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The key accomplishments from the research during FY 1991 were:

(1) the finding by K. Harvey and P. Foukal that the photospheric network is the third significant component that accounts for observed variations in the total solar irradiance; (The first previously recognized component is the temporary decreases due to sunspots and the second is variation due to plage brightness.)

(2) the K. Harvey results from studying magnetic flux over the solar cycle: (a) increases in the total magnetic flux by a factor of 4 to 5 from solar minimum to solar maximum with the variation from active regions flux (>25 Gauss) by more than a factor of 20 from cycle minimum to maximum while the variation from quiet sun fields (<25 Gauss) was no more than a factor of 2. (b) interpretation of (a) as meaning that more than 70% of the magnetic flux in active regions disappears without dispersing, (c) slower decreases of weak fields in phase with the decrease in strong fields, and (d) irregular pulses of new flux which appear to be primarily associated with active region complexes;

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(3) the finding by K. Harvey and S. Martin of no evidence for the beginning of solar cycle 23 during the spring of 1991;

(4) the successful recording by S. Martin (at Big Bear Solar Observatory) and J. Zirker (Sacramento Peak Observatory) of the formation of a filament during an observing run from 28 Aug. to 1 Sep. 1991; the development of a new conceptual model for the formation of filaments by S. Martin which also concurrently accounts for the cancellation of magnetic fields; her conclusion is that magnetic reconnection at the photosphere explains cancellation as the upward transport of magnetic flux from the photosphere into the corona; there the flux is stored and temporarily stabilized primarily as horizontal field providing sites where mass concurrently accumulates to form filaments;

(5) the development by S. Martin and S.H.B. Livi of a scenario relating cancelling magnetic fields to the occurrence of solar flares via the intermediate stage of filament formation; they conclude that the storage of magnetic flux at the sites of filaments is a one-way process which eventually results in the expansion and upward motion of coronal magnetic fields until the configuration becomes unstable; the moment of instability initiates rapid magnetic reconnection in the corona and results in the simultaneous occurence of a coronal mass ejection, the eruption of the filament magnetic field, and a flare.

(6) the recognition by S. Martin that the H-alpha fibril structure around filaments consists of two types of patterns: right-oriented and left-oriented, which are related to the direction of the magnetic field along the long axes of filaments; S. Martin directed R. Bilmoria in a student summer project in which Bilimoria found the first indications of a division of the two types of filaments by hemisphere; the hemispheric pattern applied to quiescent filaments with left-oriented ones in the northern hemisphere and right-oriented ones in the southern hemisphere; a similar partial division by hemisphere was found for filaments on the border of active regions and while no hemipsheric pattern was found for filaments in active regions.

(7) successful imaging experiments in H-alpha by S. Martin and D. Rust using $LiNbO_3$ Fabry-Perot etalons provided by D. Rust; They demonstated that the etalons can yield images of a quality equal or superior to the best brirefringent filters now in use at Big Bear Solar Observatory.

(8) the beginning of plans for the Solar Cycle Workshop at Sacramento Peak and the selection of K. Harvey as Chairperson of the Organizing Committee.

LARGE-SCALE VELOCITY FIELDS AND SMALL-SCALE MAGNETIC FIELDS DURING THE MAXIMUM OF SOLAR CYCLE 22

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1.0 RESEARCH OBJECTIVES

During FY 1991, our primary objective has been to learn about the distribution of magnetic flux in the form of bipolar regions over the solar cycle. Our emphasis has been on the small-scale end of the spectrum of active regions because least is known about the small-scale magnetic flux. A facit of the solar cycle that has become recognized as important is the degree of temporal overlap of successive cycles. A third important arena of research is on the clustering of active regions into complexes of activity. Such clustering apparently does not occur by chance; the recurrence of new active regions at sites of pre-existing bipoles occurs 30-40 times more frequently than expected if the regions were distributed randomly in longitude. We seek to understand this clustering.

Secondary manifestations of the solar cycle are also important to acquiring a comprehensive view. The secondary phenomena that we have concentrated on during FY1991 has been the formation and eruption of filaments.

A third objective is to acquire new data on some facit of the solar cycle. During FY1991, we continued our systematic search for the beginning of solar cycle 23. We also continued to look for active regions which might display large-scale velocity patterns of the type discovered by Marquette and Martin (1988, Solar Phys. 121, 215).

