ON THE PERIODICITY OF HIGH SPEED SOLAR WIND STREAMS

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Abstract. In the paper we have investigated the periodicity of high speed solar wind (HSSW) streams using the technique of power spectrum analysis. The data for HSSW streams has been taken from the papers by Lindblad and Lundstedt (1981, 1983) and Lindblad *et al.* (1989) The power spectrum analysis of the daily HSSW streams events for the period 1964–1975 (solar cycle 20) shows peaks of 14, 7, 2.9 and 2.6 days, and daily HSSW events for the period 1976–1982 (solar cycle 21) shows peaks of 15.4, 7, 2.9 and 2.6 days. The HSSW events for period 1964–1982 (solar cycles 20-21) shows peaks of 15.4, 7 , 3.7, 2.9 and 2.6 days. The common periods from above study are 7, 2.9 and 2.6 days. The 2.9, 2.6 days and other periods are folding frequency. The 7 days periodicity is close to the $\frac{1}{4}$th of solar rotation which may be the time for energy build up for coronal holes to produce HSSW streams.

1. Introduction

In the past four decades the satellites and spacecrafts have provided detailed information on the solar wind electron density, temperature and velocity. 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 solar wind study (Hundausen, 1972). The new era saw the development 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 a larger distance the expanision velocity increases still further, and the solar wind speed becomes supersonic. The average volocity of the solar wind is 400 km s^{-1} with minimum and maximum speeds at 200 and 900 km s^{-1}, respectively. The speed varies little within a radius of 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 important nature of these streams is their apparant tendency to occur at an interval of 27 days. Earlier study of Sawyer (1976) shows that the rotation period

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of the solar wind indicates a rigid rotation period of 27 days. Gosling *et al.* (1976) carried out an auto-correlation analysis of solar wind speed data and found a peak of 27.1 days. Peaks corresponding to 13.5 days were present in certain years while peaks near 7 days were weak or absent. Recently, Verma and Joshi (1994) carried out power spectrum analysis of high speed solar wind (HSSW) events for period of 1972–1984 and reported a 9 days periodicity of HSSW events. According to Hundausen (1977) there is one to one relationship between coronal holes and high speed solar winds. The above study of Hundausen (1977) was based on *Skylab* data. The streams corotate with the spiral magnetic field geometry of 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 to be relatively difficult. The conceptions regarding stucture of the corona, solar wind and solar magnetic field were based only on these observations, which were made at 1 AU and beyond.

In the present paper we have carried out a power spectrum analysis of HSSW events data for the period of 1964–1975 (solar cycle 20) and 1976–1982 (solar cycle 21), respectively. We have also carried out power spectrum analysis of HSSW data for the period of 1964–1982 and discussed the results obtained in the light of recent research works.

2. Observational Data and Analysis

The HSSW data used in the present study has been recorded between 1 January 1964 to 1 November 1982 and has been taken from three papers by Lindblad and Lundstedt (1981, 1983), and Lindblad *et al.* (1989). A high-speed plasma stream or HSSW event is characterized by a large increase in solar wind velocity lasting for several days and HSSW plasma stream usually has a well defined edge with a steep velocity increase. The detailed criteria for selection of HSSW events are described in papers by Lindblad and Lundstedt (1981, 1983), and Lindblad *et al.* (1989). A catalogue of HSSW events for period 1964–1975 (Lindblad and Lundstedt, 1981), 1976–1978 (Lindblad and Lundstedt, 1983) and 1979–1982 (Lindblad *et al.*, 1989) was prepared by Drs B. A. Lindblad, H. Lundstedt and B. Larson. They prepared the above catalogue on the basis of interplanetary plasma/magnetic field data set published by King (1977, 1979) and Couzens and King (1986).

According to Lindblad and Lundstedt (1981) there are several temporal data gaps in King (1977) publication, in particular during the fall months of 1968, 1971, and 1972 and these data gaps in period 1964–1975 were supplemented with solar wind data from other sources. Further, a few data gaps are also present in in the list of HSSW events (1978–1982) for the period from 1 June 1978 to 1 November 1982. According to Lindblad *et al.* (1989) these data gaps were minor and so it will not affect the results of our study.

