# TIME-LATITUDINAL DEVELOPMENT OF THE WHITE-LIGHT CORONAL STRUCTURES OVER A SOLAR CYCLES

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**Abstract:** Large-scale coronal structures (helmet streamers) observed in the white-light corona during total solar eclipses and/or with ground-based coronagraphs are mostly located only above a quiescent type of prominences. These helmet streamers are maintained due the magnetic fields of the Sun. Time-latitudinal distribution of prominences during a solar cycle, however, shows both the poleward and equatorward migrations, similarly as the 530.3 nm emission corona (the green corona) intensities. Distribution of observed coronal helmet streamers during total solar eclipses, enlarged with the helmet streamers as were obtained by the ground-based coronagraph observations, are compared with the heliographic distribution of prominences and the green corona intensities for the first time. It is shown that the distribution of above mentioned helmet streamers, reflects – roughly - the time-latitudinal distribution of prominences and emission corona branches, and migrates together with them over a solar cycle.

## 1. Introduction

Total solar eclipses and ground-based observations of the white-light corona provide long-term data sets of this part of the solar corona over a solar cycle. The longest set of the white-light coronal structures (helmet streamers) is created with eclipse observations that began to be made seriously at the end of 19$^{th}$ century. Distribution of eclipse helmet streamers shows that the shape of the white-light solar corona is changing during a solar cycle. To describe this variation, two parameters are usually used: (a) an ellipticity of isophotes, and (b) distribution of helmet streamers above the solar surface (morphology).

The ellipticity, parameter of the white-light coronal brightness, was introduced by Ludendorf (1928), and characterizes the flattening of the white-light solar corona isophotes at the 2 solar radii by the relation:

$$\varepsilon = (R_e/R_p)-1, \qquad \text{(Equation 1)}$$

are used
where $R_e$ and $R_p$ represent equatorial or polar distances of individual coronal isophoties from the center of the solar disk, respectively. The medial values are used of the three measured ones ($0^o$ , +/- $25^o$, $90^o$, +/- $25^o$). Long-term observations show the tendency of variability of coronal flattening during the solar cycle in the range 0.0 to 0.3 (Rušin and Rybanský, 1985), the zero value around cycle maximum, and 0.3 around cycle minimum, with a tendency of one year prior to the minimum. Around the solar minimum, the white-light corona shows the

so-called minimum type of the shape (corona minima), where large-scale helmet streamers are located around the solar equator only (see Fig. 1, left). On the other hand, around a solar maximum, helmet streamers can be observed symmetrically around whole solar limb (see Fig. 1, right). This type of the corona is called corona maxima. There is an intermediate shape of the white light corona between above the mentioned coronal shapes. Helmet streamers in the intermediate corona shape are distributed asymmetrically around the solar limb as seen in Figure 2. We note that the maximum and minimum of a solar cycle are defined according to the sunspot number.

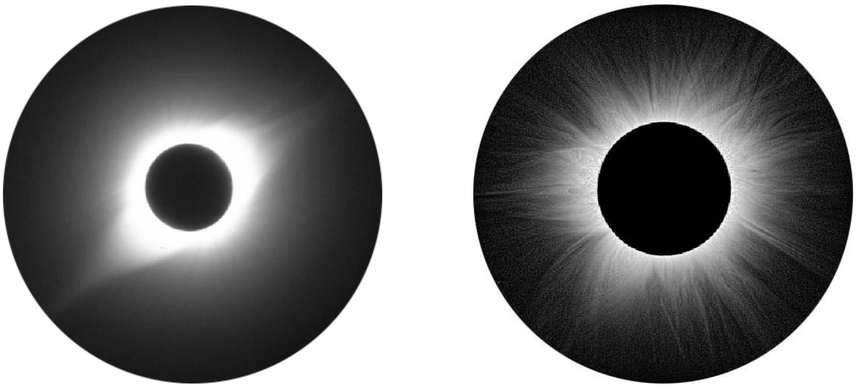

Fig. 1. Minimum type of the white-light corona during the total solar eclipse on October 25, 1995 (left), and maximum type of the white-light corona as observed during the total solar eclipse on June 21 2001, (right).

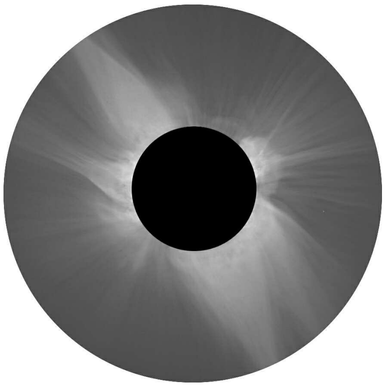

Fig. 2. The white-light solar corona as was observed during the total solar eclipse on July 11, 1991. (Courtesy Rhodes College, Memphis, Tennessee, and High Altitude Observatory (HAO), University Corporation for Atmospheric Research (UCAR), Boulder, Colorado; UCAR is sponsored by the National Science Foundation).