2.0 SUMMARY OF ACCOMPLISHMENTS - FY 1991

2.1 CHANGES IN THE PHOTOSPHERIC MAGNEIC NETWORK AS RELATED TO 11 YEAR VARIATIONS IN THE TOTAL SOLAR IRRADIANCE

The largest changes in the total solar irradiance over the 11 year solar cycle are explained first by changes in the area and disk position of large sunspots and second by bright faculae corresponding to strong magnetic fields (reviews by Chapman 1988, Hudson 1989, Foukal 1990). However, there is a remaining component of the irradiance variations that could not be accounted for by the active regions. Various investigators suggested that measures of the photospheric network such as area, brightness and latitude distribution might account for the remaining 11 year variations (Foukal and Lean 1988, Schatten 1988, Livingston and White 1988, Willson and Hudson 1988).

K. Harvey, P. Foukal and F. Hill collaborated in a study to see if the amplitude of the photospheric magnetic network was sufficient to explain the remaining 11 year variation of the total irradiance. First, an expression for the irradiance contribution produced by the network was developed in terms of its area and broad-band photometric contrast. Then the expression was evaluated using recent measurements. After it was established that the expression was satisfactory, photospheric magnetograms were used to estimate the area variation of hte network over the 11 year cycle.

During the interval from 1981 to 1986 the smoothed total irradiance measured by ACRIM declined by approximately 0.06% after removal of the variation caused by active regions. The change due to the photospheric network was measured to be 0.043%. However, the measurements of the network included only the quiet network; the enhanced network around active regions was explicitely avoided. Hence the value found is large enough to indicate that the photometric contrast and area change in the network are probably sufficient to explain the 'missing component of the '11 year irradiance variation. To significantly improve the accuracy of this estimate, it will be necessary to measure the area of the network andits wide-bancd photosmetirc contrast at exactly the same spatial resolution.

2.2 ROTATIONAL AVERAGES OF MAGNETIC FLUX OVER THE SOLAR CYCLE

K. Harvey was invited to give a talk at the SOLERS22 Workshop in Boulder, CO, 3-7 June 1991. The talk was entitled 'Measurement of Solar Magnetic fields as an Indicator of Solar Activity Evolution. The primary objective was to compare magnetic flux measurements with measures of the solar irradiance. A second specific goal was the analyses of the active and quiet components of solar magnetic flux. This distinction was made by considering magnetic flux <25 Gauss as representing the quiet component and magnetic flux >25 Gauss as the active component. The magnetic flux data was from the NSO full-disk magnetograms converted to 27 day synoptic charts. These active and quiet magnetic flux components were compared with measures of irradiance variations in (1)10.7 Cm radio emission (Ottawa), (2)1-8A X-ray emission (GOES), He I 10830A equivalent width (NSO), Lyman Alpha (SME), and ACRIM data (SMM). The primary conclusions are:

(1) The total magnetic flux of the Sun increases from its minimum to maximum phase by at least a factor of 4 in cycle 21 and by a factor of about 4 in cycle 22. Dividing the magnetic fields into a strong and weak component using a threshhold, it is found that the magnetic flux contributed by the active region fields (>25 Gauss) varies by at least a factor of 20 from cycle minimum to maximum in cycle 21 and by a factor of 23 in cycle 22. The quiet-Sun fields (<25 Gauss), however, increase by no more than a factor of 2 in either cycle during the same interval. It is concluded that most of the flux that emerges in

active regions disappears before it is able to disperse. More than 70% of the magnetic flux in active regions is estimated to disappear *in situ*, with only a small fraction (30%) of the flux dispersing into the background.

(2) The decrease of the weak fields during the decline of the cycle occurs in phase with the stronger fields, suggesting that disappearance of magnetic flux continues in the weak field component, though at a slower rate than is observed in active regions. (This corroborates previous direct measures of the magnetic flux in active regions and on the quiet sun (Martin, Livi, and Wang 1985; Livi, Martin and Wang, 1985; Livi et al. 1989).

