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The green corona database and the coronal index of solar activity

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Abstract. The green coronal line Fe XIV 530.3 nm ranks amongst the most pronounced emission lines in the visible part of the solar spectrum. Its observations outside solar eclipses started sporadically in 1939 (the Arosa coronal station), being extended, in 1946, to more coronal stations. It was found that the green corona intensities vary with solar cycle, so they are a good candidate to express solar activity in the corona. Several attempts have been made to create a single homogeneous coronal data set from different coronal stations. We will present our homogeneous coronal data set, based on the Lomnický Štít photometric scale. Also, the coronal index of solar activity as created from this database in the period 1939–2010 will be discussed.

Key words: Sun – solar cycle – green line data

1. Introduction

As it is well known, the Sun is a magnetically variable star with an average period of about 11 years, known also as a solar cycle. A plethora of indices were introduced to express this variability and its magnitude, like the sunspot number, radio flux at 2800 MHz, averaged large-scale magnetic field strength and/or total solar irradiance, to mention a few. They all aim not only at grasping the essential features of solar variability but also at its predictions. Each of the indices represents a solar activity pertinent to particular areas and heights about the solar surface and reflects different physical conditions (temperature and density) of the origin of solar radiation. Given an assumption that the main agent behind solar activity is magnetic fields, these indices allow us to gather essential information about the distributions of the latter, whose origin is still, despite a great theoretical progress within past the decades, not well understood (Hathaway, 2010).

Principal manifestations of solar activity in the solar corona are a periodic change of its shape and the total amount of irradiated energy. The most pronounced spectral line in the visible part of the solar spectrum is that of Fe XIV, originating at a temperature of about 2 million K. Its first sporadic observations were made soon after the invention of a coronagraph (Lyot, 1932) in 1939 at the Arosa observatory by Waldmeier (Waldmeier, 1957); more systematic observations started in 1946 at several coronal stations worldwide. Why this spectral

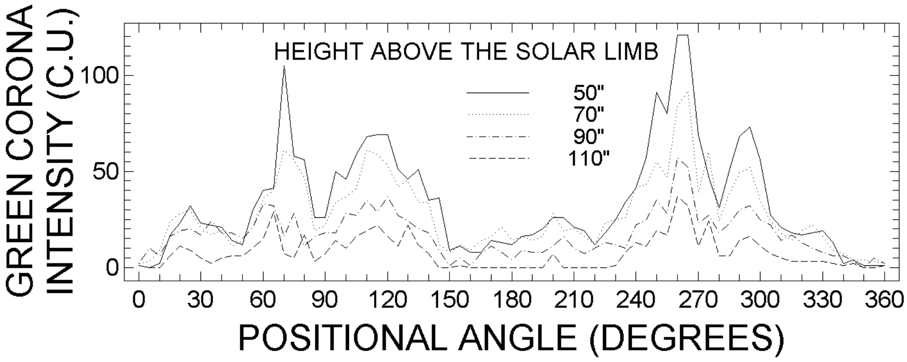

Figure 1. A plot of the green corona intensities at different heights above the solar limb, measured at the Lomnický Štít coronal station.

line is so attractive is the fact that it can be observed around the whole solar limb, not only in the regions close to the equator, and – unlike many other emission lines – throughout a whole solar cycle.

Observing the solar corona is quite difficult. This is not only because such observations are extremely weather-sensitive, but they are also accompanied by a number of technical problems. Therefore, the coronal data from a single coronal station feature a number of gaps. In order to reduce the number of "missing" observations, attempts were made to bring observations from various coronal stations to a unified photometric scale, see, *e.g.*, Sýkora (1971) and Makarov *et al.* (2003). The homogeneous data set of the intensities of the green corona, presented below, is based on the method proposed by Rybanský (1975). This method reduces all the data to the photometric scale of the Lomnický Štít coronal station, which started observations in 1965 and the green emission line has been observed there till present. The reader who is interested in learning more about this method is referred to an expository paper by Rybanský *et al.* (2005).

In what follows we shall briefly describe our homogeneous set of the green line intensities and related calculation of the coronal index of solar activity.

2. Homogeneous data set for the green corona

Intensities of the green coronal line are obtained with a spectrograph, or through narrow pass-band filters (usually 0.3 nm), and are expressed in coronal units. Measurements of the green corona intensity at Lomnický Štít are done with a spectrograph attached to a 20 cm coronagraph. Individual measurements with a lag of 5 degrees at the height of around 50 arcsec above the solar limb, starting at the north pole, are calibrated to the center of the solar disk to get absolute units; these are expressed in the intensity of the Sun's disk, or in absolute coronal