Distribution of the flattening index, ε, as defined by Ludendorf (1928) over solar cycles from all available white-light corona pictures, as observed during total eclipses, is in detail described in Rušin and Rybanský (1990). However, a detail inspection shows, that there are some eclipses when flattening index is very close to the value 0.0, but the distribution of helmet streamers is asymmetric. Such a case of the white-light corona was observed on July 11, 1991 (see Figure 2), for example.

While the time-latitudinal development of the green corona local maxima intensities (Rybanský, Minarovjech and Rušin, 2003) are well known, and a similar conclusion is known for the distribution of solar prominences, see, e. g., McIntosh (1992), Minarovjech, Rybanský and Rušin (1998), ~~a~~ little is known, in detail, about the time-latitudinal development of helmet streamers over cycles. The main reason for this fact is: rare occurrence of total solar eclipses, unfortunately.

In the present paper we will briefly examine the time-latitudinal distribution of helmet streamers, prominences and the green corona over the period 1988-1998 and shortly discuss a scenario how the white-light coronal structures could develop over a solar cycle.

## 2. Coronal synoptic charts and coronal structure distributions

The only observations of the white-light corona are carried out with coronameters Mark III (MK3) and Mark IV (MK4), respectively (http://mlso.hao.ucar.edu). Mauna Loa coronameters captured more than one solar activity cycle with an appropriate cadency, although their data are available from 1980. We used these data to prepare synoptic charts of the white-light corona in the period from January 1, 1988 to December 31, 1998, i.e., for the 11-year period in solar cycles 22 and 23. This synoptic chart (Figure 3) displays the distribution of white-light coronal structures at the height $R/R_s = 1.7$. This distribution can represent a general view of the development of the white-light coronal shape over the one solar cycle.

This chart displays the daily position of coronal structures above the eastern solar limb. Every column represents the 1 day in the year under the study period; the north is at the top, the south at the bottom. Grey columns are no-data days. The white-light coronal structures occurring above the E-limb are marked with white color, the black parts represent regions without significant structures.

