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Magnetic Fields in Solar Prominences — A Review

DAVID M. RUST

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13. ABSTRACT

The development and regular use of magnetographs designed especially for observations of magnetic fields in prominences has sparked new theoretical interest in the structure of these solar objects. Beginning with the work of Zirin and Severny (1961) and of Ioshpa (1962), our knowledge of magnetic fields in prominences has steadily improved. The 5 to 10 gauss fields of quiescent prominences closely resemble the model of Kippenhahn and Schlüter (1967), but the observations also show that active region prominences still present an unsolved problem in magnetohydrodynamic theory. Several interesting new models for active prominence field structure have been proposed recently. Most of these models envision force-free magnetic fields in the prominences, and there is some evidence for helical magnetic fields in eruptive prominences. Helical structure is a characteristic of many force-free field models. However, Rust and Roy (1971) have had some success in fitting current-free fields to loop prominences, which are frequently observed in the hours immediately following a major flare. The implications of these observations are discussed.

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Abstract

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Magnetic Fields in Solar Prominences—A Review

1. INTRODUCTION

Solar prominences may be divided into two categories: quiescent prominences and active prominences. In this report the term active prominences refers to those solar prominences that are closely associated with an active region, and those that may not be near an active region but do display rapid motions. All other solar prominences will be simply grouped under the heading quiescent prominences. From observations of the line-of-sight component of the magnetic field in prominences, it may even be possible to classify prominences as quiescent when the field is of the order of 10 gauss and active when the field is fifty gauss or more.

2. MAGNETIC FIELDS IN QUIESCENT PROMINENCES

While observing with the magnetograph at the Crimean Astrophysical Observatory, Zirin and Severny (1961) were the first to infer magnetic field intensities in prominences from measurements of the Zeeman effect. They found that active prominences have fields of 100 to 200 G, and that quiescent prominences exhibit no field above their 50-G measurement threshold. When Zirin returned to the High Altitude Observatory (H. A. O.) after his stay in the Crimea, he designed a

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magnetograph with modifications of the Babcock (1953) scheme so that his instrument was especially suited for measurements of prominence fields.

The H.A.O. instrument was built and first operated by Lee et al (1965), and since 1964 it has been used to measure the line-of-sight field in hundreds of prominences (most of them quiescent). During the last solar minimum, I found that quiescent prominences had a mean line-of-sight field of about 6 G (Rust, 1966). More recent and more extensive measurements by Harvey (1969) and by Tandberg-Hanssen (1970) have confirmed this result. Tandberg-Hanssen finds that two-thirds of the measurements of fields in quiescent prominences fall between 1 G and 8 G. Only very rarely does the field in a quiescent prominence exceed 30 G. Results that apparently conflict with these have been published by Kotov (1969), Smolkov (1970) and Ioshpa (1962, 1968). These Soviet observers, working at the Crimea, at IZMIRAN in Siberia, and at IZMIARAN in Moscow, report fields in quiescent prominences of the order of 100 G. Their results may be brought into accord with those of the H.A.O. observers if some allowance is made for inaccuracies in calibration and for selective effects. The advantage of using the H.A.O. magnetograph is that it may be calibrated on the emission lines of the prominences during observation. It is very insensitive to asymmetries and changes in the line profile from point to point, and has a noise level of only 2 G. The Soviet magnetographs were really designed for disk observations, and in most cases they must be calibrated on an absorption line. This leads to errors of up to 40 percent in the measurements of the Zeeman effect in prominence emission lines. Furthermore, the threshold for field detection in much of the work was 50 G, and it seems that there has been a tendency to publish the details of prominence observations in which the measured field exceeded the threshold. Despite these problems and the lack of statistics on quiescent prominence fields observed by the Soviet workers, the discrepancy cannot be ignored entirely. Recently, very careful observations by Smolkov (1970) at the Sayan Observatory in Siberia gave a field of up to 85 G in a polar prominence. His resolution was better than that of the H.A.O. observations. His noise level was below 10 G. I believe more measurements of the fields by other observatories would be in order. We should know whether the fields in quiescent prominences are about 8 G or about 80 G.

The direction and height variation of the field have been investigated by Rust (1967) and by Ioshpa (1968), Harvey (1969), Smolkov (1970) and by Tandberg-Hanssen (1970). Ioshpa studied results of observations with the IZMIRAN vector magnetograph (Ioshpa and Mogilevski, 1965). He concluded that the fields in prominences are predominantly horizontal, as indeed they must be to provide the necessary support against solar gravity. The field appears to be the same when measured in lines of differing excitation potential and optical depth (Tandberg-

Hanssen, 1970), and Harvey concludes that the fields lack fine structure on a scale of a few seconds of arc. Therefore the fields in the corona adjacent to quiescent prominences are probably about the same as the measured prominence fields, since any concentration or bunching of the fields in prominences on the scale of the observations (about 10 to 20 arcsec) should have been detected. Also, one might expect some correlation between the bunching of the field lines and the temperature conditions in different parts of the prominences, but no such correlation has been found (Harvey and Tandberg-Hanssen, 1968).

All observers find that the sign of the field in quiescent prominences agrees with that expected from potential field calculations. Figure 1 is from Smolkov's study of polar prominences. The fieldlines arise from regions of positive (or north) polarity in the photosphere, pass across the filament, and reenter the photosphere in regions of negative (or south) polarity. The straight arrow in the figure shows a line-of-sight passing through different sections of the prominence. Such a view may occasionally result in measurements indicating changing polarity in a prominence, but in reality the fields appear to approximate the simple configuration shown. The details of what exactly happens inside the filament is the principle problem remaining to be solved. Although the observations could be improved in resolution, and measurements of the vector field in prominences would be helpful, we already know quite a lot and the field seems ready for some detailed theoretical models. Figure 1 shows lines of force that have dips at the tops, as hypothesized by Kippenhahn and Schlüter (1957) 15 years ago, before any measurements were available. Figure 2 shows how closely one may simulate the fieldlines of the Kippenhahn and Schlüter model with potential fields. The dip at the tops is achieved by adding two weak poles to the photospheric fields just under the filament. While such quadrupolar fields have been observed occasionally, I do not think this configuration is common enough to clinch the argument for the Kippenhahn and Schlüter model. Although this simple model fits some of the observations quite well, especially the observation that the horizontal field intensity increases with height in quiescent prominences (Rust, 1967), other observations indicate that there is a substantial component of the field along the filament axis. Tandberg-Hanssen and Anzer (1970) examined the variation of the line-of-sight component of the field versus the orientation of filament axes. Assuming that there is no correlation between field intensity and field orientation in a filament, they concluded that the field direction within a filament forms an angle of only 15° with the long axis. Vector field observations by Ioshpa (1968) and by Harvey (1969) imply the same. The alignment of chromospheric fibrilles with filament axes also supports this result. The phenomenon has been most carefully studied by Ramsey and Smith (1966). Their results agree with Ioshpa's observation that the vector