(3) There are strong north-south asymmetries of the active region magnetic flux during the solar cycle. The asymmetry of the magnetic fields in the quiet component are in the same sense as for active regions. They are of a smaller magnitude and lag the stronger-component asymmetries, again suggesting that much of the magnetic flux in active regions disappears *in situ*.

(4) During the magnetic cycle there are quasi-periodic pulses of activity, which differ in duration during the cycle and between cycles. The pulses of activity are of longer duration (~9 rotations) during the rise and decline of cycle 21, and of shorter duration (~5 rotations) during maximum. The pulses of activity in Cycle 22 have typically been of shorter duration, ranging from 1 to 4 rotations. The activity pulses appear to be a result of the occurrence of active region complexes, and may explain the periodicity observed in flare data for this cycle. Pulses of activity in the northern and southern hemisphere appear to be unrelated until late in the cycle, when they synchronize.

(5) The five irradiance indices have a good correlation with the magnetic field (and with each other) on the time scale of a cycle, a result of their variation being essentially in phase over the solar cycle. It is generally poorer for shorter-term variations seen in the rotational averages of the data and in the averages with the cycle variation removed. The exception is between 10.7 cm flux and the magnetic flux (total and >25 Gauss), indicating that they are closely coupled. The large scatter in the rotational averages and in the averages where the cycle variation is removed indicates that the relation between the indices and the magnetic field is more complicated than just a direct association with the amount of magnetic flux in the active or quiet components.

This study confirms that the magnetic fields on the Sun are the root cause of the emission structures and of their variation. The detailed physical connection between solar irradiance and the magnetic fields appears to be more complicated than has been investigated within the scope of this study. The characterization of the magnetic field of the Sun into a strong and a weak component using a threshold may not be sufficient to describe fully the nature of the magnetic fields giving rise to emission structures. Different methods are needed to provide a more reliable and effective separation of the stronger, concentrated magnetic field from the weaker, more widely dispersed fields in order to define specifically how they vary over the solar cycle and their relative contribution to the solar irradiance variations. The relations found between the five full-Sun indices used in this study and the magnetic field suggest that solar irradiance variations are not just related to the amount of magnetic flux, and the complexity and the long-term evolution of the magnetic fields. These are parameters that need to be explored further in future research in order to understand the relation of the magnetic fields to the varying emission structures on the Sun.

2.3 CONTINUING THE SEARCH FOR THE BEGINNING OF SOLAR CYCLE 23

During the spring of 1991, three observing runs were conducted simultaneously at Big Bear Solar Observatory and the National Solar Observatory at Kitt Peak. The primary purpose of this observing program was to search for the beginning of solar cycle 23. Our technique at Big Bear was to take successive fields of view from the equator to the pole for 5 consecutive days on approximately the same zone in longitude in one hemisphere. At Kitt Peak similar magnetograms were taken of the same area from the equator to the pole in the same hemisphere.

The data is secondarily useful for following the evolution of a few small active regions which developed in the selected longitude zone.

During the observing run at Big Bear, preliminary analysis was initiated by making a magnetogram movie on an Amiga computer the same night following the day that the data was recorded. This was done during and following the usual night program of replaying the day's magnetograms on a video screen and photographing the images on film. The Amiga version is similar to that one film, but can then be immediately viewed whereas the data on film must be processed and is not available for viewing until many days after the data is taken. The Amiga movies were used to identify the ephemeral active regions which would allow the detection of solar cycle 23 if a band of reversed polarity ephemeral regions could be identified at high latitudes ($> 35^{\circ}$).

No evidence of solar cycle 23 was found in the preliminary surveys of the data.

This study was effectively conducted and should be repeated approximately once a year until solar cycle 23 is identified. The data current is useful for identifying the latitudinal extent of solar cycle 22 and how much the active region belt shifts in latitude from year to year as a base from which to judge the appearance of solar cycle 23 when it does begin.

2.4 THE FORMATION OF FILAMENTS

An observing run initiated by S.F. Martin and J. Zirker in August of 1990, provided an extraordinarily good example of the formation of a filament. The observations were taken at the Sacramento Peak Observatory and Big Bear Solar Observatory from 28 August thru 1 September 1990. Analyzing this data during FY1991 led to the formulation of a new concept for the formation of filaments. The new concept of how filaments form was presented as a poster paper at the IAU meeting in Buenos Aires in July 1991.

