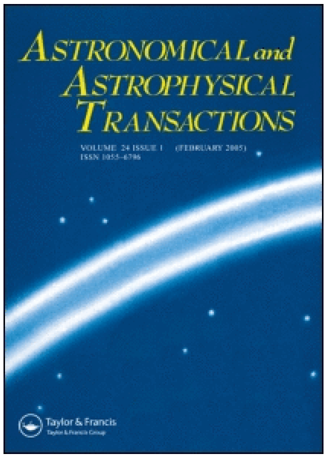


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# A NEW DATABASE OF THE GREEN-LINE CORONA BRIGHTNESS AS COMPILED FOR THE LAST FIVE SOLAR CYCLES AND ITS POSSIBLE UTILIZATION IN THE ISCS PROJECT

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Patrol coronagraphic measurements, regularly carried out by a small world-wide network of observatories, were synthesized to create a reliable and homogeneous set of the Fe XIV 530.3 nm coronal emission line intensity data. Our set of data enables to study different aspects of the solar activity, its variability and periodicity, especially in the large-scale and long-term scales. At the same time, the data on the green-line corona brightness and distribution of this brightness over the Sun's surface seem to be physically very relevant for a better understanding of the structure and some significant processes in the heliosphere. It is believed that an extensive analysis of our last five solar cycles database and its successive creation during the coming 23rd solar cycle could be a significant source of knowledge during the proposed "International Solar Cycle Studies" project.

KEY WORDS Solar corona, solar cycle, variability and periodicity

## 1 OBSERVATIONS

Basically, there are three ways to observe the solar corona: (a) during the short intervals of total solar eclipses, (b) by coronagraphs located at a few high-altitude observatories and (c) by means of the cosmic technique, of which Skylab, the Solar Maximum Mission and the Yohkoh project are the most prominent examples. Any of the above types of observation has its own advantages and shortcomings; however, each one is unique in some way. In the present paper we deal with the green-line Fe XIV 530.3 nm intensity data only, as measured by coronagraphs.

After almost a century of sporadic eclipse observations substantial progress in the investigation of the solar corona opened with Lyot's invention of the coronagraph

**Table 1.** List of coronal observatories

| *Observatory* | *Country* | *Longitude* | *Latitude* | *Altitude* | *Published data* |
|---|---|---|---|---|---|
| Pic du Midi | France | −0° 8.7′ | +42° 56.2′ | 2862 m | 1947–1974 |
| Arosa | Switzerland | +9° 40.1′ | +46° 47.0′ | 2050 m | 1947–1975 |
| Climax | USA | −106° 12.0′ | +39° 23.0′ | 3410 m | 1947–1957 |
| Wendelstein | Germany | +12° 0.8′ | +47° 42.5′ | 1837 m | 1947–1979 |
| Kanzelhöhe | Austria | +13° 54.4′ | +46° 40.7′ | 1526 m | 1948–1964 |
| Norikura | Japan | +137° 33.3′ | +36° 6.8′ | 2876 m | 1951–till now |
| Sacramento Peak | USA | −105° 49.2′ | +32° 47.2′ | 2811 m | 1953–1966 |
| Kislovodsk | Russia | +42° 31.8′ | +43° 44.0′ | 2130 m | 1957–till now |
| Alma Ata | Kazakh Rep. | +76° 57.4′ | +43° 11.3′ | 3001 m | 1957–1962<br>1973–(1991?) |
| Lomnický Štít | Slovak Rep. | +20° 13.2′ | +49° 11.8′ | 2632 m | 1966–till now |
| Ulan Bator | Mongolia | +107° 03.0′ | +47° 50.0′ | 1600 m | 1971–1973 |

in 1930 (Lyot, 1930; 1931), with which he was able to observe the solar corona daily at the high-altitude Pic du Midi Observatory (Pyrenees), independently of solar eclipses. The success of Lyot's work with the coronagraph ($D = 20$ cm, $f = 400$ cm) has stimulated the construction of other coronagraphs on the same pattern and led to the establishment of other observatories high in the mountains, where the intensity of the light scattered by the dust particles of the Earth's atmosphere is already substantially suppressed, not exceeding $10^{-4}$ of the solar disk brightness. First of all, in 1938 Waldmeier (1939; 1940) began systematic observations of the coronal emission lines at Mt Arosa, Switzerland. The full set of his green-line Fe XIV 530.3 nm and red-line Fe X 637.4 nm measurements in the period 1939–1949 was published (Waldmeier, 1951) in the form of "coronal contours". Later, shortly after the Second World War, a world-wide network of coronal stations originated. The participating observatories are shown in Table 1.