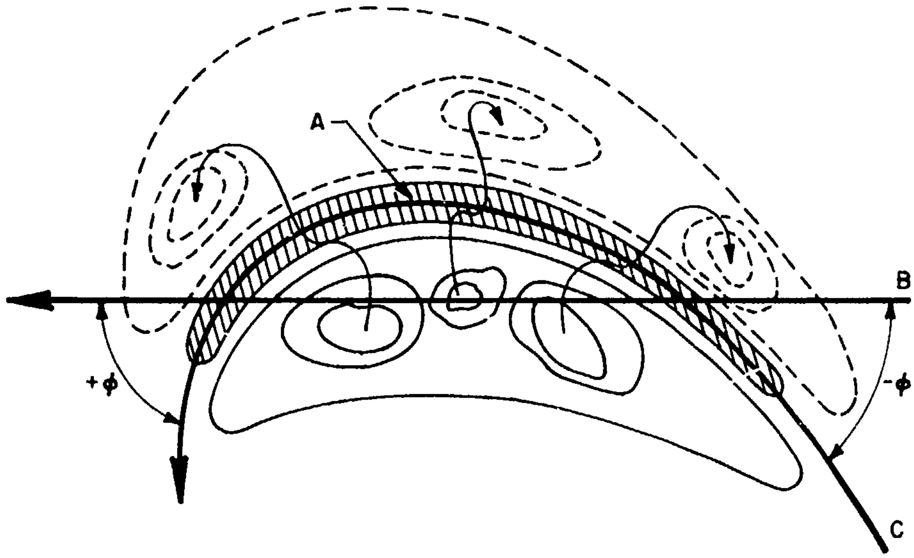

Figure 1. Lines of Force (with dips) Passing Through a Quiescent Filament. The straight arrow is a hypothetical line-of-sight for magnetic observations made on the limb

Figure 2. Computed Current-Free Fieldlines Capable of Supporting a Prominence

field seems to be most aligned with narrow, low-lying parts of filaments, especially where they bisect regions of intense field in sunspot groups. He finds, however, that the field in higher, more massive filaments runs predominantly across the filament. However, the vector magnetograph observations may not be reliable because of a number of radiative transfer effects that can produce linear polarization or reduce the polarization that one expects when a given magnetic field is present.

Ioshpa's result does have some confirmation in chromospheric pictures that show no trace of fine structure along the axes of aged quiescent filaments. Therefore, contrary to the assumption of Tandberg-Hanssen and Anzer (1970) that there is no correlation between field intensity and field direction in a filament, there is evidence for a relationship of the following sort for quiescent filaments:

$$\alpha = 90^{o}\left(\frac{B_{max} - B}{B_{max}}\right),$$

where α is the angle between the field and the filament axis, and B_{max} is about 30 G. B is the field in the filament. The above relation is not founded upon a detailed study of the data. It is only intended to be an instructive possibility suggested by the observations I have reviewed.

3. COMPARISONS BETWEEN QUIESCENT AND ACTIVE PROMINENCES

What is the range of field intensities in filaments? In particular, what is the minimum field that will support filament material? Malville (1968) studied my prominence field observations and compared the field intensity point-for-point with spectra he had taken simultaneously. He finds that the turbulent velocities in prominences increase with decreasing field. Prominences appear to be unstable when the field falls below 3 G. Other evidence for a minimum field of about 5 G comes from Harvey's (1969) statistical analysis of his many prominence observations. Figure 3 shows that under the assumption that field direction in filaments varies randomly, Harvey finds that there is a sharp drop in the number of prominences observed when the field is below 5 G. The field intensity distribution in active region prominences seems to have two peaks. One peak could correspond to those prominences that are really the same as non-active region prominences except that they happen to be near an active region. The other peak in the distribution is near 80 G. If asked to give a field value for active prominences, I think all observers would agree that 100 to 200 G is typical. It is primarily on the basis of the curves shown in Figure 3 that I think we may add to the various