In the August 1990 example, the formation of a filament coincided with the cancellation of magnetic fields of opposite polarity which migrated together. The migration of the fields was evident over the entire 5 day interval of observation. The filament formed by the beginning of the third day. The network fields which migrated together and cancelled were clearly not the end points of field lines which form an arcade over the filament channel. Instead the end points were at opposite ends of the filament channel. Hence the cancellation was taking place between separate bipolar magnetic fields. The migration of the flux caused the separate bipolar fields to move together sideways instead of end to end.

The motion of the opposite polarity fields together would then have to result in magnetic reconnection. The reconnection was thought to be low in the solar atmosphere because the chromospheric fibrils revealed that the fields which had migrated together were tilted in opposite directions with respect to vertical. In this configuration, the consequence of the reconnection would be for field lines to rise from near the photosphere into the corona. Many such reconnections would then build a concentrated magnetic field along the polarity inversion between the separate bipolar magnetic fields. Each reconnection would result in bringing some mass from the chromosphere or photosphere into the corona. Eventually the accumulation of mass would reach the critical density at which cooling would take place. The formation of the filament would then be seen as the apparent condensation of filament mass along the filament channel.

This concept of the formation of filaments differs from all previous theories in two fundamental respects. First, rather than being formed within a bipole, the formation takes place between separate bipolar fields. Secondly, the mechanism of magnetic reconnection, only invoked in two other models, differs in this concept by its occurrence at or near the photosphere. The disappearance of magnetic flux, as it is observed to cancel, is explained as the upward transport of magnetic field from a layer of the solar atmosphere at or below the level at which the magnetic fields are detected. That level is slightly above the photosphere because the observations are taken in the wing of a magnetically sensitive spectrum line.

This model is significant departure from all other filament models in that energy is extracted from the photosphere and deposited in the corona at the time of observation of the cancelling magnetic fields.

A paper on this concept of the formation of filaments is in preparation. An abstract describing this process of filament formation is published in the Proceedings of IAU Colloquium 133 on Eruptive flares held in Iguazu Argentina, August 1991.

2.5 THE ROLE OF CANCELLING MAGNETIC FIELDS IN THE BUILD-UP TO ERUPTING FILAMENTS AND FLARES

Sara Martin and Silvia Livi co-authored an invited paper at IAU Colloquium 133 and chose the topic of the relationship of cancelling magnetic fields to erupting filaments and flares. Examples of eruptive flares observed in a small active region in October of 1990 were selected as being representative. First the cancelling sites were observed to develop. Secondly, filaments formed at the sites of cancellation. Lastly, the filaments erupted as flares occurred at the two sites.

These examples demonstrate several important characteristics of eruptive flares. First, they are predictable. The first flare occurred at the boundary of the active region with weak fields. The rapid formation of the filament during the second day of development suggested that a relatively large percentage of the weak fields had cancelled. This also meant that the field overlying the filament was relatively weak. A parameter that should be studied in relation to predicting such events is the ratio of the cancelling magnetic flux to the magnetic flux inferred or observed (in X-rays only) at the footpoints of the overlying magnetic field.

In this example, the filament showed strong activation during the hour before it erupted. This is another clue that can be important in short-term flare prediction. As in this case, strong mass motions within filaments are frequently observable within several minutes to several hours before they erupt.

The site of cancelling magnetic fields for the second eruptive flare did not begin to develop until near the second day of evolution of the active region. During that day the active region poles were moving apart as usual during the growth of a region. However, some of the positive polarity flux was apparently caused to reverse its direction of motion as a new supergranule cell formed. The positive magnetic flux was forced into contact with some of the negative polarity flux and formed a site where the fields were cancelling at a high rate. The plage became very bright at this site and sunspots formed in the positive flux as it coalesced against the negative flux. A thin filament formed. Then the filament erupted and the flare began at the site where the field was cancelling most rapidly. The core of the flare was bright. Then the flare spread throughout the entire active region.

Although the concepts in this paper are presented in a qualitative way, the data merits quantitative analysis. We suggest that the ratio of the cancelling magnetic fields to the total flux in the active region above the polarity inversion zone could be a significant parameter to the forecasting of eruptive flares.

