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Long-term Cyclic Variations of Prominences, Green and Red Coronae over Solar Cycles

Vojtech Rušin*, Milan Minarovjech & Milan Rybanský *Astronomical Institute, Slovak Academy of Sciences, 059 60 Tatranská Lomnica, Slovak Republic*
**e-mail: vrusin@ta3.sk*

Abstract. Long-term cyclic variations in the distribution of prominences and intensities of green (530.3 nm) and red (637.4 nm) coronal emission lines over solar cycles 18–23 are presented. Polar prominence branches will reach the poles at different epochs in cycle 23: the north branch at the beginning in 2002 and the south branch a year later (2003), respectively. The local maxima of intensities in the green line show both poleward- and equatorward-migrating branches. The poleward branches will reach the poles around cycle maxima like prominences, while the equatorward branches show a duration of 18 years and will end in cycle minima (2007). The red corona shows mostly equatorward branches. The possibility that these branches begin to develop at high latitudes in the preceding cycles cannot be excluded.

Key words. Prominences — emission corona — cycle activity.

1. Introduction

So far a wide variety of phenomena have been used to study solar activity, e.g. sunspots, irradiance in the whole range of the electromagnetic spectrum, coronal mass ejections, and so on (see for example Pap *et al.* 1994). These studies have led to a better understanding of magnetic activity of the Sun as a star, and its influence upon Earth. Individual features of this activity in the outer layers of the solar atmosphere are caused by both small- and large-scale magnetic fields stored at the base of the convection zone. Active regions emerge as a result of occasional disturbances given to this toroidal field by the convection (dynamo mechanism). Prominences and the corona are observed around the entire solar disk. Thus, these phenomena allow us to study magnetic activity not only around the equator and/or mid-heliographic latitudes, but at high latitudes and around the poles as well, and will help improve our knowledge on the origin of solar activity. In this paper we present some results on 'cyclic' variations as obtained from prominences and green and red coronal emission lines.

2. Observations

Observations of prominences have been regularly made at the Lomnický Štít coronal station since 1967. Data on the green-line corona over the period 1939–1996 were taken from the compiled homogeneous coronal data set (e.g. Altrock *et al.* 1997 and references therein). Data for 1997–1999 were taken from Kislovodsk and Lomnický Štít. Coronal red-line intensities were taken from data published in Quarterly Bulletin on Solar Activity and Solar Geophysical Data.

3. Results

1. Prominences clearly show poleward-migrating branches which are separated in cycle minima from the main zone in mid-latitudes, and then shift to the poles, where they decay in cycle maximum. Our results confirm the former results presented by many researches, e.g., Secchi, Waldmeier, d'Azambuja, Makarov and others, e.g. Rušin, Rybanský & Minarovjech (1998). However, the time of arrival of these branches to the poles differs between northern (N) and southern (S) hemispheres. The N-branch comes to the pole about one year earlier than the S-branch, at present. There are two polar branches observed in some cycles, e.g. in cycle 20 in the N-hemisphere and in cycle 22 in the S-hemisphere. Similar cases have occurred in some former cycles as can be seen from filament observations (e.g., Coffey & Hanchett 1998). Comparison of the prominence distribution in the present cycle 23 with former prominence cycle distributions indicates that the north branch will reach the north pole at the beginning of 2002, the south one a year later (2003), respectively. More details about the time-latitude distribution of prominences can be found in Minarovjech, Rybanský and Rušin (1998).

2. The local maxima in latitude distribution of the green line intensity show also poleward and equatorward branches (Fig. 1). Sequences of their development are as follows: The main equatorial branch begins to develop approximately 2–3 years after the previous minimum, in latitudes of 50–60 degrees, separating from the principal zone of the previous cycle. Then, these increased intensities move to the heliographic latitudes of 70 degrees, and turn off (around cycle maxima) to move to the equator,