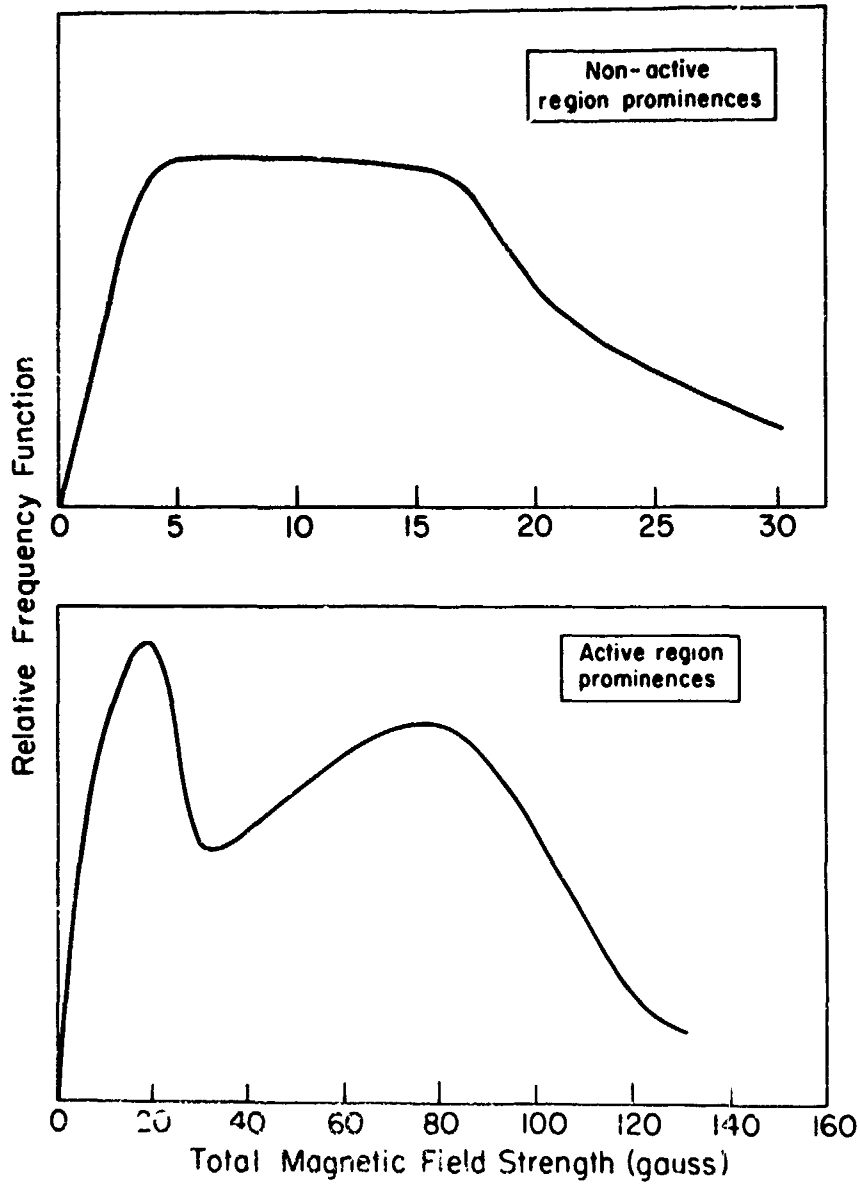

Figure 3. Frequency of Occurrence of Prominence Magnetic Field Intensities After Transformation of the Observations by the Assumption That the Field in the Prominences has No Preferred Direction

spectral and morphological classifications of prominences a magnetic one. Indeed, before field measurements were available, the standard wisdom was that quiescent prominences had to have fields of at least several gauss just to balance the kinetic energy of internal turbulence. Active prominences frequently have rapidly moving knots of material constrained to move along curved trajectories by magnetic fields. These were estimated long ago by Warwick (1957) to be several hundred gauss.

Direct observations suggest that the maximum field for filaments is 200 to 300 G. In high resolution H_α filtergrams, active region filaments frequently terminate at a point of very high field gradient. The filamentary material ceases to run along the neutral line bisecting the region. Its path is terminated by a series of dark fibrilles, similar to Bruzek's (1967) arch filaments. I think there is little doubt that the field is aligned with these fibrilles and that the magnetic intensity is at least several hundred gauss.

I have already discussed two kinds of quite different filaments The first was the thin, snake-like filament aligned with chromospheric fibrilles. These occur most frequently in active centers. The second kind is the massive filament with periodic thickness variations but no fine, linear structures running parallel with the axis. These occur in quiet areas of the solar surface. Figure 4 shows a dramatic, if uncommon, example of a third filament type. This one is composed of parallel fibrilles all crossing the long axis of the filament. Figure 5 further complicates the picture by reminding us that for filaments seen at the limb, the dominant structure is not horizontally this way or that way; it is vertical. High quality photographs of prominences always reveal this vertical structure in quiescents. The fact that we lack a comprehensive model of filaments is hardly surprising.

4. MODELS OF THE FIELDS IN PROMINENCES

Models more recent than that of Kippenhahn and Schlüter combine loops with dips at the top with an axial field which may or may not be twisted. Tandberg-Hanssen (1970) concludes that the fieldlines entering a filament on one side run along the axis for some distance before exiting on the other side. Similarly, Ioshpa (1968) proposes an empirical model in which a filament has an internal field along the axis and an external field of the Kippenhahn and Schlüter type to provide support against gravity. The internal field provides coherence and stability to a long filament. Nakagawa (1970) and Nakagawa and Malville (1969) have incorporated these ideas into a theoretical model. They show that the stability of the structure depends upon the angle between the internal and external

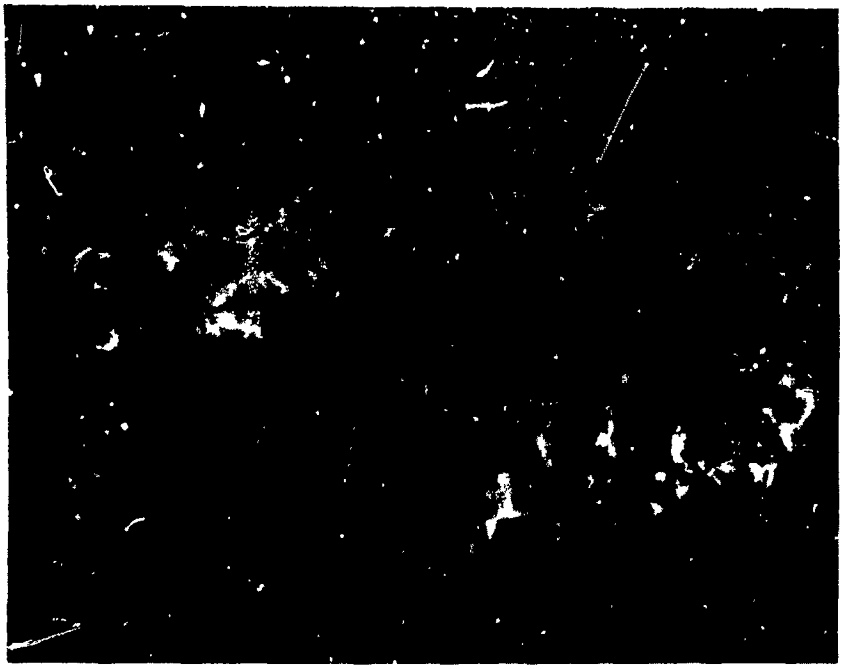

Figure 4. A Peculiar Filament Photographed on the Disk on 1967 July 29. Spectroheliogram in $H\alpha$ from the Mount Wilson Observatory

Figure 5. A Large Hedgerow Prominence Photographed in $H\alpha$ at the Vacuum Tower Telescope at Sacramento Peak Observatory by R. B. Dunn

fields. They attribute the periodic structure of filaments to instabilities to which a filament having a certain angle between internal and external field is susceptible. Anzer (1969) has completed a general study of stability requirements for fields supporting prominence material, and gives the following criteria for the spacial field variations

$$\left[B_z\right] \frac{dB_x}{dz} \geq 0 \; ; \qquad B_x \frac{d\left[B_z\right]}{dz} \leq 0 \, ,$$

where B_z is the vertical component of the field and B_x of the horizontal component perpendicular to the axis of the filament. Anzer's conditions are necessary and sufficient for stability. Unfortunately, the interesting model of Anzer and Tandberg-Hanssen (1970) does not meet these conditions. The subject of the theory of quiescent prominences has recently been reviewed by S. B. Pikel'ner (1971).

