Magnetic field polarity of quiescent prominences


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A statistical analysis of magnetographic data on quiescent solar prominences—the distributions of the magnitude of the longitudinal magnetic field \( B_l \) and of the angle between the long axis of the filament and the line of sight \( \beta \)—is carried out on the basis of observations with a Nikol'skii magnetograph. On the average, \( B_l \) ranges from 3 to 24 G. The epoch of a preminimum of solar activity (1984–1985) is characterized by several cases with \( B_l = 27–50 \) G. The distribution with respect to \( \beta \) is multimodal. A division of prominences into individual families in accordance with this multimodality and a subsequent comparison of the magnetic field polarities of the prominences and the underlying photosphere for each family individually leads to the conclusion that two systems of magnetic fields exist in prominences. The first system, oriented opposite to the underlying photospheric field, is directed at a 15° angle to the long axis of the filament and \( B_l \approx 15–18 \) G. The polarity of the second system of fields coincides with that of the underlying photospheric field and \( B_l \approx 5–7 \) G. The existence of large-scale motions along a filament at velocities exceeding 3 km/sec is noted.

INTRODUCTION

The important parameters that determine the choice of a model for prominences are the polarity and orientation of the magnetic field vector relative to the long axis of the filament (Anzer, 1979). If both components of the field vector (one of which is directed along the line of sight) located in the horizontal plane in a quiescent prominence (Athay et al., 1983; Leroy et al., 1984) lie on the same side of the filament, we say that the prominence is of the potential type, in which its field has the same direction as the underlying photospheric field, as occurs in the model of Kippenhahn and Schluter (1957). The opposite case, corresponding to the model of Kuperus and Raadu (1974), is called a prominence of the nonpotential type. A diagram illustrating the mutual orientation of the magnetic field vector components for prominences of the potential and nonpotential types has been given in Hirayama's (1985) review.

Can we evaluate the correctness of one model or the other on the basis of present-day measurements of magnetic fields in prominences, made with a spatial resolution of \( \approx 0.1^\circ \)? Earlier comparisons of the polarities of the prominence magnetic field and the underlying photospheric field (PF) are contradictory. According to Rust (1967), potential theories may be applied to most quiescent prominences. He has, however, noted cases of mixed polarity and of reversal of the sign of the field in prominences of the solar corona when observed successively at the east and west limbs. According to a "wideband" analysis of the Hanle effect by Bommier et al. (1985), prominences with a height \( h > 30,000 \) km \( (40^\circ) \) are of the nonpotential type: \( \alpha = -25^\circ, B = 5–10 \) G \((\alpha \) is the angle between the field direction and the filament axis). Prominences in the solar corona are also of this type. Prominences with \( h < 30,000 \) km, located mainly at active latitudes, are of the potential type, for which \( \alpha = +50^\circ \) and \( B = 20 \) G. A "narrow-band" analysis of the Hanle effect (Athay et al., 1983) indicates that the polarity of a prominence magnetic field can either coincide with or be opposite to the UPF polarity.

MAGNETIC FIELD POLARITY

To clarify the relationship between the polarities of prominence magnetic fields and the UPF, we have analyzed data obtained with a Nikol'skii magnetograph (Nikol'skii et al., 1984): filtergrams, the magnitude and sign of the longitudinal magnetic field component, the radial velocity, and the line profile. We selected 74 quiescent prominences using the following criteria: location far from active regions, the presence of vertical fine structure with a transverse size less than 1", and one must be able to trace the neutral lines of UPF polarity. On the disk such prominences appear as well-developed and often extended filaments with varying thickness along the length and fine structure across the filament. At the limb these prominences have a height exceeding 30" (Fig. 1).

The polarities were compared from synoptic maps published in Solar Geophysical Data and Solncehnye Dannye (Solar Data). Of the 69 prominences analyzed, we note that the polarities of the prominence magnetic field and the UPF differ in 42 of them, there is mixed polarity along seven of them, and in one case polarities were opposite in successive observations at the east and west limbs.

The picture becomes more orderly if we allow for the multimodality of the distributions of prominences with respect to the magnitude of the longitudinal magnetic field \( B_l \) (the mean value of the

FIG. 1. Distribution of quiescent prominences with respect to observed height in 1979–1985.
field along the prominence, corresponding to 9-30 individual measurements) and to the angle $\beta$ between the long axis of the filament and the line of sight, which it was possible to estimate in 61 cases. The accuracy in determining $\beta$ was 1-3 $.\text{G}$. In accordance with Student's criterion, the probabilities of the maxima at 3-6 and 9-12 $\text{G}$ in Fig. 2a are 85 and 98%, respectively. The probability of the minimum at 10-20$^\circ$ in Fig. 2b is 77%. These probabilities indicate the possible multimodality of the distributions, which prompted us to divide these prominences conditionally into four families, corresponding to different intervals of $\beta$ in Fig. 2b: A, B, C, and D. In Table I we give the mean values of the following physical parameters for each family: $\beta$, the angle between the long axis of the filament and the line of sight; $B_1$, the mean value of the longitudinal magnetic field; $A$, the heliolatitude; $\delta \lambda_1$, the width of the profile at the half-intensity level; $V_4$, the radial velocity; and $N$, the number of prominences of the potential (P) and nonpotential (NP) types.

An analysis of Table I leads to the conclusion that the type of prominence — potential (P) or nonpotential (NP) — is determined mainly by the location of the filament relative to the line of sight. Prominences that are observed from the side correspond to the potential type. Mixed polarity may be observed for prominences located at a 40-60$^\circ$ angle. From this we conclude that two systems of magnetic fields exist [Ishiba, 1968]. The first system is oriented predominantly along the filament, its polarity is opposite to that of the UPF polarity, and $B_1 \approx 16-19$. The second system is oriented across the filament, its polarity coincides with that of the UPF, and $B_1 \approx 5-7$.

### Table I

<table>
<thead>
<tr>
<th>Family</th>
<th>$\beta$</th>
<th>$B_1$</th>
<th>$\delta \lambda_1$</th>
<th>$V_4$</th>
<th>$N$</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>0-15</td>
<td>19</td>
<td>30-90</td>
<td>0.85</td>
<td>3</td>
</tr>
<tr>
<td>B</td>
<td>20-35</td>
<td>16</td>
<td>0-50</td>
<td>0.80</td>
<td>5</td>
</tr>
<tr>
<td>C</td>
<td>30-55</td>
<td>15</td>
<td>0-40</td>
<td>0.78</td>
<td>6</td>
</tr>
<tr>
<td>D</td>
<td>60-60</td>
<td>7</td>
<td>0-40</td>
<td>0.73</td>
<td>7</td>
</tr>
</tbody>
</table>

### Conclusion

Quiescent prominences are encountered at all heliolatitudes. Their distribution with respect to the magnitude of the longitudinal magnetic field one may note several cases with $B_1 \approx 27-50$ (Fig. 2a).

The distribution with respect to the angle between the long axis of the filament and the line of sight has predominant maxima. A comparison of the polarities of the prominence magnetic field and the UPF for individual families (see Table I) has enabled us to conclude that two systems of magnetic fields exist in a quiescent prominence. The first system is oriented at a 15$^\circ$ angle to the filament axis, its direction is opposite to that of the UPF, and $B_1 \approx 16-19$. The second system is oriented across the filament, the direction of the field coincides with that of the UPF, and $B_1 \approx 5-7$.

Radial velocity measurements indicate the existence of large-scale motions at velocities $\gtrsim 3$ km/sec, directed along a filament.

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