The important stages are: (1) the driving of opposite polarity magnetic fields together, (2) the formation of a filament as the opposite polarity fields cancel, (3) the destabilizing of the filament and surrounding magnetic fields by the continued cancellation. In these stages energy is first transported from the photosphere into the corona. Because this transfer is a one-way process, the stored energy in the corona is alway increasing as long as the cancelling fields continue. This eventually results in the outward motion of the magnetic field lines surrounding the filament and the filament; as the filament and its surrounding arcade field begin to move upward, the stage is being set for the occurrence of a flare beneath the ascending filament. When the rising coronal magnetic fields become unstable, rapid coronal reconnection begins in the corona beneath the filament. The filament then erupts along with the accompanying coronal mass ejection. The flare is understood to be the mass that is energized by the acceleration of particles during the rapid reconnection in the corona.

2.6 THE DIRECTION OF THE MAGNETIC FIELD COMPONENT ALONG THE LONG AXIS OF FILAMENTS

A statistical study of filaments and adjacent fibril structure was initiated as a summer undergraduate research project by Rajesh Bilimoria under the sponsorship of S.F. Martin. The purpose of the project was to determine the direction of the magnetic field along the long axes of filaments. It was realized by S.F. Martin that two configurations were possible for the direction of the magnetic field component along the long axis relative to the polarity of the adjacent photospheric magnetic fields. The two filament types were designated as 'left-oriented' and 'right-oriented'. The objective of the study was to learn if there was a reason why some filaments were left-oriented while others were right-oriented.

No reason was found for the orientation but some new and interesting statistics were compiled. It was found that among active regions, there were 1.5 to 2 times as many left-oriented filaments as right-oriented filaments. Although the number of quiescent filaments analyzed were relatively few, it was noted that those in the northern hemisphere were left-oriented and those in the southern hemisphere were right-oriented. In their tendency to show the hemispheric pattern, filaments on the borders of active regions were intermediate between the active region filaments which showed no hemispheric pattern and the quiescent filaments which showed a marked hemispheric pattern. It was concluded that another study would have to be done in order to show whether the hemispheric effect was real.

At the end of August 1991, a daily observing program was initiated to collect information on the quiescent filaments. Observations were made throughout the month of September 1991.

2.7 FURTHER EXPERIMENTS WITH A LITHIUM NIOBATE ETALON

During the fall of 1990, experiments were continued using the $LiNbO_3$ etalon loaned by D. Rust. Dr. Rust came to Big Bear for a 4-day visit to initiate the first observations of magnetic fields using the $LiNbO_3$ etalon. Magnetograms were successfully obtained having sensitivity and resolution comparable to the magnetograms usually taken at Big Bear with Zeiss 1/4 birefringent filter. However, the magnetograms taken using the $LiNbO_3$ etalon were more non-uniform. There are three possible sources of the non-uniformity. First is the KDP crystal; some non-uniformity is alway present from this source even in the daily magnetograms taken at Big Bear. Second is the prefilter; an extremely narrow prefilter is required for best results and the ideal prefilter was not available. The third source of non-uniform images can be the configuration of the optical system in which the filter is placed. The high f-ratio required for the etalon was used; however, there was limited space on the optical bench of the telescope for changing the optical configuration. Possible further experimentation was discussed for the future.

In spite of the non-uniform images during obtained during these few days of testing the etalon, the quality of the images and the throughput of light make this filter the best one available today for acquiring improved magnetograms. The experiments conducted were only of the line-of-sight component. The etalon is even better suited for acquiring transverse magnetograms because of its narrow profile. Additionally, magnetograms taken with a $LiNbO_3$ etalon can be more easily and accurately calibrated than the magnetograms taken with a birefringent filter.

After experimenting with magnetograms, the etalon was then set-up with various H-alpha pre-filters loaned by Del Woods of the Daystar Filter Co. The Daystar prefilters were not adequately uniform in their passbands to yield good results. Also transmission of these filters as prefilters was lower than desired. The best prefilter was a 3A prefilter manufactured by the Andover Corporation. Very good H-alpha images were obtained. However, even this narrow prefilter did not completely block all of the light from one of the adjacent passbands of the etalon. The main visual difference from the birefringent filter images was that the sunspots were more completely visible; this indicates that a small component of photospheric light was being transmitted by the adjacent passband. For further improvement, experimentation was done using a single birefringent element tuned to eliminate the light from the adjacent passband. This worked very well. Consequently, a special birefringent element of the appropriate thickness of calcite was made for the next set of experiments in November of 1990.