5. ACTIVE REGION PROMINENCES

On the subject of active region prominences, Jack Harvey's (1969) doctoral thesis is the most comprehensive description of observations. The median field that he found for active region prominences was 26 G. This is at least five times less than the median field found by Ioshpa, so here again there is a need for further observations by others to clarify the situation. Observations of active region prominence fields are in good agreement with potential field calculations of the polarity, but the field intensity is usually higher in the observations than in the calculations. Most measurements indicate that the principal component of the field is along the axis of active region filaments, and it is impossible to conjure up a plausible distribution of poles in the photosphere that will give this kind of field configuration with the current-free approximation. The lines of force for potential fields will always cross filaments, which lie between regions of oppositely directed field in the photosphere. Only for loop prominences, which commonly straddle the neutral line, does this result coincide nicely with our observations.

The strongest fields occurring in ordinary active region prominences are 200 to 300 G, and these are observed in bright knots. I used the word 'ordinary' because the dashes (Krat, 1968) that have been studied most extensively by the workers at Pulkovo (Prokofjeva, 1957; Shpitalnaja, 1964) must surely be termed extraordinary. Figure 6 shows some 'dashes' - very broad features in spectra of loop prominences. The 9 June 1959 spectrum includes some features that are nearly identical to dashes analyzed for Zeeman effect by Shpitalnaja and

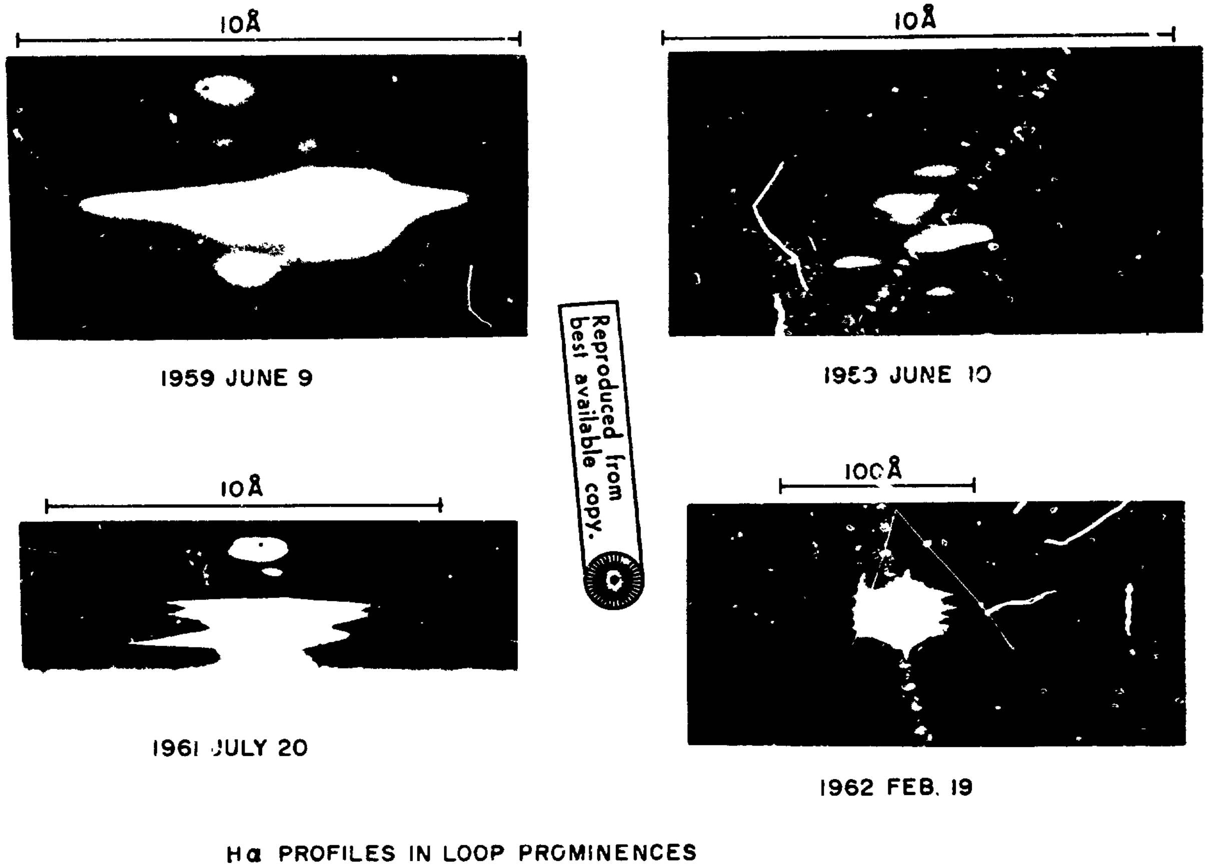

Figure 6. Typical 'Dash' Spectra as Foun. in Loop Prominences

Vyalshin (1970). They find that dashes live only about five minutes and exhibit magnetic field intensities up to 10000 G. Figure 7 shows profiles of the He D_3 line obtained at Pulkovo in two senses of circular polarization at two points of a large dash. The splitting corresponding to 5000 G is about 1/10 Å. Admittedly, the lines appear to be split by about that amount, but I do not understand why the profiles in the two polarizations are so different. The instrumental setup consisted of a quarter-wave plate in front of the spectrograph and a Wollaston prism in front of the spectrograph's focal plane. The authors admit that the grating is a strong polarizer. Now, if there is a significant variation in linear polarization across these D_3 profiles, which may be composites of profiles arising from independent prominence knots, then there would be an instrumental distortion of the resultant profiles. Linear polarization in dashes can be as high as 16 percent (Vyalshin and Shpitalnaja, 1969). If this polarization varies across the line profile it clouds the interpretation. I am voicing skepticism about these results not only because I do not understand the line profiles, but also because if the results are right, we probably are looking at pinch instabilities as claimed by Kuznetsov and Shpitalnaja (1970). This fact and the association between dashes and flares may be of tremendous importance in our research on flares. The indicated field varies from perhaps -5000 G to +10000 G within a few seconds of arc. This result presents a formidable challenge to other observers and to theoreticians. I am also disturbed by the field measurements of dashes described by Smolkov and Bashkirtsev (1970), who report that a field of 1400 G measured with the quarter-wave plate at one orientation became only 600 G when measured with the quarter-wave plate rotated by 90°. They estimate the error to be about 50 percent, due to the difficulty of determining the displacement of the broad profile. Fields as high as some of those reported do not occur even in sunspots. Some of the observations refer to prominences not associated with sunspot groups. This is clearly an area in which polarimeters, such as the one being constructed now at H.A.O., will be of great use.

