GREEN CORONA VERSUS PHOTOSPHERIC MAGNETIC FLUX: SOLAR CYCLE DEPENDENCE

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ABSTRACT

The relation between the green corona and the photospheric magnetic flux has been analyzed over the period from 1995 to 2001. The homogeneous dataset of the green coronal line intensities and the Kitt Peak magnetic flux data were used for determining this relation. Focus was on the solar cycle dependence of the numerical relation between these two parameters has been investigated. Any overall fit with fixed parameters for the period of several years was shown to be unrealistic for describing this relation because the fit was found to be time dependent. The coefficients of the linear fit used in the paper show quite significant changes in their values with time. Moreover, the inverse relation of the absolute and the linear coefficients of the fit was obtained during the ascending phase of the solar cycle between 1998 and 2001. Therefore, in order to extrapolate magnetic flux data before 1975 using the existing longer datasets of the green coronal intensities, it is necessary to take into account the revealed solar cycle dependence of their relation and to estimate the quantitative parameters of the relation separately for the individual phases of the solar cycle.

Key words: Sun: corona; Sun: magnetic fields.

1. INTRODUCTION

As is generally known, solar activity, including the coronal one, is governed by magnetic fields. Therefore a strong connection exists between the green corona intensities, coronal temperature, and the local magnetic fields concentrations at the solar surface. This connection was intensively studied in the past. A review of recent advances in understanding the quiet corona and coronal holes was given e.g. by Sakurai (2000). Wang et al. (1997) analyzed images of the green line corona made with the LASCO C1 coronagraph on SOHO by applying current free extrapolations to the observed photospheric field. They found that the strongest enhancements in the green line corona occur where the high-altitude unipolar fields become reconnected to active region flux at lower latitudes. Ramesh et al. (1999) analyzed the relation between the green coronal intensity enhancements and the underlying photospheric and chromospheric activity. According to their results, the coronal intensity enhanced feature is almost sure to occur at the locations of sunspots with the strong magnetic fields and at the locations of plages having larger areas though the peak intensity does not depend on the strength of the underlying magnetic field. Ramesh et al. (2000) measured magnetic field gradients along the neutral line scanning from east limb to west limb at the locations of the intensity enhanced features. Their analysis showed that the peak intensity does not depend on the level of field gradient and that the given degree of gradients does not always produce the same degree of brightness. Moreover, Makarov and Tlatov (2002) found a decrease of temperature in the polar zones of the Sun of the order of 0.1×10^6 during the last 50 years. The temperature decrease, connected probably with an increase of the magnetic flux from high-latitude regions of the Sun during the last 120 years, influences the coronal intensity. Recently, Rušin and Rybanský (2002) compared the homogeneous coronal green line data set and a surface magnetic flux data set trying to find a relation between them from both the qualitative and the quantitative points of view. They used an overall fit for a numerical relation between the green corona intensities and the photospheric magnetic flux for the period of 24 years.

In this paper we present the first results on the solar cycle dependence of the relation of these two indices of solar activity.

2. DATA SETS AND THEIR PROCESSING

Coronal emission (CE) is represented by the homogeneous data set of the green coronal line (Fe XIV 530.3 nm) intensities based on the data of several coronal stations (Rybanský, Rušin, and Minarovjech, 2001). This dataset is transformed to the pho-