The time intervals in the last column of Table 1 indicate the periods when the measured data were published in numerical form in the Quarterly Bulletin on Solar Activity (fortunately, the Pic du Midi numerical data from 1943 were at our disposal). The Sacramento Peak Observatory, after changing its method of measurements, reestablished its observations in 1973. Its very fruitful data are now published in graphical form and in the form of synoptic charts in the Solar–Geophysical Data Bulletin (see "explanation of data reports" in SGD 515 (Supplement), 1987 and Altrock, 1990). Through limited periods of time other observatories, for example, Crimea (Ukraine), Abisco (Sweeden), Kodaikanal (India) and Arcetri (Italy) have tried and sometimes succeeded in making coronal measurements but they never published their data. At present there are only four observatories (Sacramento Peak, Norikura, Kislovodsk and Lomnický Štít) where patrol measurements of the solar coronal emission lines are performed regularly; their data are published in the QBSA or SGD, or they are available, on request, to the solar community, prior to publication.

The green emission line intensities are usually measured in steps of five degrees around the Sun's disk (three degrees at Sacramento Peak Observatory), starting from the north pole, continuing through the east, south and west limbs, and going back to the north. Mostly the intensities are expressed in so-called absolute coronal units, i.e. in millionths of the energy radiated from the centre of the Sun's disk in the 0.1 nm strip of the spectral continuum near the coronal emission line. Thus, to obtain the "coronal contour", characterising the large-scale distribution of the coronal brightness around the whole solar disk, spectral measurements have to be made at 72 points. Some years ago, it took more than half an hour to record the photographic spectra at those points and it took almost the whole day to reduce and derive the final intensities by applying the methods of classical photometry. That is why there were continual efforts to develop and to use faster procedures for obtaining the final data.

Unfortunately, such uncoordinated efforts meant that the methods of observation and reduction of coronal intensities were not identical at the various coronal observatories throughout the history of green emission line corona measurements. For example, visual, radial-slit photographic, circular-slit photographic and photoelectric methods of observation have all been applied. Another source of variation was that the heights above the Sun's limb, at which the intensities were recorded, were not the same among the observatories. They varied from 40 to 60 seconds of arc (at Sacramento Peak Observatory it is now about 140 seconds of arc). Even the units to express the value of the intensity of the green emission corona were not identical – both absolute and arbitrary units have been used.

Evidently, for the vast majority of large-scale and long-term studies of the solar corona brightness, it is insufficient to use the data of a single coronal observatory only. Owing mainly to the weather conditions or occasional technical problems, the data of one observatory are usually deficient (on average, they cover from about 50 to about 200 days per year only). The gaps in observations of one observatory are sometimes so large that, for example, about 10 measurements (cf. days) per month can in no way be considered as representative for a given month and, consequently, no comprehensive synoptic charts can be effectively constructed from such a small number of measurements (Sacramento Peak Observatory with its about 200 observations in the year is an exception). That is why, in the case of large-scale and long-term investigations of the solar corona, it is very useful (or even necessary) to utilize accessible data from all the observatories. But then, however, the very serious problem connected with the homogeneity of measurements performed at different observatories arises.

It has been found (Sýkora, 1971) that there exist several systematic errors (differences) among the data of different coronal observatories due to instrumental differences and due to different methods used to reduce the raw measurements. It was emphasized that, at the very least, the differences among the photometric scales of the observatories, casual "jumps" in the stability of the photometric scale of a given observatory (for example, due to occasional changes of the observational technique and method of observation or due to modifying the reduction of the data, etc.), systematic errors in linearity of the position angle scales, errors in position of the zero points of those scales and objectively different tresholds of measurements at various observatories should be taken into account and eliminated when all the accessible data are being compiled and treated together. Such an analysis of the heterogeneity of the data was carried out and described by Sýkora (1971; 1983; 1992a). Compiling our present database, all the results and experiences of that analysis were considered and the 51-year homogeneous row of green corona data was now produced and updated. Since the longest, most homogeneous and extensive set of green corona measurements at the beginning of seventieth was that of the Pic du Midi, we have decided to transform all the other data to the photometric scale of this observatory. In spite of the termination of green-line corona patrol measurements at the Pic du Midi observatory in 1974, we still maintain its previous photometric scale in the presently compiled data through the whole 1943–1993 period.