On several occasions Harvey (private communication) found dash profiles in prominences he was observing at H.A.O. He did obtain measurements of the fields in them. The fields were about the same as other active feature fields - under 200 G. It is difficult to understand why the dashes failed to give a tremendous signal if the fields are really thousands of gauss.

6. ERUPTIVE PROMINENCE FIELDS

If the observations of fields in dashes are correct, then these objects have a very complicated field structure. For most prominences, this is not the case.

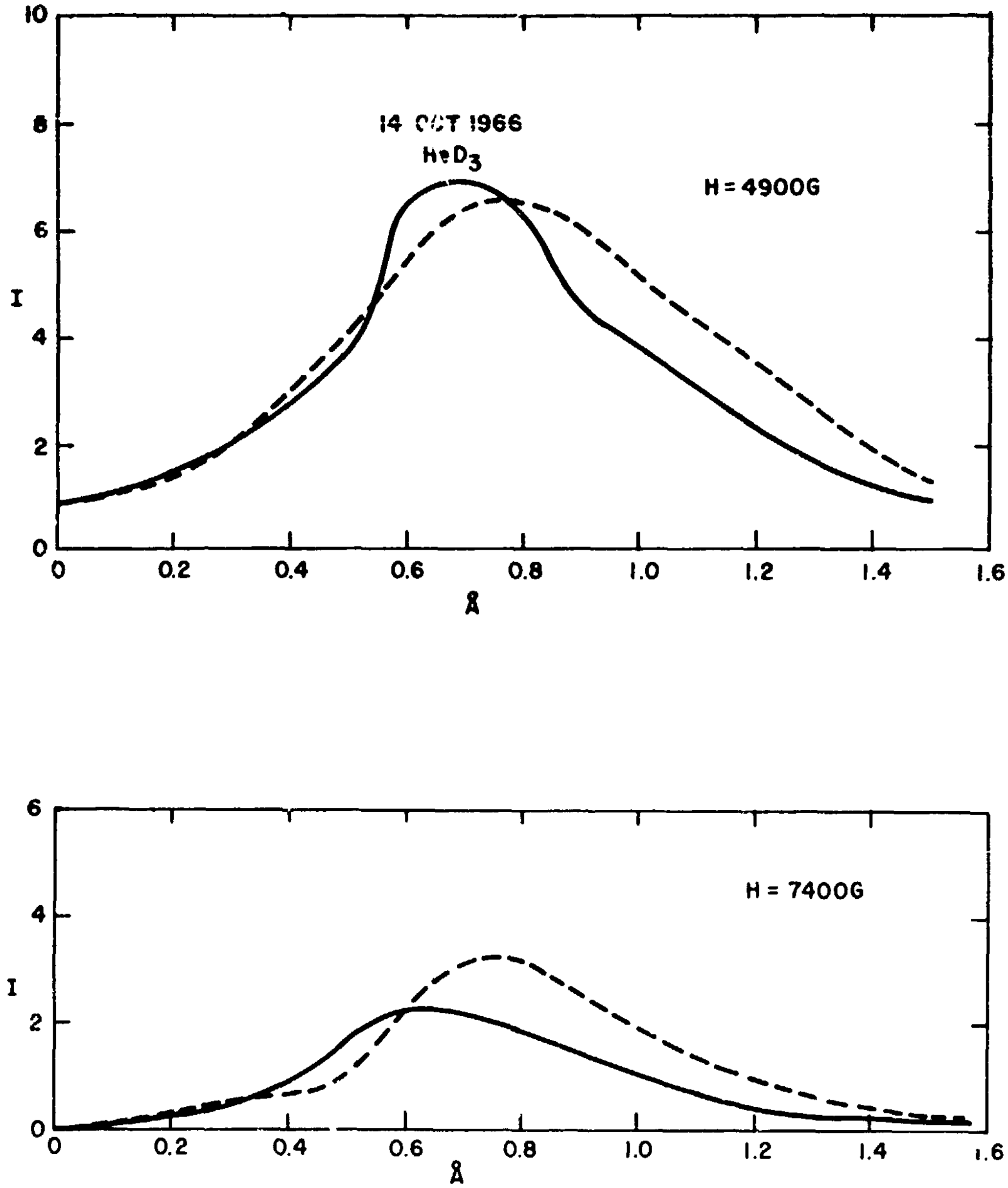

Figure 7. Microphotometer Tracings of Dash Profiles Made at the Pulkovo Observatory. (Top) Profiles from top 12 arcsec of a dash. (Bottom) Profiles from bottom 12 arsec of the same dash. Dashed lines denote profiles corresponding to the lower image. Solid lines denote profiles corresponding to the upper image

There are, however, two distinct kinds of prominences that do have complex fields; that is, fields which vary quite a lot in polarity and magnitude from point to point. Harvey (1969) reports that eruptive prominences have complex fields. Many observers (for example, Öhman, Hosinsky and Kusoffsky, 1968) have been telling us for some time that eruptives have helical structure that must be associated with similar, helical fields. Until recently, I was not a believer of these assertions, since I felt that a person could easily get a false impression of helical structure from viewing knots moving along many different loops in the line of sight. However, this summer J. Edgar Coleman of the Sacramento Peak Observatory obtained some very high quality pictures and spectra of the vertical helix shown in Figure 8. Although stable objects have not been proven to have helical fields, there seems to be no question that some eruptive prominence fields, at least, are helical. The observed field intensity in eruptives decreases with height, contrary to the trend in quiescents.

7. SURGES

A most difficult class of prominence to understand is the surge. At first glance it would seem very easy to understand them because they unquestionably follow fieldlines established by photospheric sources. However, Harvey (1969) finds that they have a complex field structure, as judged from the noise in his records. He also finds surge fields to be about 35 G on the average, and that they tend to be stronger when associated with small line-of-sight velocities and weaker when associated with large line-of-sight velocities. Large surges have weak fields and small surges have strong fields. This correlation could be due to a projection effect, assuming that the surge field is parallel with the direction of the motion. But this explanation conflicts with the inverse correlation between field intensity and line-of-sight velocity. Harvey finds that homologous surges have different field intensities. Ioshpa (1962) measured fields in a surge that varied from 200 G to -800 G.

