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More on the Gnevyshev Gap During the 11-year Solar Activity Cycle

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Abstract: Structured activity maxima are detected, in all the solar atmospheric layers up to the interplanetary space, during the 11-y sunspot cycles. A clear trace of a dual-peak maximum was found in past works and here is confirmed for cycle 23, remarking the relevance of the time interval between the two activity peaks (the so-called Gnevyshev Gap) for Space Mission planning. Results supporting the Gnevyshev Gap definition are derived by analysing the 27-d periodicity of Kp and Dst indices.

Introduction

Prediction of solar activity features is a major goal not only for Cosmic Ray Physics but also for the Space Mission planning. A bimodal distribution around the sunspot cycle maximum was suggested to exit for solar-terrestrial parameters ([1, 2] and references therein).

The period between the two solar activity peaks (the dip interval) was called the Gnevyshev Gap by the Rome Cosmic Ray Group [3, 4], and it is world-wide accepted by the scientific community. Nevertheless, the concept was recently questioned by some investigators, because analyzing the time history of several solar-terrestrial parameters some dips were often found during the solar activity cycle. Here we discuss more on the matter.

Gnevyshev Gap features

The Gnevyshev Gap presence in solar parameters was identified and extensively discussed by Feminella and Storini [5], and Bazilevskaya et al. [6]. Moreover, Storini et al. [7] demonstrated for the current solar cycle (n. 23) the reliability of the Gnevyshev Gap, by using the monthly sunspot number, grouped solar flares and spot areas. In such a paper the emergence of several peaks and dips is indeed evident during the cycle. Nevertheless, it should be reminded that solar activity periodicities are present in the different parameters (e.g. [8] for cosmic ray data) and it is quite natural to expect waves in their time history.

However, the Gnevyshev Gap occurs during the activity maximum and has a very peculiar feature (as can be seen in Figure 1): the dip tends to reach the characteristic values of the minimum solar activity phase. This is particularly true for the flare occurrence, the interplanetary magnetic field intensity and sunspot areas. Although not shown, there is a similar effect in the solar proton flux (e.g. P2 channel: 0.50-0.96 MeV, from CPME instrument on IMP8 satellite; http://sd-www.jhuapl.edu/IMP/imp_cpme_data.html).

We recall that the double-peak morphology is more distinct when the time history of intense and/or long-lasting solar active events are considered, being the low-energy and short-lived events characterized by a single-peaked 11-y cycle [5].

The use of an average parameter (containing low and intense events) can bring sometimes to wrong conclusions.

Because the 11-y cycle in the interplanetary medium is affected not only by active solar phenomena (creating transient interplanetary perturbations) but also by the coronal hole presence on the Sun (at the origin of recurrent solar wind streams), we investigated the 27-d periodicity in two geomagnetic parameters (Kp and Dst) during the Gnevyshev Gap (see next section).

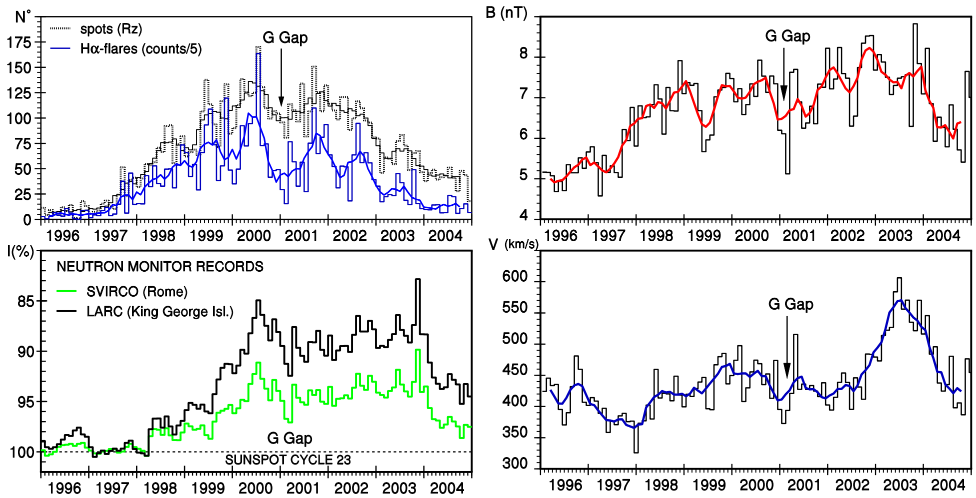

Figure 1: Time history of monthly sunspot and flare number (upper left panel), neutron monitor records (lower left panel), solar wind speed (lower right panel) and interplanetary magnetic field intensity (upper right panel) during the current solar activity cycle. Thick trends show the 5-month running averages (note the wave trends). Arrows refer to the Gnevyshev Gap identification.

27-d periodicity of Kp and Dst

The 27-d periodicity from 1957 to 2000 was investigated by using daily values of the Kp and Dst indices (http://swdcwww.kugi.kyoto-u.ac.jp).