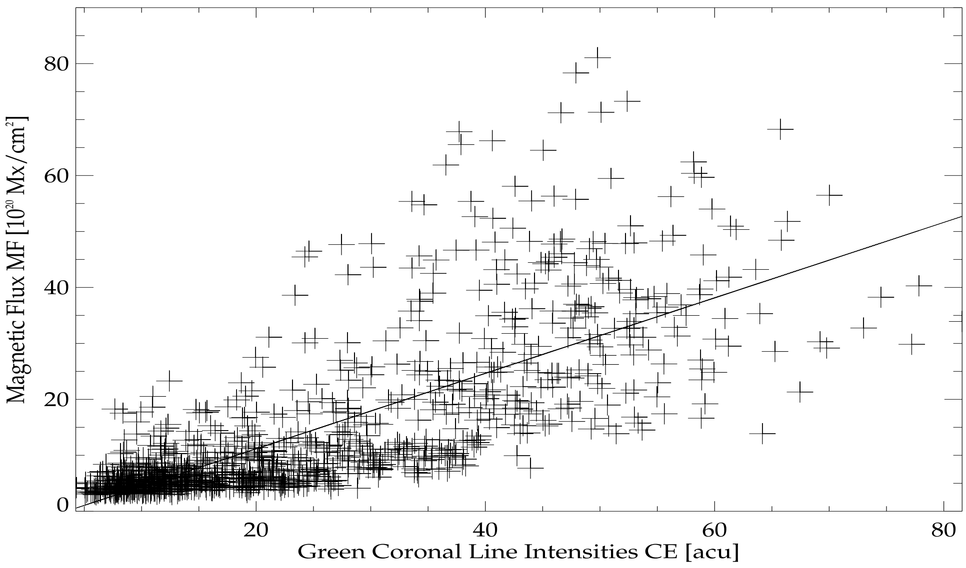

Figure 1. Scatter plot of the green coronal line intensities CE (x-axis) and the magnetic flux MF (y-axis) between 1995 and 2001, range of latitudes ±55°. Both types of data were processed to the final resolution 10° and 1 CR. In total 11×94 data are plotted.

tometric scale of Lomnický Štít coronal station (e.g., Rybanský, 1975). The magnetic field (MF) is covered using the photospheric Kitt Peak magnetic flux data (Livingston et al., 1976; Worden and Harvey, 2000) in the form of the Carrington rotation maps.[1] Both data sets have been limited for the purpose of this study just to the ascending phase of the solar cycle 23 (1995 – 2001) and to the heliographic latitude range of ±55° avoiding the polar regions. The data sets were processed to the final latitudinal resolution of 10° providing 11 independent data within the used latitude range. The CE data were truncated to the final temporal resolution of 1 Carrington rotation (CR) calculating the average of all daily values within one CR. The total magnetic flux calculated for the purpose of the comparison with the CE data is summing the magnetic flux over the whole CR longitude range. In total, 94 Carrington rotations were obtained from the CR 1891 till CR 1984.

These two data sets were investigated using the linear fit formula $MF(t) = a_0(t) + a_1(t) \,.\, CE(t)$, for the whole range of the selected CRs. In each CR the fit is based on 11 data available within the given latitude range of ±55°.

3. RESULTS

At first the overall relation of these two datasets is shown using a scatter plot given in Fig.1. The figure shows that the relation between the green coronal line intensities and the photospheric total magnetic flux is of large scatter. Moreover, most data are of very low magnetic flux (below $2-6\times10^{20}$ Mx) while the green line intensities cover a larger interval up to 2 – 20 acu (absolute coronal units). The rest of the data are far away from a simple weak linear trend between the MF and CE data mentioned above. Due to these facts we have decided to study this relation including its temporal behaviour.

Therefore, in the next step we investigated the behaviour of the linear fit only for the particular CRs in three different phases of the solar cycle 23. Fig.2 show the clear solar cycle dependence of the MF on CE. This supports reasons for studying the temporal evolution of the MF∼CE dependence as both data sets seem to change their ranges with time.

The course of the linear fit coefficients a_0 and a_1 also shows the solar cycle dependence (Fig.3). From the onset to the maximum of the solar cycle the coefficient a_0 gradually decreases from the value 6 to value −20 and the coefficient a_1 gradually increases from 0.1 to 0.8. This represents a significant inverse relation during the ascending phase of the solar cycle between 1998 and 2001.

The values of absolute and linear coefficients corresponding to the linear fit in Fig.1 are as follows: a_0=−2.33 and a_1=0.67 (1995 – 2001). Rušin and Rybanský (2002) found for similar parameters the values of a_0=21.8 and a_1=4.74 (1976 – 1999). Average values of these coefficients from our analysis are $\bar{a}_0$= −3.79 and $\bar{a}_1$=0.61, respectively; the range of the absolute coefficient a_0 is ⟨−24.2,+6.36⟩ and of the linear coefficient a_1 is ⟨−0.064,+1.2⟩.

Although the behaviour of the mean green line coronal intensity averaged over the whole latitude range and the total magnetic flux averaged over the same range is very similar in the period studied, the intrin-

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sic relation of MF and CE varies considerably in that period. This fact is documented in Fig.4 where the linear coefficients a_0 and a_1 are compared with the magnetic flux data range $MAX(MF) - MIN(MF)$. The inverse relation of the paricular plots is evident. The relation of the averaged magnetic flux data and the coefficients of the linear fit is of a very similar character.

