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WHY IS GEOMAGNETIC ACTIVITY DURING THE ENDING YEARS OF A SOLAR CYCLE WELL-CORRELATED TO THE MAXIMUM OF THE NEXT CYCLE?

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ABSTRACT

The 'two component nature' of the solar activity cycle, as resulting from the 'shock-transition model' of the solar magnetic cycle, provides for a correlation between a measure of coronal hole formations during the ending years of one solar cycle and the maximum annual sunspot number R_{max} of the next cycle. This might account for the observed correlation between the geomagnetic activity during the last few years of one cycle and the R_{max} of the next cycle.

Key words : solar cycle — solar magnetic fields — geomagnetic activity

1. Introduction

During the course of an 11-yr cycle of solar activity, the variation of geomagnetic activity shows *two* peaks corresponding to the 'two maxima' of the solar activity cycle, followed by a *third* peak during the last few years of the solar cycle (Hakura, 1974, Gnevyshev, 1977). This third 'peak' is characterized by the abundance of "27-d recurrent geomagnetic storms", which are presumably caused by the fast solar wind from the long lived coronal holes. 'The two-component model' of the solar activity cycle (Gokhale, 1979) provides for the formation of such long lived coronal holes during the ending years of each activity cycle. Thus, this model accounts for the 'third' peak also, but with coronal holes, instead of flares, as the cause of geomagnetic disturbances during this peak.

Here we show that the model provides a correlation between the coronal hole formations during the ending years of each activity cycle and the maximum annual sunspot number $\underline{R}_{max}$ of the next cycle. This might account for the observed correlations between the geomagnetic activity indices during the last few years of each cycle and the $\underline{R}_{max}$ of the next cycle.

2. Observed Correlations, Their Importance and Interpretation

2.1 *The Correlations*

Several indices of geomagnetic activity during the 'ending years' of a solar cycle are known to be well correlated to the maximum sunspot number during the *next* solar cycle. Thus, for example, the number of days of abnormal time profiles of the horizontal component of the magnetic field (Brown, 1974), the level of the '27-d recurrent' geomagnetic disturbance, (Bhargava and Rangarajan, 1975) and the K_p and *aa* indices of this activity (ref. in Kane, 1978), all during the ending years of a cycle no. '$\underline{n}$', are well correlated to the maximum annual sunspot number $\underline{R}_{max}$ ($\underline{n}$+1) during the cycle no '($\underline{n}$+1)'.

2.2 *The Importance*

In agreement with the forecasts based on such correlations (*e.g.* Brown, 1974; Kane 1978), the sunspot number during the current cycle is now almost certain to attain a 'maximum' exceeding 150. (In contrast, the purely statistical forecasts made before the beginning of this cycle, which did not take into account any special relation between the successive cycles, were all below 100 : *cf.* Gleissberg, 1971 ; Cole, 1973 ; Cohen and Lintz, 1974). Therefore, it seems that the afore-mentioned correlations manifest from some fundamental relation between the successive solar cycles, which must be a consequence of the basic mechanism of the solar cycle.

2.3 *The Interpretation*

Clearly, the amplitude $\underline{R}_{max}$ ($\underline{n}$+1) of the maximum annual sunspot number during the ($\underline{n}$+1)th cycle must be well-correlated to some appropriate measure of the 'solar cause' of the geomagnetic disturbances during the ending years of the nth cycle. The only likely 'cause' known at present is the fast streams associated with the long lived coronal holes formed on the Sun during such years (*cf.* Section 4.4 of Gokhale, 1979). Therefore, $\underline{R}_{max}$ ($\underline{n}$+1) must be well-correlated to an appropriate index 'CH ($\underline{n}$)' of the *number, areas* and *persistence* of coronal holes during the ending years of the $\underline{n}^{th}$ cycle.

This interpretation involves the following assumptions :

i) the fraction of the coronal holes located favourably for the fast streams from them to reach the earth does not vary too much from cycle to cycle,

ii) the geomagnetic activity produced by unit area of a coronal hole per unit time does not vary much from one coronal hole to another.

These assumptions may be only approximately true ; but such approximate validity would still yield adequate correlations.

3. The Correlation Provided by the Model

The main question is : why should CH ($\underline{n}$) be well correlated to $\underline{R}_{max}$ ($\underline{n}$+1)? The answer seems to follow as a corollary of the 'two-component nature' of the solar activity cycle as provided by the 'shock-transition' model of the solar magnetic cycle.

From Sec. 4.4 of Gokhale, 1979 it follows that

$$\text{CH}\ (\underline{n}) \longleftrightarrow \phi_{\underline{R}}\ (\underline{n}), \qquad (1)$$

where ϕ_R (n) is the *total* magnetic flux in the *"front portions"* of the "flux rolls" (which form the *'R'* family flux tubes of the $\underline{n}^{th}$ cycle and provide the 'IInd component' of that activity cycle). The symbol $\longleftrightarrow$ represents a 'good correlation'.

According to Gnevyshev (1977), $\underline{R}_{max}$ ($\underline{n}$+1) would essentially be the maximum of the 'Ist component' of the sunspot cycle. It follows from Sec. 4.1 of Gokhale 1979 that this maximum will be determined mainly by the *total* magnetic flux ϕ_s ($\underline{n}$+1) in the *'S'* family flux tubes of that cycle.

Thus,

$$\underline{R}_{max}\ (\underline{n}+1) \longleftrightarrow \phi_s\ (\underline{n}+1), \qquad (2)$$

Now, according to the 'shock-transition model', the *S* family flux tubes of the ($\underline{n}$+1)th cycle are formed from the magnetic flux in the 'back portions' of the "flux rolls" in the $\underline{n}^{th}$ cycle, which must be same as ϕ_R ($\underline{n}$).

$$\text{Therefore}\ \phi_{\underline{s}}\ (\underline{n}+1) = \phi_R\ (\underline{n}) \qquad (3)$$

[Incidentally, relations (2) and (3) would also provide a correlation between $\underline{R}_{max}$ ($\underline{n}$+1) and the *polar field* at the sunspot minimum at the end of cycle 'n' as suggested by Scherrer *et al* 1978].

From relations (1), (2) and (3) it follows that

$$\underline{R}_{max}\ (\underline{n}+1) \longleftrightarrow \text{CH}\ (\underline{n}).$$

Thus, the 'two-component model' of the activity cycle' provides a basic physical relation between successive solar cycles which might account for the observed correlation between the geomagnetic activity during the 'ending years' of one cycle and the maximum sunspot number in the next cycle.

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