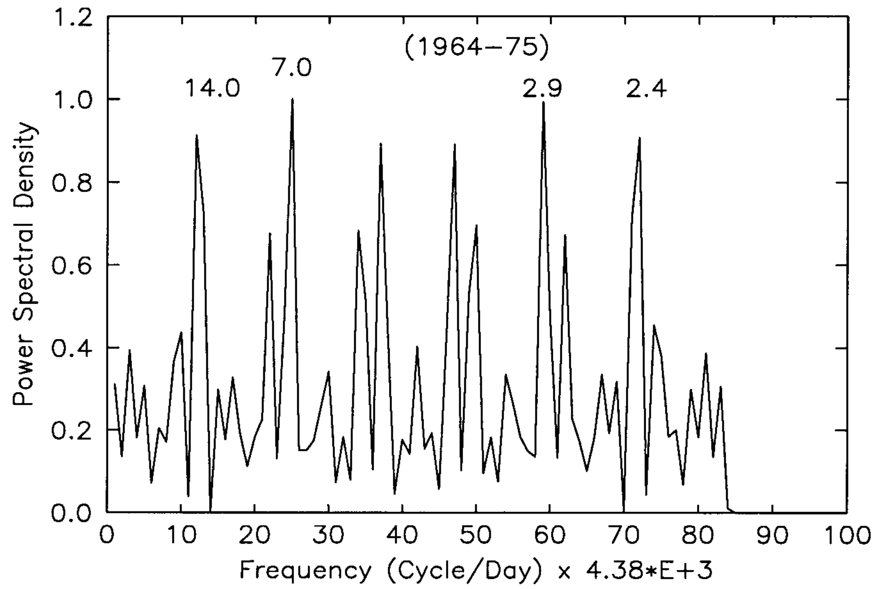

Figure 1. Plot of spectral density of HSSW data vs frequency.

The paper by Lindblad and Lundstedt (1981) contains a list of HSSW events for the period 1964–1975. The papers by Lindblad and Lundstedt (1983), and Lindblad *et al.* (1989) contain a list of HSSW events for the period of 1976–1982. To know the periodicity of HSSW events we have carried out a power spectrum analysis of HSSW events at an interval of one day. The power spectrum analysis of daily HSSW events has been carried out for periods of 1964–1975 (solar cycle 20) and 1976–1982 (solar cycle 21) separately and their plots are shown in Figures 1 and 2, respectively. To know the overall periodicity over the span of 1964–1982 we have also carried out a power spectrum analysis and its plot is shown in Figure 3. In Figures 1, 2, and 3 we have plotted the normalised power spectrum density of HSSW events versus its frequency. In Figure 1, power spectrum analysis of the daily HSSW events for the period of 1964–1975 shows peaks at 14, 7, 2.9, and 2.6 days. In Figure 2 power spectrum analysis of HSSW events for the period of 1976–1982 shows peaks at 15.4, 7, 2.9, and 2.6 days. Similarly Figure 3 shows power spectrum analysis of HSSW events for a period of 1964–1982 shows peaks of 15.4, 7, 3.7, 2.9, and 2.6 days. The common periods from Figures 1, 2 and 3 are 7, 2.9, and 2.6 days where 2.9 and 2.6 days peaks are folding frequency. The 7 days periodicity appears to be the real frequency of HSSW events.

3. Discussions and Conclussions

In the previous section we have carried out a power spectrum analysis of HSSW events data for the period of 1964–1975, 1976–1982, and 1964–1982 and found

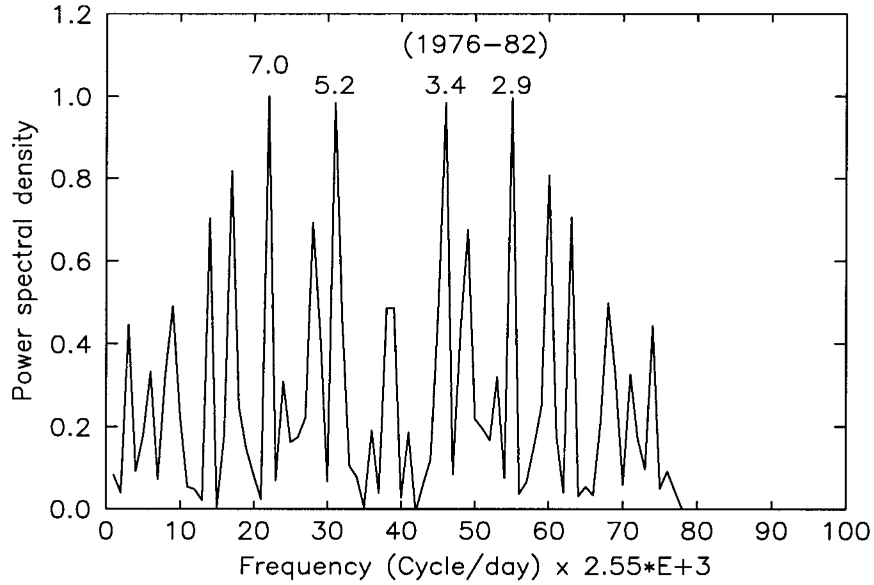

Figure 2. Plot of spectral density of HSSW data vs frequency.