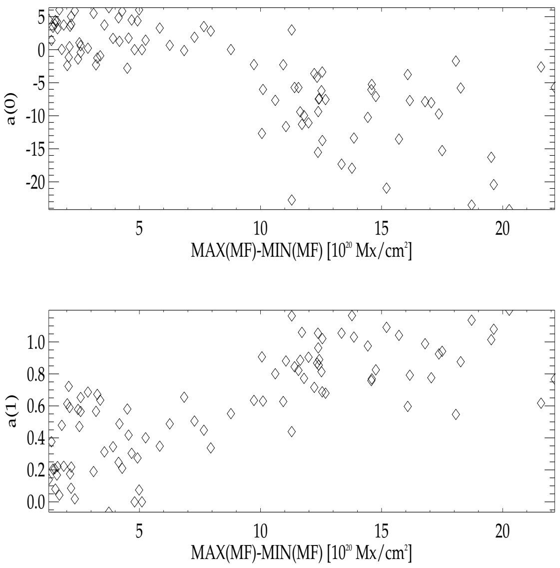

Figure 4. Relation of the magnetic flux data range MAX(MF)-MIN(MF) (x-axis), which describes the range of the total magnetic flux over the given latitude interval and the coefficients a_0 and a_1 (upper and lower panels, respectively) of the linear fit (y-axis).

4. CONCLUDING REMARKS

We have found that any fit with fixed parameters, which are not time dependent, is unrealistic for describing the relation between the green coronal line intensities and the photospheric magnetic flux on the Sun. If we would like to describe a quantitative relation between coronal intensities and magnetic flux (in order to extrapolate the magnetic flux data using existing longer datasets of the green coronal intensities), it is necessary to do it separately for the minimum, the rising or descending phase and the maximum of the solar cycle (or for more phases within one cycle). The difference between the values of the coefficient a_0 and a_1 found in this paper and by Rušin and Rybanský (2002) might be caused by the facts, that we used different sources of the magnetic flux data and a different data processing method. The periods of both data sets were also different.

The solar cycle dependence of the MF$\sim$CE relation is probably connected with the evolution of the surface and coronal magnetic fields during the solar activity cycle. An open configuration of the magnetic lines of the coronal hole is typical of the minima and the range of the magnetic flux and green coronal line is low. The polar coronal hole area can be determined from green coronal intensities using a method presented by Dorotovič (1996). On the other hand, more complex loop configuration of the magnetic field of active regions is typical near the maxima and the range of these parameters is higher. The changes in the character of the linear fit over a solar cycle might be connected with a ratio of the loop magnetic configurations in active regions and open magnetic configurations of the coronal holes. This fact causes changes in the the character of scatter plots of the MF$\sim$CE relation for individual CRs (Fig.2).

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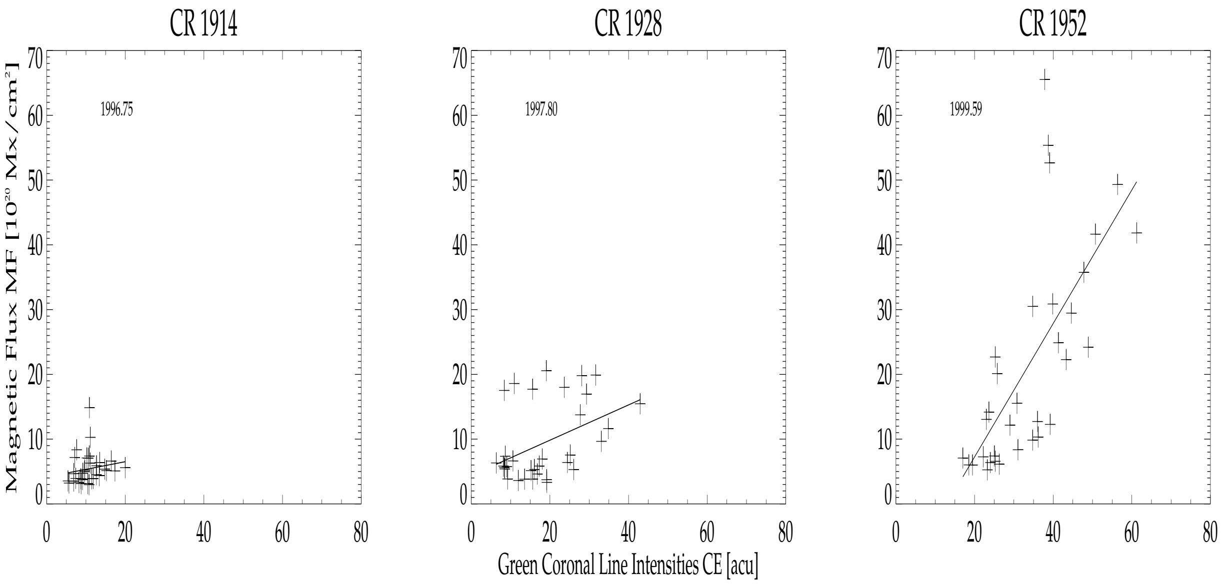

