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A CATALOGUE OF HIGH-SPEED SOLAR-WIND STREAMS: FURTHER EVIDENCE OF THEIR RELATIONSHIP TO A_p-INDEX

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Abstract. A reference catalogue of 430 well-defined high-speed plasma streams detected in solar-wind observations from 1972 to 1984 is presented. We have given the main characteristics of the streams as the beginning time and the duration of the stream, the interplanetary magnetic field polarity, etc. We have also separated them with respect to their origin into two categories: the corotating and the flare-generated streams. As a first application of this useful catalogue, a correlative study between the maximum speed of streams and the A_p-index of geomagnetic activity is carried out.

1. Introduction

During the last few years new measurements of the interplanetary medium and Sun have produced exciting and important changes in our knowledge of interplanetary phenomena. One of the most important of these phenomena for solar-terrestrial physics we believe these are the occurent streams in the solar wind near the Earth. Various studies of the variability of the solar wind velocity in the ecliptic plane have revealed a tendency for a high-speed stream structure. Several researchers have studied the characteristics of these high-speed plasma streams giving various definitions of them (Intriligator, 1973, 1977; Gosling *et al.*, 1976; Iucci *et al.*, 1979) and many related reviews on earlier works have been presented by Hundhausen (1972), Burlaga (1975, 1979), Wu *et al.* (1977), Toptygin (1985), etc.

Lindblad and Lundstedt (1981) produced a list of high-speed streams recorded near the Earth during the period 1964–1975. This catalogue is a very useful one for studies of various solar-interplanetary and solar-terrestrial phenomena (e.g., Mavromichalaki and Petropoulos, 1985). The purpose of this study is to update the previous investigations on high-speed solar wind streams during the next solar cycle No. 21 (1975–1985). In this catalogue we have attempted to distinguish the streams (apart from their main characteristics) into two general kinds originated from two different sources (Iucci *et al.*, 1979; Venkatesan, Shukla, and Agrawal, 1982). The first kind is a long-lasting high-speed solar wind stream (HSWS) emitted by coronal holes that exhibited an apparent tendency to recur at intervals of ~ 27 days – the so-called corotating streams – and the second one, characterized by lower solar wind speed, seems to be associated with strong active regions emitting solar flares and producing Forbush decreases at the Earth – the so-called flare-generated streams. Remarkable differences have been found between the interplanetary parameters characterizing the streams of these two different regions.

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Moreover as a simple application of this catalogue of streams in the growth of our understanding of the physical processes involved in the solar wind-magnetosphere interaction we tried to study some of the interplanetary stream parameters which are most important in producing a varied geomagnetic activity. According to review papers of Akasofu and Chapman (1972) and Burlaga (1975) two general kinds of geomagnetic disturbances have been revealed. One called 'sudden storm commencements' (SSC events) which are attributed to interplanetary streams which are presented to be emitted by solar flares and the other one called 'recurrent storms' which are attributed to long-lived interplanetary streams emanating from unidentified regions on the Sun, the corotating or M-regions. Chapman (1964) has reported that there is a third type of interplanetary flow, the 'quiet wind' which was postulated to explain the continual presence of comet tails. Recently, Legrand and Simon (1985) identified four general categories of geomagnetic activity. The first category of geomagnetic activity, the sudden commencement storm, is related to a series of solar events occurring in relation to sunspot activity. The three other categories of geomagnetic activity, namely the 'recurrent storms', the 'quiet days', and the 'fluctuating activity', are related to the distribution of their sources around the Sun.

In this work we have examined the relations between the maximum speed of the two types of the interplanetary streams and the geomagnetic disturbances expressed by the A_p index and we have obtained some preliminary results.

2. Classification of High-Speed Streams

It is known that periods of enhanced speed lasting for several days are often observed in the solar-wind velocity data. In searching for streams various definitions for a high-speed stream have been used. Intriligator (1973, 1977) defines a high-speed stream as one having a rapidly rising increase in solar wind speed and a peak velocity greater than or equal to 450 km s^{-1}. Bame *et al.* (1976) and Gosling *et al.* (1976) define a high-speed solar wind stream as an observed variation of solar wind speed characterized by an increase of at least 150 km s^{-1} within a 5-day interval. Broussard *et al.* (1977) define a high-speed stream as a period in which the solar wind speed is ≥ 500 km s^{-1} averaged over a day. Lindblad and Lundstedt (1981) indicate a high-speed stream as a period in which the velocity difference Δv_0 between the smallest 3-hr velocity value a given day (v_0) and the largest 3-hr value the following day is equal or greater to 100 km s^{-1} and lasts for at least two days. Venkatesan, Shukla, and Agrawal (1982) define a high-speed solar wind stream as one having a rapidly rising increase in the solar wind speed (V) over a short period ($\Delta V \geq 200$ km s^{-1} in ≤ 24 hr) reaching a maximum value of ≥ 550 km s^{-1} which persist at high values for at least 3 days after the increase.

In the present study we have defined a high-speed solar-wind stream as a period in which the difference $\Delta V_{\max}$ between the maximum daily mean speed ($V_{\max}$) and the mean value between the speeds immediately preceding and following the stream (V_0) is greater or equal to 100 km s^{-1} lasting for at least two days. We consider that this definition for a HSWS is more adequate for the purpose of solar-terrestrial studies. The

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velocity profile as well as other plasma and field data for the dates of large ΔV_{max} were studied by visual inspection of the intensity versus time profiles published in the *Interplanetary Medium Data Book* (King, 1977a, b, 1979, 1983, 1986a, b). The difference ΔV_{max} was computed for the solar wind streams of the time period January 1972 to December 1984. In order to fill out several data gaps observations of solar wind speed spacecraft data published in *Solar Geophysical Data* WDC-A, Boulder, were used.

Apart from these characteristics of the streams we have classified them into two types: the corotating stream (CS) and the flare-generated streams (FGS). In order to identify these two classes of the streams we have studied the most important interplanetary parameters: magnetic-field magnitude and polarity, bulk speed, proton density, and temperature of the solar wind.

The basic physical features of the corotating high-speed streams with respect to the above parameters can be summarized as follows:

(1) The proton density (n) rises to unusually high values near the leading edges of the streams; the high densities generally persisted for ~ 1 day. The density profile generally seems to be developed in inverse ratio to bulk speed (V).

(2) The interplanetary magnetic field (B) magnitude is proportional to bulk speed with a constant polarity throughout the stream except for some fluctuations lasting a few hours (Iucci *et al.*, 1979; Tsurutani *et al.*, 1987).

(3) The proton temperature (T) varies in a pattern similar to that of the flow speed. It increases with speed and shows a slight decrease during the magnetic field descent phase.

On the other hand the behaviour of interplanetary parameters during flare-generated streams has a tendency to be irregular. Variation in solar wind properties, involving a large deviation of flow speed, is characterized by initial, abrupt rises in the density, flow speed, and proton temperature. Generally we can say that the structure of a flare-generated stream shows the following features:

(1) All the above interplanetary parameters show simultaneous increases possibly denoting radially outcoming fast shocks.

(2) The bulk speed, the proton density and magnetic field magnitude show large fluctuations in the maximum speed period, while the field polarity shows often inversions.

(3) The proton temperature behaviour tends to depart from speed behaviour.

A typical example of these two types of high-speed streams is given in Figure 1.