Figure 9 shows a veil of surges apparently coming from the light bridge of the large, double-umbra sunspot of 24 to 29 July 1971. This spot was the only sizeable spot to appear in the region, which was classified as αp by the Mt. Wilson observers. The field on both sides of the light bridge is the same. Figure 10 is a large scale picture of the spot, taken with the Vacuum Tower Telescope at Sacramento Peak. The unusual feature of the light bridge is that it is decorated by a chain of bright faculae. Is it possible that these faculae and the surge fingers apparently originating in them indicate the presence of a very complex and fine scale structure along the light bridge? Unfortunately, we do not have high

Figure 8. A Large Eruptive Prominence Showing Helical Structure. This event took place on 16 July 1971 (photographed by E. Coleman at Sacramento Peak)

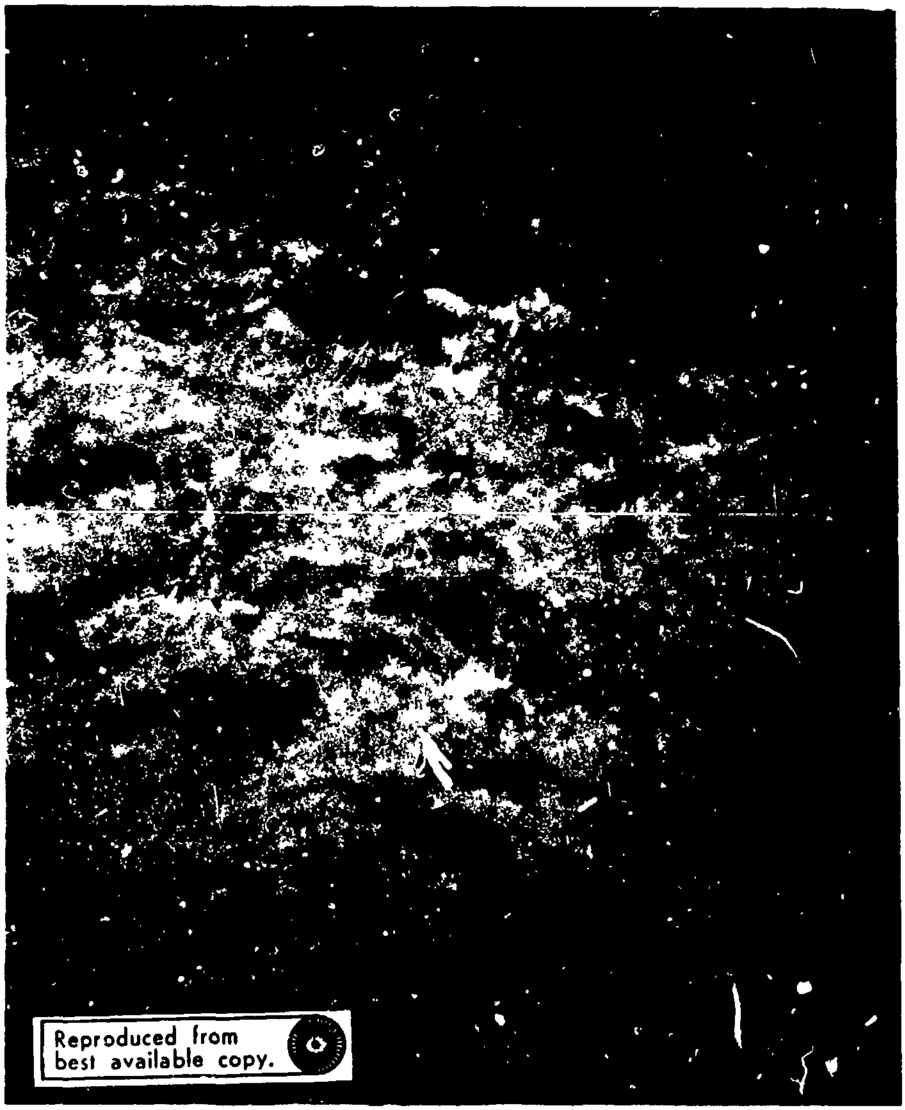

Figure 9. An Unusual Surge, or Veil of Surges, as Photographed in Hα. This photograph was taken on 25 July 1971 at Sacramento Peak by J. -R. Roy

Figure 10. A White-Light Photograph of the Spot From Which the Surge Shown in the Previous Figure Arose. Note that the surge originates on the light bridge spanning the spot. Feet of the surge threads seem to arise from the bright faculae along the bridge

resolution magnetic observations of this spot. To conclude the discussion of surges, then, as I have shown earlier (Rust, 1968), they follow fieldlines that can be drawn even with the current-free approximation, but their internal field structure must be far from simple.

8. LOOP PROMINENCES

Loops occur above active regions after flares, and can be immediately associated with strong magnetic fields because they join spots of opposite polarity and look like plasma-filled fieldlines. Bumba and Kleczek (1961) found that a particular set of loops they studied could be fitted nicely to the field of a dipole rooted in the underlying photosphere. Harvey (1969) computed potential fields to compare with measured loop fields and concluded that the agreement in shape is good, but the potential fields he found were too weak by about a factor of two. Since that time there has been a general recognition that the photospheric field measurements carried out with Babcock-type magnetographs operating on the 5250 Å line of iron have led to underestimation of the photospheric source fields (Harvey and Livingston, 1969). Using the Doppler-Zeeman Analyzer (DZA) (Dunn, 1971) at the Sacramento Peak Observatory, Rust and Roy (1971) measured photospheric fields in 5250 Å and used the computer program devised by Schmidt (1964) to compute current-free fieldlines. Before making any comparisons, we eliminated from consideration any region that had changed significantly from center to limb and we checked the measured fields in sunspots against those reported by the Mt. Wilson observers. Figure 11 shows our comparison of computed loops with the great loop system of 18 November 1968. The fit is excellent everywhere, except for a small difference in the inclination of the loops, as observed and as calculated, on the edge of the frame. Probably this may be explained as an edge effect, arising from the fact that outside the plane of observation we assumed that there is no field in the photosphere. The loops are about 9000 km high at the center. The field there equals 11 gauss, while the field intensity at the tops of the side loops is 4 G. Hyder (1964) measured fields of 45 to 60 G at a height of 45000 km in a set of loops. Harvey (1969) measured a 25 G field at 50000 km in another loop. These observations agree very well with our calculations, and they confirm our opinion that the DZA underestimates the field by less than 30 percent.