The final experiments using the narrow prefilter (3A) and the birefringent element along with the $LiNbO_3$ elatalon gave excellent results. Comparison was made with images taken the same day through the best Zeiss birefringent filter on the same optical bench. In every respect the images obtained with the $LiNbO_3$ etalon and prefilter were as good or better than those obtained with the birefringent filter. The contrast was slightly better in the images obtained through the $LiNbO_3$ etalon.

In summary, it is concluded that the $LiNbO_3$ etalons with appropriate prefiltering are extraordinarily useful filters for numerous types of solar observations and research.

2.8 PLANNING FOR THE SOLAR CYCLE WORKSHOP, OCTOBER 1991

K.L. Harvey agreed to be Chairperson of the fourth in a series of Workshops on the Solar Cycle. The Scientific Organizing Committee consisted of Rick Bogart, Karen Harvey, Mark Giampapa, Robert Howard, Sara Martin, Doug Rabin, Rich Radick, Peter Wison, Jack Zirker, and Hal Zirin. The local organizing committee involved Richard Altrock and Ramona Elrod at Sacramento Peak and the Workshop was scheduled for October 1991.

It was decided that a topical format with two invited speakers per half day session followed by a relatively long interval for discussion would be most desireable and effective. Voluntary contributions were planned to be in the form of oral discussion on the topic and poster papers.

The 6 topical questions selected for this Workshop were:

1. What does surface magnetic flux tell us about sub-surface magnetic fields?

2. Is the flux we see at the surface causally involved in the solar cycle? How can we use stellar cycles to understand phenomena of the solar cycle?

3. Do the observed large-scale velocity patterns provide information concerning solar cycle mechanisms?

4. The "extended" solar cycle: what does it mean?

5. How does solar luminosity change during a solar cycle? What can we infer about the cycle mechanisms from stellar luminosity variations?

6. Proposition: No existing model, either phenomenological or theoretical, of either solar or stellar cycles, deserves to be a paradigm.

3.0 ABSTRACTS OR SUMMARIES OF RESEARCH PAPERS

3.1 DO CHANGES IN THE PHOTOSPHERIC MAGNETIC NETWORK CAUSE THE 11-YEAR VARIATION OF TOTAL SOLAR IRRADIANCE?

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Abstract

Changes in the area of the photospheric magnetic network over the sunspot cycle have been put forward as the "missing component" required to explain the 11-year variation of total solar irradiance observed by space-borne radiometers. We show that this explanation is consistent with recent measurements of the photometric contrast of magnetic faculae, and with our measurement of the network area change during cycle 21.

3.2 CHANGES IN THE PHOTOSPHERIC MAGNETIC NETWORK AS RELATED TO THE 11 YEAR VARIATION THE TOTAL SOLAR IRRADIANCE

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ABSTRACT. This paper describes a study (a) of solar magnetic fields, using the synoptic magnetic field maps made for each Carrington rotation by the National Solar Observatory since 1975, and (b) of the relation of the magnetic fields to Sun-as-a-star measurements at four wavelengths and by ACRIM. The variations of the active-region and quiet-Sun magnetic fields and of the total Sun are determined during the period covering cycle 21 and the rise of cycle 22. The total magnetic flux on the Sun increases by at least a factor of 4 to 5; the quiet component of the magnetic fields show a factor of 2 or less increase during the same period, compared to the more than 20-fold increase in the active-component mangetic fields. The relation of the active and quiet components of the magnetic fields with 10.7 cm radio flux, 1-8A X-ray flux, He I 10830A equivalent width, Lyman -alpha, and ACRIM measurements was investigated using data averaged over a solar rotation. The 10.7 cm radio flux correlates well with both the Sun's total magnetic flux and the active-region magnetic fields. The correlations with the X-ray, He I, Ly-alpha, and ACRIM data suggests the possibility of a hysteresis as a function of the cycle and cycle phase. During cycle 21 compared to the rise of cycle 22. Some of the hysteresis might be explained by calibration uncetainties in these data sets. No hysteresis is found in the magnetic field data. The results of this study indicate a more complex relation exists between emission sources and the magnetic field than is considered within the scope of this study.