Based on the above considerations we produce an up-to-date catalogue of high-speed streams recorded near the Earth during the period 1972–1984 (Table I). In this table the three first columns give the year, month, and day, respectively, of the beginning time of a high-speed stream, defined as the 3-hr interval of the smallest speed value a given day. The fourth and fifth columns list the Bartel's rotation (number and day) corresponding to the first day of the stream. The sixth column gives the dominant polarity of the interplanetary magnetic field for the duration of the stream (Lindblad, 1981). The following three columns give the day, month, and hour, respectively, of the maximum speed appearance (FDMA). The tenth and eleventh columns give the mean value (V_0)

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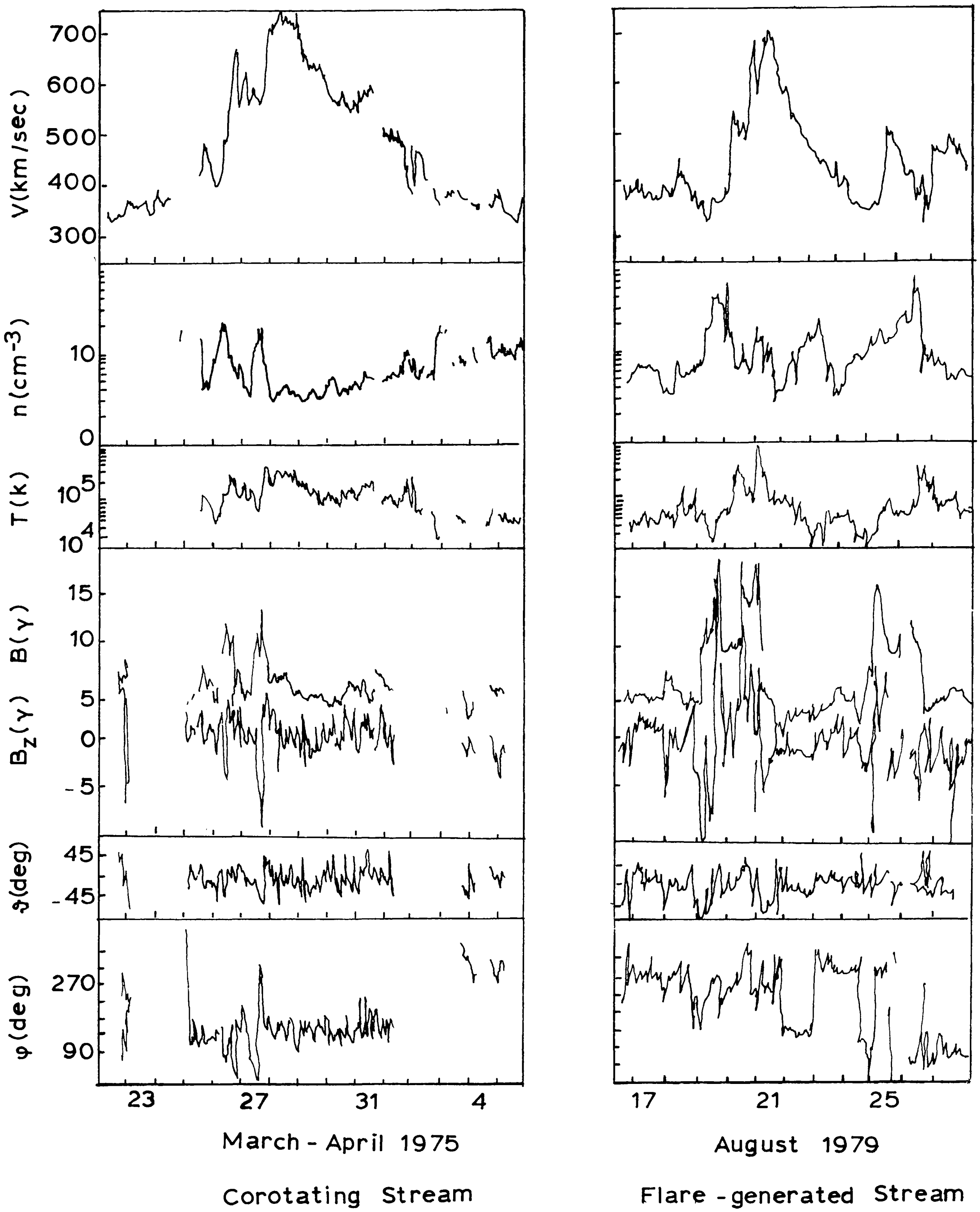

Fig. 1. A typical example of the two types of high-speed solar-wind streams: corotating and flare-generated streams.

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TABLE I

A catalogue of high-speed solar-wind streams for the years 1972–1984 giving the year, month and day of the beginning time of a high-speed stream, the Bartel's rotation (number and day) of the first day of the stream, the interplanetary magnetic field polarity for the duration of the stream, the day, month and hour of the maximum speed appearance (FMDA), the mean value (V_0) between the speeds immediately preceding and following the stream, the maximum daily mean speed (V_{max}) the duration (DUR) and the type of the high-speed stream (CS or FGS)

Y	M	D	Bartel Rotation No	D	IMF POL	FDMA D	M	Hr	V_o	V_{max}	DUR	TYPE
72	01	16	1894	01	+	18	01	10	415	649	05	FGS
72	02	13	1895	02	+	13	02	19	395	628	05	CS
72	02	24	1895	13	−	24	02	18	340	521	05	CS
72	03	06	1895	24	+	07	03	10	430	637	04	FGS
72	03	16	1896	07	+	17	03	16	310	515	04	CS
72	04	03	1896	25	+	05	04	05	377.5	647	07	CS
72	04	28	1897	23	+	02	05	18	307.5	522	11	CS
72	05	14	1898	13	−/+	16	05	03	355	600	06	FGS
72	05	27	1898	25	−	28	05	21	440	595	03	FGS
72	10	31	1904	21	−	31	10	19	390	740	06	CS
72	11	15	1905	08	+	16	11	19	300	517	05	CS
72	11	24	1905	17	+	26	11	09	310	497	08	CS
72	12	06	1906	02	−	08	12	01	265	404	06	CS
72	12	12	1906	08	+/−	14	12	01	300	512	09	FGS
72	12	22	1906	18	−	24	12	04	335	505	05	CS
73	01	03	1907	03	+	11	01	21	340	749	15	CS
73	01	18	1907	18	+/−	20	01	07	305	518	04	CS
73	01	21	1907	21	−	28	01	12	320	753	09	CS
73	02	06	1908	10	+	08	02	19	305	653	08	CS
73	02	21	1908	25	−	25	02	18	405	770	08	CS
73	02	28	1909	05	−	02	03	05	355	659	04	CS
73	03	05	1909	10	+	09	03	18	310	557	11	CS
73	03	18	1909	23	−	24	03	22	375	783	13	FGS
73	03	31	1910	09	+	04	04	01	400	635	07	CS
73	04	13	1910	22	−	19	04	20	375	797	13	FGS
73	04	26	1911	08	+	29	04	12	375	744	10	CS
73	05	06	1911	18	−	07	05	20	355	612	06	FGS
73	05	13	1911	25	−	14	05	17	350	796	13	FGS
73	05	27	1912	12	+	28	05	05	295	500	03	CS
73	06	02	1912	18	+	04	06	11	325	746	07	CS
73	06	10	1912	26	−	11	06	16	395	779	08	CS
73	06	18	1913	07	−	20	06	11	405	753	05	CS
73	06	28	1913	17	+	30	06	16	350	753	08	CS
73	07	08	1913	27	−	09	07	04	330	466	04	FGS
73	07	13	1914	05	−/+	15	07	13	375	689	05	CS
73	07	26	1914	18	+	31	07	07	385	717	15	FGS
73	08	20	1915	16	+	24	08	13	550	683	12	CS
73	09	15	1916	15	−	16	09	08	340	569	04	CS
73	09	19	1916	23	+	23	09	22	350	692	09	FGS
73	10	09	1917	12	−	10	10	19	360	676	11	FGS
73	10	20	1917	23	+/−	21	10	22	390	678	05	CS

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Table I (continued)