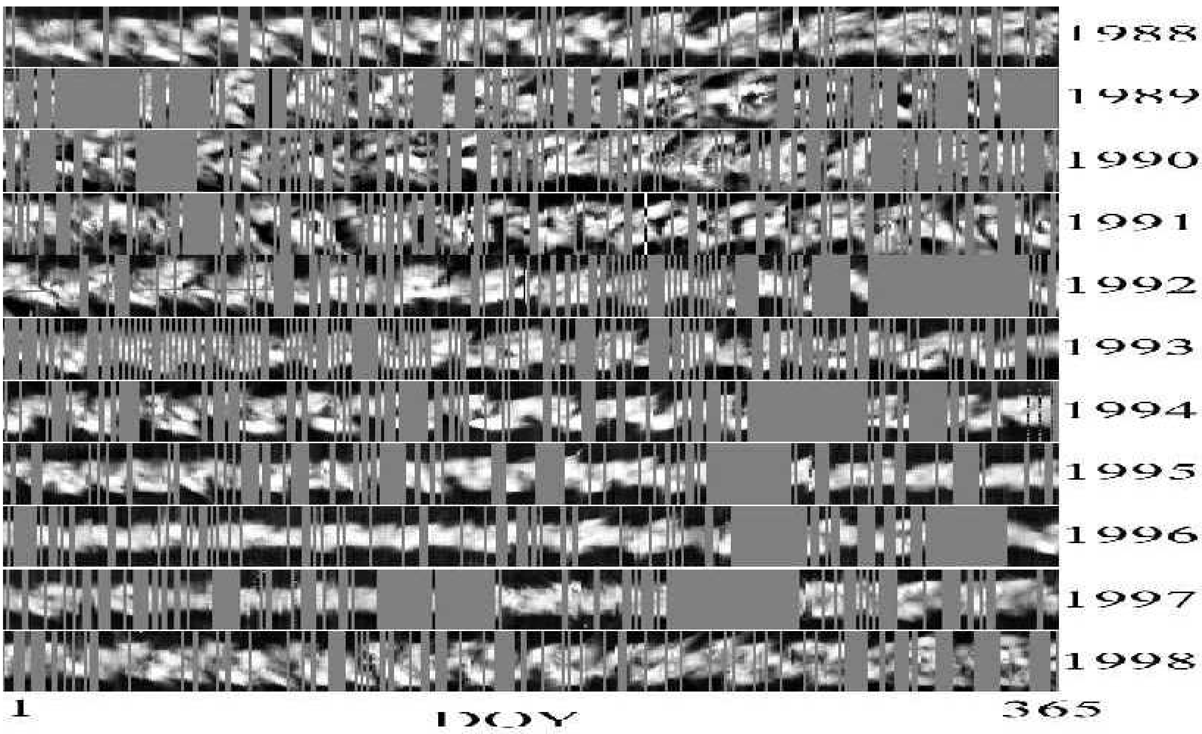

Fig. 3. Coronal synoptic chart for the period 1988 – 1998 for the E-limb helmet streamer distribution. Grey scale: no available data.

As we can see in Figure 3, the coronal shape defined according to the distribution of the eclipse helmet streamers actually show general tendency to be of minimal type during the solar minimum and of maximal type during the solar maximum. However, while the intermediate type or the minimum one of the corona could be found in some periods around the solar maximum, this can not be found in cycle minima, it means, to observe the corona of maximum type.

Although the above mentioned charts show general tendencies in the coronal shape development, they can not give us a precise description of coronal structures located above the solar limb. The main problem, at present, is the 3-D projection of coronal structures observed from one direction.

This reason led us to prepare another type of the white-light coronal streamer distribution chart as shown in Figure 4. This chart shows the time-latitudinal distribution of helmet streamer axes during studied period 1988-1998. Individual dots in Figure 4 represent central part (axis) the well defined helmet streamers as was observed with MK3 and MK4.


Fig. 4. Time-latitudinal distribution of helmet streamer axes over the period 1988-1998.

The obtained result can be easily compared with the time-latitudinal distribution of the green corona intensities (local maxima) as shown in Figure 5.

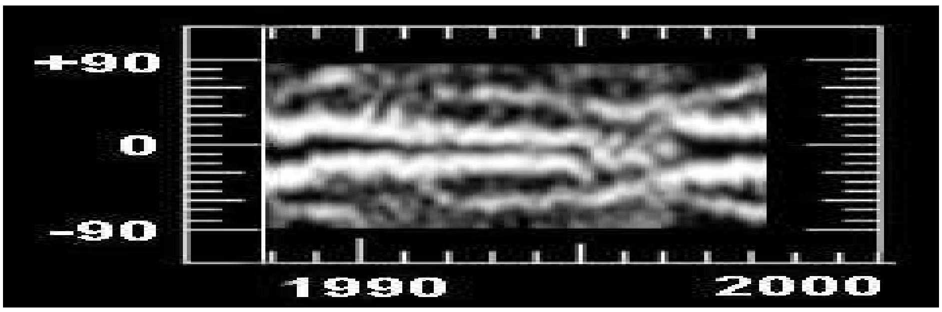


Fig. 5. Time-latitudinal distribution of the green coronal line 530.3 nm intensities (local maxima), extracted for the period under study (Rybanský, Minarovjech and Rušin, 2003, cf. Fig. 2).

Comparison of both results, the time-latitudinal distribution of the green corona local intensity maxima and distribution of the white-light coronal streamer axes are, for the first time, shown in Figure 6. Roughly, the heliographic latitude of the helmet streamer axes from the pole side is nearly at the same heliographic latitude as the principle and poleward branches of the green corona, and it moves with the similar tendency as the green corona branches.

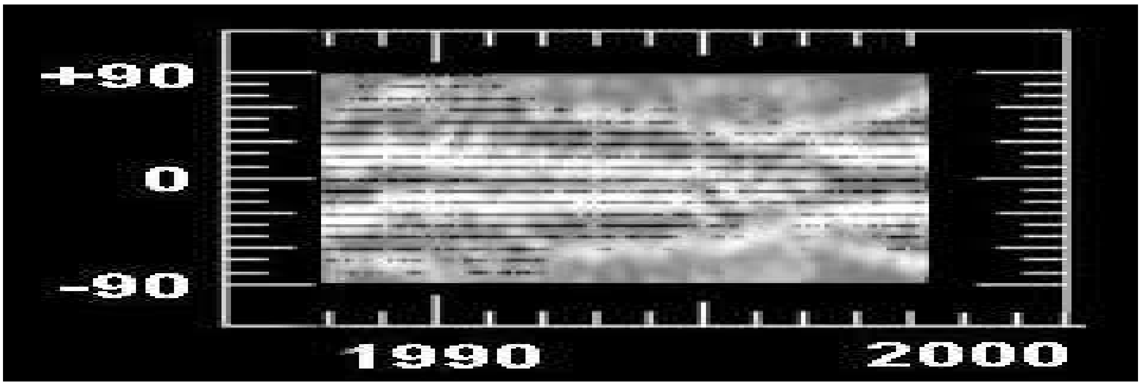


Fig. 6. Composition of Figs. 4 and 5 in the period 1988 – 1998.