Figure 12 shows the loops as seen from directly above the active center. At the top of the picture, the loops swing out above the region included in the magnetogram. If there had been some positive field there instead of the zero field we assumed, those lines of force would not have been so inclined toward the surface

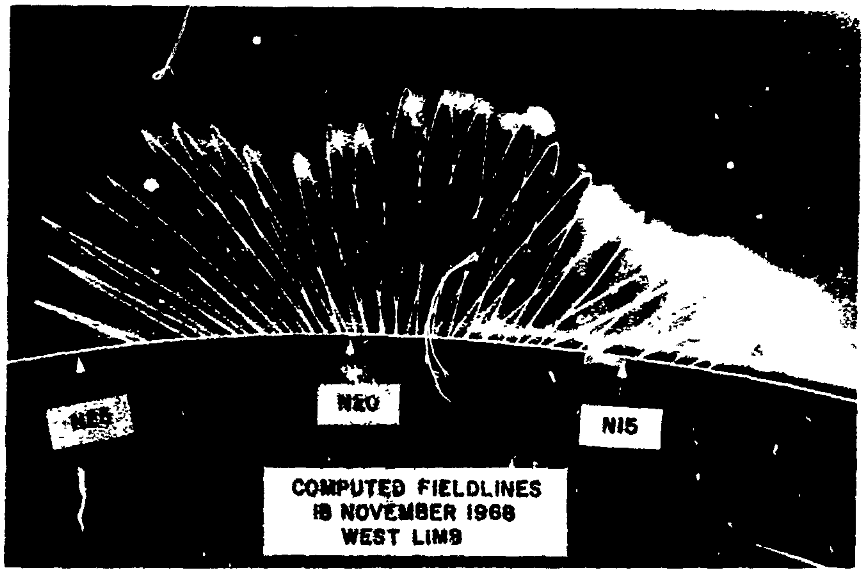

Figure 11. Comparison Between the Computed Fieldlines for the 18 November 1968, X-Ray Flare and Loops and the Green-Line Corona as Photographed by H. L. DeMastus at Sacramento Peak

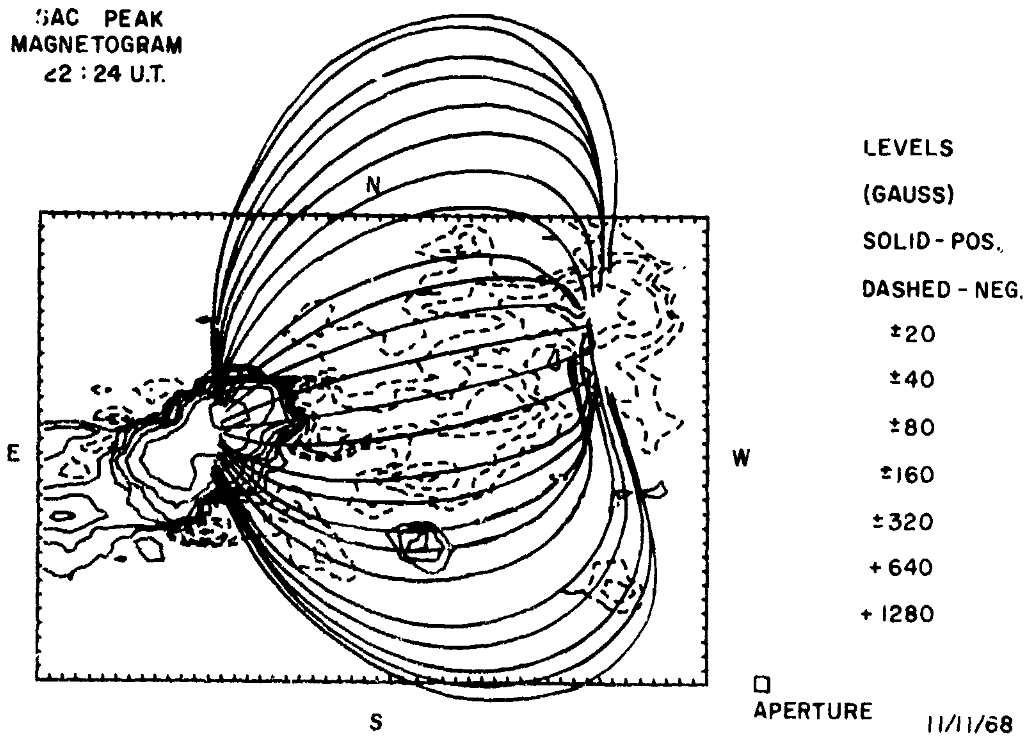

Figure 12. The Computed Fieldlines of the Previous Figure as Seen in Projection on the Disk

and would have fit the observations better. We feel that this failure to fit exactly to the observed structures derives from this limitation in the measurements, and that it is not due to currents in the corona. Notice that the lines of force fall in two ribbons which flank the line dividing magnetic polarities. Roy (1971) has recently obtained films from the Catania Observatory that show the two-ribbon flare underlying the loops. The films also show the development of the loops from early stages in the flare. At each stage in the development, from the time when the loops were only about 10 arcsec high, Roy computed a new set of fieldlines with footpoints separating in time. Within the limited resolution of the observations, it seems the loops are well represented by current-free fields from the time when they are only 7000 km high to the time when they are 145000 km high, 24 hours after the flare.

Occasionally, loop prominences are visible in projection against the disk. Figure 13 is a photograph of loops connecting the ribbons of a class 2 flare on 14 May 1971. This picture and the following ones were taken by R. B. Dunn with the Tower Telescope (Dunn, 1969) at Sacramento Peak. The loops show up very nicely, they cross the neutral line dividing the magnetic poles of the region, and they arch above the typical active region filament, which seems unperturbed by the enormous flare going on around it. Figure 14 shows the loops as seen in the red wing of the H_α line. The material is streaming down into the flare ribbons. Mr. Ray Moses (private communication) has traced the evolution of the loops through the course of the flare. He finds that as they age and grow higher they also change their orientation with respect to the neutral line, making an angle of about 50° with it. When the loops were fully developed, they stood at about 90° to the neutral line. The higher the loops go, the closer they appear to approach a current-free configuration.

