ON THE OCCURRENCE RATE OF HIGH-SPEED SOLAR WIND EVENTS

V. K. VERMA and G. C. JOSHI
Uttar Pradesh State Observatory, Naini Tal – 263129, India

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Abstract. We have investigated the rate of occurrence of solar wind phenomena observed between 1972–1984 using power-spectrum analysis. The data have been taken from the high-speed solar wind (HSSW) stream catalogue published by Mavromichalaki, Vassilaki, and Marmatsouri (1988). The power-spectrum analysis of HSSW events indicates that HSSW stream events have a periodicity of 9 days. This periodicity of HSSW events is $\frac{1}{3}$ of the 27-day period of coronal holes, which are major sources of solar wind events. In our opinion, the 9-day period may be the energy build-up time for coronal hole regions to produce the HSSW stream events.

1. Introduction

The solar wind plays an important and unifying role in modern space research. Earlier, evidence for clouds and streams of charged particles emitted intermittently by flares and other solar phenomena was found from research on aurorae and geomagnetic storms (Foukal, 1990). The advent of direct spacecraft observations in interplanetary space marked the end of what might be regarded as the first era of the solar wind (Hundhausen, 1972). This new era saw the development of the basic concept of the solar wind as well as a model of its origin in the continuous supersonic flow of plasma and magnetic field configuration and demonstrated the fundamental validity of this concept and theory.

The expansion of the solar wind speed is very low in the corona but increases rapidly with height. At the critical radius the thermal energy and the expansion kinetic energy become comparable, and also the expansion velocity becomes close to the sound velocity in the plasma. At larger distances the expansion velocity increases still further, and the solar wind becomes supersonic. The average velocity of the solar wind is 400 km s^{-1} with minimum and maximum at 200 and 900 km s^{-1} respectively. The speed varies little with radius between 1–20 AU. The solar magnetic field is carried along the expanding plasma, resulting in an interplanetary magnetic field. The solar wind plasma consists of electrons, protons, and helium and also has magnetic field strength. The solar wind phenomena have three different time scales: 50 (class I), 5 (class II) and 5×10^{-4} (class III) hr (Hundhausen, 1972). Most of the high-speed streams fit into class II of the above classification. The important nature of these streams is their apparent tendency to occur at an interval of 27 days. According to Hundhausen (1977) there is a one-to-one relationship between coronal holes and high-speed solar winds. The above study of Hundhausen

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(1977) was based on the *Skylab* data. The solar wind and the heliosphere are a product of coronal expansion driven by the heat input into the corona. The heat input may be transient when there is a coronal transient or a flare. Sometimes the heat input is steady. Studies of solar wind velocity structure show prominent high-speed regions whose mean plasma velocity of about 700 km s^{-1} with 50 as the lowest speed encountered. Studies of time-to-time and space coherence of these high-speed conditions have demonstrated that they represent long-lived streams of high-speed wind generally issuing from coronal holes. The streams corotate with the spiral magnetic field geometry of the solar wind and also the 27-day interval accounts for the well-known tendency of recurrence of geomagnetic storms. The solar wind arises from a variety of sources and the identification of a clear link between phenomena in the lower corona and solar wind features observed in interplanetary space has proved relatively difficult. The conceptions regarding the stuctures of the corona, solar wind and solar magnetic field were based only on these observations, which were made at 1 AU and beyond. The large gap of the inner heliosphere (from 0.3 to 1 AU) were bridged by the highly successful mission of Helios 1 and 2 during 1974–1986. It is said that the solar magnetic field, which is frozen in the hot, tenuous and highly conducting solar plasma, is dragged into interplanetary space by the radially outflowing solar wind.

In the present paper we have carried out a power-spectrum analysis of high-speed solar wind data for the period of 1972–1984 to learn the occurrence rate of solar wind phenomena. We have also discussed the results obtained in this analysis.

2. Observational Data, Analysis and Results

The HSSW data have been taken from the high-speed solar wind catalogue published by Mavromichalaki, Vassilaki and Marmatsouri (1988). This catalogue is based on the interplanetary data recorded by Pioneer spacecraft and other spacecraft between the period 1972–1984. To carry out this study, we have taken the start date of HSSW stream events at an interval of one day. This seems to be correct because the duration of HSSW events is less than 24 hr, or one day. The power-spectrum analysis for daily HSSW data has been carried out for a period of 4749 days (1972–1984) and its plot is shown in Figure 1. There, the normalised power-spectral density of HSSW events is plotted versus its frequency. In the figure there are only two peaks (A and B) above the zero frequency level. Peak A corresponds to 9 days, whereas peak B, which has a periodicity of 2 days, is the folding frequency. Thus we are of the view that the HSSW events have a periodicity of 9 days, which in our opinion is a new result.