Composite Figure 7 displays the time-latitudinal distribution of prominences and helmet streamer axes.

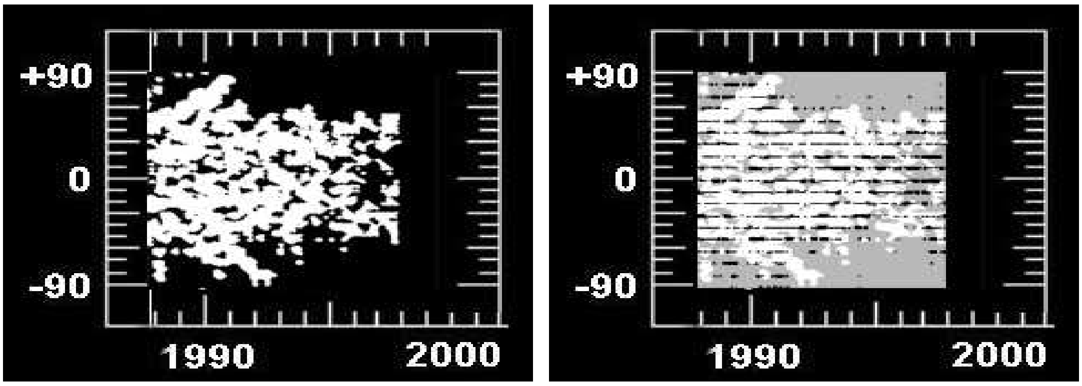


Fig. 7. Time-latitudinal distribution of prominences during studied period 1988-1998 (left) and their comparison with the distribution of helmet streamers (right). The distribution of prominences is marked by white dots, the black small dots in Fig. 7 (right) represent the distribution of streamer axes from Figure 4.

### 3. Short Discussion and Conclusion

Magnetic fields of the Sun (both global and local) are responsible for solar activity features, including structures of the white-light corona, see, e.g., Golub and Pasachoff (1997). It is generally known, e.g., Zirker (2002), that local magnetic fields are developing over the solar cycle. Time-latitudinal distribution of prominences and the green corona have been known for longer time. For the first time we have presented in this paper a comparison of the white-light coronal structures with prominences and the green corona distribution in the period 1988-1998. Our short remarks to the relations between prominences, the green corona and the white-light corona are as follows:

(A) Possible scenario for a helmet streamer distribution: helmet streamers around cycle minima are observed around the solar equator only, because there is a single neutral magnetic line (where usually quiescent prominences are located), nearly parallel with the solar equator (Zhao and Webb, 2003). In the next development, some helmet streamers have a tendency to move together with prominence and the green corona branches to the poles. Inclination of neutral magnetic field line to the solar equator according to the prominences distribution is increasing (see Figures 6 and 7). This apart, there ~~is~~ are more helmet streamers during solar maximum, connected with local magnetic fields in the vicinity the neutral magnetic lines of active regions or remnants of magnetic fields transported from active regions to the poles. So, these helmet streamers can be observed anywhere above the solar surface. Poleward migration of prominences begins from mid-heliographic latitudes at the beginning of a new cycle, and ends around cycle maximum, when prominences decay. Different orientation of these neutral lines, e.g. Zhao and Webb (2003), causes different orientation (edge-on or plane) helmet streamers located above multi-neutral lines, so the white-light corona can display intermediate type of its structure around the solar cycle maximum.

(B) As can be seen in Figure 6, the green corona local maxima intensities are observed very close to the large-scale white-light coronal structures. This result confirms Minarovjech's conclusion (Minarovjech, 2000) that the occurrence of local maximum intensity of the green corona is located in these regions, where the maximum gradient of intensities of the white-light coronal structures is observed with MK3. On the other hand, to ~~the~~ each local maximum of the green corona intensity belong some white-light coronal structures, if this part of the structure is rooted in the vicinity of the solar limb. However, if the white-light coronal structures are rooted far from the solar limb (ahead of it or behind of it), ~~so,~~ the local maximum intensity of the green corona usually cannot be observed due to the high gradient of the green corona intensity with the height above the solar surface.


## Acknowledgements

This work was partly supported by the Slovak Academy Grant Agency VEGA, Grant 2/4011, by the Grant of the Ministry of Education 2-3-15 (Cooperation with China), and by the Czech Science Foundation, Grant 205/01/0420. We would like to thank anonymous referee for his/her valuable comments.


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