The Wavelet Technique (Morlet mother wavelet) was applied to both data sets [9]. Figure 2 illustrates the results obtained by reproducing the time variation of the daily power to white noise ratio of the 27-d periodicity for both indices (Kp: orange and Dst: green) during solar activity cycles 20 to 22. The red line gives the 27-d running averages for the sunspot areas (used as a reference for the 11-y cycle). The blue line represents the daily difference between the Kp and the Dst power/noise ratio for the 27-d periodicity. From Figure 2 it can be singled out that during 1969-1970, 1980-1981 and less evident in 1990-1991 (see below) there is a strong reduction in the 27-d power to noise ratio for both geomagnetic parameters, suggesting that long-lived (recurrent) active phenomena are practically absent, as required for the Gnevyshev Gap identification. Outside such interval the power/noise is significant, except for minimum activity years.

Can the obtained result be considered as another proof for the reliability of the Gnevyshev Gap? To accept it we should explain the 27-d power trend during cycle 22.

The coronal hole occurrences for cycles 21 and 22 can be taken from the NOAA (Boulder) Web pages. The list (see [10, 11] for details) contains two types of coronal holes: (i) the extended polar coronal holes and (ii) isolated coronal holes (without connection with any pole). Because we are interested in the maximum activity phase of each cycle (when polar coronal holes disappear) we considered only isolated coronal holes.

As it is known isolated coronal holes show an occurrence rate that tends to follow the 11-y cycle [12]. Figure 3 illustrates their average latitude from 1973 to 1995 (lower panel; the upper panel shows the yearly sunspot number from 1970 to 1996). Each isolated coronal hole is represented by a dot; recurrent isolated coronal holes appear as segments. The period between 1980 and 1981 is characterized by few recurrent coronal holes, while from 1990 to 1991 there are several recurrent coronal holes. They can explain results from Figure 2 and help us in the Gnevyshev Gap characterization.

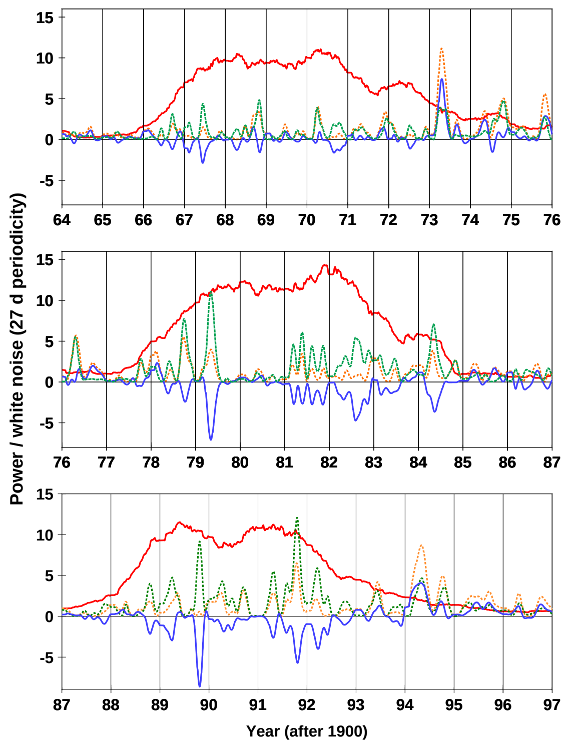

Figure 2: Daily power/noise ratio of the 27-d periodicity for Kp (orange) and Dst (green) indices (blue trends give Kp-Dst power/noise ratio differences), together with the 27-d running averages of the sunspot areas (red; right scale in 10^{-6} Hemisphere).

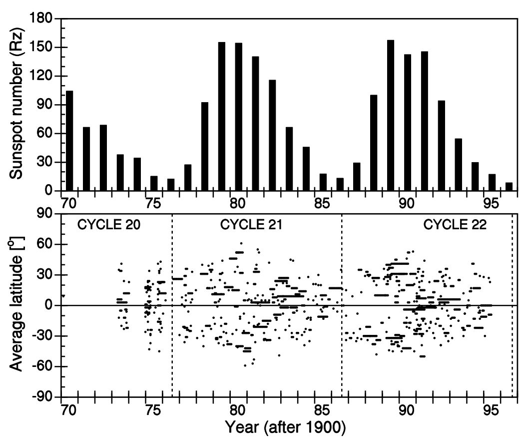

Figure 3: Isolated CH distribution in latitude, derived from data reported by NOAA (bottom panel) and yearly sunspot number (upper panel).

Conclusion

The concept of the Gnevyshev Gap has great importance, because a reduction of large and intense dynamical phenomena on the Sun are expected in such period. Its role in solar activity forecasting for Space Missions Planning could be very important.

In this paper the 27-d periodicity of two geomagnetic indices was investigated during the maximum activity phase of the 11-y cycle (from cycle 20 to 22).

Findings suggest a dumping of the power to noise signal during the Gnevyshev Gap intervals. It is interpreted as the result of a low number of recurrent solar phenomena in such periods, in agreement with the Gnevyshev Gap definition.

Acknowledgements

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