Y	M	D	Bartel Rotation No	D	IMF POL	FDMA D	M	Hr	V_o	V_{max}	DUR	TYPE
73	11	04	1918	11	−	07	11	13	335	601	09	CS
73	11	16	1918	23	+	18	11	07	345	583	04	CS
73	11	22	1919	04	+	25	11	01	305	685	11	CS
73	12	04	1919	14	−	09	12	13	329.5	596	10	CS
73	12	19	1920	02	+	23	12	01	345	670	08	CS
73	12	27	1920	10	−	01	01	01	345	668	12	CS
74	01	08	1920	22	−	10	01	14	350	515	06	CS
74	01	14	1921	01	+/−	16	01	04	325	664	10	FGS
74	01	24	1921	11	−	26	01	02	305	790	12	CS
74	02	10	1922	01	+	11	02	02	320	706	06	CS
74	02	22	1922	13	−	23	02	19	300	722	15	CS
74	03	09	1923	01	+	10	03	22	370	762	07	CS
74	03	15	1923	07	+	16	03	24	360	551	05	CS
74	03	19	1923	11	−	21	03	22	365	754	15	CS
74	04	05	1924	01	+	06	04	07	360	729	04	CS
74	04	10	1924	06	+	10	04	22	403	748	07	CS
74	04	17	1924	13	−	21	04	07	340	702	14	FGS
74	05	02	1925	01	+	04	05	17	375	750	11	FGS
74	05	14	1925	13	−	19	05	15	370	649	16	CS
74	05	30	1926	02	+	01	06	17	367	769	10	CS
74	06	09	1926	12	−	16	06	08	380	698	10	CS
74	06	19	1926	22	−	20	06	01	390	615	05	CS
74	06	26	1927	02	+	27	06	16	350	815	08	CS
74	07	05	1927	11	−	07	07	18	380	802	12	FGS
74	07	22	1928	01	+	24	07	21	345	826	11	CS
74	08	02	1928	12	−	03	08	22	325	653	16	CS
74	08	18	1929	01	+	21	08	22	380	828	09	CS
74	08	28	1929	11	−	04	09	08	340	697	15	CS
74	09	12	1929	26	−	16	09	01	375	634	06	FGS
74	09	18	1930	05	+	21	09	17	450	699	05	CS
74	09	23	1930	10	−/+	25	09	19	520	732	04	CS
74	09	28	1930	15	−	01	10	07	475	729	07	CS
74	10	16	1931	06	+	17	10	09	450	650	06	CS
74	10	24	1931	24	−	27	10	24	360	770	09	CS
74	11	11	1932	05	+	12	11	19	355	787	07	CS
74	11	19	1932	13	−	22	11	01	327.5	805	12	FGS
74	12	07	1933	04	+	13	12	19	375	721	10	CS
74	12	17	1933	14	−	19	12	12	400	809	10	CS
74	12	27	1933	24	+	28	12	07	405	581	04	CS
75	01	03	1934	04	+	06	01	22	345	857	10	CS

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Table I (continued)

Y	M	D	Bartel Rotation		IMF POL	FDMA D	M	Hr	V_o	V_{max}	DUR	TYPE
75	01	12	1934	13	-	17	01	07	347.5	761	13	FGS
75	02	01	1935	06	+/-	02	02	08	356	743	08	CS
75	02	09	1935	14	-	13	02	07	446	772	05	CS
75	02	15	1935	20	-/+	16	02	15	446	702	06	CS
75	02	20	1935	25	+	24	02	20	400	671	09	CS
75	02	28	1936	06	+	01	03	07	450	750	03	CS
75	03	03	1936	09	+	04	03	01	375	686	06	FGS
75	03	08	1936	14	-	11	03	02	330	799	12	CS
75	03	24	1937	03	+	28	03	08	340	769	09	CS
75	04	06	1937	16	-/+	09	04	01	322.5	713	10	CS
75	04	19	1938	02	+	23	04	20	305	754	11	CS
75	05	04	1938	17	-	06	05	09	340	683	10	CS
75	05	16	1939	02	+	17	05	13	375	759	03	CS
75	05	19	1939	05	+	22	05	07	450	663	05	CS
75	06	01	1939	17							09	CS
75	06	11	1940	01	+	13	06	15	445	756	04	CS
75	06	15	1940	05	+	16	06	17	430	699	09	CS
75	06	29	1940	19	-	01	07	04	377.5	608	07	CS
75	07	06	1940	26	+	09	07	16	390	596	06	CS
75	07	12	1941	05	+	13	07	20	420	653	09	CS
75	07	24	1941	17	-	27	07	10	340	659	07	FGS
75	08	04	1942	01	+	06	08	06	370	577	04	FGS
75	08	12	1942	09	+	14	08	11	325	548	06	CS
75	08	20	1942	17	-	21	08	20	337.5	671	07	FGS
75	09	05	1943	06	+				375		08	CS
75	09	17	1943	18	-	18	09	13	360	647	05	CS
75	10	02	1944	06	+	09	10	23	280	637	11	CS
75	10	14	1944	18	-	16	10	15	320	501	07	CS
75	11	02	1945	10	+	04	11	12	360	760	07	CS
75	11	17	1945	25	-	20	11	22	345	500	05	FGS
75	11	29	1946	10	+	02	12	07	385	732	06	CS
75	12	24	1947	08	+	27	12	23	340	683	09	CS
76	01	03	1947	18	-	03	01	19	380	546	03	CS
76	01	10	1947	25	-	12	01	02	312.5	571	05	CS
76	01	20	1948	08	+	23	01	18	422.5	744	05	FGS
76	01	31	1948	19	-	02	02	18	400	642	05	CS
76	02	13	1949	05	-/+	14	02	05	330	649	03	CS
76	02	17	1949	09	-/+	18	02	12	329	743	08	CS
76	02	27	1949	19	-	02	03	18	300	670	08	CS

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Table I (continued)

Y	M	D	Bartel Rotation No	D	IMF POL	FDMA D	M	Hr	V_o	V_{max}	DUR	TYPE
76	03	08	1950	02	-	09	03	13	475	715	07	CS
76	03	15	1950	09	+	19	03	20	374	623	08	CS
76	03	25	1950	19	-	27	03	16	330	605	06	FGS
76	04	03	1951	01	-	07	04	15	485	736	06	CS
76	04	09	1951	07	+	14	04	14	370	673	12	CS
76	05	01	1952	02	-	03	05	01	380	784	06	FGS
76	05	11	1952	12	+	12	05	08	350	602	06	CS
76	05	17	1952	18	+/-	20	05	10	350	544	05	CS
76	06	03	1953	08	-	05	06	24	370	667	07	CS
76	06	17	1953	22	+/-	18	06	05	330	625	04	CS
76	06	30	1954	08	+	01	07	04	340	707	15	CS
76	07	15	1954	23	+	16	07	11	355	611	03	CS
76	07	27	1955	08	+	29	07	07	340	675	08	CS
76	08	08	1955	20	-/+	10	08	04	320	514	04	CS
76	08	23	1956	08	+	25	08	05	350	668	08	CS
76	09	01	1956	17	+	03	09	22	350	604	10	CS
76	09	16	1957	04	+				355		09	CS
76	09	24	1957	13	+/-	26	09	10	360	548	04	CS
76	10	14	1958	06	+	15	10	15	325	678	08	CS
76	10	30	1958	22	+	31	10	10	325	530	05	CS
76	11	11	1959	07	+	12	11	16	330	665	06	CS
76	12	10	1960	09	+	12	12	08	370	570	05	CS
76	12	16	1960	15	-	18	12	14	332.5	523	06	CS
76	12	31	1961	03	-	01	01	07	374	589	04	CS
77	01	11	1961	14	-	15	01	07	345	589	07	CS
77	01	27	1962	03	+	29	01	18	350	520	04	CS
77	02	05	1962	12		09	02	06	330	661	11	CS
77	02	17	1962	24	-	24	02	20	300	573	10	FGS
77	03	08	1963	16	-	09	03	12	330	635	07	CS
77	04	02	1964	14	-	08	04	07	325	689	13	CS
77	04	18	1965	03	-	19	04	23	365	618	05	CS
77	04	23	1965	08	+	25	04	16	350	514	06	FGS
77	05	14	1966	02	-	17	05	02	360	604	08	CS
77	05	22	1966	10	+	25	05	10	350	563	06	CS
77	06	16	1967	08	+	18	06	15	325	604	12	CS
77	07	06	1968	01	-	10	07	10	360	636	07	CS
77	07	12	1968	07	+	16	07	20	335	723	16	CS
77	08	03	1969	02	-	06	08	13	370	742	07	CS