The behavior of loop prominences suggests that they outline the unstressed fields above an active region after a flare has relieved the earlier, stressed fields. Attempts to fit potential fields to low-lying active region prominences generally have not been successful. Attempts to fit coronal arches above an active region have not yielded convincing results except when the fit is made to the post-flare coronal condensation (Rust and Roy, 1971).

As a final note on the loop prominences, we turn to the loop system photographed in H_α and in the D_3 line of helium at Sacramento Peak on 26 June 1971 (see Figure 15). A strong X-ray burst at 0959 U. T. probably gave the only indication of the flare that the loops followed. The loops occurred over McMath Region 11402 on the East limb at 8° south of the solar equator. Our films show simultaneous H_α and D_3 images of the loops from 1259 U. T. to 1457 U. T.

Although this event was not a 'classic' loop event, and in fact some observers may prefer to call it coronal rain, there are many features shown in the film that

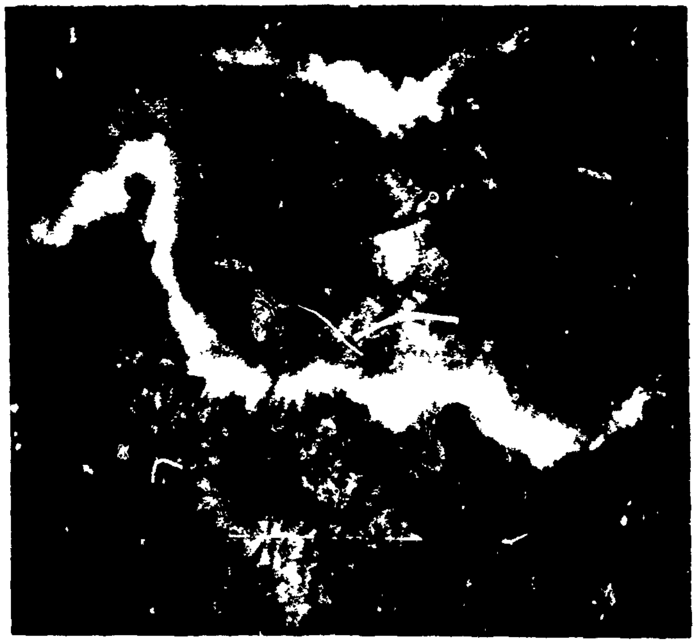

Figure 13. A Vacuum Tower Telescope Photograph of the Class 2 Flare of 14 May 1971. Notice the thin, dark loops connecting the two bright flare ribbons. Photo courtesy of R. B. Dunn

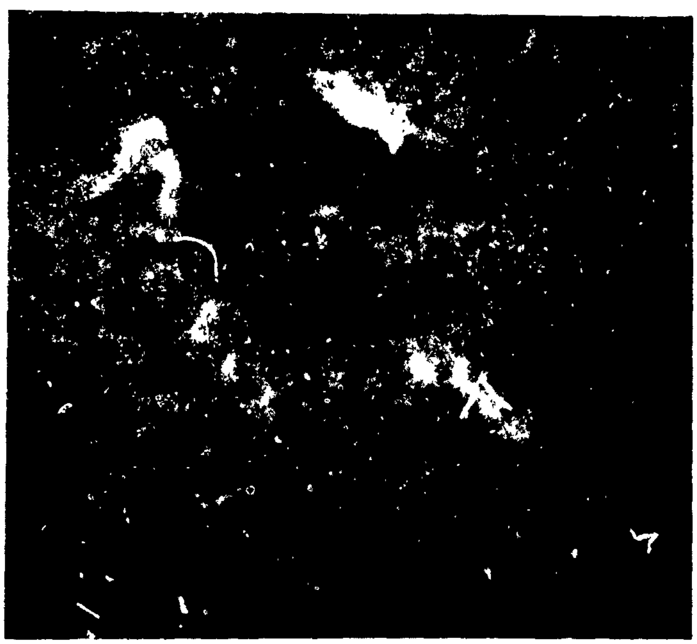

Figure 14. Photograph Showing the Same Loops as the Previous Figure Except That This Image in the Red Wing of Hα Shows the Downward-Moving Material in the Loops. The bright flare ribbons may be caused by the energy released when the falling material strikes the chromosphere. Photo courtesy of R. B. Dunn

Figure 15. Loops of 26 June 1971 as Photographed in Hα (top) and in the D_3 Line of Helium (Bottom). Photos taken with the 40-cm coronagraph at Sacramento Pe:k by L. B. Gilliam

are representative of loop events. The highest loops are about 45000 km above the chromosphere. Most of the material appears to be condensing out of the corona at the tops of arched magnetic field lines. However, condensation may also occur heavily along the legs of the loops. The passband of the hydrogen filter was 1 Å, while the passband of the helium filter was 3 Å. Keeping this fact in mind while noticing the identical appearance of the loops in the two images (H_α and D_3), one becomes convinced that the condensations along the legs of the loops and elsewhere are truly occurring where they appear to be. That is, they are not simply the effect produced by material moving into the passband of the filter. In general, the D_3 image is identical to the H_α image except that it is fainter. Typical times for a condensation to develop from a tiny point to full size lie between three and ten minutes. Whatever mechanism is causing the condensation seems to act over large distances at several points on different fieldlines simultaneously.

In viewing the film as a movie, one finds an exception to the rule that material always rains downward. One blob of material in the midst of the loops is accelerated upwards. It appears to pulsate in brightness as it moves along a path with changing curvature. The velocity of the blob in the plane of the sky varies from about 40 to 130 km/sec. A preliminary analysis of the motion indicates that the blob could be moving at constant velocity along a helical fieldline. The pulsation in brightness is much more pronounced in the H_α image than in the D_3 image, which was obtained with a passband three times as wide. Thus, the brightness variations could be due to varying velocity along the line of sight. This particular loop region, then, may be demonstrating both the typical post-flare loops which fit potential fields quite well and unstable, helical fields, which are frequently associated with eruptive prominences. Unfortunately, the fields in the active region underneath the loops were changing rapidly from the East limb appearance to the center of the disk. Potential field calculations based upon center-of-the-disk observations of the region would be meaningless for comparison with this limb event.

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