines, unipolar regions, strong field regions, weak field regions, and magnetic boundaries — and from these, magnetic associations are determined for 159 $V_0$ lines separating areas of relative blueshift and redshift observed in and around active regions. The cases are subdivided on the basis of whether blueshifts or redshifts are observed on the side of the $V_0$ line nearest the solar limb.

Two main results are that $V_0$ lines associated with neutral lines tend to have limbward blueshifts, while $V_0$ lines associated with unipolar regions tend to have limbward redshifts. These and other results provide supportive evidence for the active region model proposed recently by Klimchuk, in which relative redshifts occur where strong vertical fields penetrate the surface, and relative blueshifts occur where these same fields have spread out to become horizontal. It is likely that the relative blueshifts correspond to absolute Doppler shifts of very small amplitude, possibly even absolute redshifts.

1. Introduction

One of the many interesting results to come from the Solar Maximum Mission was the discovery that C IV Doppler shifts are organized into well-defined patterns within active regions. Athay et al. (1982) and Athay, Gurman, and Henze (1983) were the first to study these patterns and noted their resemblance to line-of-sight magnetic polarity patterns seen in photospheric magnetograms. It was found that many $V_0$ lines, which are the lines of demarcation between adjacent areas of redshift and blueshift, correspond both in shape and approximate location with magnetic neutral lines. Only about half of the $V_0$ lines could be identified with neutral lines, however.

In a later study, we also examined the relationship between Doppler shift and magnetic field patterns (Klimchuk, 1987; hereafter Paper I). We used magnetogram images better suited for distinguishing field strength and found that redshifts tend to occur where the field is strong (> 100 G) and blueshifts tend to occur where the field is weak (< 100 G). Thus, many $V_0$ lines coincide approximately with the boundaries between strong and weak field. It was noted that a significant number of $V_0$ lines are well removed from regions of strong field, however.

It became apparent that a more detailed and systematic study of the relationship between C IV Doppler shift patterns and photospheric magnetic field patterns was needed. In this paper we report on the results of such a study.

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Our approach has been to identify and classify the variety of magnetic features with which \( \text{V}_0 \) lines are observed to coincide. Since nearly all C\textsc{iv} emission originates within 2–4 \( \times 10^3 \) km of the photosphere (Klimchuk, 1987), the coincident \( \text{V}_0 \) lines and magnetic features must be nearly vertically aligned (although projection effects could be important near the limb; see Athay and Klimchuk, 1987). We have concerned ourselves with both the polarity and the strength of the field, and we have paid careful attention to the redshift/blueshift orientation of the \( \text{V}_0 \) lines with respect to the solar limb. That is, we distinguish between \( \text{V}_0 \) lines in which there are redshifts on the side nearest the limb and \( \text{V}_0 \) lines in which there are blueshifts on the side nearest the limb. Athay et al. (1982) and Athay, Gurman, and Henze (1983) found evidence for a systematic trend in this regard; however, as we will see, the trend they identified was incorrect.

In Paper I we showed that the magnetic field vector is mainly vertical within strong field regions, but mainly horizontal within weak field regions (see also Malherbe et al., 1987). This led us to propose a simple active region model in which the vertical fields diverge very rapidly with height to become essentially horizontal in the low-lying surrounding areas. Such horizontal fields occur not only at the perimeters of active regions, but also in the weak field corridors that separate the opposite polarity parts of most active regions. The basic topology is in many ways similar to the canopy topology discussed earlier by Giovanelli (1980), Giovanelli and Jones (1982), Jones and Giovanelli (1983), and Jones (1985). One important consequence of the model is that \( \text{V}_0 \) lines should have a preferred Doppler shift orientation, depending on whether they overlie magnetic neutral lines or unipolar regions. This provides a useful test of the model and has been an additional motivation for this study.

2. Observations and Data Reduction

The Dopplergram and magnetogram data used for this study were described in detail in Paper I, and we therefore provide only a brief summary here. The Dopplergram observations were made in the 1548 Å resonance line of C\textsc{iv} by the Ultraviolet Spectrometer and Polarimeter (UVSP) on board the Solar Maximum Mission spacecraft. They indicate approximate Doppler shifts at a temperature of roughly 10\(^5\) K in the transition region. No absolute wavelength reference was available on UVSP, and it is customary to normalize the Dopplergrams such that the intensity-weighted average Doppler shift vanishes within each image. This is not equivalent to an absolute calibration, however, and absolute Doppler shifts are likely to be more than 5 km s\(^{-1}\) to the red of the normalized values (Klimchuk, 1986). Examples of normalized Dopplergrams are shown in Figures 1(a)–3(a). The images are 4′ on a side and have a spatial resolution of 3″. The magnitudes of the Doppler shifts are typically between 5 and 10 km s\(^{-1}\).

The magnetogram data are from the recently superseded 512-channel Babcock-type magnetograph at Kitt Peak. The measurements were made in the 8688 Å line of Fe\textsc{i} and indicate horizontally and vertically averaged line-of-sight fields within a 500 km thick layer of the middle to upper photosphere, just below the temperature minimum (Jones and Giovanelli, 1982). Although the measurements are usually discussed in terms of