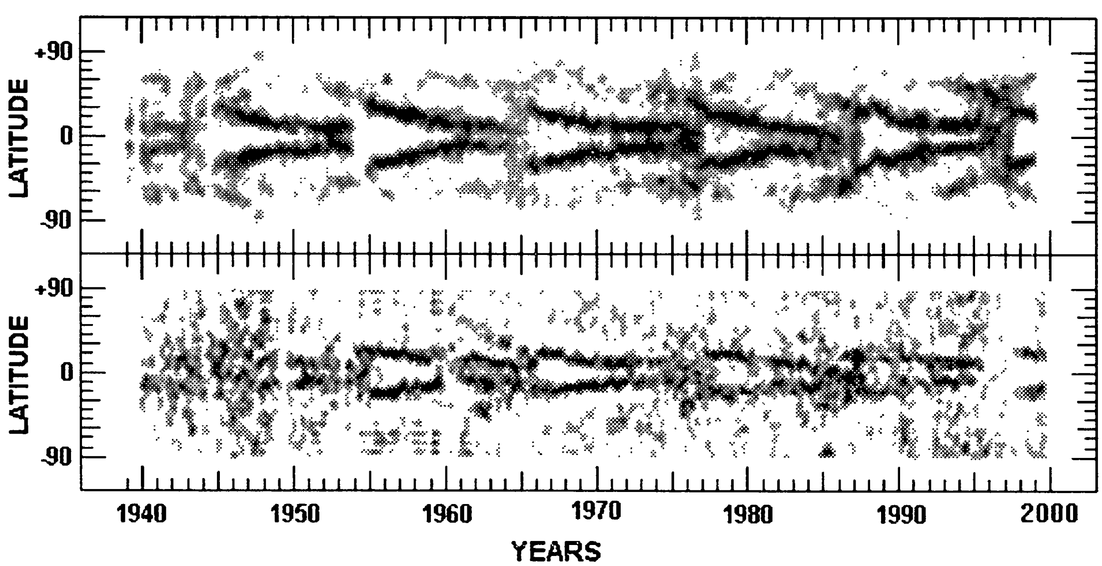

Figure 1. Time-latitude diagrams of local maxima of the green- (top) and red- (bottom) line intensities, respectively, indicating how solar cycles overlap for several years.