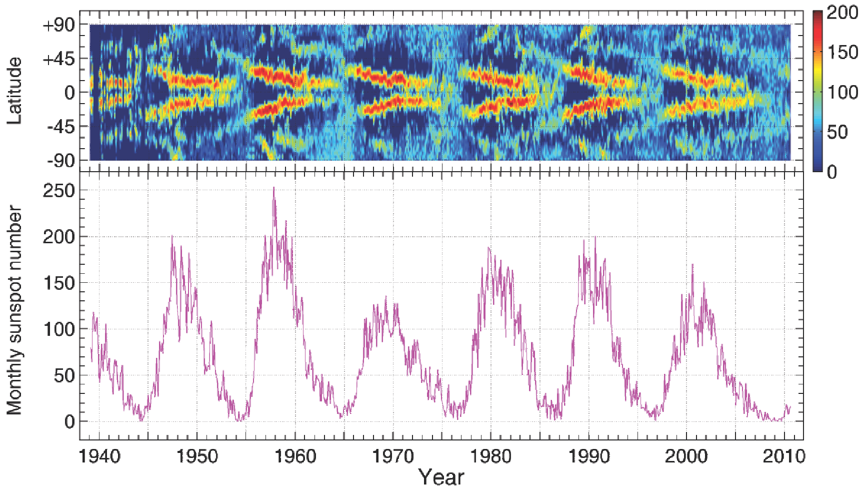

Figure 2. A time-latitudinal distribution of the local green corona maxima (top) as compared with the sunspot number (bottom) in the period from 1939 to 2010.

units (ACU). One ACU represents the intensity of the continuous spectrum of the center of the solar disk in the width of 1 Å at the same wavelength as the observed coronal spectral line (1 ACU = $3.89\,\mathrm{W\,m^{-2}\,sr^{-1}}$ at 530.3 nm). An example of such measurement is shown in Fig. 1, where there are also depicted observations at higher heights on the same day.

Obtained data can be used for different studies, *e.g.*, for latitude-time development, comparison with solar surface magnetic fields, localization of green line coronal holes, *etc.* We present, in Fig. 2, a time-latitudinal development of the local maxima of green line intensities. Both, the polar and equatorial belts are nicely seen, similarly as an "extended" solar cycle of 17–18 years, starting at heliographic latitudes around 70 degrees in the previous solar cycle and ending around the next solar minimum. This, it seems, is a very good example of a study of large-scale circulation on the Sun as confirmed by many ground-based or space observations (*e.g.*, Ribes *et al.*, 1985; Hathaway & Rightmire, 2010).

3. Coronal index of solar activity

In view of comparing ground-based green line measurements with observations in extreme ultraviolet and/or X-ray wavelengths made from space, Rybanský (1975) introduced the coronal index of solar activity (CI) as a general index of solar activity. CI, a full-disk index, represents the averaged daily irradiance (power) emitted through the green coronal line into 1 steradian towards the Earth. It is expressed in $\mathrm{W\,sr^{-1}}$ as measured from ground-based obser-

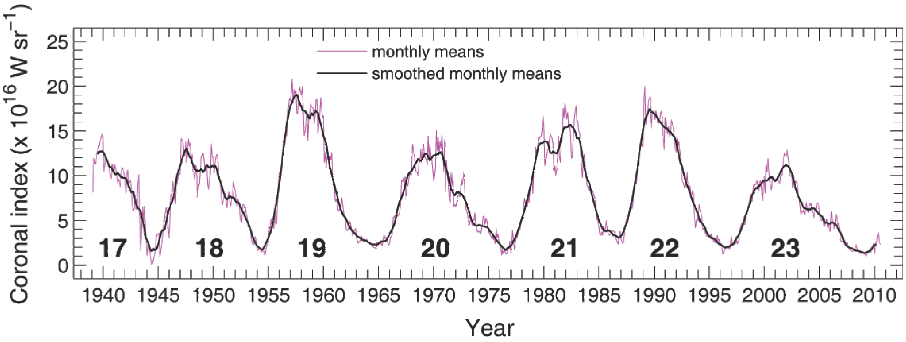

Figure 3. Solar cycle activity expressed in terms of the coronal index.

vations of the green corona emission. A basic idea was a simple comparison of this "energetic" index with similar full disk solar indices, *e.g.*, X-ray emission, the 2800 MHz total solar radio flux, *etc.* Solar radiation detected by satellites, the emitted coronal output, is expressed in $\mathrm{W\,m^{-2}}$ or in the number of photons crossing $1\,\mathrm{cm}^2$ per second at 1 AU from the Sun. To convert CI into these units (or *vice versa*), the following relation is used: $1 \times 10^{16}\,\mathrm{W\,sr^{-1}} = 4.5 \times 10^{-7}\,\mathrm{W\,m^{-2}} = 1.2 \times 10^{8}\,\mathrm{photons\,cm^{-2}\,s^{-1}}$ (Rybanský *et al.*, 2001).

The CI is computed from a homogeneous coronal data set, where intensities from individual coronal stations were converted to a single photometric scale, that of the Lomnický Štít. Then, the CI is prepared covering 13 days, projected onto a sphere and integrated over the visible solar disk. The main input for a given day are intensities observed above the limb, and intensities of a weaker power/magnitude for previous or following days (up to 6 days). The variations of the CI from 1939 to present are shown in Fig. 3.

4. Discussion and conclusion

The green corona is an important part of the Sun's atmosphere and its intensity is very sensitive on the distributions and variations of large scale magnetic fields. Being observed, unlike active regions/sunspots, around the whole solar limb it represents – together with prominences and filaments – a unique tool for the study of manifestations of solar activity at high latitudes. Moreover, recent studies (*e.g.*, Donnelly, 1990; Mavromichalaki *et al.*, 2002; Rušin *et al.*, 2006; Prikryl *et al.*, 2009) demonstrate that it is also a very useful "parameter" for studying solar-terrestrial effects. Our data concerning the homogeneous set of green corona intensities and the associated coronal index are also available on-line at `http://www.noaa.edu/corona`.

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