3.3 **AN OBSERVATIONAL-CONCEPTUAL MODEL**

OF THE FORMATION OF FILAMENTS

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Abstract

Examples of the formation of filaments are analyzed from high resolution H-alpha filtergrams from the Big Bear Solar Observatory, the U.S. National Observatory at Sacramento Peak, the Ottawa River Solar Observatory and the Udaipur Solar Observatory along with line-of-sight magnetograms from the Big Bear Solar Observatory and the U.S. National Observatory at Kitt Peak. It is deduced that the magnetic field in the environment of filaments has a rotational configuration that requires depiction in three dimensions and looks like a 'rotational discontinuity' (Spreiter and Alksne, 1969, Reviews of Geophys. 7, 11), a magnetic field geometry that is also commonly observed in the plasmas of the interplanetary medium at some interfaces between oppositely-directed magnetic fields. Evidence for this magnetic field configuration in the environment of filaments comes from the asymmetric rosettes and patterns of the fibrils adjacent to the filaments, from the direction of the structure within and under the filaments, and from the deduced direction of the magnetic fields adjacent to the filaments as they are forming. The directions of motion of the magnetic fields adjacent to the filaments reveal that the assymetry of the rosettes and direction of the fibrils is not due to the flow pattern of the photospheric magnetic fields adjacent to the filaments. Instead, the asymmetry of the rosettes and patterns of the fibrils are related to the local direction of the magnetic fields in and around the filaments as previously interpreted by Foukal (1971, Solar Phys. 19, 59). Immediately adjacent to filaments, the magnetic field lines from the rosettes are inclined from vertical in planes approximately parallel to the sides of the filaments; they are also inclined in opposite directions from vertical on the two sides of the filaments. In general, the inclinations of the field lines around and in filaments are: (1) in the same general direction as the fibrils that appear to stream from the core of the rosettes or adjacent plage, (2) greatest adjacent to the filaments, decreasing with increasing distance from the sides of the filaments, and (3) 90 degrees (horizontal) in the filament channel. Recognition of this pattern of inclined magnetic fields in the environment of a filament as being like a 'rotational discontinuity' brings new information for consideration in modelling the formation of filaments.

The formation of the filaments coincides with the observed convergence, encounter, and cancellation of knots of magnetic

flux of opposite polarity in the horizontal region of a polarity inversion. It is hypothesized that the horizontal magnetic fields in the coronal part of the polarity inversion increase simultaneously with the cancellation observed in the line-of-sight magnetograms. It is further hypothesized that these changing magnetic fields occur simultaneously due to a slow type of magnetic field reconnection whose point of initiation is at or near the photospheric/chromospheric interface and between the oppositely-inclined and opposite polarity magnetic fields which have converged together from the two sides of the filament channel. This proposed configuration of reconnection would result in the conversion of pairs of oppositely-inclined field lines into single, nearly horizontal field lines which rise into the corona, coming to equilibrium as additional field lines in the horizontal, coronal region of the polarity inversion (which would correspond to the middle of a rotational discontinuity). Mass concurrently accumulating in the horizontal part of the polarity inversion, eventually reaches a density and temperature which allows it to be detected as a filament. By means of the proposed reconnection, magnetic and kinetic energy are extracted from regions close to the photospheric-chromospheric interface and stored in the chromospheric and coronal parts of the polarity inversion. The energy stored within the coronal part of the polarity inversion is then available for subsequent release in dynamic coronal events.

Abstract submitted for presentation by S.F. Martin as a poster paper in the Session on 'Prominences' at the IAU meeting in Buenos Aires, Argentina, July 1991 and at the IAU Coloquium on Eruptive Flares in Iguazu, Argentina, August 1991.