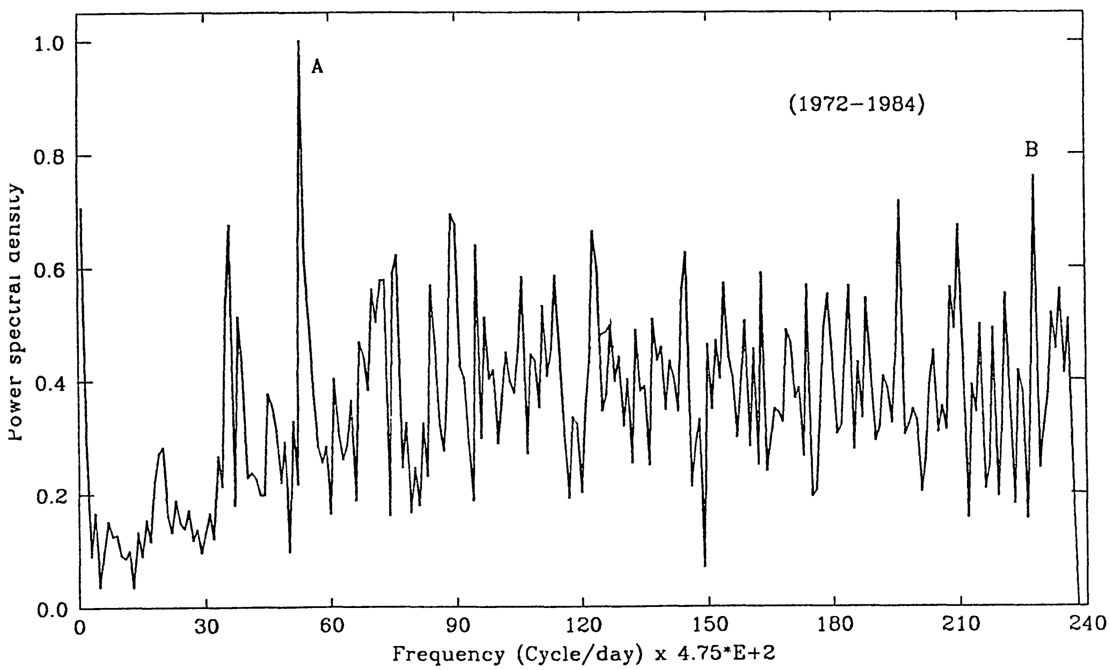

Fig. 1. Plot of spectral density of HSSW data vs frequency.

3. Discussions and Conclusions

As mentioned above, the HSSW events have a periodicity of 9 days. Presently, at least three sources of solar wind have been identified. These are the coronal holes (CH), coronal streamers (CS) and coronal mass ejections (CME). It is found that the HSSW events seem to flow out of regions in the corona where the magnetic field configuration is divergent and open. Such regions are often marked by the appearence of coronal holes (CH). During the *Skylab* mission in 1973–1974, the CHs were discovered as the sources of steady high-speed streams, which emanated from these dark coronal regions of weak divergent solar magnetic fields (Krieger, Timothy, and Roelof, 1973; Timothy, Krieger, and Vaiana, 1975). The *Skylab* finding that HSSW originate in CHs was explained by Levine, Altschuler, and Harvey (1977). CMEs are one of the most extensively observed coronal phenomena by coronagraphs on board spacecraft since 1970 and by a ground-based coronameter since 1980. The other sources of solar winds are coronal mass ejections associated with flares and eruptive prominences. The role of other coronal structures in the generation of the solar wind is less clear (Withbroe, 1986). Although CMEs are established as coronal sources of solar wind, they account for only 5% of the total solar mass loss by the solar wind. The contribution of the solar wind from CSs comes only in the form of slow solar wind.

The above study shows that the HSSW events seem to flow out of regions in the corona where the magnetic field configuration is divergent and open. Individual CHs range from 1% to 5% of the area of the Sun and persist from one to more than 10 solar rotations. During *Skylab* observations, CHs were connected to the polar hole of the same magnetic polarity at same time of their lives and are situated in large unipolar magnetic cells. Such magnetic conditions of CHs are usually quite stable and persist for several rotations giving rise to a pronounced tendency for high-speed streams to occur. According to Zirker (1977) the coronal holes rotate 'rigidly' (i.e., only 3% variation from pole to equator) with a synodic period of 27 days. The power-spectrum analysis of HSSW events shows that HSSW stream events have a periodicity of 9 days.The periodicity of HSSW events is $\frac{1}{3}$ of the 27-day periodicity of coronal holes, the main source of origin of HSSW events. Thus the 9-day periodicity may be the time for the coronal hole regions for energy build-up to produce the HSSW stream events.

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