TIME-AVERAGED SPECTROHELIOMGRAPHS

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Abstract. The great improvement in signal-to-noise as a result of time-averaging a sequence of \(\lambda 6103\)-core spectroheliograms is shown. It is suggested that such a technique should greatly enhance the network seen on filtergrams made with the 3840 Å violet filter (Chapman, 1970). Finally, the evolution of a sunspot, observed with time-lapse spectroheliograms is discussed.

1. Introduction

Sheeley (1971) has shown the dramatic improvement in signal-to-noise in detecting weak CN-faculae obtained by time-averaging a series of CN spectroheliograms (\(\lambda = 3883 \text{ Å}\)). As is well known, the photospheric network of faculae is cospatial with photospheric magnetic fields (e.g., Chapman and Sheeley, 1968; Harvey and Livingston, 1969). This time-averaging procedure was tried on a time-series of Ca i 6103 Å spectroheliograms. (The time series consisted of simultaneous spectroheliograms in the core of \(\lambda 6103\) and in the nearby continuum about \(1/2 \text{ Å}\) to the red of the \(\lambda 6103\) line, both with a bandpass of about 60 mÅ). The purpose was not only to reduce background ‘noise’ but also to reduce the smearing of the photospheric network features caused by atmospheric seeing and telescope motion. For example, a common feature of spectroheliograms, a ‘sawtooth’ pattern caused by image motion along the slit of the spectroheliograph as it scans the image, can be reduced by averaging.

2. Photospheric Network Enhancement by Averaging

One can eliminate seeing distortions of magnetic-field related features by time-averaging because their positional lifetimes are considerably longer than either the oscillatory or slowly-varying components of the solar atmosphere as shown by Sheeley (1971). Figure 1 shows a portion of one \(\lambda 6103\) spectroheliogram from 20 August 1970. The spatial resolution on this frame varies from about \(1\frac{1}{2}–6''\) and is typical of the remainder of the 34 frames of this sequence. The result of averaging all 34 frames (covering approximately 1 h) is shown in Figure 2. The most dramatic effect is the reduction in background noise such that the facular elements stand out clearly. However, there is also an improvement in resolution and a marked reduction in distortions. Figure 3, for comparison, shows a photographic magnetogram of the same region less than two hours before Figure 2. The spatial resolution of the magnetogram is better than that of the averaged spectroheliogram but the latter has better sensitivity to \(|B|\). Several weak magnetic features are indicated in Figure 3 that can be seen as weak features on Figure 2.

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Fig. 1. Frame 1 of a 34-frame time sequence of spectroheliograms made in the center of the $\lambda$ 6103-line of Ca I on 20 August 1970. This sequence was obtained with the 61 cm vacuum telescope and 3 meter spectroheliograph of the San Fernando Observatory. The bandpass was 60 mÅ and the scanning speed was 7.5° s$^{-1}$. North is up and east to the left (in heliographic coordinates). The width of the picture is equivalent to 266000 km on the Sun.
Fig. 2. Time-average of 34 frames covering about 1 h. There is a great reduction in distortion and an improvement in sensitivity in detecting weaker network features.
This technique of averaging to enhance the photospheric network of faculae could be used to greatly improve the appearance of filtergrams obtained through the 3840 Å violet filter (Chapman, 1970). One could, for instance, obtain a series of 20 or 30 selected 3840 Å pictures covering about 20 to 30 min and average them photographically to obtain a picture of the photospheric network having good sensitivity. As pointed out by Sheeley (1971) a certain minimum time, determined by the lifetime of background structures, must elapse during the time sequence in order to substantially weaken non-magnetic background features.

3. Some Comments on Moving Magnetic Knots

The smearing of the faculae due to their lateral motion was studied by a time-wise subtraction and a time-lapse movie. Both techniques showed no clear motion except for a few small features near the sunspot. On the other hand, Sheeley (1969) has shown numerous small faculae that flowed outward from a well-developed sunspot with speeds of about 1 km s\(^{-1}\) (a proper motion of 5″/h). Vrabc (1971), with a longer time base than Sheeley, showed numerous moving magnetic features, but in a rather complex active region rather than an isolated sunspot. One might expect that the number and, perhaps the velocity of outflowing magnetic knots would depend on the evolutionary behavior or age of the sunspot. Some support for this notion can be obtained by examining the behavior of the sunspot seen by Sheeley (1969) which was Mt. Wilson No. 16924 and the sunspot seen in Figure 1 of this report which was Mt. Wilson No. 18064 (McMath region 10882).

Let me briefly describe the behavior of these two spots as seen in Solar Geophysical Data (1968, 1970). The spot observed by Sheeley on August 13, 1968 was in a region that was invisible on the 10th of August but grew slowly and steadily on the 11th, 12th and 13th. At that time the leading spot (the region was type βp) began to decline until it disappeared by the 18th of August. However, the associated Hα plage remained bright during the decline after the 13th. Thus we see that at the time Sheeley observed this short-lived spot it was already beginning its decline. The region observed on August 20, 1970 had a large spot when it was first seen on the 13th of August and remained stable in size until about 22 August at which time it began to slowly decline until it was carried over the limb on 26 August. This slow decline appears to be in accord with 2 and 3½ h magnetic movies obtained on 22 and 23 August, respectively. These movies show little evidence for ordered motion like Sheeley observed on 13 August 1968. Thus the observations of this spot reported here were obtained at least 2 days before the spot began to decline.

Vrabc (1971) obtained a 6-hour magnetic movie showing many moving magnetic knots. However, the region observed was very complex, comprised of 8 sunspots, and was the site of a conspicuous Hα flare. Therefore, no attempt has been made to analyze the motions of that region in terms of the simpler isolated sunspots described above.

Although it is dangerous to generalize from so few cases, it appears that the small
Fig. 3. Photographic magnetogram corresponding to the region of Figure 1 and 2. Dark features correspond to positive polarity by the Mt. Wilson convention. The best spatial resolution is between 1.5 and 2". The white square is 10" on each side.
magnetic features around sunspots move outward in connection with the decline in area (and probably flux) of the associated spot. This outward motion represents a natural way of carrying away flux. Therefore, the correspondence between outward motion and the decline of the spot lends support to the idea that these knots are flux elements breaking off from the main spot and not outward-moving kinks in the outer magnetic field lines of the sunspot.

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References