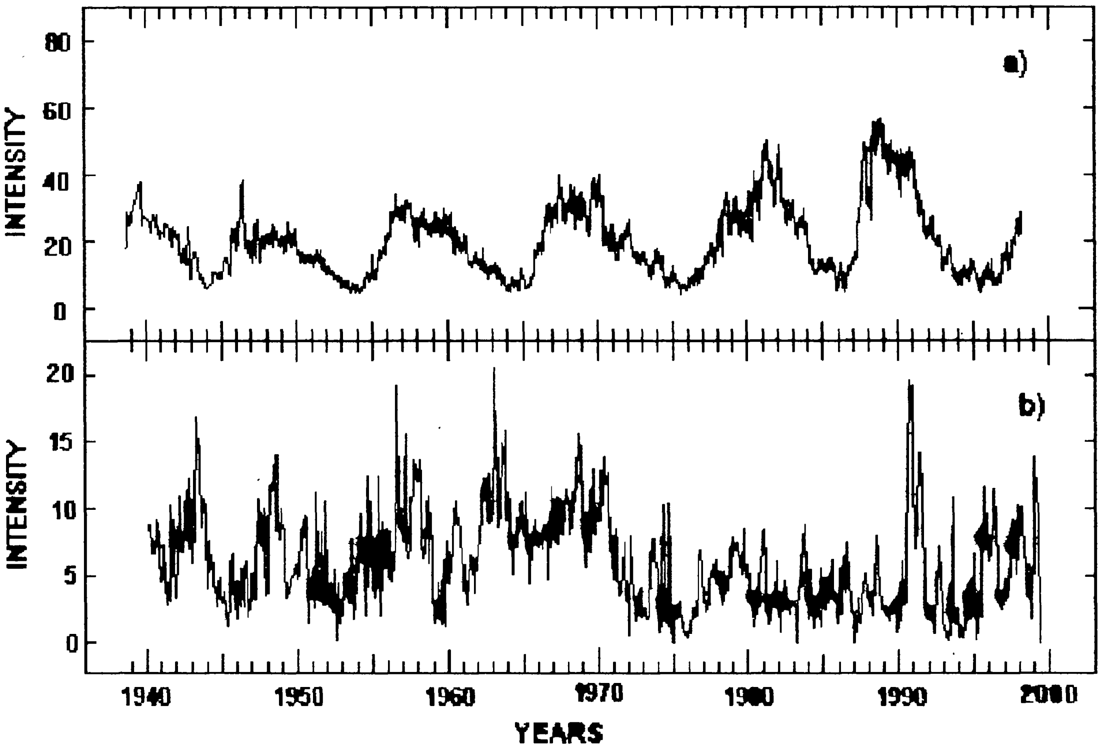

Figure 2. Changes in solar activity over monthly scales, as evident in the green (top) and red (bottom) coronae for the entire Sun.

where they end (decay) in the following minimum in latitudes around 5–10 degrees. The whole process takes 17–18 years. The poleward-migrating branches reach the poles around cycle maximum, and decay when the polar magnetic field reversal occurs. These branches are separated in cycle minimum just 2–3 years prior to the beginning of the next principal equatorward-migrating branch. The poleward-migrating branches of the green-line corona are better seen when only one poleward migration branch occurs in prominences.

3. Distribution of the red line (637.4 nm) intensities shows only the principal equatorward-migrating branches (Fig. 1). They begin clearly to develop around cycle minima at heliographic latitudes of 20–25 degrees (their maxima are 5 degrees closer to the equator than those of the green-line corona), and end in the next minimum. Nevertheless, one may recognize, in some cycles, outlines of high-latitude branches that migrate to the mid-latitude principal branches.

4. The long-term behavior of the green-line corona (Fig. 2) indicates that the peak amplitudes increased over the period of 1939-1998 by a factor of 2. We did not see double or multiple maxima in cycle 20 as discussed by Sýkora (1992). The changes in intensity over scales of months are complicated due to the quasi-biennial periodicity during the '11-year' cycles (e.g. Rušin & Zverko 1990). The peaks of the green-line emission mostly coincide with the sunspot numbers, even though a shift of two years was observed in cycles 20 and 21. We did not confirm the existence of two red-line peaks, in sunspot maximum and minimum, as discussed by Waldmeier (1971) in cycle 21. The peak of the red-line intensity is only one, nearly coincident with that of the green-line corona. Nevertheless, increased intensities were observed around cycle minima (Rušin, Rybanský & Minarovjech 1998), and the changes of the red-line

intensities are much more complicated than for the green-line corona. Even though 'chaotic' changes in the red-line corona are seen in data of monthly averages, the existence of low-latitude branches confirm a long-term development that is similar to the green-line corona.

4. Conclusion

We have presented here distributions of prominences, and green and red coronal intensities over the period of 1939 (1967)–1999. All observed phenomena confirmed cycle variations, even though with a very complicated manner, and sometimes are confused. This stresses the necessity of coordination in both ground-based and space solar observations.

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References

Altrock, R. C. 1997, *Solar Physics*, **170**, 411.

Coffey, H. C., Hanchett, C. D. 1998, In *Synoptic Solar Physics*, ASP Conference Series, Vol. 140, (eds.) K. S. Balasubramaniam, J. W. Harvey and D. M. Rabin, 447.

Minarovjech, M., Rybanský, M., Rušin, V. 1998, In *New Perspectives on Solar Prominences*, ASP Conference Series, (San Francisco), (eds.) D. Webb, D. Rust and B. Schmieder, 484.

Pap, J. M., Fröhlich, C., Hudson, H. S., Solanki, S. K. 1994, *The Sun as a Variable Star* (Cambridge University Press).

Rušin, V., Zverko, M. 1990 *Solar Phys.* **128**, 261.

Rušin, V., Rybanský, M., Minarovjech, M. 1998, In *Synoptic Solar Physics*, ASP Conference Series **140**, (eds.) K. S. Balasubramaniam, J. W. Harvey and D. M. Rabin, 353.

Sýkora, J. 1992, *Contr. Astron. Obs. Skalnaté Pleso* **22**, 55.

Waldmeier, M. 1957, *Die Sonnenkorona*, Vol II., Birkhauser, Basel.