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Table I (continued)

Y	M	D	Bartel Rotation No	D	IMF POL	FDMA D	M	Hr	V_o	V_{max}	DUR	TYPE
77	08	16	1969	15	+	19	08	02	357.5	703	06	CS
77	09	02	1970	05	-	05	09	20	324	456	06	CS
77	09	12	1970	15	+/-	14	09	17	317.5	490	07	FGS
77	09	19	1970	22	+/-	22	09	06	375	744	06	FGS
77	10	11	1971	17	+	12	10	06	298	466	04	CS
77	10	17	1971	23	-	20	10	23	335	575	10	CS
77	10	26	1972	05	-	30	10	22	280	542	14	CS
77	11	10	1972	20	+/-	15	11	10	429	695	16	CS
77	11	25	1973	08	-/+	27	11	11	320	539	05	FGS
77	12	10	1973	23	+	13	11	10	285	548	10	FGS
77	12	25	1974	11	+	26	12	16	320	547	04	FGS
78	01	03	1974	20	-	04	01	08	395	756	05	FGS
78	01	23	1975	13	-	26	01	08	300	505	05	CS
78	01	28	1975	18	-	30	01	03	360	636	05	CS
78	02	13	1976	07	-	15	02	09	302.5	679	08	FGS
78	02	21	1976	15	+/-	23	02	07	335	514	03	CS
78	02	25	1976	19	-	26	02	19	342.5	714	08	CS
78	03	07	1977	02	+	09	03	10	350	545	07	FGS
78	03	14	1977	09	-	17	03	15	340	593	08	CS
78	03	25	1977	20	-	27	03	11	377.5	703	09	CS
78	04	03	1978	02	+	06	04	11	360	603	07	FGS
78	04	10	1978	09	-	10	04	19	354	662	07	FGS
78	04	17	1978	16	+	20	04	05	400	816	06	FGS
78	04	28	1978	27	-	01	05	20	400	996	10	FGS
78	05	09	1979	11	-	09	05	10	357.5	720	06	FGS
78	05	21	1979	23	-	24	05	12	325	575	08	CS
78	06	01	1980	06	-	02	06	14	350	697	09	FGS
78	06	10	1980	15	-	10	06	16	350	621	06	CS
78	06	20	1980	25	-	22	06	03	360	632	04	CS
78	06	24	1981	03	-	25	06	21	410	573	04	FGS
78	07	12	1981	21	+	14	07	07	345	507	05	FGS
78	08	02	1982	15	+	06	08	21	301	578	08	CS
78	08	16	1983	02	-	19	08	06	301	471	09	CS
78	08	27	1983	12	+	01	09	11	320	603	10	CS
78	09	23	1984	13	+	29	09	05	325	911	13	FGS
78	10	08	1985	01	+/-	16	10	02	330	548	10	FGS
78	10	17	1985	10	+	19	10	10	317.5	476	7	CS
78	10	24	1985	17	+	28	10	10	270	451	14	CS

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Table I (continued)

Y	M	D	Bartel Rotation No	D	IMF POL	FDMA D	M	Hr	V_o	V_{max}	DUR	TYPE
78	11	07	1986	04	-	09	11	20	321.5	510	04	CS
78	11	12	1986	09	-/+	12	11	02	327.5	685	06	FGS
78	11	20	1986	17	+	20	11	18	350	688	05	CS
78	11	25	1986	22	+	27	11	07	352.5	632	06	CS
78	12	03	1987	03	-	05	12	03	265	486	09	FGS
78	12	12	1987	12	+/-	14	12	06	320	561	06	FGS
78	12	18	1987	18	+	18	12	11	365	703	07	CS
78	12	28	1988	01	-	30	12	13	362.5	741	06	FGS
79	01	02	1988	06	-	03	01	02	415	598	03	FGS
79	01	06	1988	10	-	07	01	12	372.5	581	03	FGS
79	01	15	1988	19	+/-	15	01	17	350	497	04	FGS
79	01	25	1989	02	-/+	26	01	01	430	649	05	CS
79	02	11	1989	19	-/+	12	02	05	315	467	04	FGS
79	02	17	1989	25	+	18	02	14	355	599	04	CS
79	02	21	1990	02	+	23	02	09	350	629	08	CS
79	03	01	1990	10	+/-	06	03	16	340	524	07	FGS
79	03	09	1990	18	+	11	03	07	300	486	05	CS
79	03	14	1990	23	+	17	03	13	309.5	631	07	CS
79	03	22	1991	04	-	25	03	01	375	539	05	CS
79	03	27	1991	09	-	28	03	12	390	664	05	FGS
79	04	01	1991	14	-	02	04	13	395	680	04	FGS
79	04	05	1991	18	+/-	06	04	18	380	724	03	CS
79	04	12	1991	25	-	17	04	06	395	682	08	CS
79	04	21	1992	07	-	22	04	18	367.5	532	04	CS
79	04	25	1992	11	-	25	04	15	345	651	10	FGS
79	05	17	1993	06	-	19	05	22	350	472	04	FGS
79	05	22	1993	11	-	26	05	12	375	652	08	CS
79	05	29	1993	18	-	30	05	05	335	638	06	CS
79	06	05	1993	25	+/-	09	06	07	309.5	655	08	FGS
79	06	15	1994	08	-	16	06	18	310	478	05	CS
79	06	19	1994	12	-	23	06	17	290	503	11	FGS
79	07	05	1995	01	+/-	06	07	22	337.5	648	07	FGS
79	07	12	1995	08	-	18	07	19	275	560	14	CS
79	07	28	1995	24	-	30	07	19	302.5	511	03	CS
79	08	01	1996	01	+	01	08	11	340	569	05	CS
79	08	05	1996	05	-	06	08	16	320	500	03	CS
79	08	11	1996	11	-	13	08	19	355	602	05	FGS
79	08	19	1996	19	-	20	08	22	342.5	707	05	FGS

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Table I (continued)

Y	M	D	Bartel Rotation No	D	IMF POL	FDMA D	M	Hr	V_o	V_{max}	DUR	TYPE
79	08	29	1997	02	+	29	08	17	322.5	555	04	FGS
79	09	25	1998	02	+	27	09	01	370	546	04	CS
79	09	29	1998	06	+	29	09	22	340	568	03	CS
79	10	02	1998	09	-/+	03	10	09	322.5	518	04	CS
79	10	06	1998	13	+	08	10	18	340	596	04	FGS
79	11	01	1999	12	+	01	11	16	305	519	07	CS
79	11	07	1999	18	+/-	12	11	08	285	574	09	FGS
79	11	17	2000	01	+	18	11	10	285	519	06	CS
79	11	30	2000	14	+	02	12	02	300	467	06	CS
79	12	08	2000	22	-	08	12	20	290	474	06	CS
79	12	14	2001	01	+	17	12	06	305	474	07	FGS
79	12	25	2001	12	+	29	12	17	345	552	07	CS
80	01	03	2001	21	-	04	01	01	375	651	05	CS
80	01	10	2002	01	+/-	13	01	07	330	492	06	FGS
80	01	16	2002	07	+/-	18	01	01	350	528	05	CS
80	01	28	2002	19	-	30	01	12	325	524	07	CS
80	02	06	2003	01	+	06	02	20	300	545	08	FGS
80	02	25	2003	20	+/-	27	02	15	275	590	05	CS
80	03	05	2003	27	+	06	03	24	325	448	04	FGS
80	03	18	2004	15	+/-	19	03	11	275	390	03	FGS
80	03	25	2004	22	-	26	03	15	280	458	05	CS
80	04	03	2005	06	+/-	06	04	18	355	658	07	FCS
80	04	11	2005	14	-	12	04	23	305	666	04	CS
80	05	11	2006	15	-	11	05	20	305	679	05	CS
80	05	24	2007	01	+/-	25	05	13	281.5	473	05	FGS
80	06	06	2007	14	+/-	10	06	19	300	734	13	FGS
80	06	23	2008	04	-	24	06	04	320	452	07	FGS
80	07	05	2008	16	-	08	07	01	315	542	06	CS
80	07	18	2009	02	-	21	07	17	327.5	574	06	FGS
80	07	25	2009	09	+	27	07	07	320	557	05	FGS
80	08	04	2009	19	-	06	08		415	750	05	CS
80	08	14	2010	02	-	20	08	04	335	453	10	FGS
80	09	06	2010	25	+	08	09	20	297.5	463	05	FGS
80	09	15	2011	07	-	17	09	02	305	447	07	CS
80	09	29	2011	21	-	30	09	14	297.5	425	03	CS
80	10	03	2011	25	+	05	10	04	342.5	557	04	FGS
80	10	08	2012	03	-	10	10	02	385	646	04	CS
80	10	12	2012	07	+/-	12	10	22	327.5	559	04	FGS