that HSSW events have a periodicity of about 7 days. Earlier Verma and Joshi (1994) reported a period of 9 days from HSSW data for the period 1972–1982. As we know that the three sources of solar wind have been identified. These are the coronal holes (CH), coronal streamers (CS), and coronal mass ejections (CMEs). It is found that the HSSW events seem to flow out of region in the corona where magnetic field configuration is divergent and open. Such regions are often marked by the appearance of CH. During the *Skylab* mission in 1973–1974, coronal holes were discovered as the source of steady high speed streams, which emanated from these dark coronal regions of weak divergent solar magnetic fields (Krieger *et al.*, 1973; Timothy *et al.*, 1975). The studies of Nolte *et al.* (1976), Bohlin (1977), Broussard *et al.* (1978), and Lindblad (1990) also establish relationship between HSSW events and coronal holes. The *Skylab* finding that HSSW originate in CH was explained by Levine *et al.* (1977). We all know that CMEs are one of the most extensively observed coronal phenomena by coronagraphs aboard spacecraft since 1970 and by ground based coronameters since 1980. The other source of solar winds are CMEs associated with solar flares and eruptive prominences. The role of other coronal strucures in generation of solar wind is less clear (Withbroe, 1986).

The studies of Krieger *et al.* (1973), Timothy *et al.* (1975), Nolte *et al.* (1976), Bohlin (1977), Levine *et al.* (1977), Broussard *et al.* (1978), and Lindblad (1990) show that the coronal holes are one of the sources of HSSW events therefore we can say that HSSW streams seem to flow out of coronal hole regions in the corona where the magnetic field configuration is divergent and open. Individual CHs area range from 1–5% of the area of Sun and persist from one to more than 10 solar

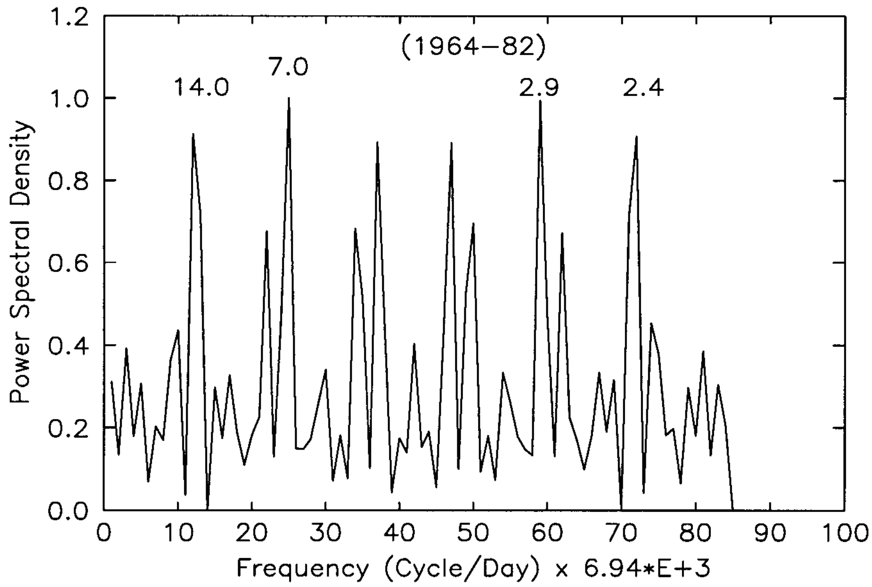

Figure 3. Plot of spectral density of HSSW data vs frequency.

rotations. According to Zirker (1977) the CH rotate (i.e., only 3% variation from pole to equator) with a synodic period of about 27 days. The power spectrum analysis of HSSW events in present study has a periodicity of 7 days while in earlier study by Gosling *et al.* (1976) reported a weak or absent 7-day peak. The present study covers the data period, 1964–1982, while the study made by Goshing *et al.* (1976) covers data period of 1964–1973. The 7-day peak may be related to the 2nd harmonic at 8 days, of the solar rotation period which requires further investigations. The 7-days periodicity of HSSW events is about $\frac{1}{4}$th of the 27-days periodicity of coronal holes, the main source of origin of HSSW events. Thus the 7-day periodicty may be the time for the coronal hole regions for energy build-up to produce the HSSW stream events.

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