Figure 2. Relations of CE and MF for the minimum (left panel), rising phase (middle panel) and the maximum of the solar cycle (right panel) together with their linear fits.

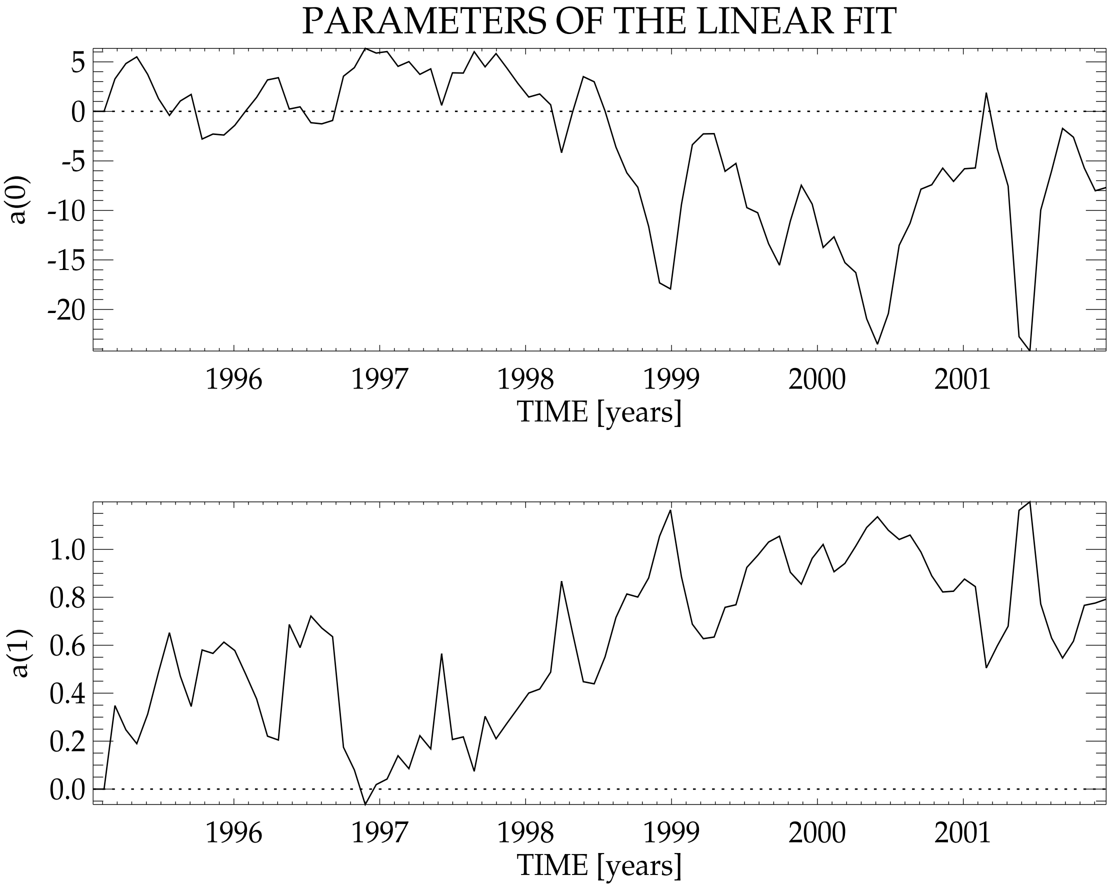

Figure 3. Plots of the absolute and linear coefficients of the linear fit depending on time (upper and lower panels, respectively) between 1995 and 2001.