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Table I (continued)

Y	M	D	Bartel Rotation No	D	IMF POL	FDMA D	FDMA M	FDMA Hr	V_o	V_{max}	DUR	TYPE
80	10	22	2012	17	-	25	10	03	280	643	08	CS
80	10	30	2012	25	+	03	11	08	294	565	04	CS
80	11	10	2013	09	-	12	11	02	387.5	655	04	FGS
80	11	18	2013	17	+						05	CS
80	11	24	2013	23	-	26	11	16	425	576	03	FGS
80	12	02	2014	04	+/-	03	12	20	385	579	04	CS
80	12	08	2014	10	-	11	12	20	345	640	05	FGS
80	12	15	2014	17	+	16	12	20	370	568	04	CS
80	12	19	2014	21	-/+	20	12	24	335	607	05	FGS
80	12	30	2015	05	+/-	31	12	22	327.5	559	03	CS
81	01	02	2015	08	-	05	01	04	369	528	07	CS
81	01	10	2015	16	+	11	01	05	345	551	04	CS
81	01	30	2016	09	-	02	02	23	365	617	06	FGS
81	02	05	2016	15	+	06	02	11	370	551	06	CS
81	02	18	2017	01	+	20	02	02	322.5	471	04	CS
81	02	26	2017	09	-	27	02	15	392.5	589	03	FGS
81	03	01	2017	12	+/-	02	03	13	380	550	04	FGS
81	03	05	2017	16	+	05	03	08	355	645	05	CS
81	03	12	2017	23	+	14	03	13	324	672	11	CS
81	03	24	2018	08	-	25	03	21	322.5	626	06	FGS
81	03	30	2018	14	-	01	04	09	365	606	04	FGS
81	04	11	2018	26	-/+	13	04	05	350	633	03	CS
81	04	20	2019	08	-	23	04	11	455	852	05	CS
81	04	25	2019	13	-	26	04	13	467.5	763	04	FGS
81	04	30	2019	18	+	01	05	09	330	520	04	CS
81	05	10	2020	01	+/-	11	05	13	362.5	550	03	FGS
81	05	14	2020	05	-	16	05	12	427.5	704	03	CS
81	05	17	2020	08	-	18	05	09	380	799	06	CS
81	05	31	2020	22	+	01	06	13	330	480	06	CS
81	06	06	2021	01	-	07	06	22	340	500	05	FGS
81	06	25	2021	20	+	26	06	15	372.5	557	04	FGS
81	07	10	2022	08	+	13	07	13	302.5	511	05	CS
81	07	22	2022	20	+	27	07	17	365	802	07	FGS
81	07	31	2023	02	+	03	08	08	335	575	07	CS
81	08	09	2023	11	-	12	08	03	335	719	07	FGS
81	08	27	2024	02	+/-	27	08	22	355	538	04	FGS
81	09	04	2024	11	-	05	09	18	357.5	487	04	CS
81	09	08	2024	14	-/+	08	09	24	305	444	10	FGS

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Table I (continued)

Y	M	D	Bartel Rotation No	D	IMF POL	FDMA D	M	Hr	V_o	V_{max}	DUR	TYPE
81	09	18	2024	24	-	20	09	08	282.5	439	05	CS
81	09	23	2025	02	+	27	09	06	310	435	05	FGS
81	09	29	2025	08	+/-	03	10	11	322.5	710	07	CS
81	10	07	2025	16	-/+	10	10	17	335	561	06	CS
81	10	13	2025	22	+/-	16	10	03	285	670	04	FGS
81	10	17	2025	26	+/-	20	10	02	390	716	05	FGS
81	11	08	2026	21	+/-	08	11	24	346	477	03	CS
81	11	11	2026	24	+	12	11	02	425	695	05	FGS
81	11	16	2027	02	+	16	11	24	442.5	802	04	CS
81	11	25	2027	11	-	25	11	14	300	524	06	CS
81	12	01	2027	17	+	03	12	15	285	435	07	CS
81	12	09	2027	25	+/-	12	12	15	300	531	05	CS
81	12	28	2028	17	+	29	12	13	345	608	10	FGS
82	01	20	2029	13	+/-	24	01	14	320	582	08	FGS
82	01	28	2029	21	-	30	01	21	340	665	03	CS
82	02	02	2029	26	-	03	02	09	357.5	769	09	CS
82	02	10	2030	07	-/+	11	02	16	357.5	668	07	FGS
82	02	17	2030	14	+	18	02	13	360	803	07	CS
82	02	23	2030	20	+	26	02	05	405	667	06	CS
82	03	01	2030	26	+	01	03	24	400	768	07	FGS
82	03	08	2031	06	-/+						10	CS
82	03	20	2031	18	+/-	21	03	01	357.5	630	03	FGS
82	03	23	2031	21	+	25	03	13	355	657	10	CS
82	04	03	2032	05	-	06	04	10	350	577	05	CS
82	04	14	2032	16	+	21	04	14	400	727	10	CS
82	04	23	2032	26	+/-	24	04	23	455	641	05	FGS
82	05	02	2033	07	-	04	05	08	365	702	08	CS
82	05	13	2033	19	+	16	05	12	370	577	05	CS
82	05	17	2033	22	+	18	05	12	364	621	09	CS
82	05	25	2034	03	+/-	30	05	07	311.5	799	12	FGS
82	06	06	2034	15	+	12	06	22	313.5	688	17	FGS
82	06	24	2035	06	-	30	06	05	276	637	12	CS
82	07	06	2035	18	+	07	07	23	302.5	579	05	CS
82	07	11	2035	23	+	14	07	01	446	986	05	FGS
82	07	16	2036	01	+	17	07	01	476	805	03	CS
82	07	19	2036	04	-	20	07	03	428.5	682	06	CS
82	07	25	2036	10	-	27	07	11	430	679	05	CS
82	08	01	2036	17	+	03	08	13	400	612	05	CS
82	08	06	2036	22	+/-	07	08	01	412.5	643	03	FGS

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Table I (continued)

