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Near-transyear in solar magnetism

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Abstract

Daily data on solar magnetism, available from May 1975 to April 2002, were analyzed by linear–nonlinear rhythmometry, with particular focus on the near-transyear, slightly longer than the calendar year. The time structure of solar magnetism is compared to that of solar activity, gauged by Wolf numbers. An about 27-day component corresponding to the solar rotation period, is common to both variables but differs in harmonic content. About 10-year component characterizes solar activity but not solar magnetism. A near-transyear with a period of about 1.05 years is detected in solar magnetism. In solar activity, a near-transyear is also found but its period of about 1.10 years is longer than that characterizing solar magnetism, and it may be paired with an about 0.9-year component to correspond to an about 10-year modulation in amplitude or phase of an about-yearly component.

Keywords

Chronome; Near-transyear; Solar activity; Solar magnetism; Wolf numbers

1. Introduction

Far- and near-transyears, with periods differing from (and slightly longer than) the calendar year, the former described by physicists earlier [1], have recently found counterparts in biology. Near-transyears were defined as having a period between 1.0 and 1.2 years with a 95% confidence interval (CI) not overlapping these limits [2]. The time structures of solar magnetism and solar activity, gauged by Wolf numbers, are examined herein, with particular focus on any near-transyear that would be in keeping with a rule of reciprocal cycles in and around us [3].

2. Materials and methods

Daily averages of the solar magnetic field were downloaded from NOAA's website (http://ftp.ngdc.noaa.gov/STP/SOLAR_DATA/SUNASASTAR/Stanford/). SUN-AS-A-STAR data measure the solar magnetic field summed over the disk as the net magnetic field, expressed in microTeslas. The data from PH Scherrer of the Stanford Solar Observatory are available from May 16, 1975 to the present. Data up to the end of April 2002 are analyzed herein.

Several observations are typically made daily, centered around local noon. Each value reported is a weighted average of all measurements for that day. The weighting arises from effects that

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include solar rotation, limb darkening, and weakening of the sensitive absorption line within active regions [4].

Daily values of Wolf numbers gauging solar activity for the same 27-year span (May 1975–April 2002) are also analyzed. In order to assess any spurious effect due to missing values in the record of solar magnetic data, the series on Wolf numbers was analyzed as such and after removing values on days when no solar magnetic data were available.

Least squares spectra were computed for each data series in the frequency range from one cycle in 27 years to one cycle in about 6.5 days [5,6]. Spectral peaks were further resolved by nonlinear least squares to obtain a 95% CI estimate of the period [6–9].

3. Results

Fig. 1 illustrates the least squares spectrum of the solar magnetic field data, averaged over consecutive 3-day intervals. The most salient feature of a broad band around 27 days and harmonics thereof corresponds to the solar rotation period, known to vary as a function of solar latitude [10–12], considered for medical implications in the 1930s by Drill and Drill [13]. In the low-frequency part of the spectrum, apart from a component with a period of about 6 years, spectral peaks can be seen at one cycle in 1.059 years and at one cycle in 0.495 year. Nonlinearly, the zero-amplitude test cannot be rejected for the 0.495-year component, but a near-transyear is validated. The near-transyear's period is estimated to be 1.048 years (95% CI: 1.030, 1.065) and its amplitude 3.90 μT (95% CI: 0.90, 6.91). The about 6-year component is also validated, its period being estimated to be 6.1 years (95% CI: 5.5, 6.7).

Least squares spectra of Wolf numbers, averaged over consecutive 3-day intervals, are very similar whether all data are considered or only those on days when values are available for the solar magnetic field, Fig. 2. A major feature is again a broad peak around one cycle in 27 days, the solar rotation period, but the harmonic content is much less pronounced in this case. The spectral peak corresponding to the about 11-year Schwabe cycle in solar activity is clipped in this figure to prevent other features to be completely obscured by it. Nonlinearly, during this limited 27-year span, the Schwabe period is estimated to be 10.16 years (95% CI: 10.07, 10.24) and its amplitude 69.4 (95% CI: 66.8, 72.0). A component with a period of 5.26 years (95% CI: 5.13, 5.39) and an amplitude of 19.4 (95% CI: 14.8, 24.0) also resolved nonlinearly likely corresponds to the second harmonic of the solar activity cycle. The period of this component differs from the about 6-year cycle detected in the solar magnetic data, the 95% CIs of the respective periods being non-overlapping. Whereas during this 27-year span, a near-transyear is also found to characterize Wolf numbers, its period also differs from that of solar magnetic data: it is estimated to be 1.102 years, with a 95% CI extending from 1.079 to 1.125 years, non-overlapping the 95% CI of the period of solar magnetism. While its amplitude of 5.1 (95% CI: 0.4, 9.7) is smaller than that of the about 10.1-year cycle, it is larger than that of its second harmonic with a period of about 5.3 years. The spectral peak around one cycle in 0.43 year is also resolved nonlinearly: the period is estimated to be 0.433 year (95% CI: 0.429, 0.437) and the amplitude 4.8 (95% CI: 0.2, 9.5).

