Variability of the Solar Chromospheric Network Over the Solar Cycle

R.Kariyappa and K.R.Sivaraman
Indian Institute of Astrophysics, Bangalore 560 034, India

Abstract. From a large sample of the Kodaikanal spectroheliograms in the CaII K line we have studied the variations in the intensity of the network elements over two solar cycles and have estimated their contribution to the overall variability seen in the disc-averaged K line profiles. The relative contribution of the network elements and the bright points to the K-emission are of the order of 25% and 15% respectively. We have shown that the area of the network elements is anti-correlated with the solar activity, and it increases by about 24% during the solar minimum compared to the maximum period.

1. Introduction

The H and K lines of ionized Calcium have been recognized as useful indicators for identifying regions of chromospheric activity on the solar surface since the time when Hale and Ellerman (1904) and Deslanders (1910) first observed the bright reversals in these lines. A two-dimensional image of the Sun in the CaII H or K line under high spatial resolution shows that the three agencies responsible for CaII emission are :
i. Plages, which are most conspicuous by virtue of the emission that far exceeds the emission from other features and represent the active regions on the sun,
ii. the network elements which are co-spatial with the boundaries of supergranular cells in the underlying photospheric levels, and
iii. the bright points with dimensions of 1-2 arc sec that populate the interior of the supergranular cells.

One important point is that the spatial correlation between areas of chromospheric emission and the photospheric magnetic fields is well established, and this relation holds good right from plages down to features as small as a few arc-secs across (Babcock and Babcock, 1955; Leighton, 1959; Skumanich, Smythe and Frazier, 1975; Sivaraman and Livingston, 1982). From minimum to maximum of the 11-year solar cycle, the fraction of the solar disc covered by the plages increases, and there is a corresponding increase in the observed K emission from the full solar disc, i.e. for the sun observed as a star (White and Livingston, 1978; 1981; Sivaraman, Singh, Bagare and Gupta, 1987). During the peak of solar activity, plages occupy about 10% of the solar surface. Although this is only a fraction of the area occupied by all of the network elements put together, because of the higher intensity

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contrast of the plages, their contribution to the total K-flux is very large compared with those of the remaining contributors. The area occupied by the plages over the visible solar surface varies in time and exhibits modulation of two different time scales. The first one is the 27-day modulation caused by solar rotation (Bappu and Sivaraman, 1971), and the second one is the well-known 11-year cycle modulation (Kuriyan, 1967). There is a less evident variation related to the smaller-scale chromospheric activity that occurs in the network structure bordering supergranule cells. Skumanich, Smythe and Frazier (1984) have derived a three-component model of chromospheric activity variation over the solar cycle using the observed data of White and Livingston (1981). Their model includes the flux from a cell component, a network component, and a plage component. They have estimated the fractional area covered by the cell points and their contrast and concluded that they cannot be important contributors to the K-flux. Pap (1992) has shown that the 72% of the solar-activity-related changes in Lyman alpha irradiance arise from plages and network elements and the network contribution is estimated by the correlation analysis to be about 19%, which is in good agreement with the photometric results of Pap, Marquette and Donnelly (1990b). The main contribution of the emission from the network elements to the K-flux, its temporal evolution in the intensity enhancements with the solar cycle, and the behaviour of the area of the CaII bright network with the solar activity are less documented and remain unanswered.

In this paper we made an attempt to answer these problems using the CaII K-spectroheliograms covering the period from 1957 to 1983.

2. The observations and the data analysis procedures

We have used in this study the Kodaikanal collection of CaII K-spectro heliograms obtained using the spectroheliograph. The K-spectroheliograph is a two-prism instrument with a dispersion of 7Å/mm near λ3934Å. The spectroheliograms employ a 60 mm image with a spectral window of 0.5 Å centered on K_{232}. The image scale is about 33 arc sec/mm. The span of years included is from 1957 to 1983, with plates clustering around dates of sunspot maxima, the intermediate and minima during this span. The main criteria used for selection of spectroheliograms were that the seeing be good to excellent; further that the region around the disc centre up to μ=0.8 be free from active regions.

We have singled out the chromospheric network elements of dimension 10 mm x 5 mm at the disc centre on each plate and which correspond to 330 arc sec x 160 arc sec on the sun. Then we made the two dimensional scans of this region on all the plates using the PDS Microphotometer of Indian Institute of Astrophysics. The scanning aperture used is 50μ x 200μ, which corresponds to 1.5 arc sec x 6 arc sec on the sun. The digitized density values have been converted into relative intensities via the calibration curve following the standard photometric reduction procedure. We have derived the intensity plots for all the plates for the scanned regions. We have marked the network elements on the intensity plots (keeping the background intensity as a lower threshold value) after projecting the scanned region of the plate to the same size as the plots using a Carl Zeiss enlarger cum projector. From these plots we have estimated the residual intensity and the area of the network elements.

3. Results and Discussion

3.1. The Variation of Intensity Enhancement at the Network Elements with the Solar Cycle and Their Contribution to K-Emission Flux

We have shown in Figure 1 the variation of the residual intensity of the network elements with time. The year 1975/1976 was the period of the lowest emission and can, therefore, be taken as the reference over which the excess in other years can be measured. Between 1957/58 and 1963/1964 the averaged network emission decreased by 64%, and remember that 1957/1958 was a most powerful solar maximum. Between 1969/1970 and 1975/1976, the averaged network emission decreased by 23%, while in 1979/1980 the increase to solar maximum was 16%. It is very clear from Figure 1 that the variation in the intensity enhancement at the network elements is related to solar activity. White and Livingston (1981) have measured the intensity variation of the quiet CaII network and supergranular cell centers observed near the equator and shown that the network elements do not participate in the solar cycle variation. In the present study we have measured the intensity enhancement only for the network elements without including the supergranular cell centers in it, and the network elements were selected for the measurements at the center of the solar disc on a quiet region. We find from Figure 1 that the network elements do participate in the solar cycle variation.