Y	M	D	Bartel Rotation No	D	IMF POL	FDMA D	M	Hr	V_o	V_{max}	DUR	TYPE
82	08	09	2036	25	–	12	08	11	352.5	593	07	CS
82	08	17	2037	06	–/+	23	08	09	335	726	11	CS
82	08	28	2037	17	+	30	08	10	360	597	06	CS
82	09	03	2037	23	+	06	09	15	400	874	05	FGS
82	09	08	2038	01	–	09	09	05	385	897	11	CS
82	09	19	2038	12	–	21	09	07	335	1021	07	FGS
82	09	26	2038	19	+	27	09	15	335	530	04	CS
82	10	10	2039	06	–	10	10	20	325	546	05	CS
82	10	15	2039	11	–	27	10	06	382.5	720	11	CS
82	10	26	2039	22	–	29	10	21	420	739	03	FGS
82	10	31	2039	27	+	01	11	05	375	675	05	CS
82	11	11	2040	11	–	12	11		375	630	08	CS
82	11	21	2040	21	+/–	25	11	07	402.5	783	06	FGS
82	12	06	2041	09	–	10	12	13	360	723	06	FGS
82	12	16	2041	19	+	20	12	02	480	805	09	FGS
82	12	26	2042	02	–	29	12	17	380	709	07	FGS
83	01	09	2042	16	+	12	01	04	370	648	07	CS
83	01	15	2042	22	+	17	01	15	360	753	14	CS
83	01	29	2043	09	+				345		06	CS
83	02	04	2043	15	–	05	02	22	340	572	07	FGS
83	03	01	2044	13	–/+	03	03		305	610	09	CS
83	03	09	2044	21	–/+	14	03	23	362	754	10	CS
83	03	19	2045	04	+/–				375		05	CS
83	03	28	2045	13	–	31	03	02	357.5	565	09	CS
83	04	04	2045	20	–	09	04	22	437.5	788	08	CS
83	04	12	2046	01	–	14	04	24	402.5	750	10	CS
83	04	21	2046	10	–	24	04	24	350	633	09	CS
83	05	01	2046	20	+/–	05	05	20	372.5	633	10	CS
83	05	11	2047	03	+/–	12	05	01	387.5	731	10	FGS
83	05	20	2047	12		25	05	19	360	752	11	FGS
83	05	29	2047	21		02	06		367.5	510	07	CS
83	06	10	2048	06	+/–	13	06		367.5	595	07	FGS
83	06	17	2048	13	–/+	18	06	12	367.5	645	10	CS
83	06	25	2048	21		28	06	02	350	540	11	CS
83	07	06	2049	05		09	07	11	365	511	07	CS
83	07	12	2049	11					365		10	CS
83	07	22	2049	21	+/–	25	07	02	355	572	09	CS
83	08	01	2050	04		03	08	24	337.5	660	07	FGS
83	08	19	2050	22					345		11	CS

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Table I (continued)

Y	M	D	Bartel Rotation No	D	IMF POL	FDMA D	M	Hr	V_o	V_{max}	DUR	TYPE
83	08	30	2051	06	+	31	08	10	325	691	10	CS
83	09	08	2051	15	−	10	09	11	337.5	574	08	CS
83	09	23	2052	03	+	26	09	16	320	703	12	CS
83	10	03	2052	11	+	08	10	17	357.5	632	07	CS
83	10	15	2052	25	+	18	10	10	355	546	06	CS
83	10	28	2053	11	+	29	10	21	325	545	05	CS
83	11	01	2053	15	−	02	11	18	350	677	06	CS
83	11	06	2053	20	+	10	11	03	395	654	08	CS
83	11	23	2054	10	−				350		11	CS
83	12	04	2054	21	+	07	12	04	387.5	650	06	CS
83	12	11	2055	01	−	12	12	19	380	669	08	CS
83	12	25	2055	15	+				375		10	CS
84	01	03	2055	24	+	05	01	13	374	633	04	CS
84	01	19	2056	13	+				347.5		09	CS
84	01	26	2056	20	+	30	01	15	365	751	07	FGS
84	02	22	2057	20	+/−	24	02	10	370	651	04	FGS
84	03	01	2058	01	−	03	03	01	400	769	05	CS
84	03	05	2058	05	−	06	03	15	370	594	05	CS
84	03	16	2058	16	+/−	19	03	13	345	533	06	CS
84	03	21	2058	21	+				340		07	CS
84	03	28	2059	01	−	29	03	10	455	744	05	CS
84	05	07	2060	14					370		13	FGS
84	05	19	2060	26		23	05	21	380	654	11	CS
84	06	02	2061	13					360		13	CS
84	06	13	2061	24		16	06	08	427.5	706	05	CS
84	04	28	2062	12					355		15	CS
84	07	31	2063	18		01	08	16	355	663	08	CS
84	08	14	2064	05		15	08	07	350	615	06	CS
84	08	26	2064	19		28	08	24	330	639	06	CS
84	09	08	2065	03		10	09	20	385	790	15	CS
84	09	22	2065	17		24	09	05	375	783	13	CS
84	10	04	2066	02	−	09	10	11	352.5	719	14	CS
84	10	17	2066	15	−	20	10	08	342.5	754	13	CS
84	10	31	2067	02	−				370		15	CS
84	11	14	2067	16	−							FGS
84	12	10	2068	15	+				360		11	CS

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between the speeds immediately preceding and following the stream and the maximum daily mean speed (V_{max}), respectively. The next one gives the duration (DUR) of the high-speed stream in days. Finally the last column indicates the type of the high-plasma stream.

In this search we have tried to emphasize well-defined streams. A stream is listed only if the data coverage was reasonably complete. Each appearance of a stream is listed

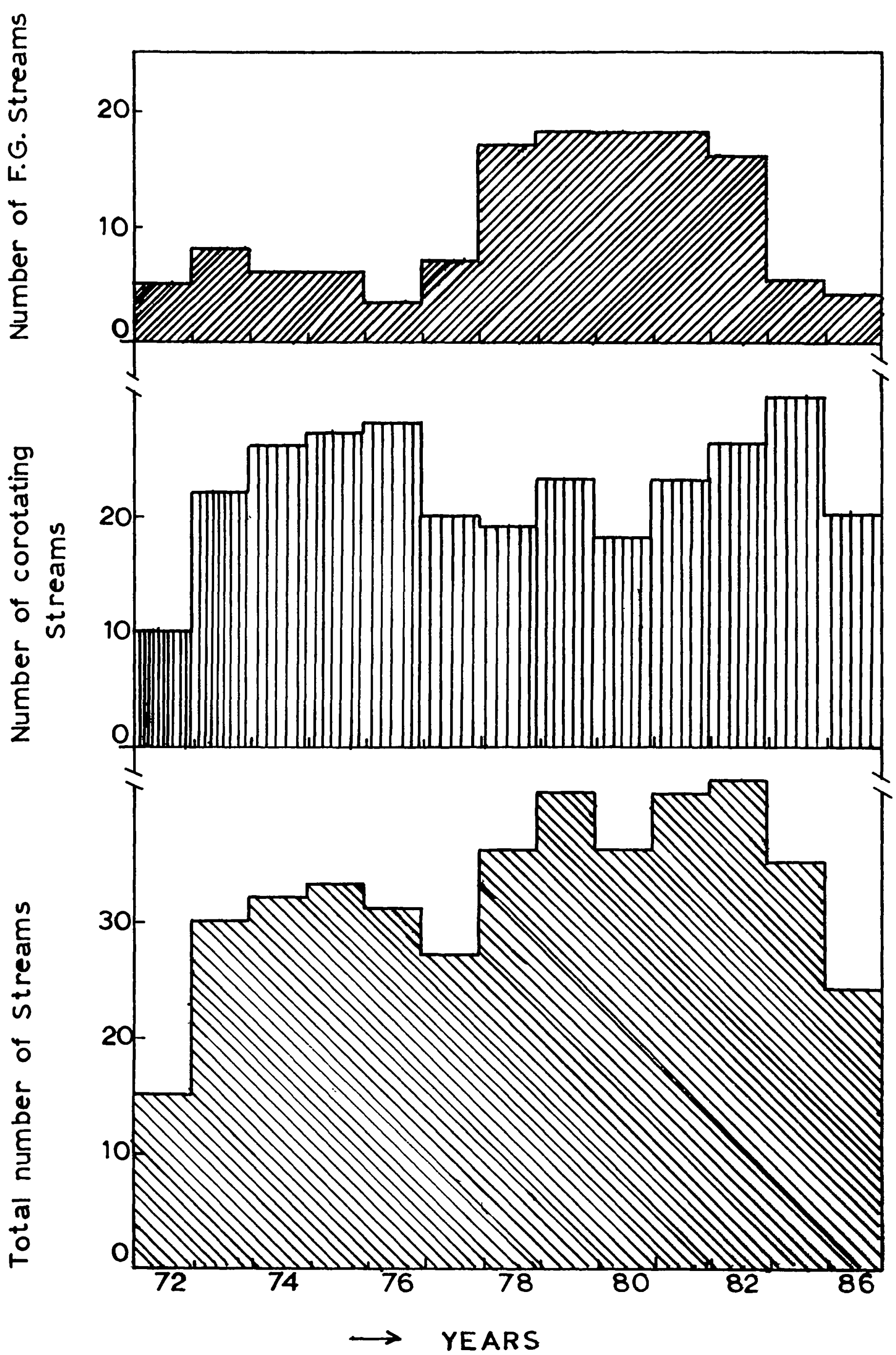

Fig. 2. Histograms showing the distribution of the number of total high-speed solar-wind streams (*below*), flare-generated streams (*above*) and corotating streams (*middle*) for the period 1972–1984.