3.4 THE ROLE OF CANCELLING MAGNETIC FIELDS IN THE BUILD-UP TO ERUPTING FILAMENTS AND FLARES

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Abstract

We present a scenario for understanding the role of cancelling magnetic fields in the build-up to eruptive solar flares. The key intermediate step in this scenario involves the formation of a filament magnetic field in the corona above a photospheric polarity inversion where cancelling magnetic fields are observed. The formation of a filament magnetic field is accomplished in several recent models by first interpreting the cancelling fields as a visible effect of a slow, steady magnetic reconnection. This reconnection results in a reconfiguring of the magnetic field; line-of-sight pairs of closely-spaced opposite-polarity fields disappear from the photosphere thereby accounting for the cancellation; simultaneously the horizontal component is increased in the corona above the polarity inversion. The new and increasing horizontal component is synonomous with the building of a magnetic field where mass can accumulate to form a filament. If the magnetic reconnection continues for a sufficient length of time, the changing equilibrium between the growing filament magnetic field and the overlying, coronal magnetic field will result in a very slow, simultaneous ascent of both the filament magnetic field and the overlying coronal magnetic field with greater motion in the outer, weaker coronal field. This upward stretching of the magnetic fields eventually results in a closer spacing of oppositely-directed coronal magnetic fields (resembling a tangential discontinuity) beneath the filament. As depicted in some flare models, magnetic reconnection then suddenly occurs in the corona beneath the filament; flare loops form in the lower part of the reconnected field and a coronal mass ejection and erupting filament comprise the upper part of the reconnected field. To illustrate the observable phases of this scenario, we describe the build-up to two simple eruptive flares in a small active region.

4.0 PUBLICATIONS: FY1991

4.1 Research Papers - Published

1. 'Elementary Bipoles of Active Regions and Ephemeral Active Regions' in *Solar Magnetic Fields* (ed. G. Poletto), Mem. S.A.It., 61, 293 (1990).

2. 'The Evolution and Orientation of Early Cycle 22 Active Regions' by A.T. Cannon and W.H. Marquette, *Solar Phys.* (1990).

4.2 Research Papers - Submitted for Publication

1. 'Do Changes in the Photospheric Magnetic Network Cause the 11-year Variation of Total Solar Irradiance?' by P. Foukal, K.L. Harvey and F. Hill, accepted for publication in the Astrophysical Journal (1991).

2. 'Measurements of Solar Magnetic Fields as an Indicator of Solar Activity Evolution' by Karen L. Harvey, Proceedings of SOLERS22 Workshop, Boulder, CO, 3-7 June 1991.

4.3 Research Papers in Preparation for Publication

1. 'The Role of Cancelling Magnetic Fields and Flares in the Eruption of Filaments and Flares', IAU Colloquium 133, *Eruptive Flares*, (eds.) Z Svestka, M. Machado, B. Jackson, 2-6 August 1991, Iguazu, Argentina.

2. Invited Review Paper on 'The Formation of Prominences' for *Solar Physics*, by S.F. Martin and C. Zwaan, deadline postponed until 30 June 1992.

3. 'The Cyclic Behavior of Solar Activity by Karen L. Harvey, in preparation for the Solar Cycle Workshop

5.0 PROFESSIONAL PERSONNEL ASSOCIATED WITH THE PROJECT

1. Sara F. Martin (Principal Investigator)
   Solar Astronomy Group
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   Solar Astronomy Group
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6.0 INTERACTIONS

6.1 Papers Presented at Formal Scientific Meetings

1. 'Measurement of Solar Magnetic Fields as an Indicator of Solar Activity Evolution' Invited talk by Karen L. Harvey at the SOLERS22 Workshop, Boulder, CO,3-7 June 1991.

2. ' An Observational Conceptual Model of the Formation of Filaments' by S.F. Martin, Poster Paper presented at IAU General Assembly, July 1991, Buenos Aires, Argentina and at the IAU Colloquium 133 on Eruptive Flares in Iguazu, Argentina, 2-6 Aug. 1991.

3. 'The Role of Cancelling Magnetic Fields in the Eruption of Filaments and Flares' by S.F. Martin and S.H.B. Livi at IAU Colloquium 133 on Eruptive Flares, 2-6 Aug. 1991, Iguazu, Argentina.

6.2 Other Scientific Interactions

1. K.L. Harvey and S.F. Martin attended SPD Meeting of AAS, April 1991, Huntsville, AL.