Pap et al. (1991) have shown that there is a good relationship between the variation of the Lyman alpha irradiance and the other solar indices like, for example, Ca plage index. Pap (1992) has also shown that the plage contribution to Lyman alpha irradiance is about 50%. Using this figure and also assuming that the remaining 50% contribution from the network elements, the inner network bright points and the weak emission seen between the bright points (background emission), we have derived the relative contribution from these structures from our network intensity plots to the total K-emission flux. The estimated quantities of the relative contribution to K-emission flux from various chromospheric structures for the years of the

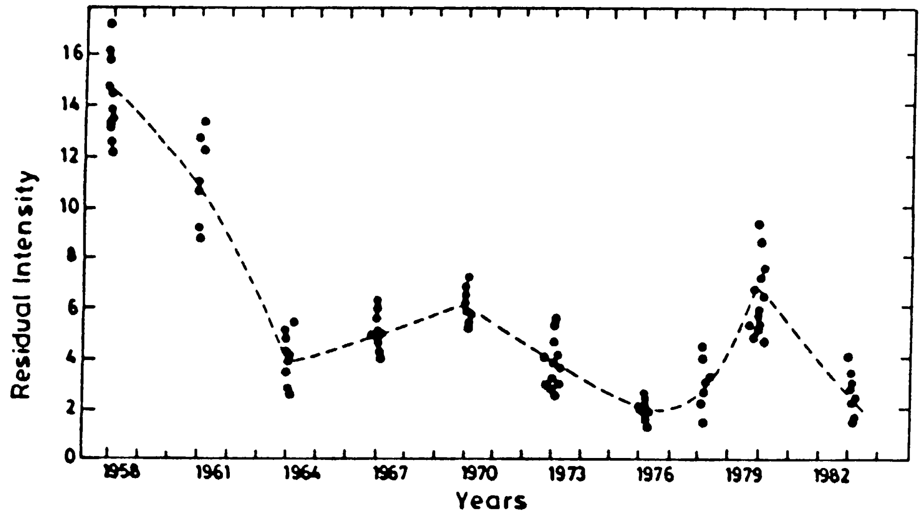

Fig. 1. The cycle variation of residual intensity of network elements.

TABLE I
The relative contribution from the network elements, the bright points and the background emission to the K-flux

Year	Network (%)	Bright point (%)	Background (%)
1958	30	12	8
1964	23	18	9
1970	22	17	11
1976	23	15	12
1980	25	15	10

solar maximum and minimum are presented in Table I. We conclude from Table I that the network elements and the bright points will contribute, respectively, an average of 25% and 15% to the K-emission flux. This network contribution is in good agreement with the value (19%) estimated in Lyman alpha by Pap (1992), and it also shows solar cycle related changes.

3.2. The Variation of the Area of the Network Elements with the Solar Cycle

We have measured the area of the CaII bright network from the intensity plots of the network using a planimeter. We have estimated the error in the area measurements by repeating several times, and it comes to about ± 0.542 cm^2. Figure 2 shows the variation of the area of the CaII bright

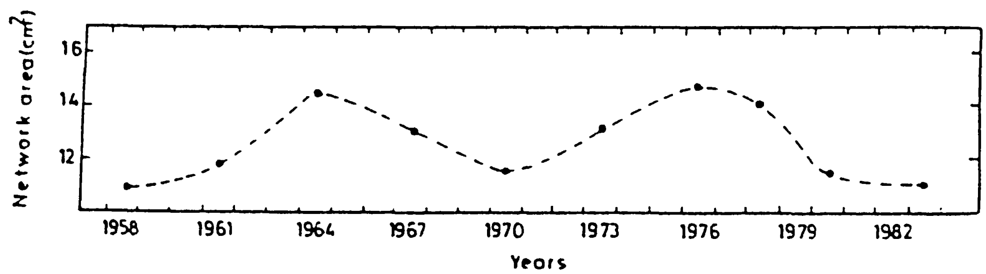

Fig. 2. The cycle variation of area of the network elements. The image scale on the intensity plot is about 0.65 arc sec /mm.

network with time. It is clear that the area occupied by the network elements decreases with the increase of solar activity but it is not a constant quantity as shown by Raghavan (1983). Singh and Bappu (1981) have measured the supergranular cell size defined by the locus of peak intensity as a function of epoch, along with bright network, by the auto-correlation technique. They find that the cell size decreases from 22000km at solar minimum to 20000km at solar maximum. But Raghavan (1983) has shown that the average interior network cell size decreases with decreasing activity. In the present study, we have shown that the area of the network elements is anti-correlated with solar activity, and also we find that (Figure 2) there is an increase of 24% in the area of the CaII bright network during the solar minimum (1964) compared to the solar maximum (1958). Figure 2 shows that the area occupied by the network elements is larger at sunspot minima than during maxima. Since the magnetic enhancements in the upper photosphere are co-spatial with the emission seen in the network elements (Skumanich, Smythe and Frazier, 1975), this would imply that the magnetic fields occupying a larger area of the solar disc during sunspot minimum.

4. Conclusions

We find that the variation in the intensity enhancement at the network elements is related with solar activity. The estimated relative contributions from the network elements and the bright points to the K-emission flux are of the order of 25% and 15% respectively. We find that the area of the CaII bright network is anti-correlated with solar activity and increases by about 24% during solar minimum compared to solar maximum.

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