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separately regardless of whether or not it is a member of a recurrent series. In Table I a total of 423 individual high-speed streams are listed. Among them a total of 294 (69%) corotating streams and 131 (31%) flare-generated streams are found. It is obvious that the number of corotating streams appears to be greater than the number of flare-generated streams during the solar cycle No. 21 (1975–1984). This result is also confirmed from a statistical analysis of the two types of high-speed streams obtained the distributions of Figure 2. According to this figure a large number of flare-generated streams appear during solar maximum, whereas the existence of coronal holes during solar minimum most likely gives such a lot of corotating streams.

3. General Effects of Streams on Geomagnetic Activity

It is known that the consideration of the relation between interplanetary streams and geomagnetic activity promises to be the key link between interplanetary dynamics and the dynamics of the solar wind–Earth interaction. But the problem of relating the physical processes and the configuration of the solar wind to the physical parameters that produce geomagnetic activity has not been solved.

A series of statistical correlative studies have been presented with opposite results. Snyder, Neugebauer, and Rao (1963) reported a strong correlation between solar wind

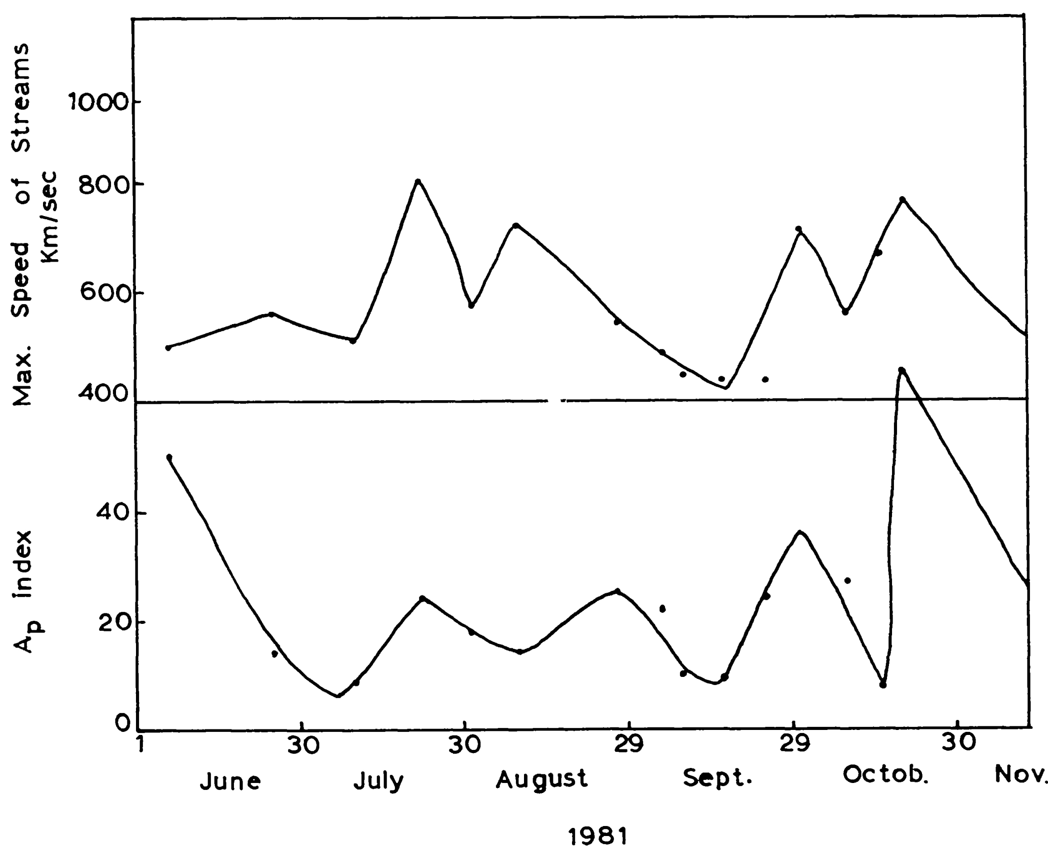

Fig. 3. Relation between the index A_p and the maximum speed of high-speed streams from June to November 1981.

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velocity and the three-hour geomagnetic index K_p. Later Gosling *et al.* (1972) showed that the persistence of streams is not as great as Snyder, Neugebauer, and Rao (1963) originally suggested. Bobrov (1973) suggests that geomagnetic activity is high during the passage of the interaction regions from both corotating and flare-associated streams because both the negative southward component of the interplanetary magnetic field and the fluctuations of magnetic field are high in the interaction regions. He showed that the K_p index was high in the trailing part of corotating streams due to the presence of large fluctuations of magnetic field there.

In this work with the solar wind parameters we have choosen the maximum speed of the high-speed solar-wind streams which is not influenced by the north–south effect (Tsurutani *et al.*, 1987) to correlate with the A_p index of geomagnetic activity. The A_p index is a daily index of geomagnetic activity on a linear scale (*Solar Geophysical Data*). A typical example of the relation between the maximum velocity of streams and the A_p index for a short time period is presented in Figure 3. Even though the eye tends to see a high correlation, a close look at this figure shows that A_p is not always proportional to $V_{\max}$, but presents an almost similar behaviour with it. The correlation for the years 1972–1984 is generally satisfactory (correlation coefficient $r = 0.50$), particularly considering that both variables are not free from errors.

From a regression analysis between the A_p index and the maximum speed of total streams, the flare-generated streams, and the corotating streams we have obtained

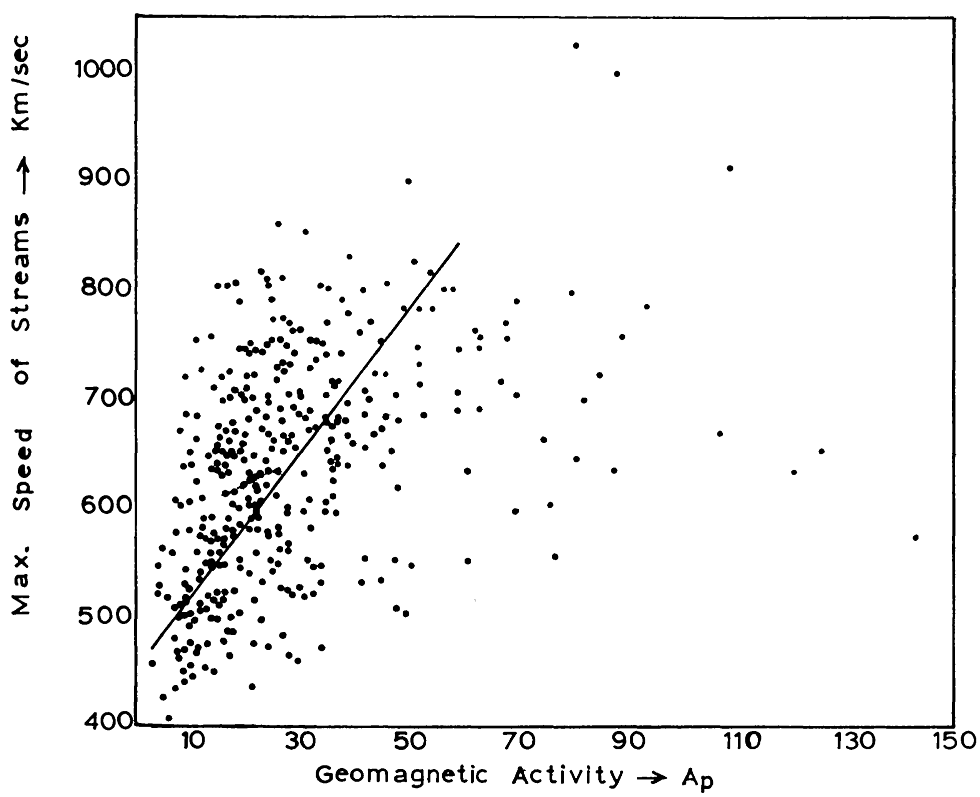

Fig. 4. Correlation diagram and 'best fit' line between the maximum speed of all streams defined in this study and the geomagnetic index A_p for the 21st solar cycle.