In our previous studies we have frequently used the semi-annually or monthly averaged Fe XIV 530.3 nm coronal data. The averaging was performed for each five degrees of position angle (cf. solar latitude). The daily data were ready and often analysed up to 1976 only. A short review of the main results on the large-scale and long-term behaviour of the green corona brightness was given, for example, by Sýkora (1993). More recently, we were looking also for possible coronal relationships with the solar wind and geoactivity (Sýkora, 1992b) and we have also analysed some aspects of the long-term cosmic-ray modulution by solar activity (Parisi *et al.*, 1992; Bavassano *et al.*, 1994; Storini *et al.*, 1995). At present, with our new extended set of daily green corona data, we hope to be able to go deeper into details, particularly for the last two solar cycles and we will also take advantage of the larger data set when applying statistical approaches to the data.

## 2 POSSIBLE EXPLOITATION OF THE GREEN CORONA DATABASE IN THE ISCS PROJECT

It should perhaps be repeated that we are speaking here about the daily measurements (1943 January 1 to 1993 December 31) of the Fe XIV 530.3 nm spectral line intensity at 72 points (five by five degrees around the Sun and 40 seconds of arc above the Sun's limb). The intensities were digitized and they have been prepared so that they can be used in any computational and graphical procedures. Our initial database represents a matrix of 18 627 × 72 points.

It is clear that from these data the green-line corona brightness can be time-analysed in different position angles (cf. solar latitudes), or in arbitrary latitudinal belts (an example is shown in Figure 1), in different solar hemispheres, or an index of coronal activity for the Sun as a star (one value per day) can be derived. The database makes it possible to draw synoptic coronal charts separately from the east or west limb measurements (similarly to the charts published by the Sacramento Peak Observatory in the Solar–Geophysical Data). On the other hand, we have often used these data to derive the coronal data for the Sun's central meridian, combining the data from the east and west limbs together (considering, of course, 14 days difference between them to cover the same solar longitude). Our present database has been prepared also with this modification. Comparisons and correlations of the

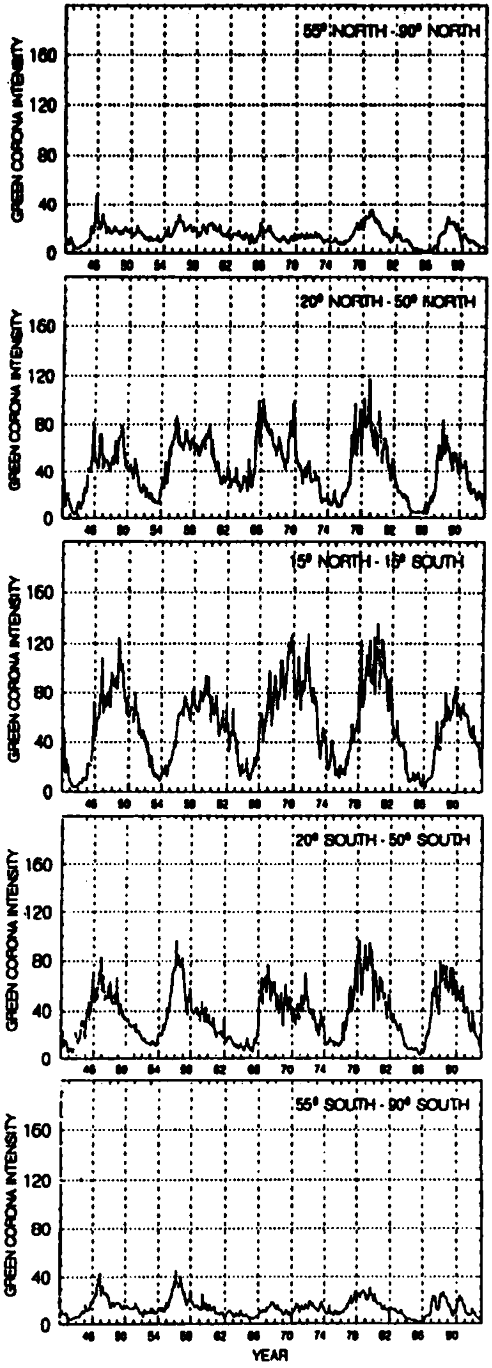


**Figure 1** Monthly averaged green-line intensity (1943–1993) plotted for the chosen solar latitudinal belts.

coronal brightness distribution with most of the solar and solar–terrestrial indices are easier and more adequate in this case.

Instead of working with the ordinary daily data, an arbitrary summation and smoothing can be applied to them to obtain, for example, monthly or semi-annually averaged data. Most of the solar cycle features (e.g. the butterfly diagrams of different cycles, the N/S or E/W asymmetries, etc.) may be better expressed in this way. Autocorrelation and cross-correlation analyses can reveal different periodicities in the solar activity and indicate possible relations for many of the solar and solar–terrestrial phenomena.

The present information on the green-line corona database is stimulated by an anticipation of its multilateral usefulness during the ISCS project. Therefore, we foresee collaboration with different scientists and research teams.

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