4. Discussion and conclusion

Whereas the near-transyear appears as an isolated peak in the least squares spectrum of solar magnetic data, another peak of even larger amplitude is found in the least squares spectrum of Wolf numbers at a frequency of one cycle in 0.90 year, raising the possibility that the about 0.90- and 1.10-year spectral lines are sidelobes around the year representing an about 10-year modulation in amplitude and/or phase of an about-yearly variation. Such an about 10-year modulation could also be related to the solar activity cycle.

An analysis of monthly averages of daily values of all 40 variables included in the OMNI 2 database available from 1963 to 2003 (41 years) had shown the presence of a single spectral peak around one cycle in 1.05 years, resolved nonlinearly, only for the north–south component of the induction vector of the interplanetary magnetic field (Bz GSM), proton density, plasma speed and its standard deviation. These variables thus show a near-transyear similar to that detected in solar magnetism herein. Other variables in OMNI 2 such as Bx and By, the two horizontal components of the interplanetary magnetic field, are characterized by two components with periods of about 0.95 and 1.05 years, rather than by a single about 1.05-year component.

The mapping of time structures (chronomes) in physical variables of our environment near and far may help understand the origin of similar components found in biological variables [3]. Evidence for near-transyears or at least candidate near-transyears has been found in a 15-year series of urinary excretion of 17-ketosteroids by a clinically healthy man [14], in a longitudinal series of blood pressure data collected around the clock for 7 years [15], and in epidemiologic data discussed elsewhere in this volume. Earlier, influences of non-photic solar effects on biota were shown to involve a host of other components, including the far-transyear with a period between 1.2 and 2 years, its 95% CI not overlapping these limits [2]. Far-transyears with an about 1.3-year period documented for the solar wind speed by physicists [1] have been found in all longitudinal blood pressure series available to us for analysis thus far [16]. Other pertinent components include the half-year [17,18], the circadecadal and multi-decadal cycles [3], and of course the circaseptans and multiseptans [19–22], constituting an unfolding spectrum of magnetperiodisms. The latter may underlie any direct association of geomagnetic storms with heart rate variability [23,24] and melatonin [25,26], topics reviewed elsewhere in this volume [27].

Far-transyears were reported by Howe et al. [28–30] in helioseismology at the sun's equator, whereas at higher solar latitudes, 1.0-year components prevailed. When we found the near-transyear in the solar wind speed, its standard deviation and in the proton density, we requested and obtained the helioseismologic data from her, anticipating finding a near-transyear rather than a precise yearly component. Our anticipation was not validated by the analyses, showing a 1.0-year component in helioseismology, in keeping with the original report by Howe et al. [28–30], presumably on series shorter than those analyzed herein. There remained the enigma of the source of the near-transyear in several solar wind features. This enigma is apparently solved by the analyses presented herein. The sun has many facets, and a spectral approach in this study resolves some differences between solar activity, gauged by Wolf's relative sunspot numbers, and solar magnetism, and also between solar magnetism and helioseismology.

In most non-photic variables such as Wolf's relative sunspot numbers, we are not dealing with rigorous periodic phenomena. Many components have changing amplitudes and frequencies. Spectral components were detected by time series analysis techniques used for rigorously periodic phenomena. The changing characteristics of these components can be visualized by gliding spectra, provided the record is long enough. In the case of the near-transyear, an interval of at least 20 years would have to be used to distinguish it from the calendar year. No independent replication could thus be obtained from a 27-year record such as the data analyzed herein. For components with shorter periods such as circaseptans, gliding spectra show the changing characteristics as a function of time, notably in relation to solar cycle stage [22]. The prefixes 'pseudo-', 'para-' or 'quasi-' do not help in conveying their wobbly, transient nature. What helps is a transdisciplinary approach, a finding of the same phenomenon with the same method in a number of different disciplines that all focus from different viewpoints on a given feature. Similarities and important subtle and statistically significant differences can thus be assessed that may help shed light on putative underlying mechanisms. The finding of a near-transyear in solar magnetism seen in Fig. 1 provides the long sought counterpart for physical

near-transyears in several characteristics of the solar wind, in the north-south component of the induction vector of the interplanetary magnetic field, of the geomagnetic antipodal index aa and, most importantly of a number of biological variables.

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Fig. 1.

In addition to the very prominent about 27-day variation related to the solar rotation period, an about 1.059-year component is detected in the least squares spectrum of solar magnetic data recorded daily for 27 years. This component is validated by nonlinear least squares.

Fig. 2.

Similar spectral structure of Wolf numbers based on all data or after removing data when none are available for solar magnetism. The about 11-year amplitude (68.5) is clipped in order not to obscure other features, including a prominent about 27-day variation corresponding to the solar rotation period and a near-transyear candidate with an about 1.10-year period differing from that characterizing solar magnetism and having a symmetric 0.9 (or 0.88) counterpart, suggesting a modulation.