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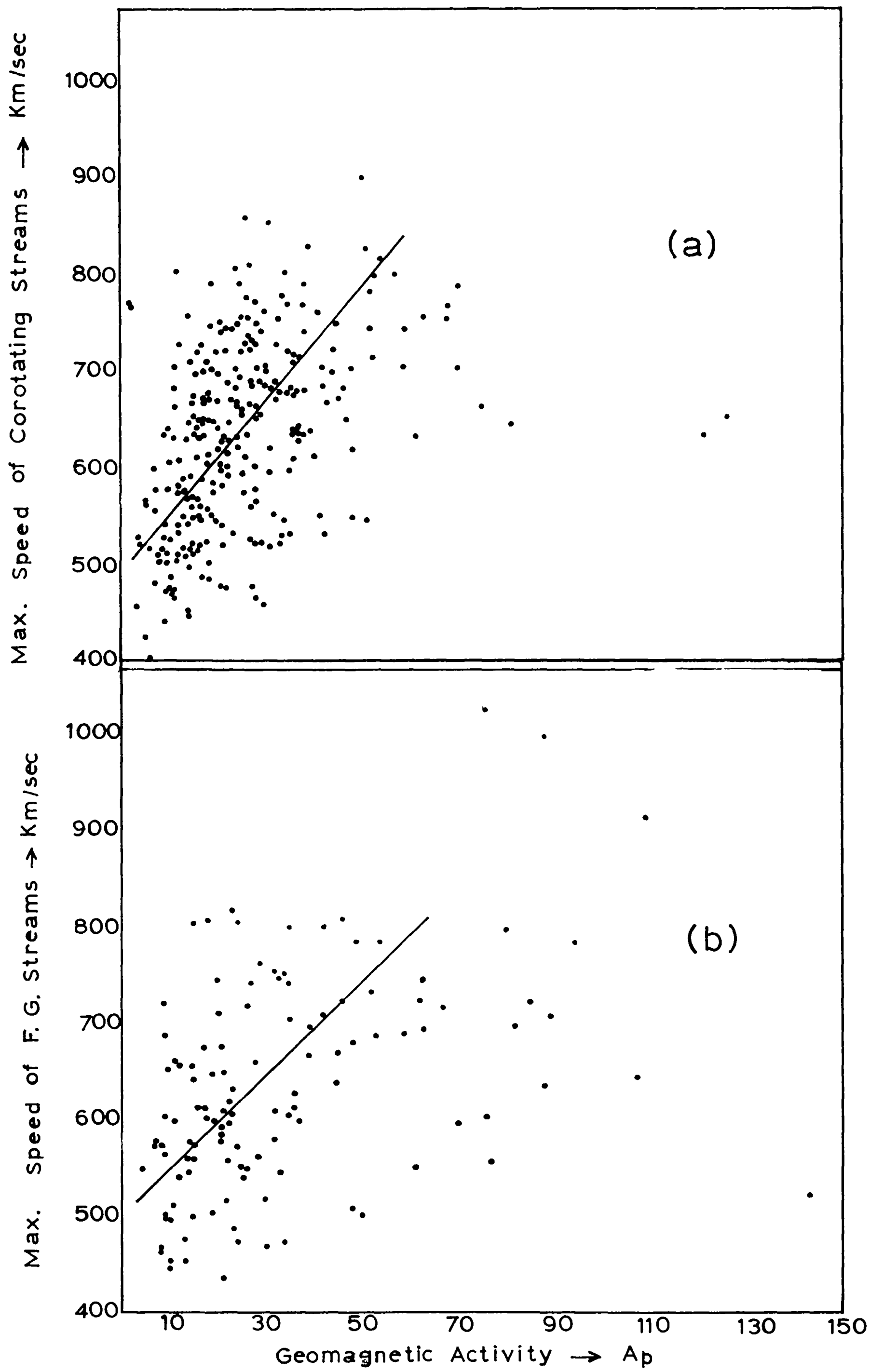

Fig. 5. Correlation diagram and 'best fit' line between the A_p index and the maximum speed of (a) the corotating streams and (b) the flare-generated streams, respectively.

Figures 4 and 5. A linear relation between V_{max} of the high-speed streams and the A_p index can be given. The constant, the slope and the correlation coefficient of this analysis for the total, the corotating and the flare-generated streams are given in Table II. According to the Fisher's Z-transformation of significance of correlation coefficients we have found that the above estimated correlation coefficients for the data series of

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TABLE II

Linear regression analysis of V_{max} of high-speed solar-wind streams (total, corotating, and flare-generated) and A_p index for the period 1972–1984 giving the constant, the slope, the correlation coefficient, and the significance level

	Constant	Slope	Correlation coefficient	Significance level
Total streams	523	4.5	− 0.45	0.05
Corotating streams	510	5.4	− 0.43	0.05
Flare-generated streams	521	4.0	− 0.52	0.05

maximum speed of streams and the A_p index are at a 0.05 significance level. A similar relation between the solar wind speed and the geomagnetic index C has been evaluated by Chirkov and Kuzmin (1977).

Searching through Figures 5(a) and 5(b) we note that high values of geomagnetic activity appear to be caused by the flare-generated streams. Indeed there is an accumulation of the maximum speed values of corotating streams around small values of A_p-index (Figure 5(a)) while the maximum speed values of flare generated streams are extended around greater values of A_p-index (Figure 5(b)). From a first attempt these high values of A_p correspond to sudden storm commencements which are attributed to interplanetary streams and seem to be emitted by solar flares. According to Simon and Legrand (1986) these events are related to a series of solar events occurring in relationship with the sunspot activity. They noticed that most of the geomagnetic activity, i.e., 85% of the occurring activity is of solar wind origin. These shock events contribute weakly to the geomagnetic activity but with high values. On the other hand the corotating streams give geomagnetic events with a low activity. These disturbances are attributed to long-lived interplanetary steams emanating from unidentified regions on the Sun, the corotating or M-regions (Burlaga, 1975). According to Legrand and Simon (1985) these geomagnetic events of corotating regions are related to the distribution around the Sun of the corotating sources of solar wind and include three categories of geomagnetic activity: the recurrent storms, the quiet days and the fluctuating activity. So any increase or decrease of such geomagnetic activity is related to the rotation with the Sun of alternate sources, i.e., coronal holes of the high and low speed wind which successively reach the Earth magnetosphere.

4. Conclusions

From all the above the following conclusions can be drawn:

It is believed that the catalogue of high-speed solar-wind streams containing all their main characteristics may be useful in studies of various solar interplanetary and terrestrial phenomena.

Indeed the streams are the key link in the chain that connects solar and geomagnetic activity. The factors that most influence geomagnetic activity are probably related to

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streams and determined by the dynamics of streams. In the study of understanding the solar wind parameters which are most important in producing geomagnetic activity, we found that the maximum speed of the flare-generated streams gives large values of geomagnetic activity if produced by the sudden storm commencement events, as opposite to corotating streams.

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